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Eco-innovation in agriculture: building a theory from a DSS case study

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Abstract

In the last few years, innovation and environmental sustainability become central concepts for both research and companies. Integrating innovation and sustainability can be a key factor to achieve increased growth rates for companies, and a better quality of life for society. Within the agricultural sector all these evidences are especially true. Indeed, it is one of the more related field to the eco-innovation issue.

Given such premises, the aim of this thesis is to investigate the research theme of the eco-innovation to understand which factors influence its diffusion process, namely the adoption and use phases, within the agricultural sector.

In order to reach this objective overcoming the problems faced within this research theme, namely the lack of an adequate theoretical and methodological framework of analysis and the not complete investigation of the eco-innovation process, the *Theory building from cases (TBFC)* research approach proposed by Eisenhardt in her two key works of *Eisenhardt, 1989* and *Eisenhardt and Graebner, 2007* and aiming to construct or modify theories starting from case studies, has been used.

To do so, four different research questions have been defined. The first research question (RQ1) aims to find a suitable eco-innovation case to study. Through a deductive process starting from the general innovation issue, the specific case of v*ite.net*, a DSS eco-innovation developed for the wine grapes supply chain, has been identified. The second methodological research question (RQ2) aims to understand whether and how the *TBFC* is the right research approach to analyze such case study. The last research questions belong to the *TBFC* analysis. The third one, (RQ3) is the more empirical one and strictly related to the case study. It aims to understand which characteristics affect the innovation process, namely adoption and use, of the specific DSS *vite.net*. The last research question (RQ4) aims to understand, according the existent literature, if the same characteristics influence also the innovation process of a general eco-innovation and, consequently, if they are useful statements to propose a theory about the diffusion of eco-innovation in agriculture.

Introduction

Background

Why study eco-innovation in agriculture?

From a general point of view, the importance of a better understanding of innovation processes is well known. Indeed, innovation is the only way to generate progress.

In the last few years, beside innovation, also the environmental sustainability has become a central concept for research and companies' management activities.

Innovation and sustainability should be well assimilated and developed together (Bossle *et al.*, 2016) because they are, on one hand, part of everyday life for firms and, on the other, a field of scientific research (Rennings, 2000). Integrating innovation and sustainability can be a key factor to achieve increased growth rates for companies, and a better quality of life for society (Dangelico and Pujari, 2010). This is the reason why eco-innovation, even if is a recent topic, is generating an increasing interest in both from an academic and business point of view.

Within the agricultural sector all these evidences are especially true. Indeed, agriculture is one of the more related fields to the eco-innovation issue in terms of both cause and consequence. Indeed, as agriculture is one of the main influencing sectors on environment, in order to limit its negative impact new sustainable processes must be developed. At the same time, effects of eco-innovation processes strongly impact on the agricultural sector in terms of final product and way to produce, but also from a social and organizational point of view.

Such premise introduces the decision to focus on the eco-innovation features within the agricultural sector in such thesis. Moreover, such choice is justified and strengthened by the lack of studies about the analysis of the eco-innovation process in such productive sector. Therefore, the aim of this thesis is to investigate the research theme of the eco-innovation to understand which factors influence its diffusion process, namely adoption and use phases, within the agricultural sector.

From a general point of view, as Rennings argued in 2000, the importance of a better understanding of innovation processes and the consequently great demand for the reductions of environmental burdens implies that existing technologies and regulation strategies are not sufficient. Furthermore, the technological progress by itself is not sufficient to reach long-term sustainability goals and it must be supported by corresponding lifestyles and institutional changes from local networks to global organizations. For this reason, promoting both innovative policy and scientific research is necessary to improve the understanding of global environmental change and its relation to economic and social systems.

Innovation is expected to balance loads and costs induced by such environmental regulations. Actually, secondary benefits of an environmental friendly innovations are often seen in reduced costs, increased competitiveness, creation of new markets for environmentally desirable products and processes. So, eco-innovation is an increasingly important issue for many firms from different points of view, even small or medium sized firms.

From the research perspective, the many and different experiences of eco-innovation seem to be crucial to identify key determinants and success factors of sustainable innovation processes. In this regards, two considerations can be made.

According to the Schumpeter's model, the innovation process starts when an idea gets to the market becoming a true innovation and ends when it turns out in normal practice and procedure (Schumpeter, 1939). If the innovative process is ideally divided into two phases, a first phase which from the innovation birth reaches its adoption and a second one, which moves from the innovation adoption to a normal practice.

The majority of researches concerns the analysis of the first phase of the innovation and the related literature, principally focuses on internal and external factors influencing the adoption of innovation, e.g. characteristic of innovator, adopters and innovation itself and drivers. A limited number of studies are available about the second phase, namely the use or implementation of an innovation by its adopters until it becomes a normal practice. Indeed, little attention has been given to such aspect in both cases of general innovation and eco-innovation (Cheng and Shiu, 2012; Kemp, 2009). Therefore, some questions may arise: once the eco-innovation has been adopted, it is also used? And how? Is it used in a proper way? These questions are especially valid with product and process innovations, rather than the organizational and the marketing ones, because in the first two categories of innovation the adoption and the utilization phases are definitely separated.

The second consideration is fundamental and not so unexpected.

Until 2000, the problem addressed by Rennings was the lack of an adequate theoretical and methodological framework able to improve the understanding of the relations between innovation processes and sustainability in their different dimensions, complex feedback mechanisms and interrelations.

Although eco-innovation has been discussed for a long time within numerous scientific researches, an objective vision of its innovative process and an adequate framework of analysis about its diffusion in all sectors and, therefore in the agricultural one also, have not yet been reached. Nonetheless, there is a widespread consensus about the eco-innovations key role (Rio *et al.*, 2016), even if the diversity of eco-innovations is very wide (OECD, 2011; Carrillo-Hermosilla *et al.*, 2010). Such research field is becoming larger and larger both in academia and in practice, but many research gaps remain to be filled. Starting from the difficult definition of the eco-innovation, as a common definition has not been yet reached (Carillo-Hermosilla *et al.*, 2010; Hojnik and Ruzzier, 2016; Bossle *et al.*, 2016), additional investigation and more analysis of the generative mechanisms and critical conditions for different types of eco-innovation are needed (Hojnik and Ruzzier, 2016). As the lack of an adequate framework is particularly felt in literature (Rio *et al.*, 2016; Bossle *et al.*, 2016), recently some authors tried to understand how literature results could suggest key paths for further research and policy (Hojnik and Ruzzier, 2016; Rio *et al.*, 2016;) or define a conceptual framework for eco-innovation in general (Bossle *et al.*, 2016;), for its implementation (Cheng and Shiu, 2012) and for supply chain networks (Roscoa *et al.*, 2016).

In Rio *et al.* (2016), the authors review the literature on firm-level determinants of eco-innovation in order to provide recommendations for both policy-makers and researchers. As literature on eco-innovation is ample and many of the most cited papers on eco-innovation used econometric methods, they focused only on contributions analyzing firm-level drivers with such methods, in order to highlight their positive aspects, biases and limitations. The methodology proposed by the authors, in order to conduct the literature review and to identify the main articles, consists of a Scopus search, issue-by-issue search in key eco-innovation journals and references in preselected articles. Once the final sample has been defined (29 papers), the articles have been grouped in two broad categories: studies analyzing the drivers of eco-innovation with firm-level data in general and those analyzing the drivers to eco-innovation versus general innovation. The review shows many and different results. A main remark is the explicit lack of a theoretical root: as the authors argued: «*There is not an agreed theoretical framework and different approaches emphasize some drivers, while neglecting others*» (Rio *et al.*, 2016: 2168). Moreover, the authors argued that research about eco-innovation is lacking in terms of determinants of different eco-innovations (and eco-innovators) types and drivers to eco-innovation vs. general innovation. They also found that literature is concentrated on Western European countries (e.g. Germany and Spain) whereas analyses in other developed, middle-income and developing countries are missing as well as comparative studies at international level. A similar consideration concerns sectorial and regional features of eco-innovation. Indeed, the relevance of the local and particular institutional and socioeconomic context influences the propensity of firms to eco-innovate. Finally, many problems, questions and details, which could introduce relevant differences in the analysis, have not adequately been addressed and included in the models, probably because such variables are very hard to measure with econometric methods.

To this regard, Hojnik and Ruzzier (2016), reviewing the academic literature on 155 articles focusing on drivers of eco-innovation, their theoretical foundations and typical characteristics, concludes that: «*although quantitative analyses are usually considered more rigorous and objective than qualitative analyses, they are less able to capture the relevance of the local institutional and socioeconomic context*» (Hojnik and Ruzzier, 2016: 39). Indeed, qualitative analyses usually provide more details about a specific case study but the generalization phase of data gathered from a small number of encompassed cases is much difficult.

Another interesting study, which aims to define a conceptual framework of general eco-innovation moving from empirical evidences, has been conducted by Bossle *et al.* (2016). In this study the authors try to reach this objective through a systematic literature review focused exclusively on empirical papers. As the aim was to identify the main drivers and motivation for companies' adoption of eco-innovation, they considered just the empirical and business part of researches, instead of mapping all the literature on eco-innovation. The final sample was about 35 papers. From a general and methodological point of view, they found that:

- the general interest about the concept of eco-innovation is growing, as since 2008 the number of papers has been increased;
- the broad and new concept of eco-innovation is lacking of rules to select cases and consequently to reach shared and adequate definition of eco-innovation;
- case studies were commonly used in the papers;

- quantitative research was also broadly applied (questionnaire survey) such as a multi method approach;

Finally, the authors emphasized all the conceptual models, which have been found relevant in their analysis. In general, they propose that external factors (regulatory and normative pressures, cooperation and technology) impact on internal factors (efficiency, environmental capability, environmental managerial concern, human resources and environmental technology) and both influence the adoption of eco-innovations, leading to a positive performance of companies.

A study where an empirical approach has been applied is Carillo-Hermosilla *et al.* (2010). The authors, starting from the evidence about the considerable diversity of the eco-innovations, argued that a case study approach is very useful for generating both theoretical and practical insights in the case where literature disagrees or not addresses adequately a given phenomenon (Eisenhardt and Graebner, 2007). Therefore, in order to light on the eco-innovation concept, Carillo-Hermosilla *et al.* conducted a multiple case studies analysis by identifying a framework to explore different dimensions of eco-innovations, namely design (the way the eco-innovation improve existing systems or create/transform to an entirely new system), user (the key role of users within the eco-innovative process), product-service (the benefits and added-value of the eco-innovation) and governance (the techno-institutional changes achieved by the eco-innovation). They found that the design dimension is decisive to determine the environmental impacts of the innovation, but the capacity of eco-innovations to provide benefits, new opportunities and, in general, a transformation towards a more sustainable society depends on the interaction between all dimensions. Moreover, also the engagement of key stakeholders results a crucial factor. Finally, the authors argued that their framework, although it could be applied to different eco-innovation types, may not be applicable to all eco-innovations because of the subjectivity component which affected the analysis and eco-innovation process itself.

Roscoa *et al.* (2016) reviewed literature about sustainable supply chain management through a grounded theory approach. They have deeply investigated the eco-innovation theme within the industrial supply chain focusing their study on how firms might find and develop eco-innovations, rather than see the eco-innovation only as a key factor in sustainability. In particular, they see sustainability «*as embedded in the way an organization conducts its business rather than be seen as something 'in addition' to its general business practices and procedures*» (Roscoa *et al.,* 2016: 1949). In their conceptual framework for eco-innovation in supply networks the authors state that three typologies of supply network designs (tight, loose and bridging) can bring eco-innovations.

A study of Chen and Shiu (2012) is the one which, most of all, faces the problems (i) of the lack of a general framework of eco-innovation and (ii) of the under investigated theme of the use of an eco-innovation. The authors started their analysis from the unique study about implementation of innovation existing in literature (Arundel and Kemp, 2009) where an instrument for measuring eco-innovation considered from an input-output perspective has been constructed. It consists of four types of indicators: input (R&D expenditures), immediate output (number of patents; number and typology of scientific publication), direct output (number of innovations, descriptions of individual innovations, data on sales of new products) and indirect impact (changes in resource efficiency and productivity). As such instrument was unable to meet the needs of firms to measure the effective implementation of their eco-innovation strategy, Cheng & Shiu (2012) worked to improve such tool towards this perspective.

All the authors cited in this short review raised key problems and critical questions and some interesting considerations can be made basing on their study.

First of all, as already argued by Rennings (2000), the lacking framework of analysis on eco-innovation (Rio *et al.*, 2016; Hojnik and Ruzzier, 2016; Bossle *et al.*, 2016; Carillo-Hermosilla *et al.*, 2010; Roscoa *et al.*, 2016) and the primary role of the empirical case studies (Bossle *et al.*, 2016; Carillo-Hermosilla *et al.*, 2010) must be highlighted. Moreover, other important factors to note are the lack of national studies (except for Germany and Spain) and, in particular, of sectorial researches (Rio *et al.*, 2016) and the fundamental role of the networks within the eco-innovation process (Roscoa *et al.*, 2016). Finally, also the under investigated theme of the eco-innovation implementation have been highlighted (Cheng and Shiu, 2012).

Therefore, considering the specific case of analysis, i.e. the eco-innovation in the agricultural sector, the first, and crucial, problem to face is to find a robust theoretical and methodological approach.

Many authors in their empirical study start from literature about eco-innovation following a classical research approach. In this dissertation, the idea is to follow an opposite process which starts from the singles case study. As each eco-innovation has unique and distinguishing features (Hojnik and Ruzzier, 2016), the role of the specific situation, the specific territorial context and the characteristics of the individual actors involved suggest to not refer to a pre-defined and generalizable framework.

Therefore, in order to afford the study of eco-innovation in agriculture, the idea is to move from the single case studies and not from literature. It implies to adopt an empirical and inductive approach rather than a theoretical and deductive one.

Coherently to such idea, the Theory Building From Cases approach formulated by Eisenhardt (Eisenhardt 1989; Eisenhardt and Graebner, 2007) has been chosen as key reference for the research. This approach, which aims to construct or modify theories, or a part of them, starting from the case studies analysis, seemed to offer an efficient way to face the study of eco-innovation in agriculture without underestimate the rich legacy of the past research about eco-innovation, that comes to play in the second phase of the research.

Research questions

Given the purpose and the research approach, four different research questions have been identified. The first research questions affect the first part of the thesis while the others are referred to the second one.

The first preliminary problem to solve is which case study of eco-innovation to analyze. In other words, a suitable eco-innovation must be chosen and the first research question (RQ1) aims to solve this first issue. The first part of the thesis is quite theoretical and, here, the TBFC is not yet applied. Indeed, it is totally devoted to a deductive identification of the eco-innovation case study starting from the general innovation issue. The Decision Supporting System (DSS), a specific typology of process eco-innovation developed to help farmers take their decision, has been chosen. In particular, a DSS developed by *Horta*, an academic spin off of "*Università Cattolica del Sacro Cuore*" for the vineyard management (named *vite.net*) has been analyzed. In few words, it is a computer's software developed to help farmers in improving the quality and quantity of vineyard production and, at the same time, the sustainability of the process.

The following problems to afford are: how to analyze the case study? And, is the Theory Building From Cases a right approach to assert general statements about eco-innovation starting from the case study? Therefore, the second research question (RQ2) aims to understand whether and how the TBFC could help this process considering the particular case of the agricultural sector.

The third research question (RQ3) is the more empirical one and, therefore, strictly related to the case study. It aims to understand which characteristics affect the innovation process of the specific DSS *vite.net*.

Consequently, according to this answers, the last questions (RQ4) aims to generalize such first empirical evidences in order to understand if the characteristics affecting the diffusion process of the DSS *vite.net* are also valid for a general eco-innovation process in agriculture and, hence, if they are useful to propose a theory about the diffusion of eco-innovation in agriculture.

To sum up, the research questions are:

- RQ1: "W*hich suitable eco-innovation case study to analyze?*"
- RQ2: "*Is the Theory Building From Cases a right approach to assert general statements about eco-innovation starting from the case study?*"
- RQ3: "*Which characteristics affect the eco-innovation process of the specific DSS vite.net?"*
- RQ4: "*The characteristics affecting the diffusion process of the DSS vite.net are also valid for a general eco-innovation process in agriculture and, hence, are they useful to propose a theory about the diffusion of eco-innovation in agriculture?*"

In order to answer to these multiple and different research questions, a particular research path has been carried out. This is the reason why a specific paragraph, named *Research design*, has been included in this introductory section of the thesis with the aim of clarify the general structure of the dissertation and the approaches adopted to properly face the general objective of the thesis.

Research design

As stated in the background, in this dissertation a new research process about the eco-innovation process within the agricultural sector has been chased. It combines different approaches more oriented to the case study without forgetting the rich legacy of the past research about eco-innovation.

Indeed, the four research questions have been faced thanks to the adoption of two approaches: a classical and deductive one to answered to the first research questions and a more empirical one for the three others. This second approach follows the research process proposed by Eisenhardt (Eisenhardt, 1989; Eisenhardt and Graebner, 2007) and called *Theory building from Cases* (TBFC), which aims to construct or modify theories, or a part of them, starting from case studies. According to the TBFC, the analysis starts from a single case study in order to inductively define some propositions, which have to be compared with the existent literature to be confirmed.

It seemed to be an efficient approach to study eco-innovation in agriculture where research is lacking of a shared framework although it is rich of generalized theories that, in the practice, are often far from the single and diversified realities. Moreover, the innovation process was not entirely investigated within all its features. So, first of all, this thesis is a first attempt of application of such new approach to the research about these themes.

In order to answer to the first research question (RQ1), namely to find a suitable eco-innovation case study, the first part of the thesis offers a wide overview of the research theme. Following a deductive process, namely formulating the hypothesis starting from consolidated theories, a path which remembers the logic of a *matryoshka* as it starts from the more general theme the argumentation finally focuses on the more specific one. So, in the first two chapters, from the general thematic of innovation, the case study of *vite.net* is gradually defined (Figure I).

The first chapter is dedicated to the general theme of innovation and its diffusion process (I.1.1) within the agricultural sector (I.1.2) trying also to map the diffusion of innovations in Italian agriculture (I.1.3). The chapter ends with a reflection on the specificity of eco-innovations issue trying to understand its specific nature, its characteristics (I.1.4) and which determinants influence its diffusion (I.1.5).

In the second chapter, which concerns the macro category of the eco-innovations, the Precision Agriculture (PA) practice (I.2.1) and the Decision Supporting System (DSS) instruments are identified (I.2.2). Finally, the case of *Horta* and the DSSs it has developed are described (I.2.3) focusing in particular on *vite.net* (I.2.4), chosen as specific case study to investigate in the second part of the thesis.

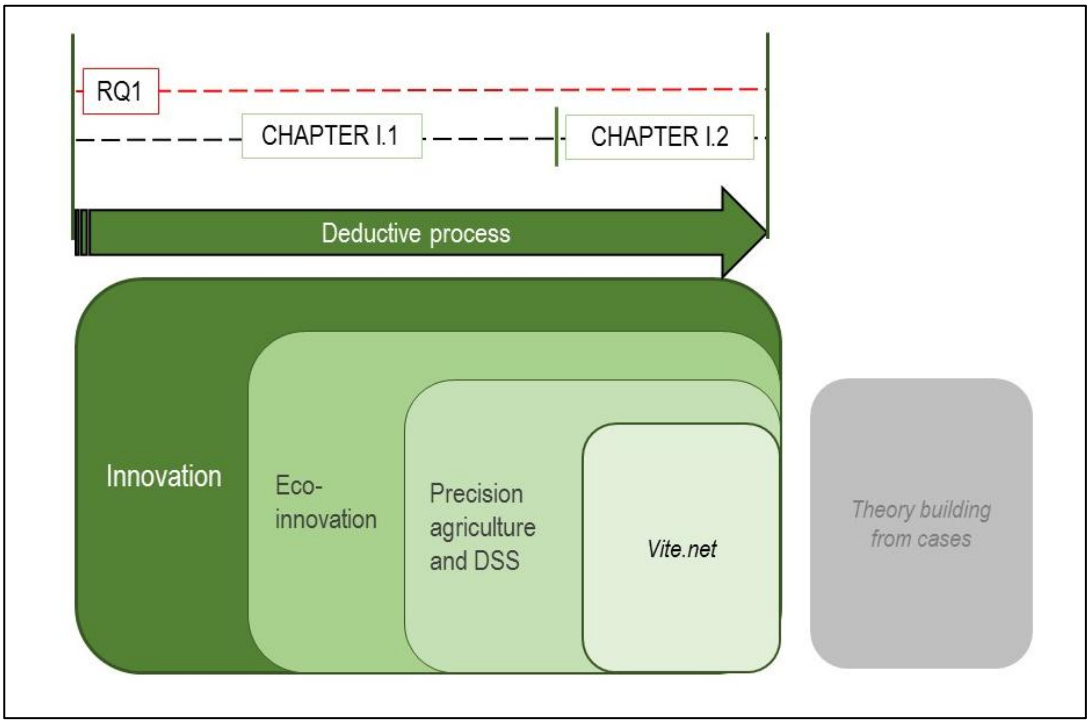

Figure I: Research path of the first part of the thesis

At first sight, *vite.net* might seem a small example compared to the importance of the main innovation issue. But, on the other hand, the difficulty of generalization, the great problem of this field of research, is always persistent. Indeed, a great number of theories exists, but a large part seems to be not very applicable to reality.

However, once the case study of the DSS eco-innovation *vite.net* has been identified, the second research question (RQ2) comes to play: is the TBFC a right approach to analyze *vite.net*? Therefore, starting from a broader perspective about the general innovation process in the agri-food sector, in the first chapter of the second part (II.1), the TBFC has been described (II.1.1) and a first overview of how much it has been used to study the general innovation issue in the agri-food sector is given (II.1.2).[1]

The next research questions affect the last chapter of the second part of the thesis (II.2), which is totally devoted to the TBFC approach applied to the eco-innovation case study of

[1] This chapter has been conceived as a single article which lies outside the overall structure of the thesis.

the DSS *vite.net*. The inductive approach adopted in this part, which, unlike the deductive one, aims to construct hypothesis starting from the observation of the reality, is very helpful to highlight the peculiarities of each case study and, only at a later time, to compare them with the existent literature.

In general, except for the chapter II.1, the research process of the second part follows a reverse path compared to the one used in the first part (Figure II). In other words, in this part the approach seems to follow an inverse *matryoshka* logic, moving from the "small" case study to the general eco-innovation research theme. While the research path of the first part starts from the general innovation issue (Figure I), in the second part the full reverse process is not possible. This is the reason why in the Figure 2 the innovation box is grey colored. This final generalization step will become possible only when all types of innovation, and not only the eco-innovation one, will be examined.

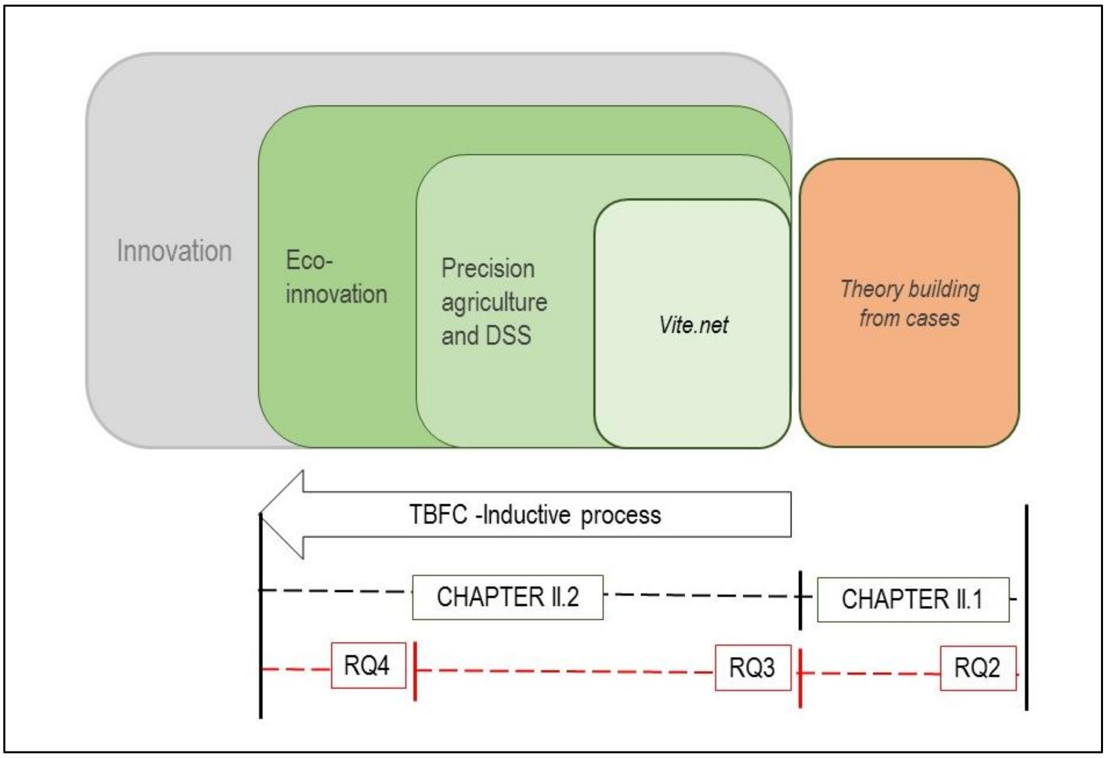

Figure II: Research design of the second part of the thesis

However, the definition of the research questions, namely RQ3 and RQ4, and the methodology are the first steps (II.2.1).

As it has already been said, while the third research question is strictly related to the case study and aims to understand which characteristics affect the innovation process of the DSS eco-innovation *vite.net* in agriculture, the fourth question aims to match such characteristics with the existent literature trying to understand if they are also applicable to the general process of eco-innovation.

In order to face the RQ3, the TBFC analysis starts with the description (I.2.2) and measurement of the case study (II.2.2): data about number of users from the launch of *vite.net* DSS in 2013 to November 2016 and their characteristics, namely all factors related to adopters, farms and their relationships with the innovator, have been collected. At this point of the analysis an adequate methodology able to highlight the peculiarities of such case study and their relations, which represent the starting point of the conceptualization and generalization process of the empirical evidences, must be find. Once it has been identified and applied, the preliminary results answer the RQ3, defining which characteristics affect the eco-innovation process represented by the adoption of DSS *vite.net* (II.2.3).

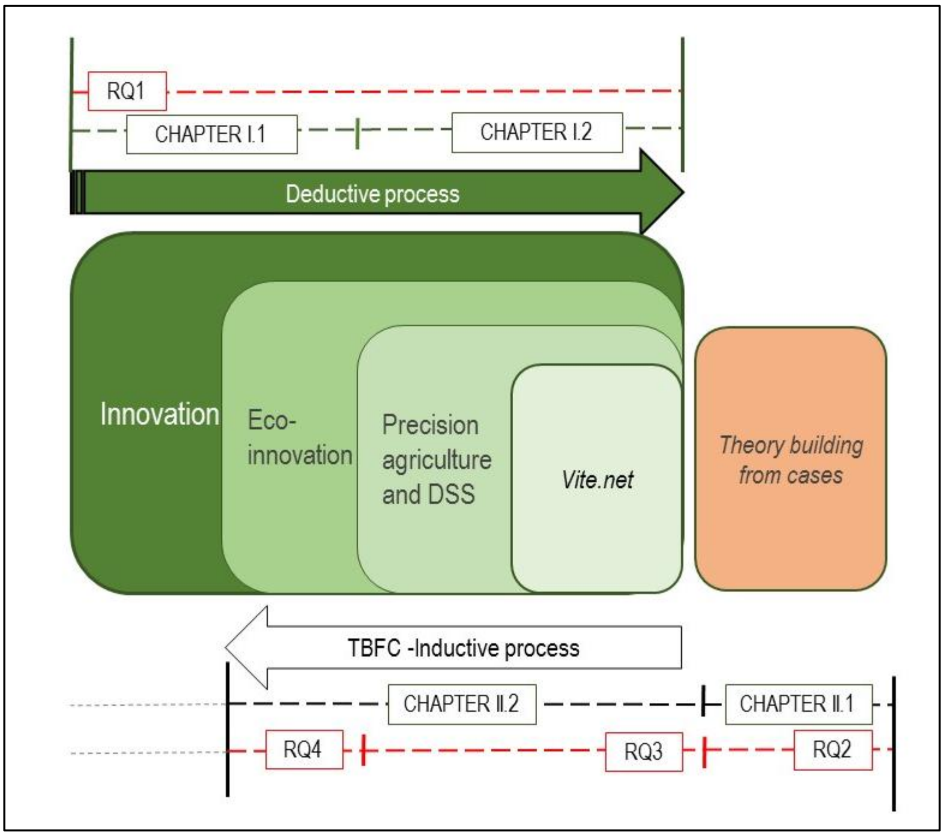

Figure III: Complete research design of the thesis

On the basis of such first evidences, the answer to the last research question (RQ4) starts with the definition of the propositions relating to the characteristics affecting the eco-

innovation process in agriculture (II.2.4). A literature review will test the congruity or incongruity between such proposition and the existing evidences about eco-innovation. After this last step the proposal of an emergent theory could be defined (II.2.5).
In this way, from the specificity of the single case study it inductively returns to the overall theme: from the DSS *vite.net* to the study of the eco-innovation process within the agricultural sector.
In conclusion, the whole research process chased in this thesis can be visually represented in the figure below (Figure III), where a classical structure and a deductive process determine the first part while and an inductive process, based on TBFC determine the second part of the research.

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First part

Eco-innovation in agriculture: general aspects and case study

I.1 The eco-innovation processes within the innovation in agriculture

I.1.1 General aspects of innovation

In the last century, the presence and intensity of innovation activities in firms and industries has been studied by economic literature starting from Schumpeter and his hypotheses which consider the firm and market characteristics as the fundamental drivers of innovation process (Martinez-Ros, 2000). However, studies on innovation are characterized by different methodologies, data set features and variables selected (Montoya-Weiss and Catalone, 1994): this fact leads to very contradictory results (Avermaete *et al.*, 2004) and the scientific debate worldwide persists.

As represented in figure 1, according to the Schumpeter's model, the innovation process is activated by the creation of an idea; as it gets to the market, it becomes a true innovation and, at the end of the process, it turns out in normal practice and procedure (Schumpeter, 1939).

PHASE	Creation	Diffusion	End
WHAT	Idea	Innovation	Normal practice or procedure
WHERE	Laboratory;mind	Market	
WHO	Scientist; inventor	Innovator; adopters	Everyone

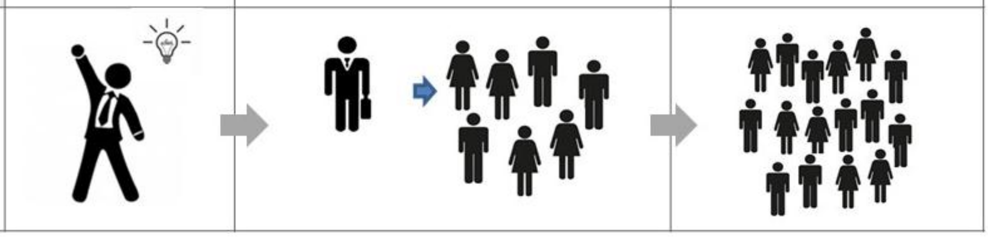

Figure 1: The innovation process (own representation)

The transition from invention to innovation is made possible by some features of the innovator, which may be related to individual aspects: the availability of financial means and market knowledge as well as specific skills (Winter, 2006). Nevertheless, innovation is inherently characterized by some key aspects that go beyond the individual capabilities (Fagerberg, 2003): uncertainty provoked by the risk of failure, speed of action to avoid the overtaking of other innovations and, finally, structural strength of the social, legal and cultural context in which the innovation is introduced.

Starting from this general framework, the innovation process can be analysed under two connected but very different perspectives. The first one sees the innovation process under the innovation/innovator perspective, studying its characteristics in order to understand the whole process; the second perspective consists of a wider analysis focusing on the context and the structure of the innovative system.

If the first approach is adopted, four macro-categories of innovations shall be discerned: product innovation, process innovation, organizational innovation and marketing innovation (OECD, 2005).

Product and process innovation can be both defined as technical innovations. Product innovations involve the creation of new products or services through a process where ideas are finally produced and commercialized by the firm; instead, through process innovations the firm develops or modifies new products or services. In general, process innovation is cost reduction driven, while product innovation is intended to differentiation (Martinez-Ros, 2000). In both, the innovative process is influenced by expenditure level, type of R&D (for example, by means of internal or external structures), and by technological characteristics of innovation like uncertainty and appropriability (Rogers, 1983; Teece, 1996).

The organizational innovations imply more complex procedures involving multiple actors and variables strongly related to the creation, integration and application of knowledge in the system. The way knowledge spread is able to affect the firm's learning process and, therefore, the innovation diffusion process itself (Johannessen *et al.*, 1999).

The so-called marketing innovations, the last macro-category, are particularly correlated to the market activities of the firm, like product diversification, respect of high quality standards, customer satisfaction, etc.

Beyond these objective features, the perception of the innovation by adopters is crucial in order to the final adoption. Rogers (1983) identified the most important: innovation's relative advantage compared to the status-quo; its complexity; its coherence with the adopters' values, beliefs and needs and with the previously introduced ideas; the possibility to measure its results; the degree to which the results of an innovation are visible and can be easily observed, described and communicated to others; finally, the possibility to test the innovation on a partial basis.

However, the innovation process strongly depends also on the structure of the innovation system and the context where innovations and innovators are involved in. So the innovation/innovator perspective is often not thorough.

Indeed, in the innovation system a number of actors, each one with a different role in the innovation process, co-exist. *Innovator* (who proposes the innovation) and *adopter* (who adopts the innovation) is the primary distinction that can be made. Either has a fundamental role: the role of innovator may change according to its institutional nature, thus changing the path of the innovation process; but adopters also can quickly turn to the innovation according to their inclination. «*Not all individuals in a social system adopt an innovation at the same time. Rather, they adopt in a time sequence, and they may be classified into five adopters' categories*» (Rogers, 1983: 241). According to the adopters' degree of innovativeness, i.e. the extent to which they are ready to early adopt an innovation compared to the others, they can be distinguished in innovator-adopters, early adopters, early majority, late majority and laggards (Blasi *et al.*, 2015). Figure 2 represents such categories measured by the time at which the individual decides to adopt an innovation.

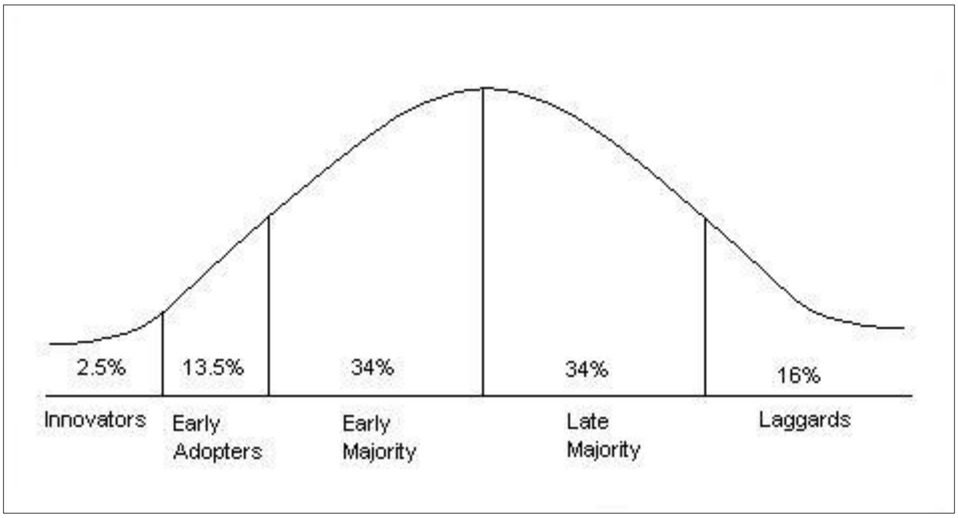

Figure 2: Categories of adopters on the basis of innovativeness (Rogers 1983)

However, in this case also, the analysis of adopters' characteristics is not enough, because it does not take into account the impact of the environment on the innovation system element. Indeed, environment greatly influences the birth, development and outcomes of an innovation. Territorial specificities, namely related to technology, society, economy and institution, can considerably enable or disable the innovation process (Klerx *et al.*, 2012;

Ghadim *et al.*, 1999). In other words, the same innovation is not likely to follow the same process of diffusion in different places, nor it will lead to the same outcomes.

Under this perspective, each area – i.e. each production system – is characterized by a specific innovation capability, according to which *National Innovation Systems* (NIS) can be identified (Lundvall, 2010). A NIS is a network made up of all the actors of the innovation system, often including institutions such as universities, R&D departments and other research institutes (Chung, 2002), with the aim of creating, diffusing and exploiting innovation. Furthermore, Lundvall (2010) identifies five NIS core elements for the innovation process: the internal organization of firms, the inter-firm relationship, the role of the public sector, the institutional set-up up the financial sector and R&D intensity and organization. Innovations systems can be also defined at regional level. Therefore, a NIS is supposed to be made up by many *Regional Innovation Systems (RISs)* (Chung, 2002), which involve interactions between different actors with the aim to increase the regional innovative capabilities (Doloreux, 2002). Within the study of the innovation process in a given area, the analysis of the systemic and specific drivers affecting the innovation process is crucial.

I.1.2 Innovation and agriculture: diffusion and drivers

As we focus on the agri-food sector, the analysis of the innovation process becomes even more complicated. Indeed, literature about the innovations process and its drivers is very fragmented. Moreover, the agricultural sector is characterized by a number of additional elements that affect the development of the innovation process and to generalize the discourse it is very difficult (Crossan and Apaydin, 2010).

Most of literature on innovation in the agri-food sector focuses on case studies held in large firms (Christensen *et al.*, 1996; Huiban and Bouhsina, 1998), whereas the research on small firms is much less developed (Avermaete *et al.*, 2004). Nonetheless, product, process, organizational and marketing innovations are strategic factors to enhance national and international competitiveness of the firms in the food sector (Avermaete *et al.*, 2004).

In order to analyse the network where the innovation develops, the role of knowledge and the importance of the information flow emerge. Indeed, the innovation diffusion process begins when individuals get to know the innovation and, in order to reduce uncertainty, they start seeking information about it. Therefore, it is very important how they can access and obtain to such information from outside the farm (De Propris, 2000; Diederen, van Meijl and Wolters, 2002; Freel, 2000, 2004; Romijn and Albaladejo, 2002; Tether, 2002), as the beliefs and perceptions resulting from this searching process affect the decision to adopt or reject an innovation (Rama and Alfranca, 2003).

Other drivers that cannot be ignored are the characteristics of the entrepreneur, related to his skills (e.g. experience and education) and age, and the capability of the workforce, particularly in case of small agri-food firms (Avermaete *et al.*, 2004). Instead, large agri-food firms have a generally «more complex and often pluralistic decision-making structures» (Bamberger *et al.*, 1990).

From the first works of Schumpeter (1934;1942), much importance was recognized to the role of the entrepreneur which, more recently, has been re-emphasised in literature (Mascitelli, 2000). The age of the entrepreneur has been particularly explored within several studies, which definitely indicate that young farmers are more inclined to innovate (Avermaete *et al.*, 2002; Bamberger *et al.*, 1990; Diederen *et al.*, 2000). Also the experience and the educational background are very stressed factors within the literature (Avermaete *et al.*, 2004). Regarding the educational background, entrepreneurs with post school qualification have been assumed to be more innovative than the others.

Additionally, because of their limited capabilities or resources, small farms rarely innovate in isolation. So they need external resources and inputs to enhance innovations. This is why co-operation between firms and other institutes is another crucial aspect of innovation in this domain (Baardseth *et al.*, 1999)

Therefore, innovation in the agri-food sector is a complex process of development and change, affected by a number of variables, either related to patent application (De Propris, 2000) and firm’s orientation to the market, R&D (Grunert *et al.*, 2007) or technological change (Huiban and Bouhsina, 1998). Innovations due to technological change are enhanced by investment in the technological and scientific capabilities of the work force (Leiponen, 2000), although some authors argue that R&D investments in the agri-food sector are not so closely related to firms’ innovativeness as they are in other sectors (Rama, 2008). Instead, firm’s market orientation, defined as ‘*the detection and fulfilment of need and wants of potential customers using skills, resources and competence of the company*’ (Grunert *et al.* 1996; Avermaete *et al.*, 2004: 475) is able to reduce risks and chances of failure in the innovation adoption, although in the agri-food sector the fragmentation of the production system may affect the farms' capability to catch the opportunities offered by the market.

In the analysis of the innovation process, the greatest difficulty probably lies in the innovation's measurement at the firm, industry or national level (Ma and McSweeney, 2008). Indeed, as we have already argued, the innovation process takes very different paths from place to place, especially in the agri-food domain where the context and the environment highly affect all sides of business.

Another key element to consider is the role of the individual farmer in promoting innovation, although sometimes other actors in the food chain limit the decision power of the farmer. However, even when farmers appear to be sensitive to issues related to innovations, they often remain resistant to change, thus slowing down the spread of innovation.

Thus, the reasons of a failure can be many and diverse; indeed, several undisclosed perception and thoughts lie behind the adoption or rejection of the innovation, related to individual cultural, legal and social background.

In this perspective, in order to analyse innovation in general terms, and in the agri-food sector in particular, it becomes crucial to identify the key drivers that, according to the literature in the topic, are able to affect the innovation process. They have been grouped in four areas, following the scheme proposed by Klerx *et al.* (2012):

1. The institutional context where the innovation develops, where regulations, rules (written and unwritten), incentives and R&D investments greatly influence the whole process and all the individuals, corporations, institutions or even territory involved (Tebaldi and Elmslie, 2008).
2. The economic environment, which is both origin and consequence of the innovation process. The innovation process is facilitated in economic contexts where firms have commercial orientation and large size units, as they are more prepared to innovate than others (Rogers, 1983). At the same time, the result of the innovation diffusion can be directly and easily observed in terms of economic growth.
3. The social context, as innovation is the result of a process of sharing and interacting among the actors involved (e.g. private sector, public sector, scientific institutions and firms). Indeed, how they relate to each other is a crucial factor to foster or hinder the innovation process.

4. The technological environment, which is directly connected to the technological level of the actors involved and, as happens for the economic domain, is at the same time a starting point (firms' inherent inclination to innovation) and a result of the process.

Focusing more specifically on agricultural sector, farms' capacity to innovate is closely related to their performance, with the result of innovation playing the role of facilitator in the organizational and management processes (Crossan and Apaydin, 2010). Once again, the twofold meaning of innovation emerges: process on one side and result on the other. In agriculture, the most challenging issue for innovation analysis is related to the first issue: it is not the evaluation and description of the results of some invention, but rather the change of farms' management processes and farmers' habits due to the completion of the innovation process.

Moreover, the analysis of the possible consequences of the adoption of different types of innovation is strongly related to this discourse. Indeed, a product innovation will have very different consequences in terms of value added and impact on farm management than a process, or even more, an organizational innovation. In this regard, in the analysis of the innovation process in agriculture the specific production sector where the innovation arises and develops is not to be overlooked.

Starting from these general considerations about innovation in agriculture, several theoretical approaches have been proposed to drive its analysis. Some of them can be defined as social approaches explaining the diffusion of innovation by the communication dynamics occurring in the networks of the social system, as the case of the *Adoption and Diffusion theories* (Rogers, 1983), or by the key role played by the relationship between farmers and scientists, as the *Farming Systems Research*' case (Dedieu *et al.*, 2009, p. 109). The *Agricultural Knowledge and Information System* (AKIS) approach expands the boundaries of the analysis; indeed, an AKIS is defined as '*a set of agricultural organizations and/or people and the link and interaction between them engaged in such processes […] of knowledge and information with the purpose of working synergistically to support decision making, problem solving and innovation in a given country's agriculture or domain thereof*' (Röling, 1990:1). Finally, the *Agricultural Innovation System* (AIS), developed from the Lundvall (1992) *National Systems of Innovation,* emerged in the same period of AKIS; here, the crucial element is the role of institutions on learning processes, which also allows to distinguish AIS from AKIS (Hall *et al.*, 2006).

As it has already been said, the analysis of the innovation process in the agri-food domain is more complicated: literature is very fragmented and, moreover, a number of additional elements affect the development of the innovation process. In several papers the relevant role of the specific situation, actor or territorial area is highlighted. This means that each innovation process is discussed as a single case study, completely different from the others. As a consequence, satisfying theories able to explain, in a practical perspective, the emergence and diffusion of innovative processes in the agri-food sector are still lacking (Avolio *et al.*, 2014).

I.1.3 Mapping innovation in Italian agriculture

As we have already argued, innovation in the agri-food sector is a complex process which displays specific features compared to innovation in other domains. Indeed, in this sector, business is by definition rooted in place and the features, history and traditions of the area strongly affect any production activity.

Moreover, in Italy the situation seems to be even more complex than in other European countries. Despite being a country with a high agricultural vocation, some structural and cultural factors appear to affect the innovation process, e.g. farmers ageing, structural features of Italian agriculture and economic, social and institutional factors.

Furthermore, the dynamics observed are quite different among the different types of innovation and so the role of product, process, organization and marketing innovations may be very diverse as well. Product innovations related to agri-food often imply incremental improvements rather than radical innovations (Galizzi and Venturini, 2008; Grunert *et al.*, 1997), whereas food firms are mainly process innovation oriented (Archibugi *et al.*, 1991) as they often use technologies developed by upstream industries (Garcia Martinez and Burns, 1999).

Focusing at the farm level, in the last twenty years the innovation process has been highly affected by the turn from the industrial to the multifunctional model of farming, which is supposed to enhance different activities than the core agricultural ones. Indeed, many of the innovations are related with multifunctional activities and diversification. The issue is how to classify them in order to distinguish the specificities of their development processes and their different links with the context they are embedded in.

With the aim of studying the innovation diffusion process in Italian agriculture, from a general perspective and without focusing on any specific area or supply chain, in a previous study (Avolio *et al.*, 2014) a first attempt to organize the several and diverse innovation types that may apply at the farm level and their diffusion on a territorial base has been carried out. Data about all possible innovations held at the farm level have been collected from the last Italian agricultural census for the Italian 110 provinces (corresponding to the NUTS 3 European territorial units). Such data were classified according to the framework of the product-process-organization-marketing innovation in order to identify the product, process, organization and marketing innovation indicators (Table 1).

The result is a dataset of the quota of farms applying each of the 10 innovations types, for each Italian province with a very different range of data due to the inherent innovation types different characteristics. The construction of such indicators allowed to express the province's performance in terms of innovation diffusion considering the weighted distance of the single province with respect to the whole set of data[2]. The indicators range from 0 to 1: the higher the indicator, the higher the number of farms that innovate in the province.

As shown in Table 1, for product innovation, where only one indicator has been taken into the analysis, the I_{ix} indicator was considered as the total performance of the province while for the other innovations types, where three different innovations have been considered, a geometric aggregation among the indicators was needed[3].

The result is a composite indicator, still in the range from 0 to 1, where provinces with more innovative farms get higher values with respect to the others.

The overall output of the elaboration is therefore a dataset where to each Italian province is associated a product, process, organizational and marketing innovation indicator.

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[2] The indicators have been then calculated as: $I_{ix} = \frac{(a_{ix} - MIN_x)}{(MAX_x - MIN_x)}$
where: *i* = province; *x* = innovation; *a* = the share of farms of the *i* province showing the *x* innovation

[3] It has been opted for a geometric aggregation because a simple additive aggregation method would not have been very suitable due to the implications for the interpretation of weights and the implied full compensability, such that poor performance in some indicators can be compensated for by sufficiently high values in others (OECD, 2008).
The synthetic indicators for process, organizational and marketing innovation performance of the Italian provinces have been then calculated as

$$I_{ij} = \frac{\sqrt{(I_{ix_1})^2 + (I_{ix_2})^2 + (I_{ix_3})^2}}{\sqrt{3}}$$

Where: i = province; j = innovation type (process, organizational, marketing) including the x1, x2, x3 innovations; x1, x2, x3 = the three innovations included in the j innovation type

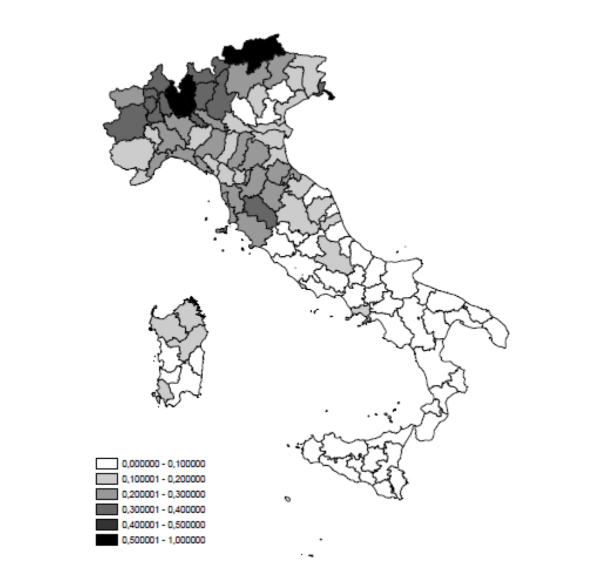
	ASPECT	DESCRIPTION	INDICATORS
Product	Incremental innovation	new varieties/product introduction	Number of farms developing at least one multifunctional activity*
		data not available	
	Multifunctionality	agri-tourism, recreational, social and educational activities, handcraft, in-farm processing of plant and livestock products, renewable energy production, aquaculture, off-farm contracting, gardening services, forestry, animal feed production	
	Diversification	data about farms performing more than one activities not available	
Process	Organic farming		number of farms with organic crops or livestock*
			number of farms with computerized crops management**
	ICT		number of companies with computerized livestock management***
Organization	ICT to manage farm accounting and/or relationships with suppliers.	to manage farm accounting	number of farms with computerized accounting*
		to manage relationships with suppliers	number of farms that purchase inputs from suppliers via e-commerce*
	Renewable energy plants	Photovoltaic, Biomass plant, etc	number of farms having placed renewable energy facilities*
Marketing	Farms' relationship with the market	ICT-Site web or e-commerce	Number of farms with a website*
		ICT- E-commerce	Number of farms selling their products through e-commerce
		Short food supply chain	Number of farms with an off-farm short marketing channel****

**expressed as a share of the total number of farms operating in the province*
***expressed as a share of the total number of farms with crops operating in the province*
****expressed as a share of the total number of livestock farms in the province*
*****expressed as a share of the total number of farms in the province that actually sell their products on the market*

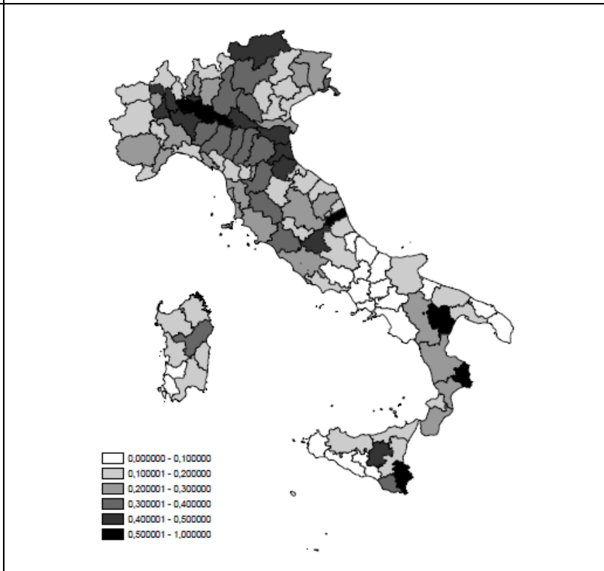
Table 1: Classification of data according to the framework of the product-process-organization-marketing innovation and definition of indicators (Istat 2011)

Finally, maps showing the incidence of such indicators have been then constructed in order to more easily display the possible differences in the innovation diffusion among the different Italian areas (Figure 3).

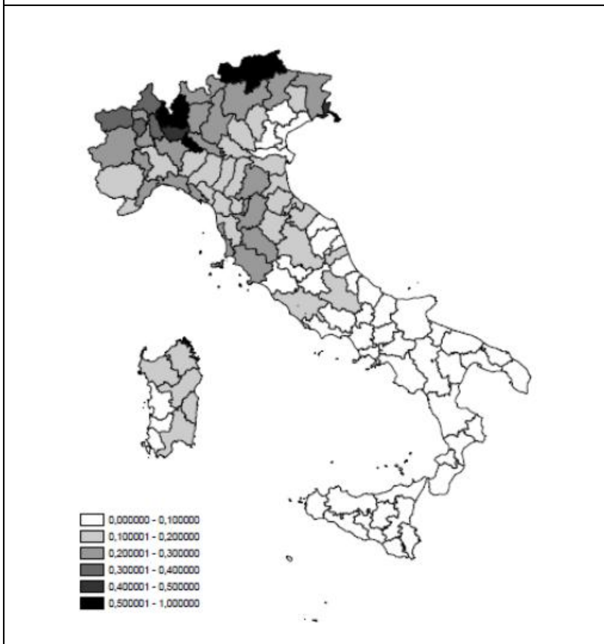
A) PRODUCT INNOVATION



B) PROCESS INNOVATION



C) ORGANIZATIONAL INNOVATION



D) MARKETING INNOVATION

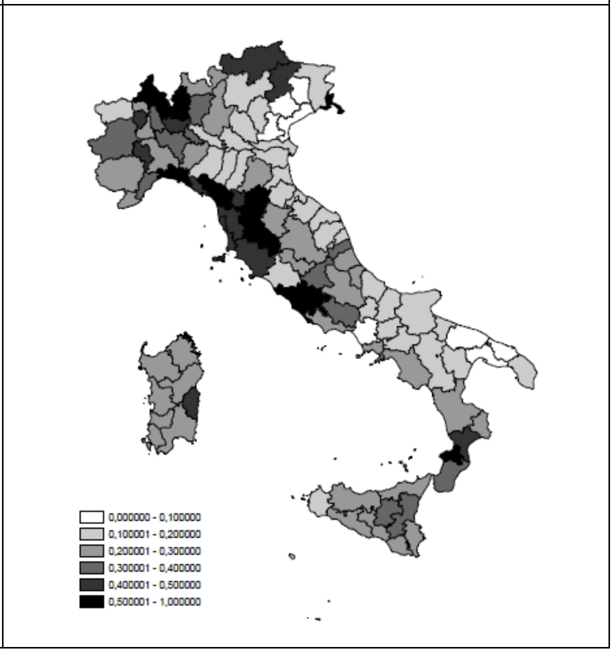


Figure 3: Maps of the product, process, organizational and marketing innovation

Some areas are characterized by a general diffusion of innovations but each typology of innovations shows different diffusion patterns.

Looking at the figure 3-A, product innovations are typical of the northern part of Italy, in particular in mountain areas near the Alps and in Tuscany, whereas most of the provinces located in the Centre and South do not show a notable diffusion of them. In the Alpine area this is probably due to the high diffusion of product processing at the farm, generally small, which allows providing the market finished typical products with a higher added value. Instead, the case of Tuscany can be explained with the development of rural tourism as a product innovation.[4]

Looking at the process innovations (Figure 3-B), the map shows a multi-coloured situation where the diffusion of this typology of innovation, more scattered along the country, seems to be a cross-cutting feature of the Italian territory. A higher concentration of process innovations can be found along the course of the Po river, in the western coast of central Italy as well as in some areas of the South. The intensive agriculture projected to the food industry and held in large farms and livestock presence explains the concentration of process innovations in the Po valley: products require a very tight control, which leads many farmers to adopt ICT in the management of the farm processes. Instead, the South Central areas, structurally more inclined to extensive agriculture, show the most widespread process innovations concern organic farming, which is very well suited to the structure of the farms in these areas which can more easily convert to organic farming. Under this perspective, the conversion to organic farming shows its nature of process innovation, with the aim of make farm processes more fitting with the structural features of the environment around the farm.

The map in Figure 3-C displays the organizational innovations diffusion, which is very similar to the product innovations, with some very coloured provinces in the very North of Italy. The incidence of wineries in this area may be considered one possible explanation because, unlike other Italian areas where vineyards are very widespread, Alpine and Tuscan farms have often an own winery, what makes the farm organization more complex, fostering ICT adoption for stock management. Moreover, the construction of renewable energy plants is almost absent in the South, despite the environmental characteristics of this area, which would inherently be very suited for solar energy exploitation.

Finally, the spatial distribution of marketing innovations (Figure 3-D) covers, here as well, the North areas, although a greater diffusion of marketing innovation can be observed in the South. In the North and in Tuscany marketing innovations are probably linked to the presence of multifunctional activities which often induces the farmer to approach the

[4] The area of Tuscany is a typical example of this situation, as more than 500,000 tourists, half of which from foreign countries, stay in the farm holidays of rural Tuscany (the area of Florence is not considered) every year, with a continuous increase over the years (Regione Toscana, 2008).

market in different ways, e.g. opening information and communication channels with potential customers and/or selling its product through the Alternative Food Networks (AFN). In the South, the presence of marketing innovations is particularly suited to the structure of the agricultural systems where the direct sale of many typical products[5] to the consumer is diffused.

By correlating the indicators values to each other, we can get some insights about the way different innovation types interact (Table 2).

	Product innovation indicator	Process innovation indicator	Organizational innovation indicator	Marketing innovation indicator
Product innovation indicator	1	,338**	,950**	,645**
Process innovation indicator	,338**	1	,440**	,187
Organizational innovation indicator	,950**	,440**	1	,635**
Marketing innovation indicator	,645**	,187	,635**	1
* *p<0.05*; ** *p<0.01*				

Table 2: Correlation matrix among the innovation indicators

Results show that, except for the relation between the process and marketing innovations, all indicators show significant and direct relations to each other. It means that, despite the territorial specificities that we have discussed, many of the provinces show a general tendency to innovate whereas other are characterized by a lower inclination to all the innovation types (for more details, see Avolio *et al.*, 2014).

The role of these qualitative elements can be more specifically evaluated in relation to more quantitative parameters linked to the economic and institutional environment.

The main institutional factor influencing the Italian agricultural system and the diffusion of innovations at the farm level is the European rural development policy which, through the regional Rural Development Programmes (RDP), implements specific interventions in order to fill local development gaps. The local expenditure for RDP interventions in the 2007-2009 years (just before the agricultural census) has been first divided into interventions categories, e.g. human capital measures, generational turnover, capital investments, food quality, environment, territorial measures such as diversification, quality

[5] Many of these products are accompanied typical geographical indication, if we consider that there are as much as 95 PDO in the region of southern Italy, Sicily and Sardinia, out of the 245 Italian PDO (EC, 2012)

of life and Leader approach (Camaioni and Sotte, 2009); then, in each province, it has been correlated with the innovation indicators, by calculating the average payment per farm at the province level (Table 3).

	Total expenditure	Human capital	Generational turnover	Capital investments	Food quality	Environ-ment	Territorial measures
Product innovation indicator	,175	,229*	,465**	,343**	-,084	,062	,263**
Process innovation indicator	,271**	,285**	,134	,248**	-,026	,169	,173
Organizational innovation indicator	,286**	,227*	,523**	,425**	-,089	,149	,293**
Marketing innovation indicator	,093	,043	,311**	,242*	-,230*	,018	,197*
Total expenditure	1	,177	,221*	,304**	-,110	,953**	,231*

* *p<0.05;* ** *p<0.01*

Table 3: Correlation matrix among innovation indicators and RDP local expenditure per farm

Results show a correlation between the total expenditure per farm and the process and organizational innovations. It means that, despite the type of measures activated, the more diffused process and organizational innovations, the higher expenditure in RDP programs. Thus, in these areas, there is a higher capacity of catching the funding opportunities offered by the institutional environment. The human capital expenditure has been found related to all the innovation types, except for the marketing innovation. Indeed, these measures are specifically intended to diffusion of knowledge, a crucial driver to foster innovations.

Instead, measures related to generational turnover are likely to result in innovations in the product, organizational and marketing domain. This is probably due to a cultural development which goes hand in hand with farmers being younger and more open-minded towards ICT, non-agricultural activities and a consumer-oriented approach to the market.

Capital investments are obviously connected to all types of innovations while interventions in food quality do not appear to be related to the development of innovations at the farm level.

RDP funding for environment and sustainable agriculture is not significantly related to any of the innovation type as well. However, the very high correlation found among this

intervention type and the total expenditure shows that it represents a significant quota of the payments to the farm, beyond the tendency to innovate typical of the different territories.
Finally, a positive significant correlation among the expenditure in RDP measures aimed at local development and the product/organizational innovation indicators has been found. Many of the interventions intended to rural development are actually connected to the development of rural tourism and bottom-up projects which grow within the network of rural actors. These kinds of projects are therefore likely to be related to the widening of the farms' offer on the market (especially for services) and an improved knowledge about how to more efficiently organize farm activities (for more details, see Avolio *et al.*, 2014).
Despite these primary results, the dilemma of the various and different interpretations concerning the study of the innovation process and diffusion still persists. Therefore, in order to overcome this dilemma, research in these topics needs to go on.

I.1.4 Characteristics of eco-innovation

The role of innovation, as a driver of economic and social progress at national level (macro) as well as a driver of business success and competitive advantage at firm level (micro), is totally clear nowadays (Jing and Jang, 2013). However, when countries want to move towards a more sustainable economic activity, in order to address current and future environmental problems and decreasing energy and resource consumption, promoting specific areas of innovation become necessary. This type of innovation is referred to a so-called eco-innovation (OECD, 2012).
The global green economic development made the green business model focus of all governments, entrepreneurs, organizations and consequently researchers (Jing and Jang, 2013). Indeed, from a practical point of view, institutions and individuals around the world are trying to address solutions for the commonly recognized global environmental problems (global warming, ozone depletion, water pollution, deforestation) (Cordano *et al.*, 2010). New ways to reduce water emissions, recycle waste, and find new energy sources, as well as protect the environment in general have being developed (Cheng and Shiu, 2012).
The general definition of innovation is neutral and open in all directions. As it has already been said in the previous paragraph, conventionally the Oslo-Manual of the OECD (1997) distinguishes innovation mainly between process, product and organizational

[6](Hemmelskamp, 1997) but no distinction is introduced between environmental and non-environmental innovations (Rennings, 2000). In 1999 the term environmental innovation (short: eco-innovation) has been used for the first time and it was defined as «*all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which develop new ideas, behaviour, products and processes, apply or introduce them and which contribute to a reduction of environmental burdens or to ecologically specified sustainability targets*» (Klemmer *et al.*, 1999).

In 2011, The "Green Growth Strategy" established by the OECD countries (OECD, 2011) underlined the key role of innovation and, especially, of the 'eco-innovation', a new concept defined as innovation in processes, practices, systems and products that, by producing benefits for the environment, contributes to an environmental sustainability improvement (Rennings, 2000) and, at the same time, increases overall system sustainability (Pujari, 2006).

Furthermore, two characteristics that distinguish the eco-innovation from the classical ''innovation'' have been highlighted (Cheng and Shiu, 2012): first, «*it is an innovation that reflects the concept's explicit emphasis on a reduction of environmental impact, whether such an effect is intended or not*» and second, «*it is not limited to innovation in products, processes and organizational methods, but also includes innovation in social and institutional structures*» (OECD, 2009: 13).

With the emerging importance of such issue, researchers addressed eco-innovation from different perspectives with some studies that identify factors driving eco-innovation and the performance outcomes arising from eco-innovation (Kammerer, 2009; Dangelico and Pujari, 2010), the dimensions of eco-innovation (Carillo-Hermosilla *et al.*, 2010) or others related to the measurement of eco-innovation (Arundel and Kemp, 2009).

Focusing on this third group of studies, there are practical and objective difficulties to assess the environmental impact of an innovation that could be local or global, intentional or unintentional with a high number of criteria able to evaluate it (Oltra, 2008). So, a more specified definition taking into this assessing problems suggests «*The production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other*

[6] According to the OECD definition, the marketing innovation is embedded within the product or organizational typology of innovation.

negative impacts of resources use (including energy use) compared to relevant alternatives» (MEI Report, 2008). This definition considers as environmental innovations every process or product more resource efficient and/or less polluting.

At macro level, many governments consider eco-innovation as part of their current growth strategy. Indeed, they see the possibility to conciliate economic and environmental goals opening new pathways for industry and, at the same time, limiting the effects of the big global challenges (the economic downturn, environmental degradation, and resource scarcity). Focusing on the European Union (EU), eco-innovation was seen as a key element, on one hand, to reach the important objectives of the Lisbon Strategy and, on the other, of the new Europe 2020 strategy (OECD, 2010).

Both academics and policy-makers of the European Commission highlighted the merit of eco-innovation (Kemp, 2009) in order to improve the beneficial environmental impact and, also, to increase the expected competitiveness of the firms and countries eco-innovators (Arundel and Kemp, 2009).

Indeed, at micro level, in recent years there was an effort by public policies (EU, 2010a; EU, 2010b; EU, 2011) and businesses to monitor and support eco-innovation practices in the agri-food sector, traditionally quite reluctant to innovation (Alonge and Martin, 1995; Abadi Ghadim and Pannell, 1999; Kühne *et al.*, 2010) because of the prevalence of small and medium-sized producers and low technological level, which is typical in case of production of low added value products (Karantininis *et al.*, 2010; Triguero *et al.*, 2013).

This attention to environmental and social implications of food sustainability and availability has encouraged many companies in the food sector to improve skills and increase resources to undertake more efficient innovative business. Jing and Jiang (2013) support the idea that the transformation towards a green economy strongly encourages eco-innovations. Similarly, a large and rapid diffusion of eco-innovation can induce a positive effect on the improvement of environmental, economic and social issues, thus promoting win-win synergies.

From the farmers' point of view, the main driver for green actions should be a strategy able to protect their production capacity and value (Tellarini and Caporali, 2000). Processors and wholesalers in the food chain try to give products explicit indications related to cultural issues, geographical origin and the environment, communicated through different declarations or green certifications (Kempa, 2013), with the aim to carve out market niches and to characterise their product on the market through some intangible cues. As a matter of

fact, combining best performance and lower environmental impact represents one of the most important strategic tools for businesses (Porter and van der Linde, 1995).
From a practical point of view, eco-innovations can be developed by firms or non-profit organizations, they can be traded on markets or not, their nature can be technological, organizational, social or institutional (Rennings, 2000). Environmental technological measures can be curative (e.g. soil decontamination) or preventive. As represented in figure 4, the preventive environmental protection measures can be integrated, referred to the product or process phases (inputs or production) (Hemmelskamp, 1997), or additive, frequently referred to as end-of pipe-technology (Figure 4). However only few papers distinguished between end-of-pipe-innovations and cleaner production while the majority analyzed eco-innovations in general (Horbach *et al.*, 2012).

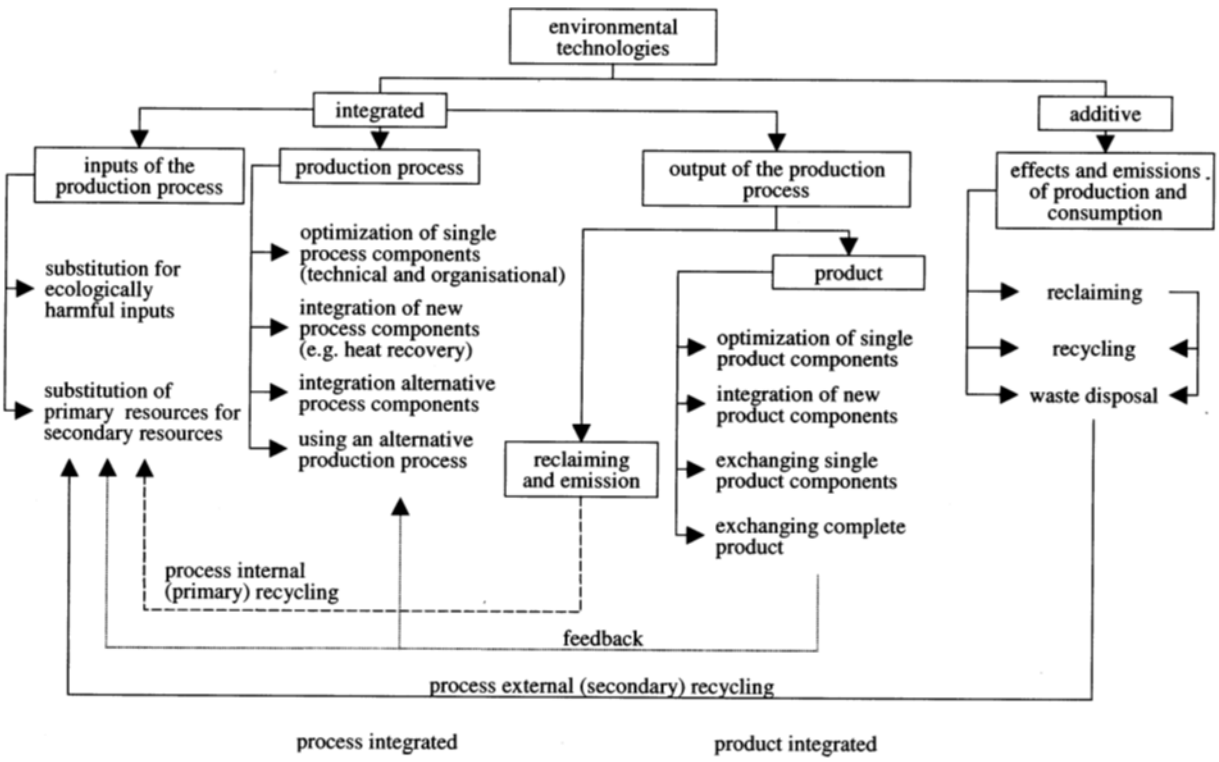


Figure 4: Preventive environmental technologies (Hohmeyer and Koschel 1995).

About the other typologies of eco-innovation, the organizational ones are, for example, management instruments at the firm level whereas lifestyles and consumer behavior are usually defined as social innovations (Scherhorn *et al.*, 1997, p. 16). Finally, the evolutions of all the incentives and regulations related to technological process can be distinguished as institutional measures. So, they are often seen as a basic foundation for a policy of sustainability (Freeman, 1992; Minsch, 1997). Obviously, the boundaries between categories of innovations are not so well-defined.

A crucial question is whether innovations toward sustainability can be treated as normal innovations or if a specific theory and policy are needed. Innovation aspects play a remarkable role to define strategies for sustainable development, also for national and international economic policies (Rennings, 2000).

As Rennings (2000) argued, the study of eco-innovation is borderline between two disciplines: environmental economics and innovation economics. In the first case an evaluation and internalization of negative external costs are developed, in the second positive spillovers of basic R&D efforts in firms are investigated.

In general, disciplines in the past did not pay so much attention to environmental innovation and, only more recently, researchers start to consider this issue as induced by regulation. Indeed, literature focuses more on the design and the implementation of the policy instruments, than on the explanation of the innovation process itself. Under the more diffused perspective, the main research questions, often addressed in quantitative terms and aiming for evaluate which policy instrument incentive more to innovate, became: how much the different environmental policy instruments effects upon innovation? (Oltra 2008). That is the reason why a complete illustration of the innovation process is still missing.

I.1.5 Determinants of eco-innovation, double externality problem and regulatory push-pull effect

This paragraph focuses on three different but strictly related aspect of eco-innovation: the drivers of eco-innovation, the double externality problem and the regulatory push-pull effect.

Many researchers have worked on the identification of the determinants of eco-innovations (Oltra, 2008; del Rio Gonzalez, 2009; Kesidou and Demirel, 2012; Triguero *et al.*, 2013; Noppers er al., 2015; Bossle *et al.*, 2016; del Rio *et al.*, 2016; Hojnik and Ruzzier, 2016; Horbach, 2016;). Some remarks from Oltra (2008) have been summarized in the table of Figure 5. The importance of technological and organizational capabilities, e.g. the environmental management systems (EMS), has been argued by some authors (Horbach, 2008; Wagner, 2007; Bossle *et al.*, 2016; del Rio *et al.*, 2016; Hojnik and Ruzzier, 2016) and, in general, many others, tried to identify determinants at the demand or supply side. But most of the traditional literature about drivers of eco-innovations focuses principally on the role of regulation (Oltra, 2008; Bossle *et al.*, 2016; del Rio *et al.*, 2016; Hojnik and Ruzzier, 2016;) and standards aiming to fight firms' pollution activities (Magat, 1979; Malueg, 1989; Milliman and Prince, 1989) enhancing investments in eco-innovations (Brunnermeier and Cohen, 2003).

Regulation and policy determinants	Implementation of environmental policy instruments: economic and regulatory instruments Existence and anticipation of environmental regulations Regulatory design: stringency, flexibility, time frame
Supply side determinants	Cost savings, productivity improvements Organizational innovations: environmental management systems, extended producer responsibility R&D activities Industrial relationships, supply chain pressure, networking activities
Demand side determinants	Environmental consciousness and consumers' preferences for environmentally friendly products Expected increase in market share or penetration of new market segments

Figure 5: Determinants of Environmental Innovation (Oltra, 2008)

Starting from the external factors (Bossle *et al.*, 2016), regulation is a stimulator to achieve first-mover advantages in markets for firms and not an undesirable cost-increasing factor (Porter, 1991; Porter and Van der Linde, 1995a, b). Furthermore, less innovative firms seem to adopt eco-innovation as a means to reduce production costs and comply with the minimum environmental standards, whilst the more innovative adopt it in order to enter new markets (Grubb and Ulph, 2002). Therefore, the effectiveness of regulations for firms could potentially differ depending on the heterogeneous capabilities of firms and their strategies to innovate (Kesidou and Demirel, 2012).

Recent empirical studies emphasize the perception of stringency by regulated firms (Frondel and al., 2007; Huang *et al.*, 2009) as the key determinant of the innovative response of firms. Others consider the regulatory design as a key factor that may influence the firms' innovative decision because of its characteristics of stringency, flexibility and limiting uncertainty (Bergquist and Soderholm, 2011; Huber, 2008). Some years before, Ashford and al. (1985) argued that the influence of regulation depends on the regulatory instruments and on the way it is implemented.

In conclusion, regulation appears as a predominant driver within literature (Bossle *et al.*, 2016) and many references seem to support the positive correlation with environmental innovation. Nonetheless environmental innovations adoptions cannot be considered as a systematic answer to the regulatory framework. Indeed, as mentioned before, there are other factors linked to market conditions which could determine the technological response of firms (Paraschiv *et al.*, 2012).

Although market forces have been generally considered insufficient incentives to innovation because consumers' willingness to pay for environmental improvements would be in any case too low (Rennings, 2000), there are several researches that study the environmental pressure coming from consumers (Arnold and Hockerts, 2011; Beise and Rennings, 2005; Gauthier and Wooldridge, 2012). Corporate social responsibility (CSR) literature suggest that the societal pressure and demand for environmentally friendly products and processes may be limited to initiate a minimum investment in eco-innovation and not necessarily to increase eco-investments (Suchman, 1995; Bansal and Hunter, 2003; Potoski and Prakash, 2003; Darnall, 2006). Others indicate that demand factors in general (Horbach, 2008) and collaboration with environmental easy moved stakeholders (Wagner, 2007; Verghese and Lewis, 2007; Carrillo-Hermosilla *et al.*, 2010; Geffen and Rothenberg, 2000;) such as firms (De Marchi, 2012; Horbach, 2008), customers, distributors, suppliers (Buttol *et al.*, 2012; Green *et al.*, 1994) and universities (Cainelli *et al.*, 2012), play an important role. In general, both customer demands and public pressure are fundamental drivers of eco-innovation (Florida, 1996; Popp and al., 2007; Horbach, 2008) but evaluate how consumers esteem the environmental characteristics of products remains very difficult.

Finally, the role of traditional supply side determinants of innovations (e.g. R&D activities, supply chain pressures, networking activities, etc.) has not been so much considered (Oltra 2008). Indeed, as Bossle *et al.* (2016) argued, internal factor are fundamental related to efficiency, by cost reduction, equipment update, investment in R&D or certifications (Green *et al.*, 1994; Demirel and Kesidou, 2011; Horbach, 2008; Horbach *et al.*, 2012); environmental capability and environmental managerial concerns, including environmental leadership (Chen *et al.*, 2012; Eiadat *et al.*, 2008); quality of human resources, including training and participation in sustainability programmes (Green *et al.*, 1994; Weng and Lin, 2011); and environmental strategy, including the culture of the firm.

In conclusion, environmental innovations, as innovation in general, seems driven by the classical set of drivers and, specifically, in spite of the controversies, is linked to the determining role of regulation (Rennings, 2000).

Trying to summarize all these considerations, in 2013, Triguero *et al.*, conducted a study with the aim to explore the drivers of eco-innovation in European SMEs drawing upon a database of 27 European countries. Results show that:

- in the case of eco-product innovation, entrepreneurs who consider collaboration with research institutes, agencies and universities and the increase of market demand for green products as important factors, are more active in all types of eco-innovations;
- supply-side factors seem to be the more important drivers for environmental processes and organizational innovations;
- market share has a significant positive influence on eco-product and eco-organizational innovations, while cost-savings are significant for eco-process innovations;
- eco-product and eco-organizational innovations seems to be influenced by the existing regulations;
- expected regulations, access to subsidies and fiscal incentives do not have any significant effect on the adoption of eco-innovation (Triguero *et al.*, 2013).

The important role of regulation is also explained by its strictly relation with the so-called "double externality" problem. It occurs because the eco-innovation produces positive spillovers in both the research/innovation phase and the diffusion phase. The diffusion phase of the eco-innovation, always socially beneficial, creates to the firms the problem to invest since the private return is less than the social one. In other words, the double externality problem reduces the incentives for firms to invest in environmental R&D and innovation (Rennings, 2000; Oltra 2008). In order to mitigate the double externality problem, «*environmental policy and innovation policy should be co-ordinated. Innovation policy can help to cut the costs of technological, institutional and social innovation, especially in the phases of invention and market introduction, e.g. by financial support for pilot projects, and in the diffusion phase it may help to improve the performance characteristics of eco-innovations. At least in the diffusion phase, however, environmental policy is responsible for internalizing external costs imposed by competing, non-ecological products or services. As long as markets do not punish environmental harmful impacts, competition between environmental and non-environmental innovation is distorted*» (Rennings, 2000: 326).

This is the reason that justifies the needs of policy instruments and of the "regulatory push-pull" effect (Figure 6), as defined by Rennings (2000). Here, the author combined the already cited important role of the regulatory framework with one of the main discussion within the innovation economics literature on which drivers foster technological innovation, the technological development (technology push) or the demand factors (market pull).

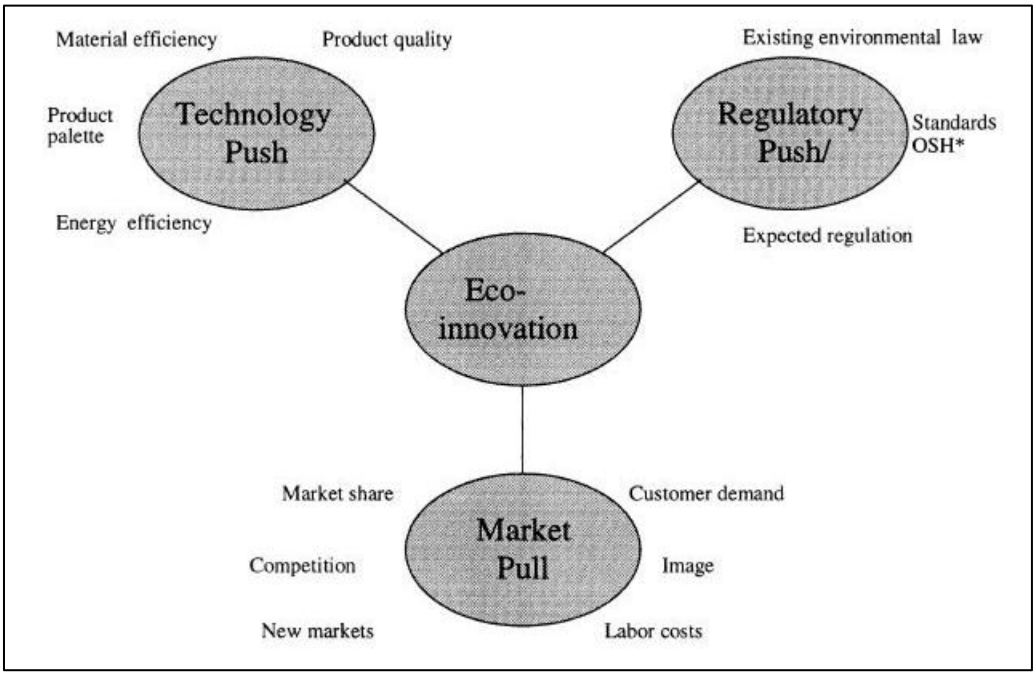


Figure 6: Determinants of eco-innovation - Regulatory push/pull-effect (Renning, 2000)

Actually, empirical evidences show they are both relevant (Pavitt, 1984). Indeed, in the case of eco-innovation, for example, some new eco-efficient technologies could be attributed to the technology push area whereas preferences for environmentally friendly products to the market pull area.

At the end, the framework represented in Figure 6 shows the determinants of eco-innovation. Indeed, the regulatory framework, and the environmental policy especially, have a very strong impact (Green *et al.*, 1994; Porter and van der Linde, 1995a, b; Kemp, 1997; Faucheux and Nicolai, 1998) compare to the technology push and market pull that alone do not seem to be strong enough. Cleff and Rennings (1999a, b), analyzing the different factor influencing eco-innovations' adoptions, found that the eco-innovative firms give much importance to the goals of cost reduction and total quality management (TQM). Furthermore, they differ between eco-product innovation and eco-process innovation: the first one driven by the strategic market behavior of firms while the second one by regulation. Also, the influence of eco-labels and the so-called "soft" regulatory instruments enabling the use of the environmental performance in the firm marketing strategies can be found. Therefore, the less/non-innovative firms seem to be more dependent on hard state regulation while "soft" measures may be sufficient for the environmentally innovative ones (Rennings, 2000).

Nowadays, from a practical point of view, it is quite clear that environmental innovations are not a simple and systematic response to environmental regulation, but should be considered as the result of a complex and interactive process (Oltra, 2008).

Indeed, from the combination of some elements of the approaches we mentioned before, e.g. neoclassical (and regulatory push/pull effect) and co-evolutionary approach, a third discipline postulating that «*important success factors are a mix of instruments, strong economic incentives, strategic planning and a consideration of the different phases of the innovation process*» (Rennings 2000: 330), took place.

Blazejczak *et al.* (1999) identified a so-called 'policy style' concerning three factors that positively affect an innovation-oriented environmental policy: instruments, policy styles and actor constellation. In this perspective, calculable goals combined with flexible mean are important elements to foster innovation. About the actor constellations, it «*should include inter- and intra-policy integration, co-ordination between regulators and target group and between stakeholders along the production chain*» (Rennings, 2000:330).

Concluding, when the innovation process is not assumed as random of unpredictable, the neoclassical theory is preferable for the research. Indeed, it explains the double externality problem and the regulatory push/pull effect. Instead, the co-evolutionary approach has been successfully used to explain the interaction between the ecological, social and institutional systems.

In general, both frameworks must be more opened toward the whole ecological systems and to the social and institutional ones. Also, the innovation policy should open up the technological definition of innovation to all kind of change, e.g. organizational, behavioral and institutional.

While research programs and projects are already going on, theoretical and methodological approaches for their evaluation seems to be still missing, or not completely satisfying in a perspective of social and institutional applications, above all. Indeed, eco-innovation policy requires constantly incentives in order to implement the coordination between research and environmental policy. In this panorama, and in the classical innovation study too, theoretical approaches are required, as well as data, to correctly evaluate the incidence of eco-innovation at different scale (Rennings, 2000).

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I.2 The case study of eco-innovation in agriculture

I.2.1 Sustainable intensification and precision agriculture

Going on the line just defined by the eco-innovation, agriculture in the course of time always satisfied major human needs affecting and depending on all other life support systems. Indeed, the increasing human population and the consequent growing global demand for food are the main challenges which must be addressed in a world with a potentially dramatically changing climate (Tilman *et al.*, 2011; Tscharntke *et al.*, 2012; Ahmadi *et al.*, 2015).

Such challenges need a new evaluation about the capacity to increase food production, without damaging the environment and ecosystem services (Ahmadi *et al.*, 2015). The question to answer is whether the capacity of agriculture to meet food needs will not impact on the environmental integrity of local landscapes and the global environment.

Traditional agricultural practices rarely focused on the concept of optimal efficiency, either in terms of maximal yield and minimal production. Therefore, in order to avoid risks, inputs such as fertilizer and pesticides are uniformly applied over the whole farm (Khanna *et al.* 1999). The consequence is that over-application of fertilizers and pesticides generates negative effects on resource quality (e.g. soil and water) and, in turn, on plants, ecosystems, economy and population. In general, these practices involve serious implications on sustainability and food security (Sheng Tey and Brindal, 2012). This is the reason why an agricultural managerial change is required and stressed by those external entities, such as governments and public institutions, with provisions and restrictions in the use of production input and incentives for engage a sustainable production. Consequently, this change of direction needs the introduction of advanced activities of monitoring systems and information technologies to respect restrictions and standards in terms of specific production guidelines, provisions for environmental conformity and management standards (Sorensen *et al.*, 2010). From a solely focus on quantity it must moves to a complete focus on quantity, quality and sustainability (Halberg, 2001).

Such problems led to the so-called sustainable intensification (SI) approach promoted by some researchers and politicians (Pretty *et al.*, 2011; Tilman *et al.*, 2011; Garnett *et al.*, 2013) but contested by others (Reed, 2012; Kuyper and Struik, 2014; Loos *et al.*, 2014). It is a multifaceted concept which yearn for maintaining, and possibly increasing, the current level of agricultural yields and, at the same time, reducing negative ecological and environmental impacts. To do so, the SI approach considers many and different production methods and technologies and it also works to alter the consumption patterns (Ahmadi *et al.*, 2015). Godfray and Garnett (2014) listed the SI key criteria which implementation must be supported and promoted by adequate agricultural, ecological and environmental policies and regulations: (i) maintain or increase yield; (ii) maintain or reduce land use; (iii) reduce negative environmental and ecological externalities; (iv) consider and use all forms of agriculture without prejudice.

Nowadays the more innovative agronomic practices are focusing on such SI with the aim to, as it has already been said, produce more food from the same area of land reducing at the same time the environmental impacts (FAO, Food and Agriculture Organization of the United Nations 2011). Indeed, an ecological approach to agriculture where both crop and livestock production systems must be managed as ecosystems, with informed management decisions of environmental costs and benefits, is necessary. Such approach will consequently require integrative ecological and socioeconomic research, as well as policy innovation and public education. The main goal is «*to produce sufficient food and fiber for a growing global population at an acceptable environmental cost*» (Robertson and Swinton, 2005: 38). As a human enterprise, agriculture is influenced by market forces, social and economic policy, and human values. Thus, the future environmental impact of agriculture depends on how we manage both the social and ecological elements of agricultural ecosystems (Tilman *et al.*, 2002).

In this panorama, precision agriculture (PA) strategies, promoting the integration of different modern technologies which, either used singly or in combination (Sheng Tey and Brindal, 2012), can help to reduce both costs and ecological impacts in agricultural production (Gebbers and Adamchuk 2010). PA is a term introduced about two decades ago (Sheng Tey and Brindal, 2012) and used to define a set of technologies promoting an improved management of agricultural production aware that «*the potential productivity of agricultural land can vary considerably, even over very short distances*» (Bramley, 2009: 197).

The PA and its technological key instruments (e.g. global positioning systems - GPS, geographical information systems - GIS, crop yield monitors, remote sensing, etc) were the answer to the recognition that lands are variable (Cook and Bramley, 1998; Pierce and Nowak, 1999; Robert, 2002; Srinivasan, 2006; Robertson *et al.* 2012): each soil particle is different from the other, as well is for each field, farming region and countries. Indeed, soil properties, rooting depth, nutrition, agronomic management, and the interaction of these factors with climate (Runge and Hons, 1999) strongly influence the crop production and the agricultural productivity of land (Bramley, 2009).

A generic definition of PA involving both space and time consideration could be: «*that kind of agriculture that increases the number of (correct) decisions per unit area of land per unit time with associated net benefits*» (McBratney *et al.*, 2005: 8). Such definition does not imply a particular technology or set of technologies: it could be applied to electronic sensors (GPS, GIS, VRT etc.) but also to humans. The associated benefits of such practices entail an increase in quantity and/or quality of production and, simultaneously, of the environment effect with the same or less inputs (McBratney *et al.*, 2005). As shown in figure 7, the PA approach involves a continuous and cyclical process of observation, evaluation and interpretation aiming to develop a calibrated management plan supported by a second phase of observation. In this way, the right crop management strategies are implemented in the right place at the right time.

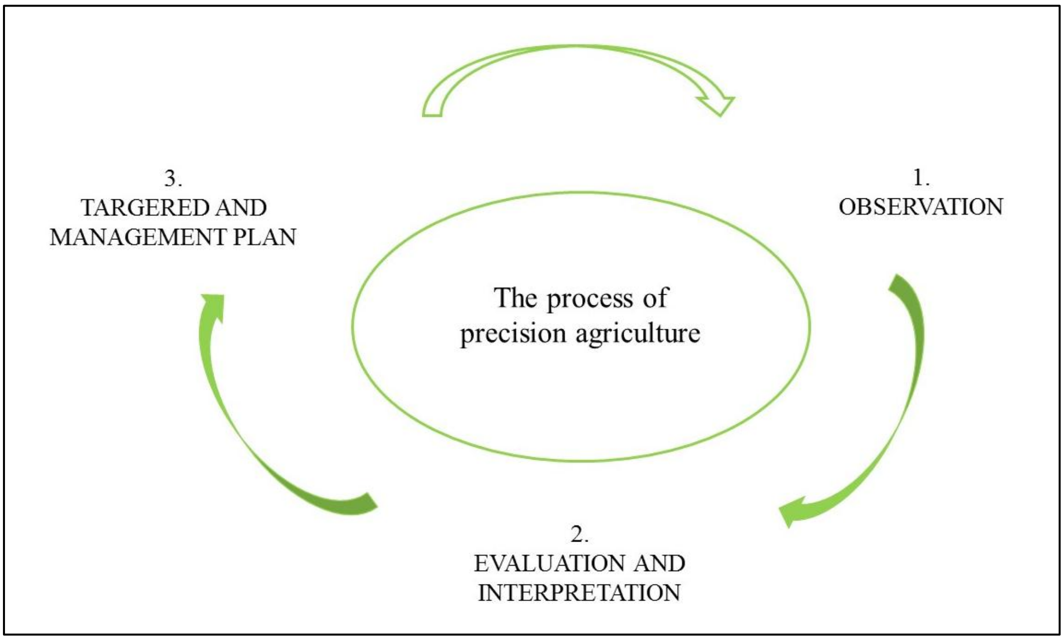


Figure 7: The process of precision agriculture (own elaboration of Bramley and Hamilton, 2005)

Over the years, PA has changed from a simple "farming by soil" (Robert, 1993), through variable technologies, to vehicle guidance systems and, finally, to product quality and environmental management. The degree of development, and consequently the focus, varies throughout the world (Bramley *et al.*, 2005). Nevertheless, there are numerous examples of successful applications of PA from different countries, often supported by a burgeoning literature (Bramley, 2009). In Griffin and Lowenberg-DeBoer (2005) a list of different kind of utilization of PA around the world was conducted: it has been used by growers of corn (maize), soybeans, potatoes, wheat, sugar beet, barley, sorghum, cotton, oats, and rice. Also in the production of winegrapes (e.g. Bramley *et al.* 2005*b*; Proffitt *et al.* 2006), citrus (Zaman and Schumann 2005, 2006), bananas (Stoorvogel and Bouma 2005), tea and date palms (Blackmore 2003), tobacco and olives (Blackmore *et al.* 2006), tomatoes (Lee *et al.* 1999; Zhang *et al.* 2005; Fig. 1*b*), apples (Praat *et al.* 2001), kiwifruit (Praat *et al.* 2007), and sugarcane (Bramley *et al.* 1997; Bramley and Quabba 2001) significant advances have been made. The application of PA to the site-specific management of weeds has been used in a range of crops (Gerhards and Christensen 2006), while PA approaches to disease management are also being explored (e.g. Heap and McKay 2005). It has been also used to assist the management of sporting venues (Smith, cited by Blackmore 2003) and railway lines (Antuniassi *et al.* 2004).

However, in the past, the PA rate of adoption by growers of many crops remained low and, in some industries, was negligible: farmers were aware about the variability of their fields, but the lack of practical tools able to quantify or manage this changeability lead them to manage crops on the basis of homogeneity (Cook and Bramley, 1998). Indeed, they seem to be perceivable to sustainable practices and aware about the negative impact of traditional agriculture but also of their role within the general environmental safety (Alonge and Martin, 1995; Blasi *et al.*, 2015).

Nevertheless, farmers remain generally quite reluctant to changes and innovation. Indeed, as PA is mostly based on information technology, high levels of machinery and computer knowledge, for farmers it refers to an increase in economic resources as ‘input’ of, for example, training time (Galindo *et al.*, 2012) and implementation costs (Booltink *et al.* 2001). This is the reason why the use of the latest technology in PA is not as widespread as believed (Lamb *et al.* 2008). In particular, in Southern Europe, its use is not so developed because of small farm size (Fountas *et al.* 2010); indeed, PA is more feasible when the farmland is larger (Roberts *et al.* 2004).

The implementation of PA techniques implies some changes for farmers which move, in general, towards a more targeted management (McBratney and Pringle, 1999) in a manner which increases profitability and reduces environmental destruction (Fountas *et al.* 2005).

The inherent variability of land (e.g. topography, soil properties) leads also to a variation in the input-output relationships, where they have to precisely match each other, and in its potential productivity (McBratney and Pringle, 1999). Thus, in a practical way, the adoption of PA aims to help farmers in their decision (McBratney *et al.*, 2005*b*) reaching their expected outcome through the targeting of inputs (Cook and Bramley 1998) - and not only fertilisers - e.g. irrigation water, pesticides, herbicides, labour, timing of operations, selectively harvesting outputs, etc. (Bramley *et al.* 2005*b*; Proffitt *et al.* 2006; Daberkow and McBride 1998). Such decisions have the potential to boost the efficient use of resources, reducing input costs and minimizing environmental degradation and, at the same time, they would improve yield and crop quality (Sheng Tey and Brindal, 2012).

About drivers of PA, some authors investigated the main for adoption in US, which have been cost efficiencies, due to the variable rate application of fertilizers and other soil amendments (Godwin *et al.* 2003; Lowenberg-DeBoer 2003; Doerge 2005), in particular with respect to the maximization of yield (Blackmore *et al.* 2006). Instead, the potential use of PA as a tool for reducing the negative environmental impact of agricultural production (Lowenberg-DeBoer 2003; Stoorvogel and Bouma 2005; Blackmore *et al.* 2006) is the main important reason for European farmers. Moreover, PA allows farmers to be more easily conformed to legal restrictions on the use of agrochemicals (Stoorvogel and Bouma, 2005).

In general, Sheng Tey and Brindal (2012) investigated the factor, which seems affect the adoptive decision making of PA technologies (Figure n. 8). They found 34 significant factors which can be grouped within seven categories: (1) socioeconomic factors, (2) agro-ecological factors, (3) institutional factors, (4) informational factors, (5) farmer perception, (6) behavioral factors and (7) technological factors.

As it has already been said, the main goal of PA is to boost economic efficiency on farm activities and, at the same time, to offer environmental protection. Therefore, the specific benefits of PA are an increasing profitability, crop quality and yield and a reducing environmental impact (Sheng Tey and Brindal, 2012).

About the profitability, it has been criticized by some authors in their early studies (e.g. Swinton and Lowenberg-DeBoer 1998): they argued that in some cropping systems, even large deviations of agricultural decision can make little difference to the final profit (Pannell 2006). Godwin *et al.* (2003), in a study conducted on the UK cereal production, demonstrated that farm size, costs of PA equipment, the yield increase required to offset these costs and their interaction, influence the benefits of adopting PA. Furthermore, these results can be attributed to technical and investment factors.

Categories	Variables	
Socio-economic factors	Operator age	Formal education
	Years of farming experience	
Agro-ecological factors	Land tenure	Part-owner farmers
	Farm specialization	Full-owner farmers
	Farm size	Farm income/profitability
	Farm sales	Soil quality
	Variable fertilizer rates	Percentage of main crop in total farmland
	Livestock sales	Percentage of farmland as county land area
	Debt-to-asset ratio	Percentage of cropped land to total farmland
	Production value	Percentage of farmland as large farms
	Owned land minus rented land	Off-farm employment
	Yield	
Institutional factors	Distance from a fertilizer dealer	Use of forward contract
	Region	Development pressure
Informational factors	Use consultant	Perceived usefulness of extension services in implementing precision farming practices
Farmer perception	Perceived profitability of using precision agriculture	
Behavioral factors	Willingness to adopt variable-rate technology	
Technological factors	Yield mapping	Farm has irrigation facility
	Use of computer	Generated own map-based input prescription

Figure 8: Significant factors influencing the adoption of PA technologies (Sheng Tey and Brindal, 2012)

Indeed, besides sophisticated knowledge, PA also involve a complex process of data management, interpretation and decision making (Robertson *et al.* 2012). However, many studies demonstrated the economic and ecological superiorities of PA technologies (Silva *et al.* 2007; Sylvester-Bradley *et al.* 1999; Takacs-Gyorgy 2008). Indeed, such technologies have been widely discussed in literature (e.g. Cook and Bramley 1998; Pierce and Nowak 1999; McBratney *et al.* 2005*b*; Srinivasan, 2006; Sheng Tey and Brindal, 2012) and, in the last 25 years, they have advanced but the potential has not been exploited yet (Behmann *et al.*, 2015).

I.2.2 Farming system and Decision Support Systems (DSSs)

In the PA perspective, also the role of the Farming systems must be considered. They can be declined into two components, «*namely the biophysical production system of crops, pastures, animals, soil and climate, together with certain physical inputs and outputs, and* *the 'Management System', made up of people, values, goals, knowledge, resources, monitoring opportunities, and decision making*» (Keating and McCown, 2001: 555).

Nowadays, the main goal of the modern agricultural crop production is to develop less intensive and integrated farming systems reducing both inputs of fertilizers and pesticides and use of natural resources (water, soil, energy). These systems aim to reach three objectives which are prerequisites for sustainable agriculture (Geng *et al.*, 1990; Jordan and Hutcheon, 1996):

- improve crop production both in quantitative and qualitative terms;
- improve farm income;
- reduce negative environmental impacts as much as possible.

In this perspective, the concepts of Integrated Crop Management (ICM) or Integrated Production (IP) (Boller *et al.*, 2004) and Integrated Farming (IF) (EISA, 2001) have been developed (Figure 9). From a holistic point of view, they involve all farming and cropping activities shaped into the individual farm (Rossi *et al.*, 2012). Indeed, the Integrated Production, which addresses to solve all crop cultivation problems (e.g. soil management, fertilization and irrigation), is embedded within the Integrated Farming, which focuses on the entire farm management cycle (including animal welfare, energy procurement, landscape management).

In the past, several authors provided different conceptual models of the farm and Keating and McCown (2001) recognize six types of systems of analysis and intervention which have been used in farming systems: economic decision analysis based on production functions, dynamic simulation of production processes, economic decision analysis linked to biophysical simulation, decision support systems, expert systems, and simulation-aided discussions about management in an action research paradigm.

Keeping the focus on the Integrated Production sphere (Figure 9), the tool that is considered in this dissertation is the Decision Support System (DSS). Helping farmers in their operational decisions, such tool aims to improve the control of input variables such as fertilizer, seed, chemicals or water in order to increase profitability, product quality and, in particular, to reduce environmental risk (Cook and Bramley, 1998).

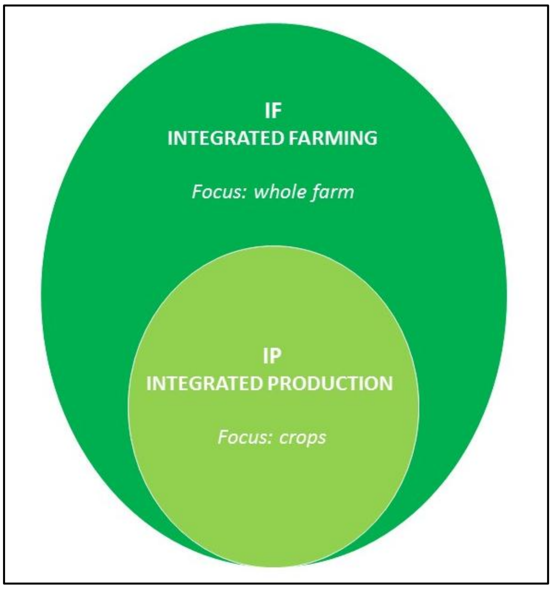


Figure 9: Integrated Farming and Integrated Production (own representation of Rossi *et al.*, 2012)

Applying the DSS approach to the four key issues of the SI listed in the previous chapter (Godfray and Garnett, 2014; Ahmadi *et al.*, 2015):

(i) Maintaining or increasing yield (intensification aspect): in order to improve the management of crops and livestock and to reach higher yield, DSS alerts farmers with control of diseases and short and long term optimum management;

(ii) Maintaining or reducing use of land (intensification aspect): DSS and its mechanistic models could provide some recommendations about the impact of reducing available land on production;

(iii) Reducing the environmental and ecological impact (sustainability aspect): it can be considered as the central object of the agricultural system proposed by this model;

(iv) Utilizing all kind of technology without prejudice (intensification and sustainability aspects): perceptions and goals of farmers with respect to using any particular technologies able to reach the previous key issues could be analyzed and included in such models.

DSSs originally born in the field of Management Science and its concept was articulated by Keen (1987): it «*meshes human judgement and the power of computer technology in ways that can improve the effectiveness of decision makers, without intruding on their autonomy. Traditional DSS provides a computerized [proxy for a] staff assistant. The manager's judgement selects alternatives and assesses results. 'What if?' became the cliché of the DSS field* » (Keen, 1987: p. 257). The autonomy, which Keen refers, is respected because the DSS resides on the farmer's personal computer.

From an innovation studies perspective, the DSS brought the convergence of two radical innovations for management practice: the first one, more recent familiar and obvious, is the technological innovation centered on the electronic computer. It has merged gradually with a social innovation, the second one, which took place much earlier based on the notion that management practices could be scientifically designed (McCown, 2002). Indeed, also the definitions of the 'Decision Support System' makes explicit the socio-technological nature of the DSS: it emphasizes, on one hand, the nature of the 'Decisions' and method of 'Support' and, on the other, the 'System' technology (Keen, 1987).

From a practical point of view, they are provided by public or private institutions and they can support multiple options for delivering information to farmers operating at different spatial and time scales and on different communication modes in order to support farmers in their decision-making activities (Rossi *et al.*, 2012).

About the decision-making, namely the mental process where the selection among several alternative solutions produces a final choice (March, 1994), there are different typologies of decisions which farmers must face. Indeed, some authors distinguished between strategic, tactical and operational management problems which operate at different temporal and spatial scale (Rabbinge *et al.*, 1993). While strategic decisions usually involve many years both at the farm level (e.g. crop rotation) and the crop level (e.g. the variety sown), tactical management decisions are made day by day in response to what is happening at the crop level and, finally, operational decisions involve a fast response to unpredicted events at crop level (Rossi *et al.*, 2012). Because modern agriculture has increased in complexity (McCown, 2002b), farmers must improve their skills and their managerial and business planning capacity in order to ensure a correct decision-making process.

Farmers usually employ a heuristic management and their decision-making processes are tacit knowledge based (Nuthall, 2006; Eastwood and Kenny, 2009). In general, the whole knowledge process is based on both tacit and explicit forms: explicit knowledge, which is based on theory and is more objective (Nonaka, 1994), and tacit knowledge, which is context-specific and often used in an intuitive way (Hoffmann *et al.*, 2007). The first one can also be exchanged with others following an externalization process whereas the tacit one, as it is stored by the learner as a memory, follow the reverse internalization process (Eastwood *et al.*, 2012).

Starting from these concepts, the first problem faced by farmers using DSS has been identified: the misalignment between a structured, data-based, and explicit-knowledge driven model of agricultural DSSs in precision farming and the tacit-based approach of farmers (Heijting *et al.*, 2010). An additional consideration is that the increasing use of computers and internet improved the way to processing internal information as well as acquiring external information since information are available from many sources (Sorensen *et al.*, 2010). This is the reason why the use of a DSS represents a new phase in the evolution of farm management.

Furthermore, DSSs can play differing roles depending upon the stage at which they are applied (Eastwood *et al.*, 2012). Indeed, Harsh *et al.* (1981) proposed four stages of information: descriptive ('what is'), diagnostic ('what is wrong'), predictive ('what if'), and prescriptive ('what ought to be'). In particular, it is at the predictive-prescriptive phase (Harsh *et al.* 1981) that technology and farmers truly interact in precision farming systems requiring for farmers a new way of operating. The last phase, finally, is the most difficult to model using DSSs because it needs most understanding of system interactions.

In general, with only few exceptions, agricultural modellers did not give interest to the theory of decision support systems (McCown, 2002) and complaints about an insufficient adoption rate have been numerous (Kulmann and Brodersen, 2001). Furthermore, from a practical perspective also, some authors have highlighted how DSSs have not generally found a significant place in farm management of even 'progressive' Management Systems (Hoag *et al.*, 1999; Parker, 1999; Kulmann and Brodersen, 2001) and they have yet to achieve widespread adoption in farming practice (McCown, 2012), because farmers have simply not used the available DSSs. Since 1970, Little argued that in this sector the problem is that managers practically never use DSS (Little, 1970). The major difficulty lies in implementation and, in particular, the critical aspect is the meeting between the manager and the model. In McCown *et al.* (2002), authors argued that most farmers in industrialized countries own and use computers; but the use of the DSS in farm management has not grown with computer ownership, as was expected (Parker, 1999; Ascough *et al.*, 1999). Indeed, compared to the number of DSSs that have been developed, only a few have been routinely used (Nguyen *et al.*, 2006; Matthews *et al.* 2008; Gent *et al.*, 2011). Keating and McCown, (2001) explained this low-adoption by the manner to see the DSS as a way to 'packaging' information. Moreover, an economist explanation could be that the potential benefits of DSSs are only for a very small proportion of farms (Webster, 1990). More recent studies justify such under-utilization by both technical limitations and farmers' attitude towards decision-making and perception of DSSs (Matthews *et al.*, 2008; Gent *et al.*, 2011).

Conversely, in the past, Zadoks (1989) reports the results of EPIPRE, a computer based DSS on pest and disease control in wheat diffused in Europe. He found a limited evidence of financial benefits but a stronger evidence of environmental benefits in terms of reduced chemical usage. Furthermore, he mentioned a universal appreciation of the 'learning effect'. The problem is that the benefit of the DSS seems to be the learning and not the decision support information itself. It could be that, once the lessons have been captured, the tool become less important. Indeed, the science behind a crop–pest–weather DSS may be complex while the management decision is too much simple — basically to spray or not to spray.

As Little said in 1970, in order to be used by farmers, a DSS should be simple, easy to control, adaptive, as complete as possible, and easy to communicate with (Little 1970). Such considerations have been made more than 40 years ago, but they seem to be still true and not so expected because modern agriculture increases continuously its complexity (McCown, 2002b).

In general, some factors which seem to influence the adoption and the use of DSSs have been identified. They are profitability, user-friendly design, time requirement for DSS usage, credibility, adaptation of the DSS to the farm situations, information update, and knowledge of the users (Kerr, 2004).

Indeed, nowadays a DSS is a properly designed interactive software-based system which obtain useful information from raw data, documents, personal knowledge in order to helps farmers in their cropping decisions (Rossi *et al.*, 2012). Therefore, in order to identify the most appropriate action to solve problems, a DSSs first collect, organize, and integrate information which will be analyzed and interpreted (Agrios, 2005).

Despite the growing development and diffusion of ICT over the last decades, the adoption and use of DSS, presents some limitations (Jones *et al.*, 2010), even if in many cases they have been overcame (Rossi *et al.*, 2012):

- Sometimes, they do not consider the wide range aspects of production (Parker *et al.*, 1997; Rossing and Leeuwis, 1999; BCPC, 2000; Magarey *et al.*, 2002) or solve not real problems for users (Magarey *et al.*, 2002);
- Some DSS are low quality, because their refinement phase is not sufficient (Magarey *et al.*, 2002);

- Many agricultural DSSs do not have user-friendly interfaces, while farmers generally require clear and concise information and negatively react to redundant information (BCPC, 2000; Ascough *et al.*, 2010);
- Several DSSs require too much time to operate (Ascough *et al.*, 2010);
- The DSS outputs are not properly updated and crop management decisions cannot be postponed (Ascough *et al.*, 2010);
- Many DSSs are not suitable maintained and developed because of their expensive cost (Jones *et al.* 2010).

Finally, from a SI point of view, as policy decisions are often supported and informed by the results of scientific and socio-economic research, DSS can be also considered as a very helpful set of scientific and analytical tools and approaches able to translate research results into policy relevant outcomes in order to assist both agricultural systems' players and policy makers to achieve objectives of SI (Ahmadi *et al.*, 2015). Indeed, they are useful for farmers to improve their plans and decisions and for policy makers to evaluate an *ex ante* assessment of future policies. The outcome of such tool may provide an appropriate plan of action that can be applied to farms or enterprises at regional, national, or global levels (Geels and Schot, 2007). Moreover, Agricultural DSSs can act as boundary objects to become a focus of social learning (Jakku and Thorburn, 2010) facilitating the development of communities of practice providing a common point around which to interact (Eastwood *et al.*, 2012).

I.2.3 Horta and its DSSs

In the previous paragraphs was presented the general idea of eco-innovation in agriculture and, within this macro-category, a specific attention to the role of precision agriculture, and particularly to Decision Support System, was devoted. In the two last sections of the first part of the dissertation a case study is presented, starting from the description of an enterprise operating in the eco-innovation field and then focusing on a DSS produced by this organization.

The case analysed concerns an academic spin off, Horta srl, which, as main activity, produces and sells in the Italian market some DSSs dedicated to improve economic and environmental performances of different types of crops.

As it has been already presented in the first chapter, the innovation process can be analysed under two different perspectives. The first one sees the innovation process observed under the innovation/innovator perspective, studying its characteristics in order to understand the whole process; the second perspective consists of a wider analysis focusing on the context and the structure of the innovative system. In this discussion, the first approach will be followed, starting from the description of the innovator and then focusing on the specific innovation.

Horta is an academic spin-off of the Università Cattolica del Sacro Cuore (Figure 10), which was established in 2008 by five founders coming from the agronomic and vegetal epidemiology research and the productive sphere.

Figure 10: The logo of Horta s.r.l.

From one hand, Horta aims to transfer and valorize the results of a wide research conducted in the agri-food sector. On the other, it provides highly quality services in the field of vegetal production, at national or international scale, in order to improve competitiveness and productivity of farms and agri-food firms, quality and stability of production and, in general, profitability, environmental sustainability and agri-food safety. In particular, the general improvement of the level of sustainability of agricultural productions is a factor to focus on as requested by final consumers and, more recently, by farmers themselves.

Horta collaborates with researchers and professionals coming from the economic, IT and communication sectors in two general lines of R&D activities: the first concerns planning and management of international and national projects, the second regards the fields experimentation.

Horta proposes its “platform” role in order to valorize all results deriving from both research and application worlds. It focuses principally on the development of technological innovation and its transfer to the agri-food productive realities, at national or international scale, from extensive and intensive cultivations to agro-energetic cultivations. In its activities, Horta also considers themes such qualitative standard certifications, environmental sustainability, food security, etc. In this perspective, the organization, the development and the finally fulfillment of new innovative itineraries affecting the agri-food production must materializes in new product, new technical instruments, new organizational rearrangement or all of them.

From a practical point of view, Horta manages an own agrometeorological network, develops technical means (varieties test and innovative genetic materials, agronomic calibration of fertilizers, new products and strategies against cultivation diseases, screening of biocontrol agents), participates in research project at regional, national and European scale. But its core business is the creation, development and implementation of Decision Support Systems (DSSs).

To bring its contribution to a more sustainable agricultural production, Horta offers the answer of the DSSs, and the new ICTs technologies linked to them, as a key instrument to promote eco-innovation in the agri-food sector.

An integration of meteorological trends, phenological development of cultivation and mathematic algorithm provides precious practical information to users, farmers or technicians, during the management of production and treatments of pest and desease. Indeed, such tools automatically collect, organize, interpret and integrate all information about the cultivation system monitored in real time (through scouting sensors or activities). Then, with advanced modeling techniques, developed as part of several national and international research projects, they analyze these data and, according to the outputs of the models, generate alarms and results useful to support farmers, i.e. the users of DSS, in their choices and decisions (Figure 11).

Horta pays a lot of attention in developing an intuitive software interface of easy and quick consultation. The DSS system is always available in real time on a web platform through username and password.

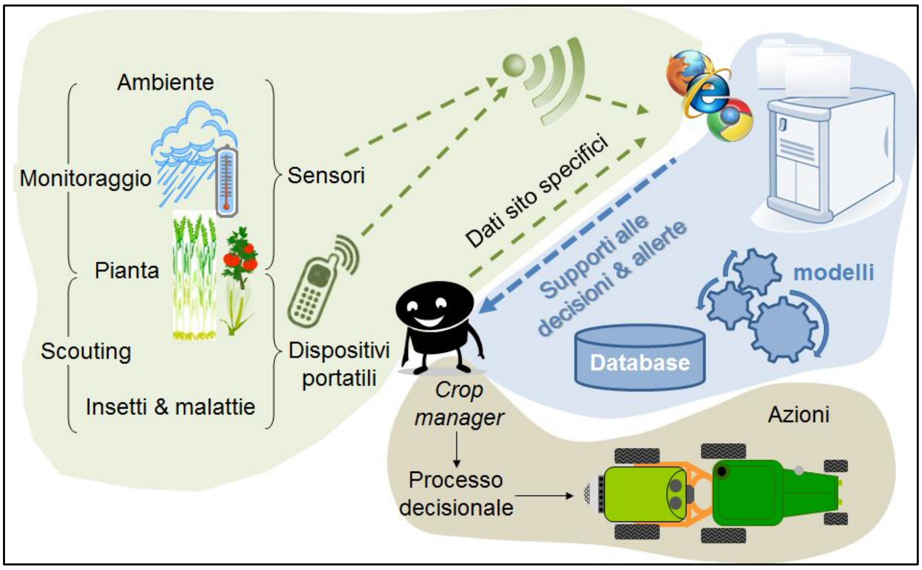


Figure 11: General representation of a DSS monitoring process (Source: Horta web site)

In short, Horta creates its DSSs according to nine crucial points.

1. Purpose: DSS has been designed as a "tool" able to provide assistance and additional information to help - and not to replace - the farmer or technician who takes decisions about the management of the crop. This service allows a better use of resources, natural or not, the implementation of a production process compliant to the principles of the integrated production (including the integrated pest defense in accordance with Directive 2009/128/EC) and, finally, to keep track of all logic decisions performed during the campaign.
2. Holistic vision: DSS provides information about the key aspects of crop management, such as defense against fungal diseases and insect pests, development of plant and estimated production, the management of foliage, thermic and water stress.
3. Specificity: each alarm and decision support provided by the DSS refers to a particular Production Unit (UP), namely a single or multiple plot presenting the same varietal characteristics, planting density, soil conditions, etc. in order to have a uniform management during the campaign phase.
4. Interactivity: each UP can be characterized by the user with site-specific information, both static (which doesn't change over the season) and dynamic (which change during the season).
5. Real time updates: the system receives real-time data collected during the cultivation; such data will be used as input variables for the forecasting models of the system, whose outputs are constantly updated.

6. Availability: the DSS services are provided via internet through any browser, always available without requiring any software installation. Users can access to the services from the Horta web site with an authentication process that requires a username and a password.
7. Meteorological data validation: DSS obtains data from the agro-meteorological network of Horta; such data are recorded and transmitted in real time via GPRS and subjected to a quality control before reaching the DSSs.
8. User interface: the navigation within the services is intuitive and dynamic, allowing the users to choose the level of detail to explore all the available information.
9. Co-development: DSS services have been developed in a closely connection with other advisory groups (e.g. representatives of producers, panels of users, etc).

Horta developed seven DSSs for different productions (Table 4): *granoduro.net* for durum wheat, *vite.net* for grapevine and table grape, *grano.net* for wheat, *orzobirra.net* for barley and beer barley, *olivo.net* for olives, *pomodoro.net* for tomato and *melone.net* for melon. *granoduro.net* and *vite.net* can be defined as the “older” DSS, namely the first technologies which have been developed by Horta, while the others are “younger”.

DSS	Product	Year of launch	Users
granoduro.net	Durum wheat	2008	200
vite.net	Grapevine and table grape	2013	225
grano.net	Wheat	2014	80
orzobirra.net	Barley and beer barley	2015	30
olivo.net	Olives	2016	27
pomodoro.net	Tomato	2016	30
melone.net	Melon	-	1

Table 4: Horta’s DSS: supply chain. Year of launch and total number of user

The structure and the technology involved are the same in each case, but the output is different and, of course, balanced with the specific peculiarity and necessity of the single cultivation.

Moreover, *yousustain.net* is an additional service created to plan and manage the sustainability of agricultural cultivations of farms, agricultural association, consortia, agri-food industries, cooperatives and producers’ organization. Such tool has been developed with the aim to sustain the wine sector concealing quality of products and food security.

From 2016 *yousustain.net* is available for the clients of DSS *vite.net*, *grano.net* and *orzobirra.net* as a prototype.

The more developed DSSs are *granoduro.net* and its evolution *grano.net, orzobirra*.net and *vite.net*.

Granoduro.net is the first DSS developed by Horta for the durum wheat and the first in Italy for autumn winter crops cereals. It has been launched in 2008. In 2014 *grano.net,* the evolution of *granoduro.net,* has been created by Horta (Figure 12). The main difference is that with *grano.net* users can create UPs of both durum wheat and classical wheat (Figure 13). Actually, they account for almost 300 users distributed around Italy (Figure 14). Actual and potential users can be farms, technicians and other typology of clients, such as organizations, which purchase seed varieties treated by the DSS' system.

Figure 12: *granoduro.net* and *grano.net* logos

Figure 13: Durum wheat fields in Italy (own photo)

Figure 14: Geographical diffusion of *granoduro.net* and *grano.net* (Source: Horta's site web)

The DSSs *granoduro.net* and *grano.net* a support the users, namely farmers, technicians or producers' organizations, during the decisional phase thanks to many available modules easily consultable:

1. Fertilization module
2. Sowing module:
3. Phytopathological models module
4. Weeding module
5. Meteorological module
6. Plant protection products module
7. Farm management module
8. Environmental impact module[7]
9. Water balance module

[7] Available only for *granoduro.net* and exclusive service of the project *BSF*- Barilla Sustainable Farming-in collaboration with *Barilla* spa.

A DSS quite similar to *grano.net* and *granoduro.net* is o*rzobirra.net,* one of the most recently DSSs developed by Horta; it has been launched in 2015 ant it counts about 30 users nowadays. It has been developed for the barley producers who give their products to the agri-food malthouse *Sud di Melfi* (Potenza). From 2016 also *Peroni,* a famous beer brand, makes use of *orzobirra.net*. Also this system consists of several modules interacting each other:

- Meteorological module;
- Plant protection products module
- Farm management module;
- Environmental impact module;

After defining one or more UPs and checking all recommendations about pre-seeding fertilization, *orzobirra.net* allows to control:

- phenological stages of the crop;
- periods of risk and related gravity of the main infections and mycotoxins;
- quantity and times of application of nitrogen fertilizers;
- choice of herbicides for weed control;
- water balance of the soil-plant system;

The three DSSs *granoduro.net, grano.net* and *orzobirra.net* have been certified by the certification authority CCPB to ensure greater quality and control of services.

Other DSSs, namely *olivo.net*, *pomodoro.net*, *melone.net*, are still in the first phase of diffusion: they have been just launched or are about to be.

During the first meeting with Horta, among all the DSSs developed, *vite.net* has been chosen as case study for various reasons. It is one of the older and more stable DSS compared to the others and, for this reasons, it has a high but manageable number of adopters. To *vite.net,* since it was chosen as the specific case study of eco-innovation analyzed in the second part of the thesis, is dedicated the next paragraph.

I.2.4 The DSS *vite.net*

From a chronological point of view, *Vite.net* was born in 2013 and it is the second DSS developed by Horta; its target is the production of wine and table grapes according to the principles of the sustainable viticulture and integrated production (Figure 15).

Figure 15: *Vite.net* logo

It counts almost 225 users nowadays along Italy (Figure 16). Actual and potential users can be farms, technicians and other typology of clients, such as public or private organizations.

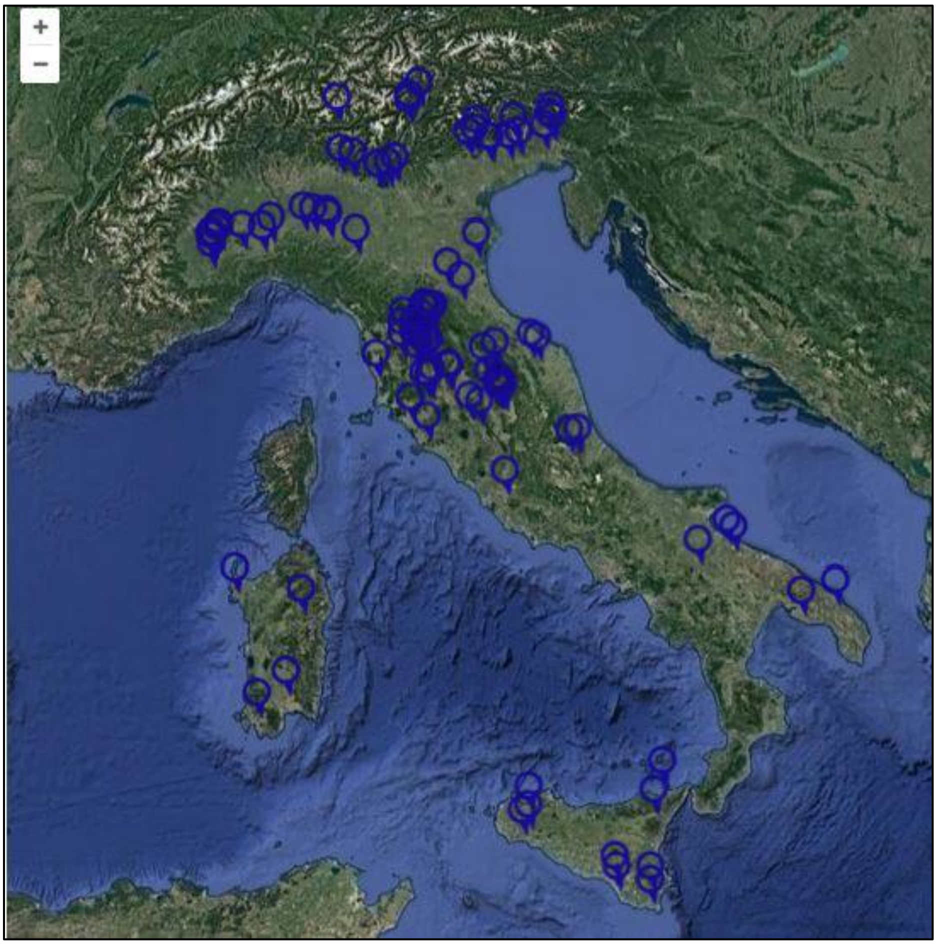


Figure 16: Geographical diffusion of vite.net

As each other DSS provided by Horta, this tool supports farmers or technicians during the decisional phase thanks to many information which can be visualized in a synthesis mode or in a detailed mode.

For each UP, the DSS system allows to control wheatear conditions up to seven days; risk of infection' periods for primary and secondary infections of Peronospora e Oidio and their relative gravity; current level of protection of vegetation guaranteed by any fungicide treatments already performed, environmental conditions and the development of the plant; optimal dose of plant production products.

As *grano.net*, also v*ite.net* has many available modules easily consultable by users:

- Primary and secondary infection module (Figure 17-a)
- Phenological model module (Figure 17-b)
- Plant protection product module (Figure 17-c)
- Coverage model module (Figure 17-d)
- Treatments record
- Water balance module (Figure 17-e)
- Insects module (Figure 17-f)

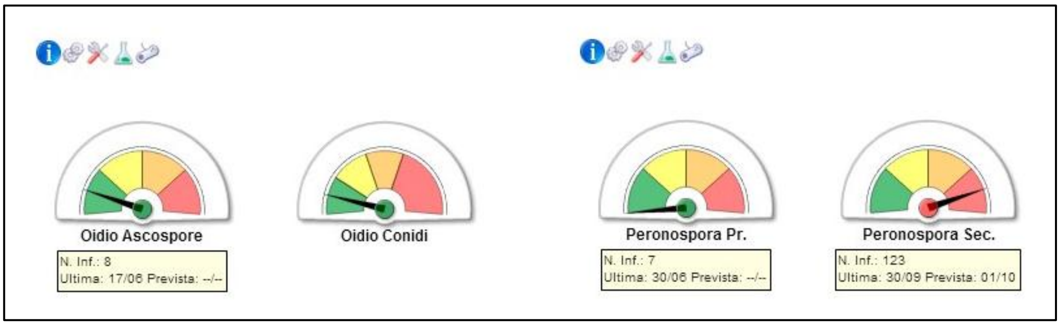


Figure 17-a: Simulation models of risk infection of Peronospora and Oidio (Source: Horta site web)

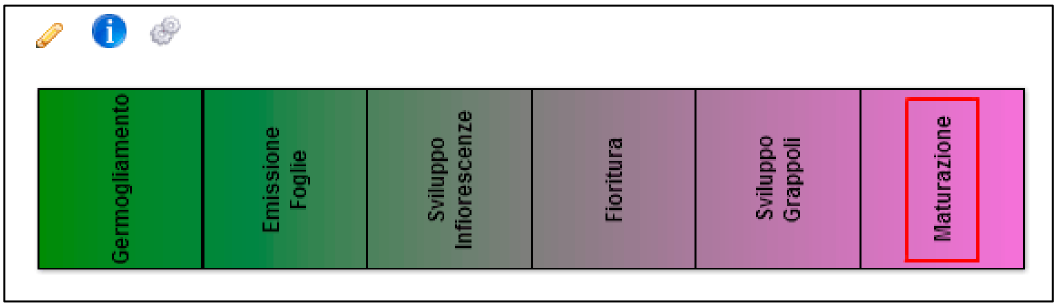
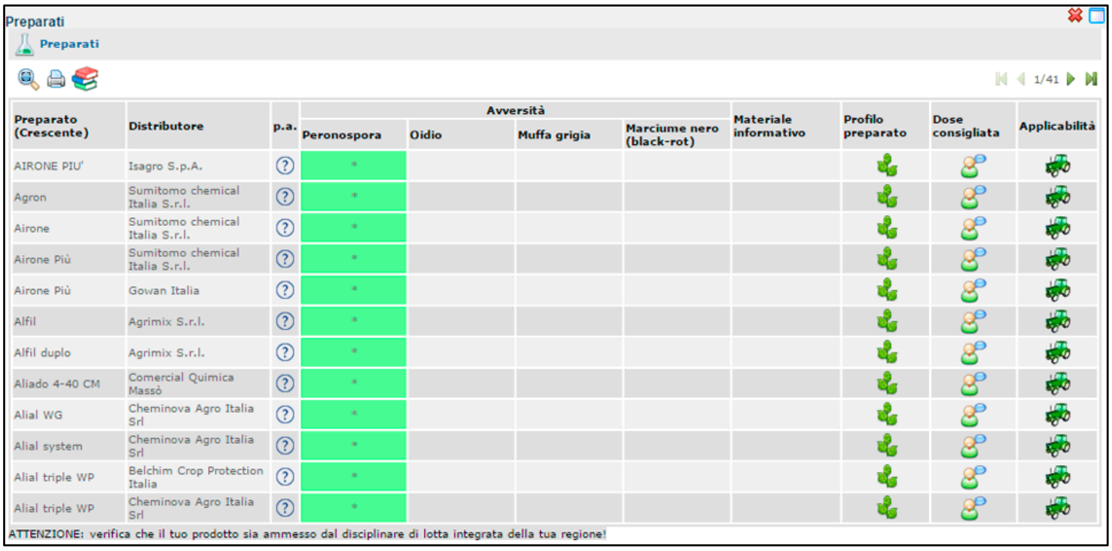


Figure 17-b: Phenological model (Source: Horta site web)



Preparati

Preparati

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Preparato (Crescente)	Distributore	p.a.	Avversità				Materiale informativo	Profilo preparato	Dose consigliata	Applicabilità
			Peronospora	Oidio	Muffa grigia	Marciume nero (black-rot)				
AIRONE PIU'	Isagro S.p.A.	?	*							
Agron	Sumitomo chemical Italia S.r.l.	?	*							
Airone	Sumitomo chemical Italia S.r.l.	?	*							
Airone Più	Sumitomo chemical Italia S.r.l.	?	*							
Airone Più	Gowan Italia	?	*							
Alfil	Agrimix S.r.l.	?	*							
Alfil duplo	Agrimix S.r.l.	?	*							
Aliado 4-40 CM	Comercial Quimica Massò	?	*							
Alial WG	Cheminova Agro Italia Srl	?	*							
Alial system	Cheminova Agro Italia Srl	?	*							
Alial triple WP	Belchim Crop Protection Italia	?	*							
Alial triple WP	Cheminova Agro Italia Srl	?	*							

ATTENZIONE: verifica che il tuo prodotto sia ammesso dal disciplinare di lotta integrata della tua regione!

Figure 17-c: Database of protection plants products and applicability model (Source: Horta site web)

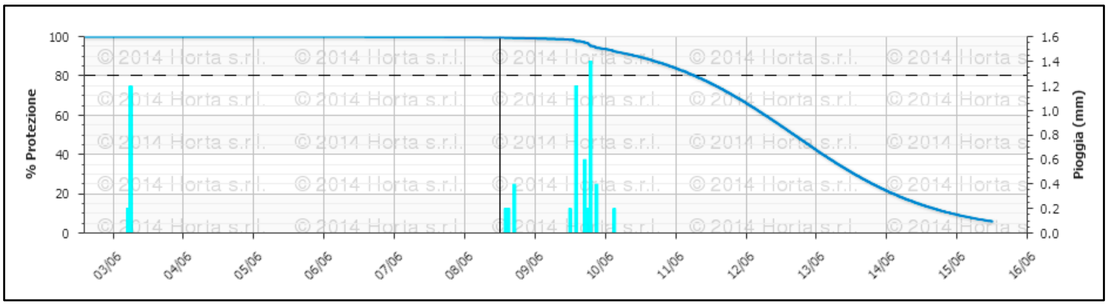

Figure 17-d: Graph showing the current level of protection of vegetation (Source: Horta site web)

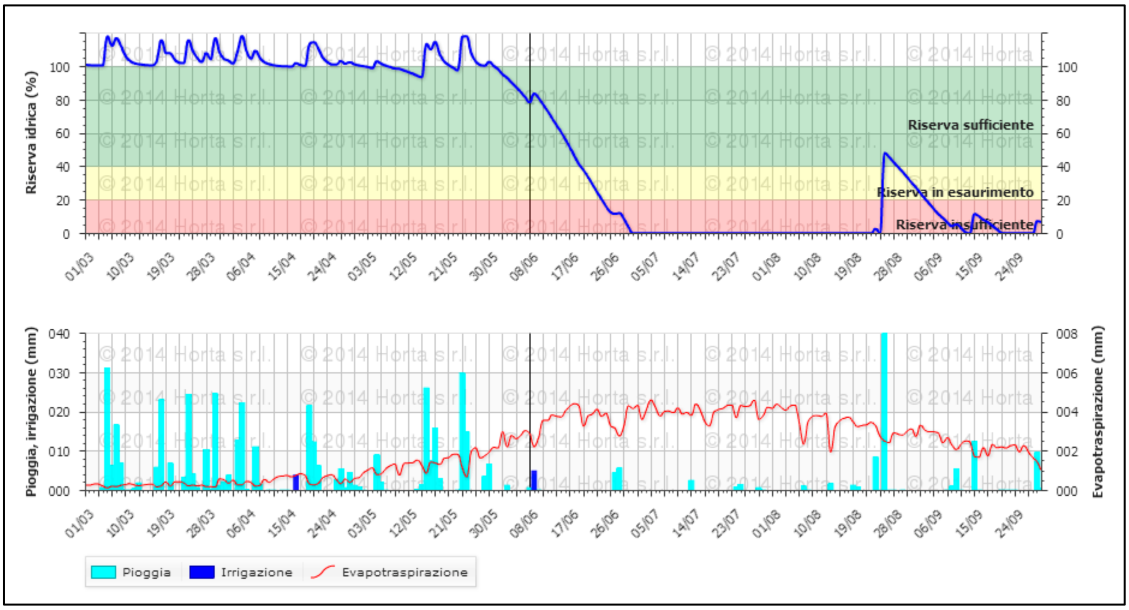

Figure 17-e: Water balance (Source: Horta site web)

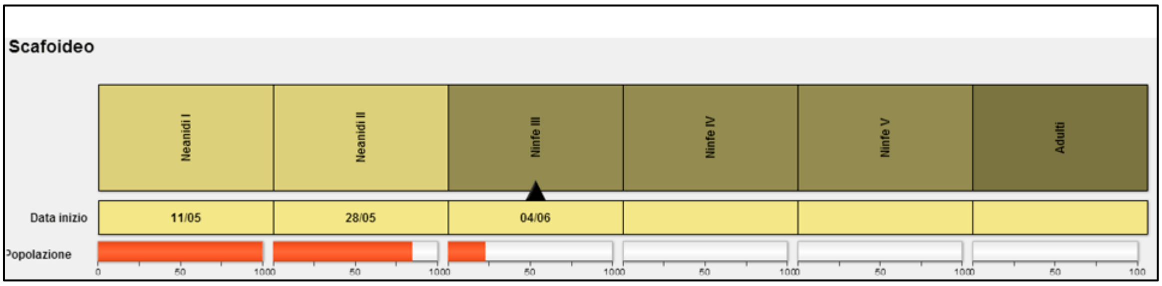

Figure 17-f: Synthesis graph about the insect pests of the vine (Source: Horta site web)

As an eco-innovation, the main goals of *vite.net*, and of any DSS in general, are improving the sustainability of the production phase calibrating, and reducing the quantity of treatments, chemical additive, etc. Figure 18 shows the sustainability benefits reached through the use of vite.net during the campaign.

In this way, beyond a cost reduction for farmers from a both biologic and integrated perspective, a reduced environmental impact has been obtained through a less use of treatments and plant protection products.

Moreover, as it has already been said, the new tool *Yousustain.net* is available for *vite.net* from the beginning of 2016. Even if it is still a prototype, some farmers already use it.

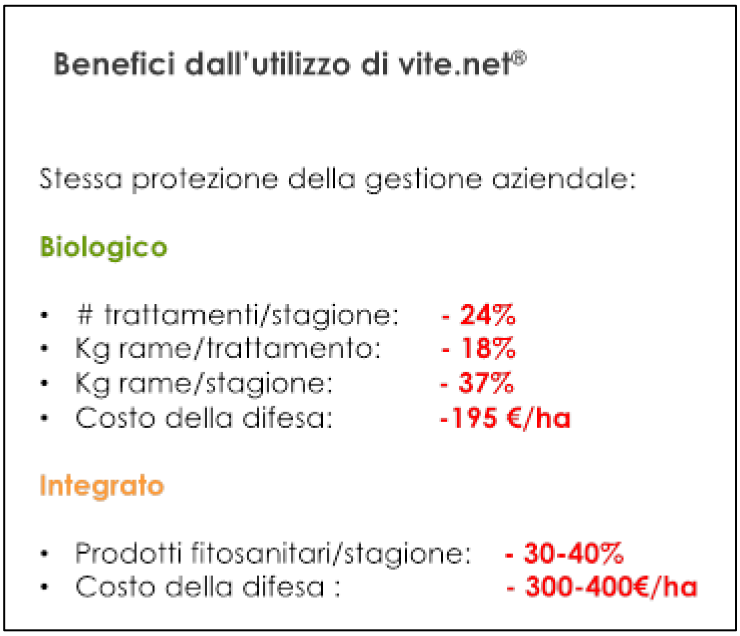

Figure 18: Sustainability benefits of *vite.net* (Source: Horta's documents)

Yousustain.net can be defined as a useful sustainable meter about agricultural production able to evaluate each cropping decision through an aggregate of indicators simultaneously considered. It is easy to use for farmers because it considers information, which are very familiar to them. Indeed, once the farmer accessed the tool and all the information requested by the system have been inserted and integrated with the default databases, the indicators can be calculated. They evaluate the environmental impact of the whole UP or culture. Therefore, once they have been obtained, farmers can understand the way to improve their sustainability, if it is necessary.

Figure 19: *yousustain.net* logo

Indicators are grouped into six categories: health, soil, air, biodiversity, energy and water.

<u>Soil</u>

1. Ecological Footprint: it quantifies the required biologically productive areas, terrestrial and aquatic, to provide resources and, at the same time, to absorb the emissions for the production of a particular good or service;
2. Organic Matter: it measures the percentage of organic matter in the soil, higher values correspond to a higher soil fertility;
3. Soil Coverage: it describes the number of days per year when the field is covered by vegetation or crop residues;
4. Erosion: it estimates the tons of soil lost each year because of the erosion caused by the rainfall;
5. Soil Compaction: it evaluates the soil compaction risk;

<u>Air</u>

6. Carbon Footprint: it quantifies the greenhouse gas emissions directly or indirectly produced by human activities;

7. Carbon Sequestration: it estimates the value of carbon sequestered by plant tissues (aerial and underground parts) during the season;

Water

8. Water Footprint: it measures the water foot print of the cropping system, namely the productive process consumption of grey water (rain water used by the plant), blue water (irrigation water used within the production system), green water (water required to dilute the contaminants within the soil system);
9. Water Supply: it evaluates the sustainability of the typology of water used in the field;
10. Water use tech efficiency: it evaluates the sustainability of the irrigation method used;
11. Acidification: it quantifies the acid gas emissions with acidifying power in the air caused by the production activities;
12. Eutrophication: it quantifies the effects of the artificial intake of phosphate and nitrogen nutrients to the soil on the water ecosystem;

Energy

13. Fuel use: it accounts the liters of fuel registered by the farmer in the Register of Cultivation Operations (ROC);
14. Renewable fuel: it evaluates the farm propensity to consumption of fuels made from renewable sources;
15. Waste: it evaluates the management of the farm waste;

Biodiversity

16. Biodiversity: it evaluates the farm biodiversity level through an assessment of the soil use;
17. Eco Tox Score: it evaluates the eco-toxicological risk exerted by the synthetic chemicals used in the field on the aquatic and terrestrial ecosystem health;

Health

18. Human Tox Score: it measures the toxicological risk exerted by the synthetic chemicals on human health;
19. Dose Area Index: it measures the chemical exposure caused by the phytosanitary treatment;
20. Treatment Frequency Index: it measures how many times a piece of land is treated with a plant protection product.

The system of *Yousustain.net* allows to compare the ongoing results of different indicators (Figure 20) or those of a single indicator during the years (Figure 21).

It is a very dynamic system which allows the farmers to simulate the effect of their different decision on the environmental impact. As you can see from Figure 22, the case *a* represents the real situation while the *b* simulates the effect of a different decision, in this particular case, the use of a different plant protection product. Such new product, with the same number of treatments reduces the health risk compared to the other.

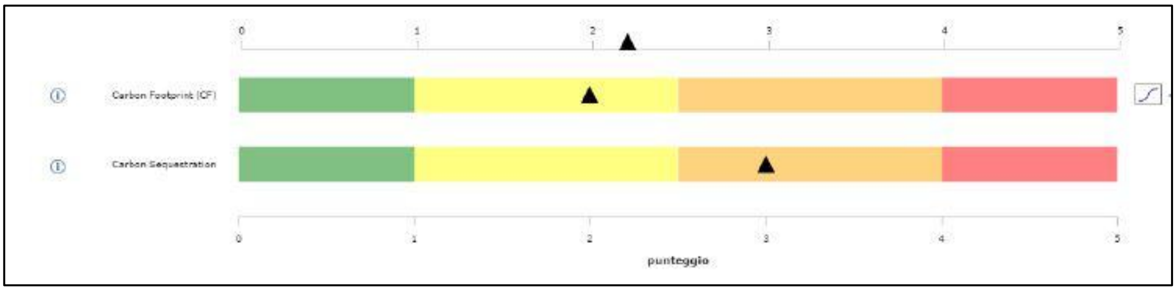

Figure 20: Example of comparison among results of different indicators (Source: Horta's documents)

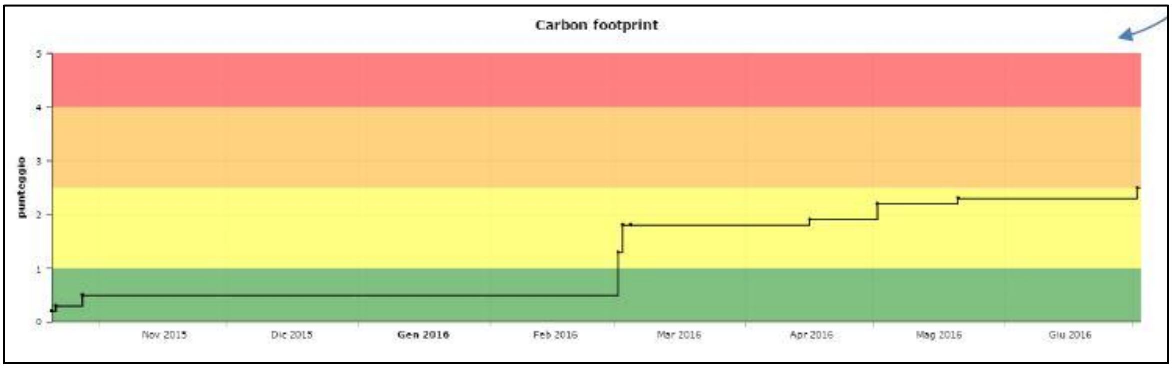

Figure 21: Example of results of a single indicator during the years. (Source: Horta's documents)

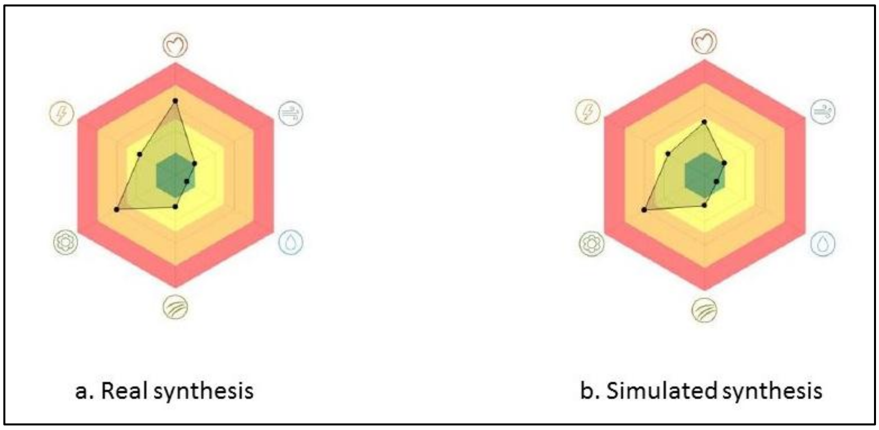

Figure 22: Examples of simulation of the effects of a different farming decision (Source: Horta's documents).

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Second part

Building a theory on eco-innovation in agriculture

II.1 The Theory Building From Cases approach

This chapter, differently from the other parts of the thesis, has been conceived as a single scientific paper.

It represents, from a chronological point of view, the first step of the whole research process, which has been made to understand if the *Theory Building From Cases* could be the right approach to study the topic of innovation in agriculture.

In order to better understand this approach and to investigate the extent to which it is diffused in scientific literature and, more specifically, in the study of innovation in the agri-food sector, an analysis based on the systematic literature review has been conducted. Since it is a preliminary study which has an original and independent value, this chapter has been conceived as a single article which lies outside the overall structure of the thesis. Nevertheless, the contents and the results which have been obtained from such study have been useful to answer to the RQ2, namely if the *Theory Building From Cases* is a right approach to assert general statements about eco-innovation starting from the case study, and, therefore, to guide the development of the remaining part of the thesis.

II.1.1 A different approach for the scientific research

Introduction

The debate on innovation in agriculture and agri-food sector remains contradictory in the international scientific arena (Avolio *et al.*, 2014). Many authors got to apparently contrasting results (Avermaete *et al.*, 2004), often because they studied innovation thorough different methodologies, data set features and variables selected (Montoya-Weiss & Catalone, 1994). Considering the innovation process in the agri-food domain, the analysis becomes even more complicated: in this sector literature is very fragmented and, moreover, a number of additional elements affect the development of the innovation process. In several papers it is highlighted the relevant role of the specific situation, actor or territorial area. In other words, each innovation process is discussed as a single case study, completely different from the others (Avolio *et al.*, 2014). This is why it is very difficult to generalize the discourse about innovation diffusion and development (Crossan & Apaydin, 2010). Not finding satisfying theories able to explain, in a practical perspective, the emergence and diffusion of innovative processes in the agri-food sector, we suggest the

possibility to afford the study of innovation processes in this context from a different paradigmatic perspective.
With the aim to afford the study of innovation processes in the agricultural sector from a different paradigmatic perspective, we searched for some conceptual basis to explain these processes from an organizational point of view to obtain, rather than theoretical statements as required for researchers, practical evidences useful for actors involved in the innovation diffusion process, from innovators to final adopters (Rogers, 1983). Indeed, as Wallace (1998) stated, "*Theory, for theory's sake, can easily degenerate into an uninteresting art form. Yet, practice without theory can quickly become a dull and dangerous occupation*" (Wallace, 1998: 361).
A possible way to face this challenge is to move from single case studies adopting the *Theory building from cases* (TBFC), proposed by the milestone works of Eisenhardt in 1989 and Eisenhardt & Graebner in 2007, as a general research approach. TBFC is a qualitative method based on one or more cases to develop theory (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) starting from the observation and measurement of a case study and proceeding with the empirical generalization in an inductively way.
Moving from this approach, in this work we want to address two different questions. The first and more general one aims to understand what is the general diffusion of the TBFC approach in literature without focusing on any specific sector. Second, we seek to understand the extent to which the TBFC approach has been used in the agri-food research, namely to analyse the innovation process in the agri-food context.
To accomplish these objectives, after a brief description of the *Theory building from cases* approach, we used a methodology of literature analysis, namely the *Systematic Literature Review*, based on the science mapping approach. This methodology has been applied on international articles published in peer-reviewed journals from 1990 to 2015, recorded in the *SCOPUS* database (www.scopus.com) and citing among their references the key works of Eisenhardt, 1989 and/or Eisenhardt & Graebner, 2007. The result of this methodology is a map offering a wide overview on the research structure of the TBFC that we discussed and commented. Some final remarks are reported in the conclusions.

Theory building from cases

TBFC approach is a qualitative method based on one or more cases to create theoretical constructs, propositions and/or midrange theory from empirical evidences (Eisenhardt, 1989). Following this research process, theory is developed inductively using case studies as a basis (Eisenhardt & Graebner, 2007). The TBFC approach provides a framework for analysis, facilitating the efficient development of the field and the applicability to practical real world problems (Wacker, 1998), and it answers research questions as "how" and "why" in unexplored research areas (Edmondson & Mc Manus, 2007).

Case studies "*emphasize the real context in which the phenomena occur*" (Eisenhard & Graebner, 2007: 25) and, for this reason, they can be used to various aim, for example to provide descriptions (Kidder 1982), to test (Pinfield, 1986; Anderson, 1983) or generate theory (Gersick, 1988; Harris & Sutton, 1986). In the TBFC process, the connection with empirical reality allows the development of a valid theory (Glaser & Strauss, 1967) focusing on understanding the dynamics of single or multiple cases involving different levels of analysis (Yin, 1984). While single case studies can richly describe a phenomenon (Siggelkow, 2007), multiple case studies provide strong base for theory building (Yin, 1994).

In 1971, Wallace set up one of the few models process-based of TBFC (Figure 23).

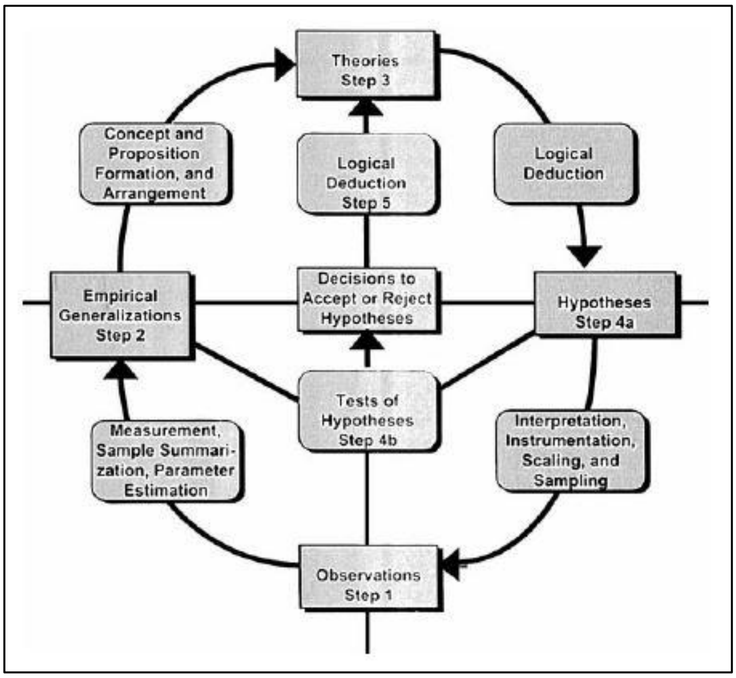

Figure 23: The Principal Information Components, Methodological Controls and Information Transformations of the Scientific Process (Wallace 1971: 18)

This model is based on the school of thought that consider science built on the three pillars of Observation, Induction and Deduction. This cyclical map identified the different stages in the whole scientific process where there is no unique starting point - Wallace decided to start from the observation (Handfield & Melnyk, 1998). Therefore, the left part of the model represents the inductive construction of theory from observation whereas the right part the deductive application of theory to observation. At the same way, the top part identifies the theorization process through both induction and deduction logic and the bottom one represents the empirical research.

Moving from the representation of the scientific process proposed by Wallace, it is possible to develop a simplified scheme (Figure 24) useful to clarify the rationale of TBFC approach.

TBFC is strongly process-oriented (Handfield & Melnyk, 1998), as it involves constant iteration backward and forward between steps (Eisenhardt, 1989: 546). Essentially, the researchers, starting from the observation and measurement of a case study, proceed with the empirical generalization in an inductively way. Finally, propositions resulting by this process must been compared with existent literature to be confirmed. This process can be mapped in the left side of figure 24.

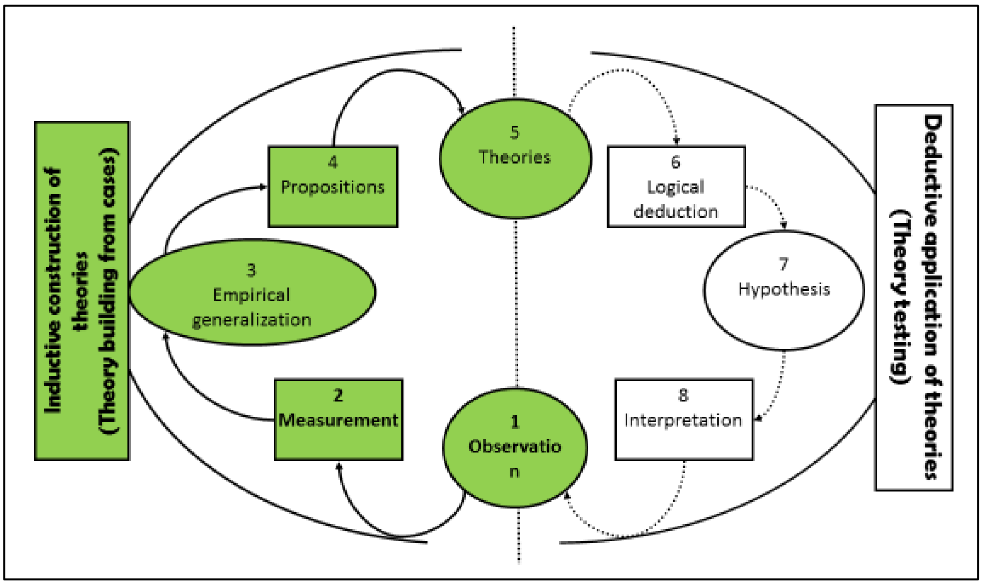

Figure 24: Own elaboration of Wallace representation of “Scientific Process”

In this perspective, the replication logic is central: each case is a single experiment, an analytic unit. Cases are selected because they are revelatory, exemplars and particularly suitable for extending relationships and logic among constructs (Eisenhardt, 2007). Through replication, contrast and extension, the researcher, moving from a single observation, obtains qualitative or quantitative evidences to determine and perfect his emerging theory (Yin, 1994).

Differently, the classical *Theory testing* research methodology (see right side of figure 24) appears to be more suitable when case studies perfectly fit with an existent theory. In this case, following a deductive process, researchers apply theories to case studies through the formulation of hypotheses and the interpretation.

However, as Eisenhardt & Graebner (2007:25) asserted, inductive and deductive process "*are mirrors of one another*": the first one produces new theories from data and the second one completes the cycle testing theories by using data (Eisenhardt & Graebner 2007). So, the relevance of TBFC is justified by its "bridging function" between qualitative evidence to deductive research.

This research process allows to generate new theories readily testable with measurable constructs, provable hypothesis and, consequently, with an empirical validity. The main weaknesses of the TBFC approach are instead related to the risk that theory can't reach a sufficient level of generalization (Eisenhardt, 1989); indeed, the basic assumption is that such approach is less precise, objective and rigorous than large-scale hypothesis testing (Eisenhardt & Graebner, 2007).

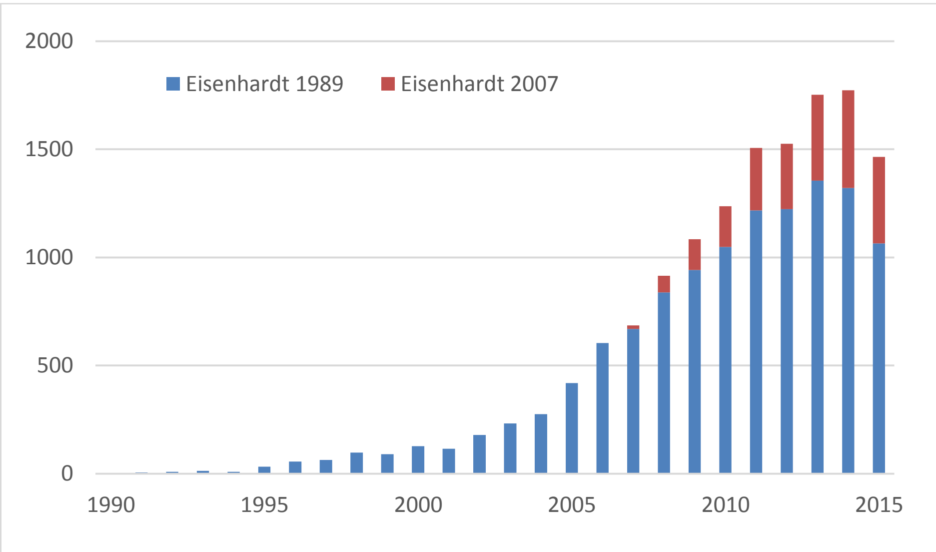

Figure 25: Articles citing Eisenhardt, 1989 and Eisenhardt & Graebner, 2007 published from 1990 to 2015.

Anyhow, regardless the strengths and weaknesses highlighted so far, this approach is gaining popularity, as shown by data on Scopus citations (www.scopus.com) of the two papers from Eisehardt, 1989 and Eisenhardt & Graebner, 2007 which established the basic framework for TBFC approach (figure 25).

Considering the growing interest on TBFC, as well as the potentiality of such approach in cases study description and analysis, we aim to investigate in an analytical way the extent to which TBFC is diffused in scientific literature and, more specifically, in the study of innovation in the agri-food sector.

II.1.2 How much the TBFC approach has been used?

Methodology

In order to provide a general assessment of how much the TBFC is diffused in literature, a two-step process was adopted. First, through *Systematic Literature Review* (SLR), we selected all papers that explicitly refer to TBFC scientific approach; then, a *Network Analysis* (NA) was carried out on such papers to understand the main topics investigated through such approach and the emerging relations among them.

SLR has become an essential tool of evidence-based practice that "*differs from traditional narrative reviews by adopting a replicable, scientific and transparent process, in other words a detailed technology, that aims to minimize bias through exhaustive literature searches of published and unpublished studies and by providing an audit trail of the reviewers' decisions, procedures and conclusions*" (Tranfield *et al.*, 2003*).* It never provides answers but accurately reports what is known and not known of a specific topic (Briner, Denyer & Rousseau, 2009).

A systematic review gives to researches a certain degree of confidence because they can reasonable justify their choices, decisions and interventions. Indeed, SLR follows some core principles; it has to propose synthetic results being systematic, transparent and replicable (Briner & Denyer, 2012). It is fundamental to define a protocol to ensure the review respecting the core principles we described (systematic, transparent and replicable); to get this result a SLR should include "*a rationale description of the research questions and the proposed methods, and includes details of how different types of study will be located, appraised, and synthesized*" (Petticrew & Roberts, 2006: 44).

NA (Carrington, Scott & Wasserman, 2005; Cook & Holder, 2006; Skillicorn, 2007; Wasserman & Faust, 1994) aims to show and make evident relationships or overlapping among different clusters of the items selected, through a set of tools (Cobo *et al.*, 2011).

Significant application of NA can be found in bibliometric analysis to study patterns in science through the so-called *bibliometric mapping* or *science mapping* approach. Specifically, science mapping is a spatial representation of how disciplines, fields, specialties, documents and authors are related to one another. These techniques aim to provide insights into the structure of a network, by answering questions such as: what are the main topics or research areas within a certain scientific domain? How do these topics areas relate to each other? How has a certain scientific domain developed over time? (Waltman *et al.*, 2011). In these cases, bibliometric data are used to generate maps based on citations, co-authorships, terms co-occurrences relationships (Van Eck & Waltman, 2014).
Such representations offer a powerful analysis tools, as mapping visualizations considerably enhance the capacity to convey complex information to researchers (Martin *et al.*, 2014).

<u>*Research design*</u>

The research design consists of a two-step process of analysis of peer-reviewed journal articles. Since they represent the main channel of communication among researchers, they are our relevant unit of analysis (Gold *et al.*, 2010).
In the first step, using the Elsevier's Scopus database, we retrieved all English articles citing among their references the papers "*Building Theories from Case Study Research*", wrote by Kathleen M. Eisenhardt in 1989, and/or "*Theory building from cases: opportunities and challenges*", wrote by Kathleen M. Eisenhardt and Melissa E. Graebner in 2007. The period covered by our search was from 1990 to 2015.
In the second step, basing on the retrieved publications, we constructed the so-called "term map" using the software VOSviewer. VOSviewer is a free computer program developed for creating, visualizing and exploring bibliometric maps (van Eck & Waltman, 2009, 2011; Waltman *et al.*, 2010; van Eck & Waltman, 2015:3). It is a very powerful application (Noyons, 2012), based on the Visualization Of Similarities (VOS) mapping technique (van Eck & Waltman, 2007).
The main feature of VOSviewer is creating maps based on bibliographic data, namely publications, authors or journals. Although VOSviewer is intended for analysing bibliometric networks, it can be used to create, visualize and explore maps based on any type of network data (van Eck & Waltman, 2015). Therefore, through this software, researchers can construct and interpret large bibliometric maps based on different similarity

measures (e.g. co-occurrences, co-citation and bibliographic coupling). Moreover, it allows bibliometric maps to be examined in full detail and in various different ways, each emphasizing a different aspect of the map itself.
In this research, we produced a term map based on the co-occurrence of terms in the title and abstracts of the collected publications. In a term map strongly related terms are located close to each other and less strongly related terms are located further away from each other (van Eck & Waltman, 2015). In the map, terms are represented by a circle with a label, where the size of the circle and label corresponds to the overall frequency in the dataset.
After terms are displayed in the map, the software uses the VOS clustering technique to obtain cluster of related terms. Each cluster represents a main research theme in which one or more research topics can be identified. Because of the items have been assigned to a cluster, the colour of the circle is determined by the cluster which the term belongs.
Once clusters of related terms are displayed in the map, it can be analysed at different levels. First, a consideration of number of clusters, a possible description of them, their size and principal subject areas was carried out. Then, each cluster position and its spatial relation with the others were analysed. Finally, some specific topics, namely the ones related with innovation and agri-food sector, were considered and studied within the map.

Results and discussion

The search in Scopus database for articles citing the two key papers representing the landmark for the TBFC approach (Eisenhardt, 1989; Eisenhardt & Graebner, 2007) found out a total of about 9,500 items, excluding double citations. As shown in figure 25, the majority of these items refer to recent years citations confirming the growing interest about this approach.
Using this data set, VOSviewer was run several times, changing the values of various algorithm parameters and using the partial results to set a thesaurus file, suitable to avoid a replication of analogue topics identified by different terms.
The final map, produced setting up a number of clusters equal to 3 (resulting from a Cluster Resolution Parameter set to 0.90) and a number of topics equal to 490 (resulting from a minimum number of occurrences of 25), is shown in figure 26.

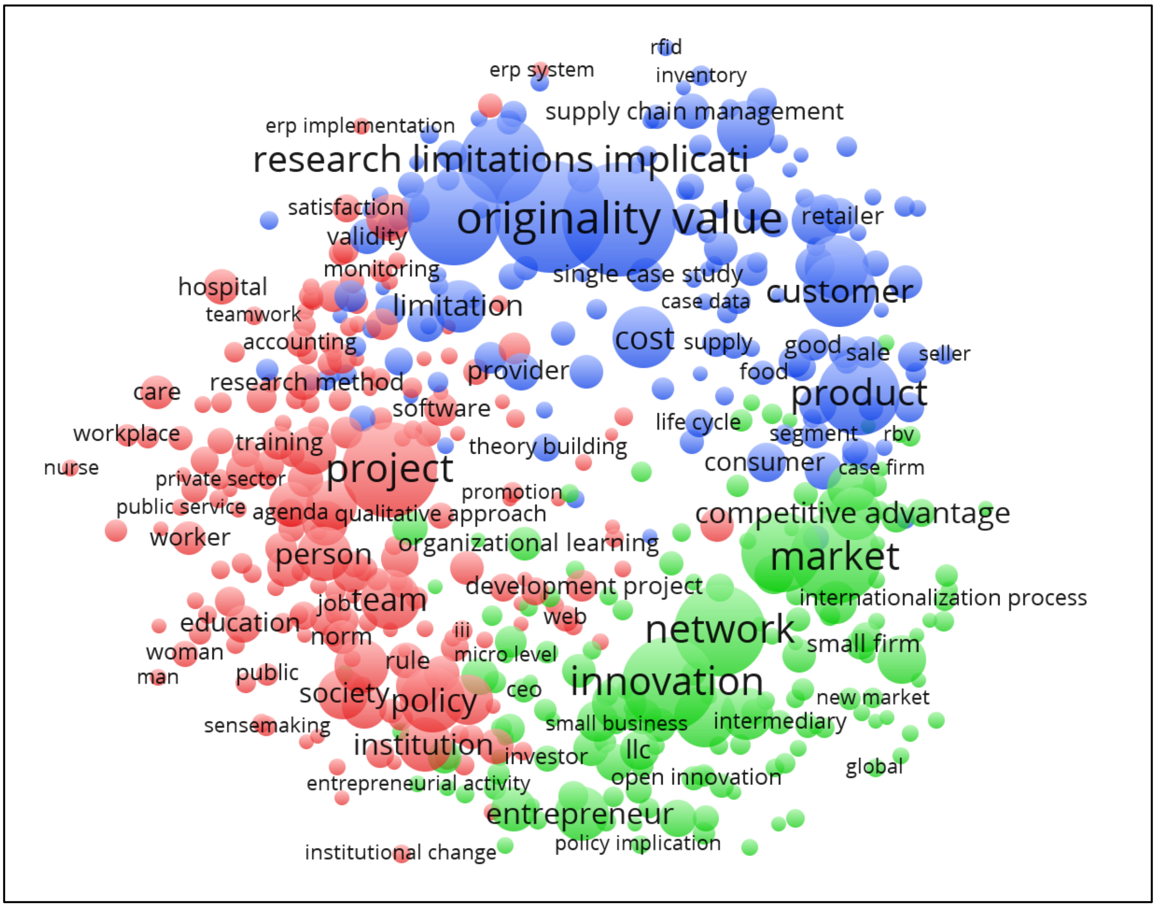

Figure 26: Network map of Theory building from cases approach processed by VOSviewer

The map (Figure 26) shows three well-defined clusters named as “social” (red coloured), “innovation” (green coloured) and “firm” (blue coloured), which the main characteristics have been briefly reported below.

- The social cluster (red coloured), on the left part of the map, is the biggest one with almost 200 terms that, in most cases, indicate the application of the TBFC approach to social issues. Terms with higher number of occurrences (i.e. “project”, “person”, “team”, “institution”, “society”, “policy”) are related to the general sphere of social policy research topic, in both private and public perspective. Moreover, the cluster shows terms related to health and human care research topics such as “education”, “gender”, “CSR” (Corporate Social Responsibility), “HR (Human Resource) management”.
- The innovation (green cluster on the right side of the map) contains about 150 terms. Most of these terms (e.g. “incremental innovation”, “innovation process”, “product innovation”, “project innovation”) are strongly related to the innovation research topic. Besides innovation, terms such as “network”, “capability”, “entrepreneur” and “multinational company” characterize this cluster.

- The firm cluster (blue coloured) includes about 140 terms associated to the idea of case study analysis related to production and management. In fact, some of the terms with higher occurrences are, on one hand, “research limitation implications”, “originality”, “practical implication” and, on the other hand, “cost”, “value”, “supplier”, “customer” and “product”. The term “food” is included in this cluster; it can bring to the conclusion that this topic, in a case study research approach, is mainly related to the idea of production and economic implications.

An important observation is that terms “theory building”, “detailed case study”, “theoretical proposition” and “cultural difference” are located in the centre of the circular map highlighting therefore their core position and multidisciplinary role.

Additionally, terms that span the boundary between two clusters highlight logical connections between them. Some of these bridge terms are “entrepreneurial activities”, “entrepreneur” and “investor” between social and innovation clusters, “computer”, “case firm” and “competitive advantage” between innovation and firm cluster, “monitoring”, “validation”, “team work”, “satisfaction” between social and firm clusters.

About the specific area of innovation in the agri-food context, while the “innovation” is one of the core topics faced in papers citing the TBFC approach, the term “food” is included in the list of 490 terms of the map while the term “agriculture” is not.

This evidence is confirmed by a specific research carried out in the Scopus database with the joint occurrence, firstly, of the terms innovation and food and, then, innovation and agriculture: in the first case 50 articles have been found, while in the second only 16.

Focusing on the topic of innovation, table 5 shows the different items contained in the map. All these terms belong to the innovation cluster, except “service innovation”, which is included in firm cluster. Leaving aside the consideration of individual terms, it emerges a general suitability of analysing the innovation topic through a TBFC research approach.

As pointed out, the topic agriculture is under investigated in the TBFC approach. Nevertheless, if we considered the agri-food sector in a more general perspective, it results that the item “food” recurs 72 times in all papers of our sample of analysis. This topic is included in the firm cluster, showing a main attention to the productive and supply chain connotation of the topic.

These results suggest that innovation processes in the agri-food sector with a TBFC approach is still largely unexplored. In other words, although this topic is approached with reference to a specific case study, very often it is not framed within a robust methodological framework such as that offered by TBFC.

Item	*Occurrences*
Innovation	1,008
Innovation process	175
Open innovation	73
Innovation project	71
Technological innovation	69
Product innovation	66
Radical innovation	58
Service Innovation	52
Innovation management	51
Innovation activity	41
Innovation capability	36
Innovation network	36
Business model innovation	33
Incremental innovation	29

Table 5: Items related with innovation and their number of occurrences.

Conclusions

This paper is a first attempt to understand how much an inductive approach, as the TBFC, has been used to study the innovation processes in the agri-food sector. Indeed, the literature about this topic is basically grounded on the description and analysis of case studies and it seems that a strong theoretical background able to fully clarify how the innovation born and spreads within the agri-food context does not exist.

The study, moving from an assessment of data on citations of the two key papers concerning the TBFC approach (Eisenhardt, 1989 and Eisenhardt & Graebner, 2007), confirmed that TBCF had a growing popularity in the last fifteen years. Then the analysis has been carried out with the aim to understand what is the general utilization of the TBFC approach in literature using the tools offered by the tools of Systematic Literature Review and Network Analysis.

Thus, starting from over 9,500 articles, a map representing the knowledge structure of TBFC was created; such map allows to identify three main research areas (clusters): social, innovation and private. In the representation “Theory building” is the key-item proving the high connection between TBFC and its applications within the three research clusters.
After this preliminary analysis, innovation in the agri-food sector has been chosen as the subject area to focus on. The network analysis shows that there is a widespread use of TBFC in papers regarding innovation, while its applications in the agri-food context is lacking, especially compared to the more diffused theory testing approach. However, despite the low diffusion of the TBFC, this research methodology seems able to represents a useful approach to investigate innovation processes in a multifaced sector such as agri-food. In this way it could be possible, moving from an empirical generalization, to establish the propositions on which to ground a theory able to explain the emergence and diffusion of innovative processes in this sector, overcoming the peculiarity of specific situations, actors or areas.
As previously stated, this study is a first attempt that requires notable improvements in the use of all instruments of research and bibliometric analysis about the TBFC in order to better understand how this approach has been used, in an explicit or implicit way, in all papers facing the innovation topics within the agri-food sector. Despite these limitations, the research perspectives seem to be very promising for both researchers and actors involved in the innovation process; furthermore, it gives to policy makers the possibility to gain innovative goals in the agri-food context.

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II.2 Applying TBFC approach to the eco-innovation case study

II.2.1 Methodological framework

Once the eco-innovation case study of *vite.net* has been chosen (answering to RQ1) and the TBFC research approach suitable for its analysis have been identified (answering to RQ2), the remaining two research questions (RQ3-RQ4) must be faced in order to understand which characteristics affects the specific eco-innovation process considered (RQ3) and whether they are generalizable in a theory through the TBFC approach (RQ4).

To answer to such research questions, the methodological process chosen is represented in figure 27.

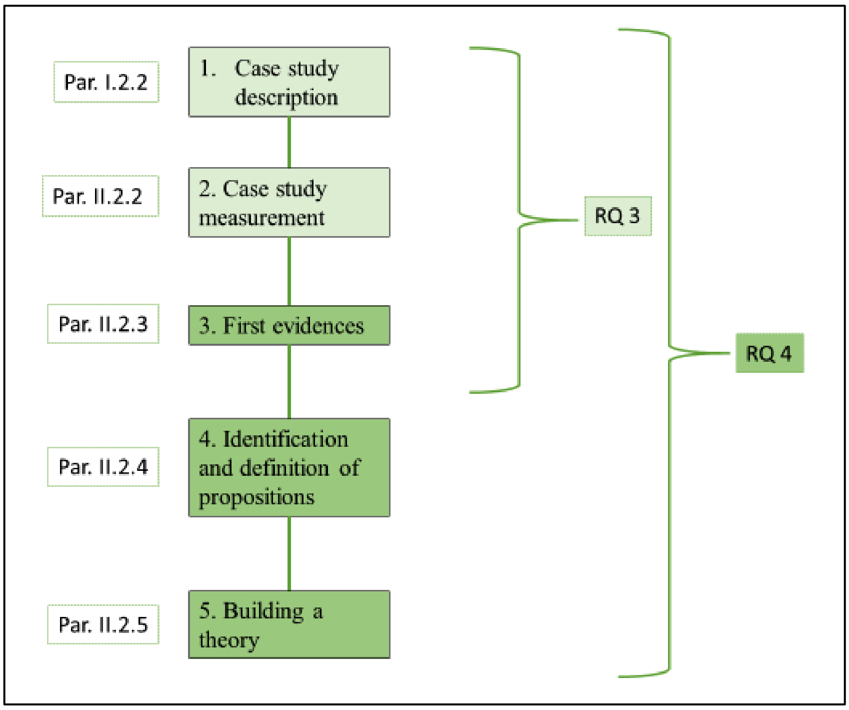

Figure 27: The methodological process

The RQ3 is strictly related to the case study as it aims to understand which characteristics affect the diffusion process of the specific eco-innovation, the DSS *vite.net*.

As it has already been said in the introduction, one of the problems which have been faced in the eco-innovation research sector is the under investigated theme of the implementation of the eco-innovation (Chen and Shiu, 2012; Arundel and Kemp, 2008). On the contrary, the case study of *vite.net* is particularly fitting with this perspective of analysis.

Indeed, as the number of rejected adoptions or abandons are quite inexistent and other data concerning the specific adoption phase were not available, the analysis has been focused on the side of the process succeeding the adoption, namely the use or implementation of the eco-innovation. In this way, the results showed how adopters use the DSS and which factors affect this side of the eco-innovation process, rather than those affecting the decision of adoption. In other words, the questions to answered became: once the eco-innovation has been adopted, it is also used? Is it used in a proper way? And, finally, which factors affect the use of *vite.net* DSS eco-innovation?

However, in order to answer to the RQ3 the first part of the research process as defined by the TBFC have been developed, namely the description (I.2.2-II.2.2) and the measurement of the case study (II.2.3). Because the innovation process officially starts when the innovation arrives to the market (Schumpeter, 1939), data have been gathered on the total amounts of users who adopt the DSS from 2013, year of launch of *vite.net* on the market.

So, the first step of the analysis consisted in the database definition. It was a time-consuming process because the data provided by Horta were non-directly suitable to be interpreted and processed. This step of the study is described in the paragraph II.2.2.

Once the database has been set, in order to study the factors influencing the diffusion/utilization process of the *vite.net* eco-innovation, data should be processed and analysed following an adequate methodology. Starting from these results, the first evidences, namely the answers to the RQ3, have been defined. This part of the analysis is described in paragraph II.2.3.

At this point, the last research question became essential. RQ4 basically focuses on the generalization of the first evidences resulting from the previous steps. It aims to assume whether the characteristics affecting the diffusion of *vite.net* also influence the diffusion and the implementation of a general eco-innovation in agriculture. Therefore, can general indications be drawn from the case study, useful to propose a theory about eco-innovation in the agricultural sector? From a methodological point of view, the last phase of the analysis concerns the second part of the TBFC process, namely the identification of the propositions and, through a literature testing, their definition (II.2.4). The literature analysis has been focused to the items of the propositions in order to test the coherence between the propositions and the existing literature about eco-innovation. Once the comparison has been done, the emergent theory can be proposed (II.2.5).

II.2.2 Database description

Database definition

First, the unit of analysis was defined. It was possible to choose between the fiscal code used by users to enter the DSS, since data about name of users was not available, and the farm to which the DSS was referred. The fiscal code has been chosen. One of the main reason justifying this choice was the case of the public institution. Indeed, if the farm is chosen as unit of analysis, it would be very difficult to manage such category. Indeed, each user belonging to the private sector category has more than one licenses of *vite.net* which, therefore, refer to different farms. After this preliminary selection, a code has been assigned to all records in order to easily identify each of them.

Data, which have been directly provided by Horta, were organized in an excel database where the 329 DSS users were listed on the row and their information on the columns.

Horta categorizes users into different typologies: private, group of private firms, general public institution, regional institution, consultant, technician, other. After a first analysis, according to Horta, the original database has been refined in order to set up a second version more suitable to the purpose of the analysis. It was a long-lasting process: as each case is quite different from the others, for many of them it was necessary to contact the supply chain manager of Horta to get specific information. In this way, incongruities, useless data, repetitions and mistakes have been deleted and all the unclear situations have been clarified.

Once this cleaning phase has been completed, the total number of user was about 225. This big decrease is mainly due to the high number of licenses related to the same user within the public institution category or to the same group of farms.

Also, the typologies of users of the original database were aggregated and reduced in three categories: private sector, public sector and technicians. The first one includes private single farms and private groups of farms; the second one combines all kind of public institutions; the third one identifies the general category of agronomists, both freelancer and working for farms, groups of farms or associations.

In the primary version of the database for each record there were information about the farm where the DSS were used (e.g. name, location, size), the fiscal code used by the farmer to enter the DSS, the name of a contact person (who can correspond or not with the real user of the DSS identified by the fiscal code) and the license (e.g. activation date,

number of visits, *etc*). Some data have been carved in order to obtain additional information missing in the original database. This was the case of users gender and age, which have been extracted from the fiscal code. Moreover, additional data have been requested, namely the number of accesses to the DSS and, for farms only, the dimension of average sales (categorized in low, medium and high) and the presence of a wine cellar.
Therefore, once category of users and all other information have been refined, the available data were the following:

- Typology of user
- Age of user
- Gender of user
- Presence of intermediary
- Size of firms (ha)
- Class of average sales
- Geographical location of the farm
- Presence of wine cellar
- Date of activation of vite.net
- Number of accesses in 2015 and 2016.

Data description

As mentioned before, at the end of the refining process, the final database of the vite.net users consisted in 225 records.
Looking at the typology users, Figure 28 shows that the great majority of them belong to the private sector (about 86% of the total) while the others are almost equally divided between public sector (about 8%) and technicians (about 5%).
About the age of users, the great majority (about 70%) are from 25 years up to 50. In second place, the older users, but not the oldest, are found (about 28%): they are from 50 years up to 75. The remaining is mainly represented by the oldest users, up to 75 years old, while just one user is younger than 25 years. Within the three categories of users (Figure 29) the situation is quite similar: the typical user is a younger middle age man; the only exception is the public sector, where older middle age users quite equals the younger middle age ones.

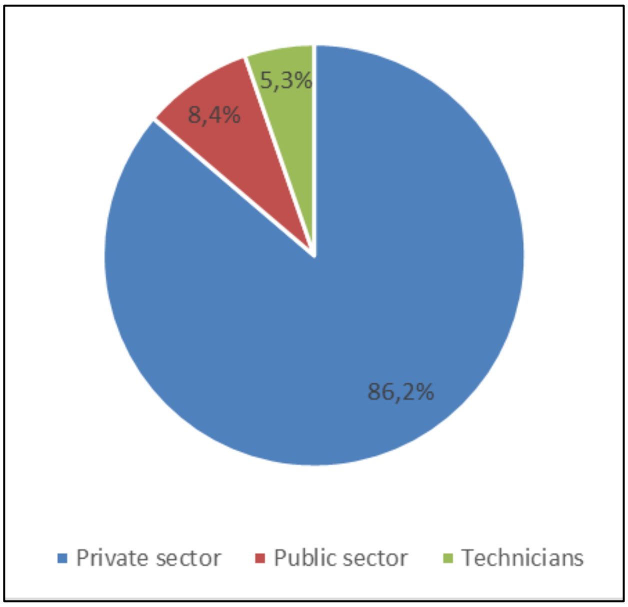

Figure 28: Categories of users of *vite.net*

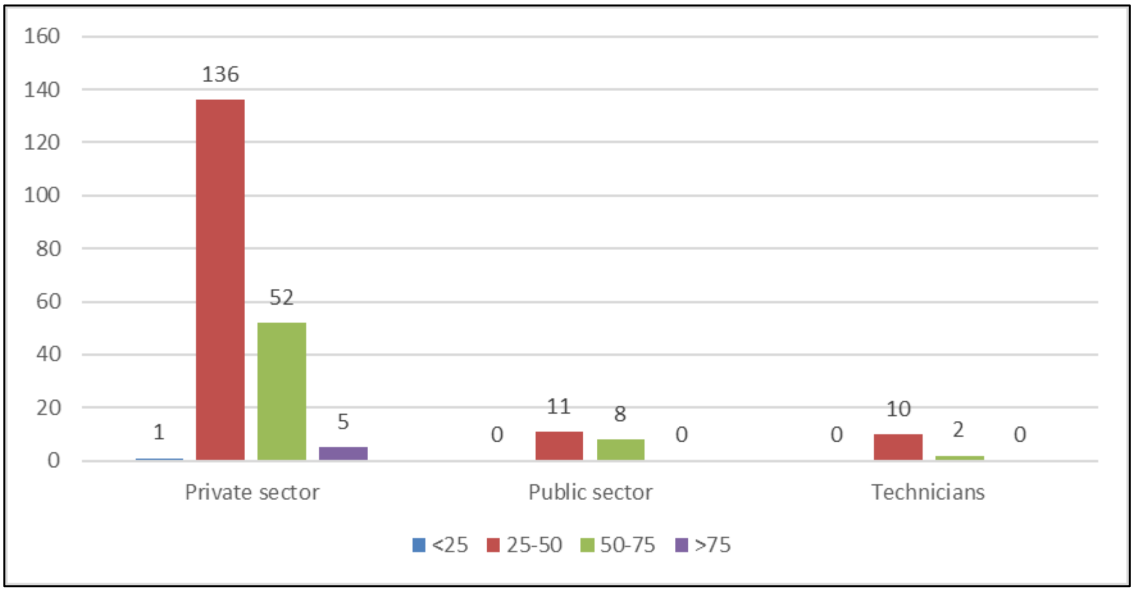

Figure 29: Age of users within the categories of users of *vite.net*

As expected, women only represent about the 7% of the total number of users. Within the three categories of users, there is no female user within the technicians' category. Indeed, in absolute terms, they principally belong to the private sector but, in percentage, they have more impact within the public sector category (Figure 30).

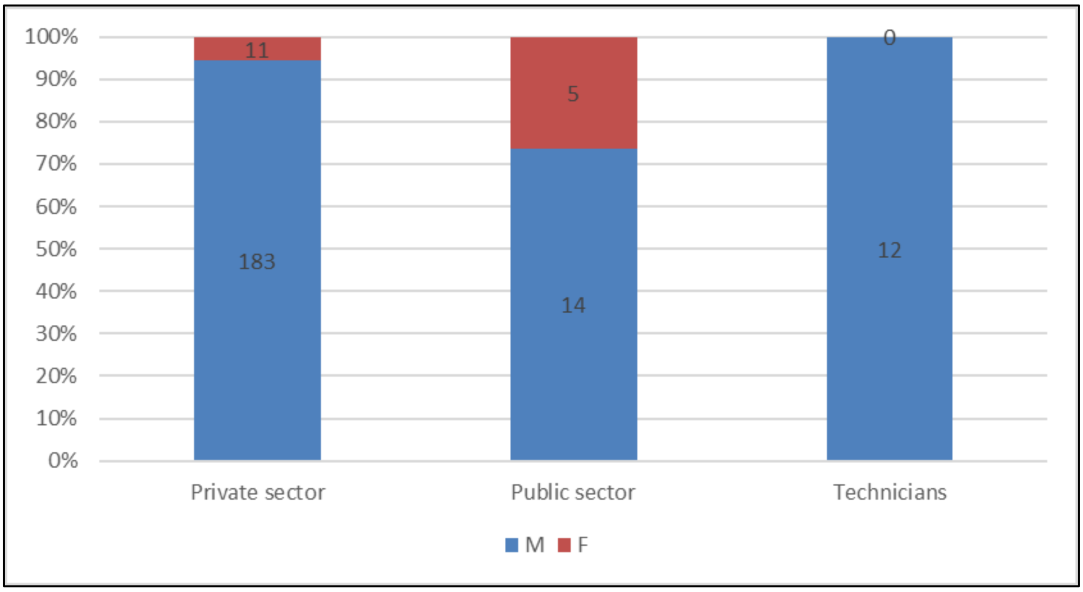

Figure 30: Male and female composition within the category of users of *vite.net*

For what concerns the information related to the farm where *vite.net* has been adopted, the following data was considered: size, class of average sales and presence of wine cellar. They are referred to the private sector category only, because users belonging to public sector and technicians' categories do not have property farms. Data about the size of the farms was provided by the first version of the database while the remaining two have been requested in a second time.

The average size of the farms is about 66 ha with a minimum of 2 ha and a maximum of 520 ha. In general, data reveal that small and medium size farms are the typical adopters of the DSS *vite.net*. Indeed, as the figure 31 shows, most farms are divided among two classes which, in terms of number of occurrences, are very similar to each other: 43% of farms are small - not micro - and manage from 10 to 50 hectares; many farms also belong to the medium size group, with 50 to 200 hectares, representing the 42% of the total number of farms. Micro farms (less than 10 hectares) and larger farms (over 200 hectares) groups are quite equals with the 9% and 6%, respectively.

In order to categorize the farms from an economic size point of view, data on the class of average sales has been gathered for each of them. Therefore, farms were grouped according to their average sales into three categories: low, medium and high (Figure 32).

The first class groups farms with average sales up to 200.000 € per year, and they represent the 27% of the total farms. The medium category embraces all farms with average sales between 200.000 and 500.000 €/year, and it has the lower number of occurrences (22%).

The majority of the farms adopting *vite.net* belongs to the third category, those with a high value of sales (over 500.000 €/year); they represent a full half of the total (51%).

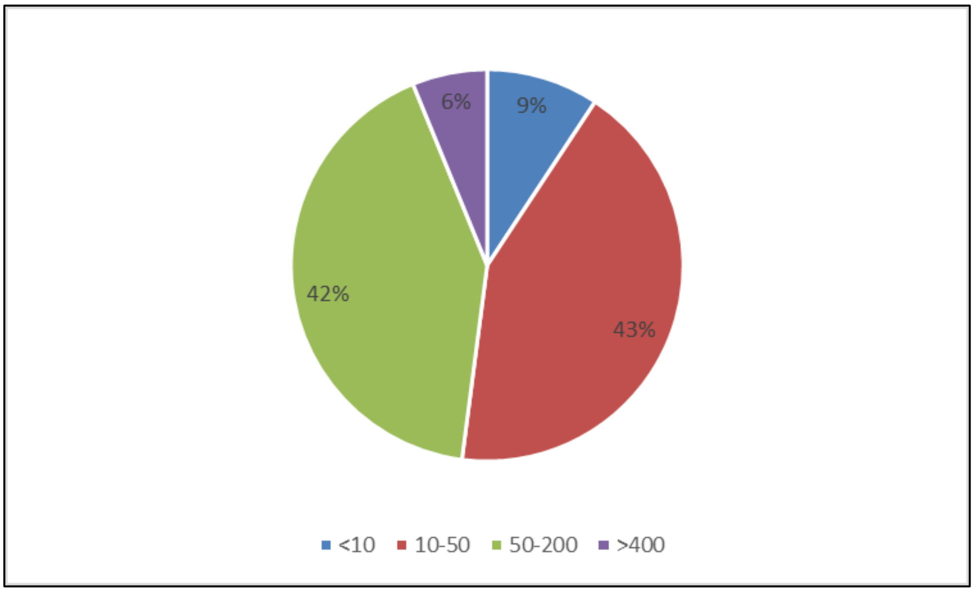

Figure 31: Size of farms adopting *vite.net*

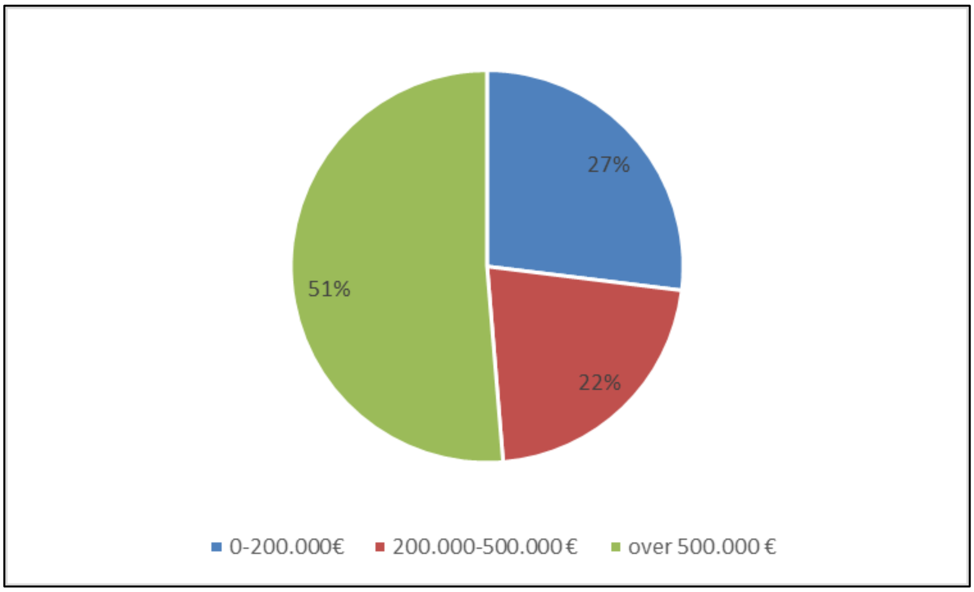

Figure 32: Class of average sales of farms adopting *vite.net*

Information about the presence of a wine cellar within the farm was requested, with the aim to detect which farms develop processing activities besides grape production, thus transforming the agricultural product, wine grapes, into a marketable product, the bottle of wine. Data shows that the majority of farms (81%) have the wine cellar.

Last data provide information about the diffusion of *vite.net* among the farms: presence of intermediary, geographical location of the farm where *vite.net* is adopted, *vite.net* activation date. As intermediary, the database reports the name of the contact person to whom Horta refers for each user. The presence of the intermediary was defined comparing the fiscal code reported for each user with the name of the contact person: when they match, there is no intermediary; vice versa, when they do not match, an intermediary is supposed to be present. This is a useful information to better understand the relationships between Horta and the DSS' users, as well as the process along which *vite.net* was adopted by the farms. Furthermore, the presence of the intermediary may also affect the way farmers use the DSS. In general, only 11% of users have an intermediary; the majority of them has a direct relationship with Horta, from the first contact until the management of the DSS use. Within the categories of users, both the private and the public sector confirm such data (Figure 33). Instead, the category of technicians shows a different situation as they have no intermediary, because they directly manage *vite.net* to offer to their customers, namely farms owners or managers, this additional service.

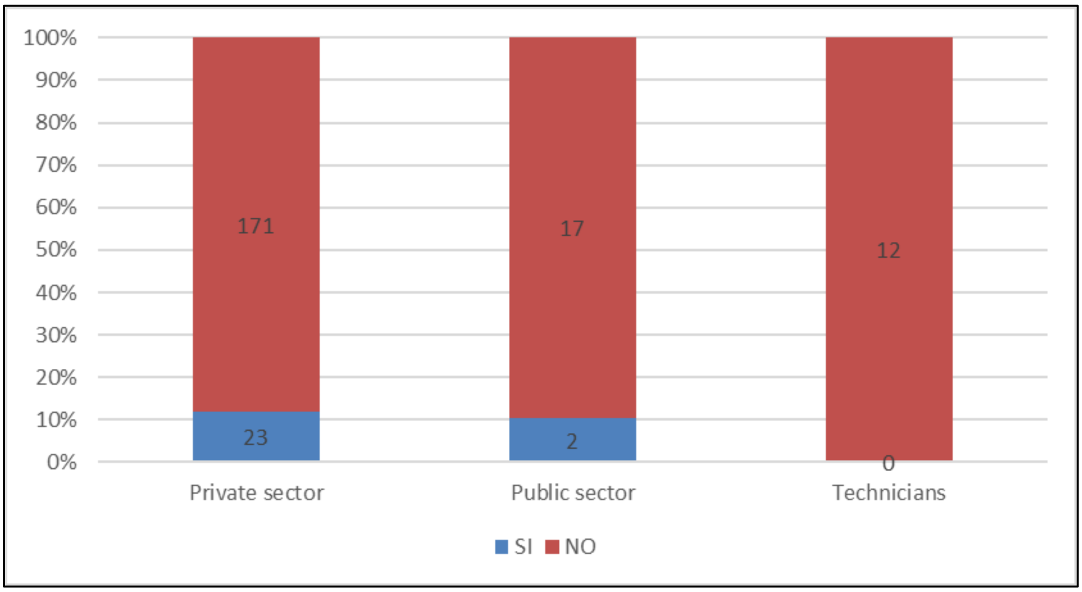

Figure 33: the presence of the intermediary between Horta and the DSS users

The geographical location of the farms where *vite.net* has been adopted was defined at regional territorial scale. Such data was quite hard to evaluate. Indeed, in the original database there were many users who follow farms located in different place and different regions. Because users, rather then farms, are our objective of analysis, this was just a secondary issue to consider but it had to be. For this reasons, it has been found a solution case by case. Whether a multiple location of a farm where the same user manages the DSS is an expression of very different realities, such realities have been considered separately. If not, only the main reality has been considered, as reported by Horta.

The map in figure 34 shows the diffusion of *vite.net* in Italian regions. As shown, farmers of many Italian regions have adopted *vite.net*, but the one where it is more developed is Tuscany with 23% of farms located in this region. Then follows Veneto and Umbria, with the 12% of farms, and Emilia Romagna (10%).

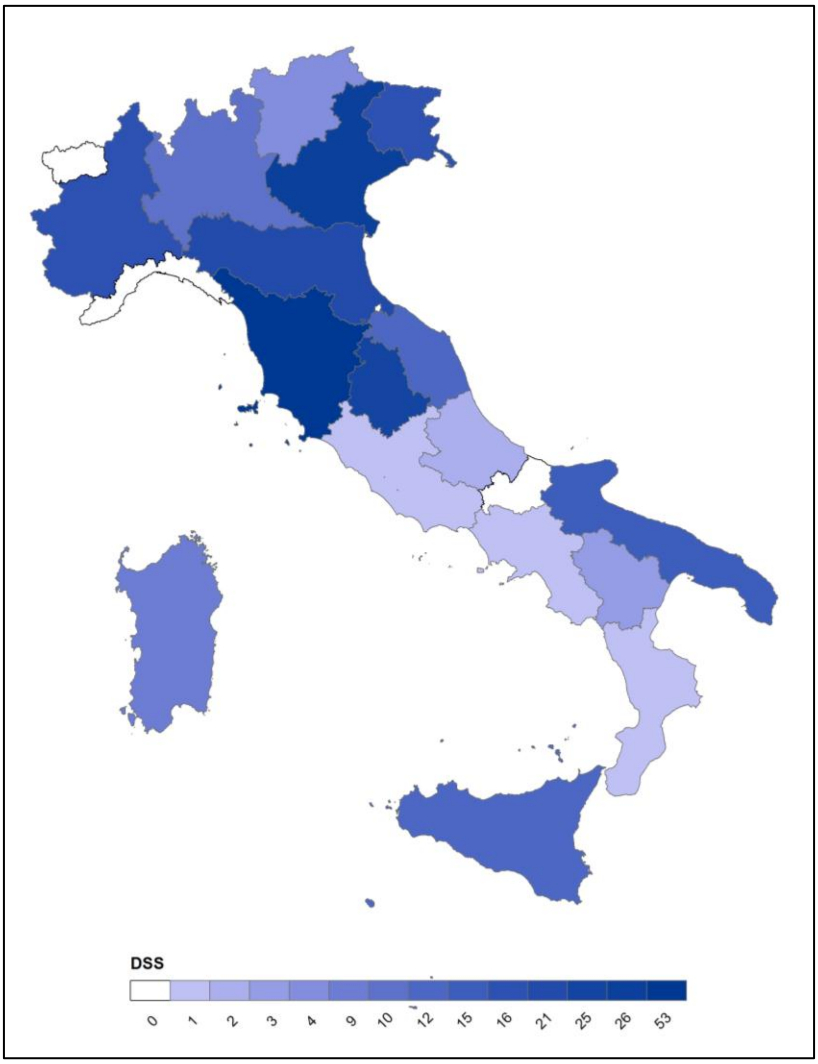

Figure 34: Geographical diffusion of *vite.net*

Another information provided by the original database is DSS' activation date. This data is very useful to consider the inclination of each user to innovation, which can be estimated through the time passed since the activation date. The figure 35 shows the number of adoptions of the *vite.net* since 2013, year of launch of the DSS, until November 2016. As it is possible to see, the firsts two years had the same number of activations, while 2015 has been the year with the highest number of adoption. However, this graph reminds the one which has been shown in the first chapter about the adoptions rate made by the different categories of adopters based on their degree of innovativeness (Rogers, 1983).

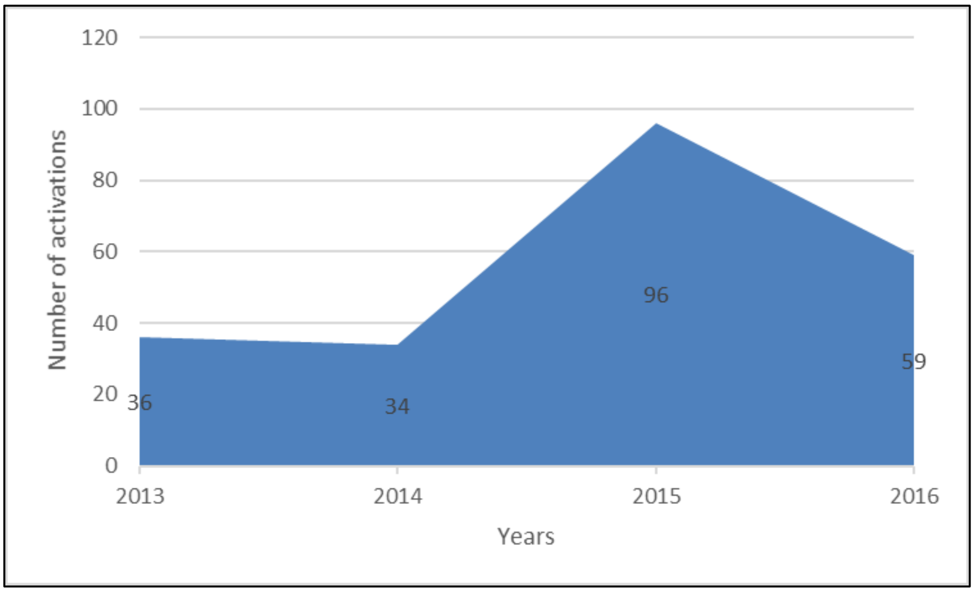

Figure 35: Time diffusion of *vite.net*

In addition to the data described so far, also the number of total accesses made by each user to *vite.net* was requested to Horta. The number of times each user entered the DSS is a data available for all users of the three categories in the years 2015-2016, while data about previous years were not available.

About this data two considerations can be made. The first is that, in absolute terms, a lower number of accesses would mean a scarce use of the DSS by its adopters while, conversely, a higher number means that *vite.net* is largely used. The second concerns the efficient use of the DSS. Indeed, a very high number of accesses is a potential sign of an incorrect use of the DSS. Of course, many are the variables affecting such data as, for example, the size of farm: users from large farms may need more frequent accesses to the system than users with smaller farms.

Horta states that, in general terms, an adequate and correct average number of accesses is about 300 per year. Considering both years for which data is available, namely 2015 and 2016, an adequate number of total accesses made by users to DSS has been established between 400 and 800. As the figure 36 shows, only the 15% of users show a number of accessed to the DSS which can be considered adequate, while the others underuse (54%) or overuse (31%) it.

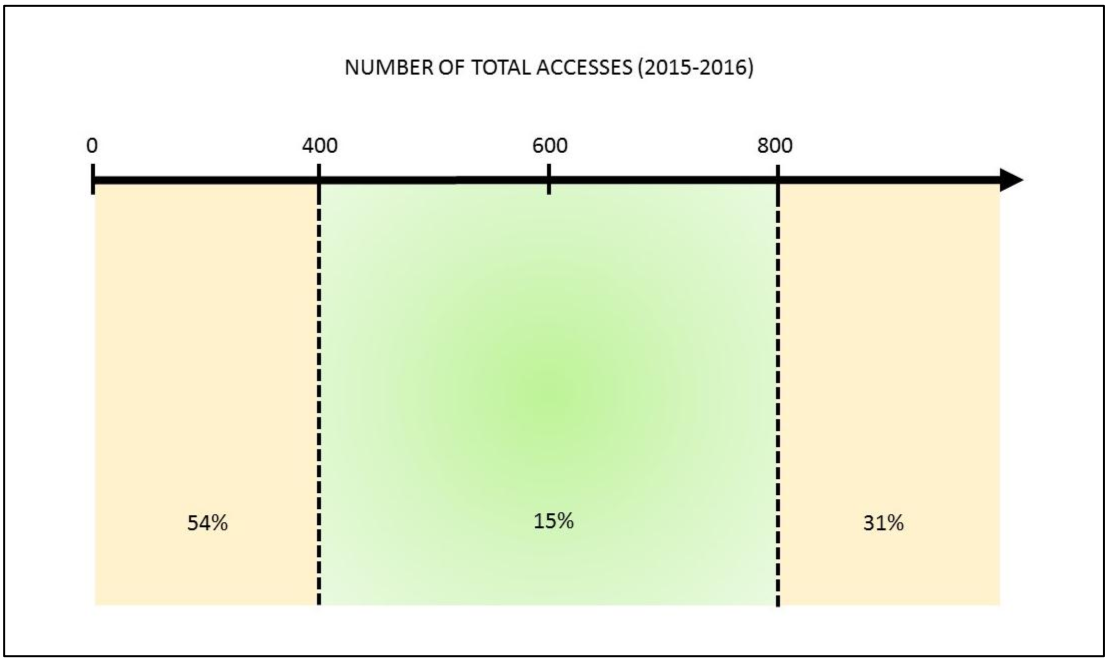

Figure 36: Distribution of the total number of accesses to vite.net in 2015 and 2016

II.2.3 Getting empirical evidences

Once the database has been set, the question to answer is how to read and interpret data in order to get empirical evidences, namely the answer to the RQ3 about the factors influencing the diffusion/utilization process of the *vite.net* eco-innovation?

To do so, as shown by Figure 37, a two steps process has been carried out. The first step consists in a quantitative analysis, which aims to assess the role of each variable in affecting the level of utilization of the eco-innovation *vite.net*. Considering such explorative objective, a regression model has been considered appropriate. Indeed, as the analysis aims to investigate only major evidences and the database counts on both continuous and categorical factors, the covariance analysis (ANCOVA) has been chosen as statistic model to get general, but useful, indication. The significant variables resulting from the regression model and showing which characteristics affect an efficient diffusion/utilization of the DSS *vite.net*, define the primary outcomes.

Finally, focusing on the second step of the analysis, such primary outcomes have been qualitatively discussed and verified through an interview with the innovator, namely the expert of Horta who manage the DSS *vite.net*. After the expert validation phase has been conducted, the first evidences can be defined and, therefore, also the answer to the third research question (RQ3) can be reached.

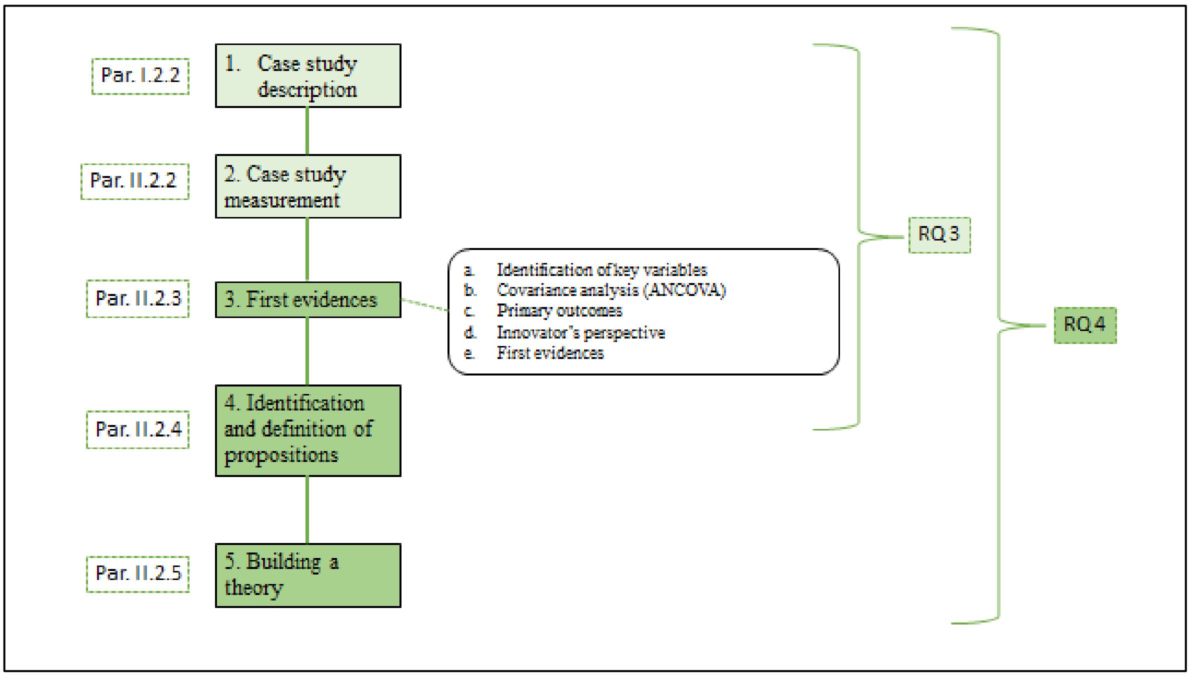

Figure 37: Detailed methodological framework (1)

Variables definition

As it has already been mentioned in the previous section (II.2.2), the great majority of users belong to the private sector (about 86% of the total number of users) while the others are divided between public sector (about 8%) and technicians (about 5%). Because the considerable role of the first category of users and the not homogeneous situation inside the other two typologies of users, the analysis has been focused on the private sector users and their farms. So, the number of observations is 194 units.

The dependent variable (Y) has been defined on the base of the data, which has been just discussed, namely the number of accesses made by each user to the DSS *vite.net*. It was defined as the AVERAGE NUMBER OF MONTHLY ACCESSES in the period between January 2015 and November 2016. As it has already been said within the previous paragraph (II.2.2), this variable highlights the correct, or the incorrect, use of *vite.net* made by users.

Then, as already mentioned, n.8 independent variables (X) have been defined from data listed in the previous section. They are both quantitative and qualitative and have been divided into three groups: (a) characteristics of user, (b) characteristics of farm, (c) aspects of DSS diffusion.

a. Characteristic of user of *vite.net*

This first group covers data about AGE OF USER and GENDER OF USER.

1. AGE OF USER: it is a quantitative variable which indicates the age of the user who accesses the DSS through the fiscal code identification;
2. GENDER OF USER: it is a dummy variable indicating the gender of the user who accesses the DSS through the fiscal code identification; a value of 0 has been assigned to male users (M), a value of 1 has been assigned to female users (F);

b. Characteristic about farm where *vite.net* is used

The second group assembles data about PHYSICAL SIZE, ECONOMIC SIZE and PROCESSING ACTIVITIES of the farm.

3. PHYSICAL SIZE: it is a quantitative variable which indicates the physical size of the farm where the DSS has been adopted, expressed in hectares;
4. ECONOMIC SIZE: it is a dummy variable indicating the class of average sales of the farm where the DSS has been adopted. As mentioned before, three sales classes have been initially defined (low, medium and high). Therefore, a value of 0 has been assigned to farms with low sales volumes (less than 200.000 €), whilst a value of 1 has been assigned to farms with medium sales volumes (200.000-500.000) and 2 to those with a high class of sales (over 500.000 €);
5. PROCESSING ACTIVITIES: it is a dummy variable stating the presence of the wine cellar within the farm where the DSS has been adopted. A value of 0 has been assigned to farms without a wine cellar (NO) whereas, on the contrary, a value of 1 has been assigned to farms with a wine cellar (YES);

c. Characteristic of *vite.net* diffusion

The third group of data, concerning the diffusion process of *vite.net* in Italy from a relational, spatial and chronological perspective, consists fundamentally in three variables: NETWORK, GEOGRAPHICAL DIFFUSION and TIME DIFFUSION.

6. NETWORK: it is a dummy variable indicating the presence of an intermediary between Horta and user, namely the contact to which Horta principally refers. A

value of 0 has been assigned when the intermediary is not present (NO) whereas a value of 1 has been assigned when there is an intermediary (YES);

7. GEOGRAPHICAL DIFFUSION: it is a dummy variable indicating the territorial localization of the farm where the DSS has been adopted. According to the ISTAT classification, Italy has been first divided into Northern, Central and Southern areas. Then, since *vite.net* is more adopted in the Northern part of Italy, these three macro-regions have been grouped into two categories. Namely, a value of 0 has been assigned to farms located in the Central and Southern Italian regions, whereas a value of 1 has been assigned to farms located in the Northern Italian regions.
8. TIME DIFFUSION: it is a quantitative variable that indicates the period since the user has adopted *vite.net*; in particular, the number of months from the activation data until November 2016 has been calculated.

The ANCOVA model

We selected the covariance analysis (ANCOVA) as a suitable statistical instrument to investigate how the different characteristics of user, farm and DSS diffusion may influence the DSS level of utilization (Piccolo and Vitale, 1981). Indeed, as the analysis has a general explorative objective, more sophisticated models have not been considered necessary.

The ANCOVA is a statistical process blending regression and ANOVA for estimating the relationships among variables (Vogt and Johnson, 2016). It aims to study the dependence of a variable (Y) by a set of *k* quantitative and categorical explanatory variables (x_1, x_2, x_3, …, x_k), the regressors, developing a linear model. Unlike regression, the ANCOVA explicitly consider the qualitative variables, and this is the reason why it was chosen in our case (Huck, 2008).

Such model is expressed by a function, namely the regression curve, which is:

$$Y = f\ (x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8) + \varepsilon$$

Adopting a linear function, the regression model can be written in the following way:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8 + \varepsilon$$

In this case the function (f) determines by means of the coefficients (β_i) the influence of each variable (x_i, i=1…8) on the dependent variable (Y) considering the general standard error (ε).

Considering the dependent and independent variables, which have been just described, the general structure of the model is represented in Figure 38.

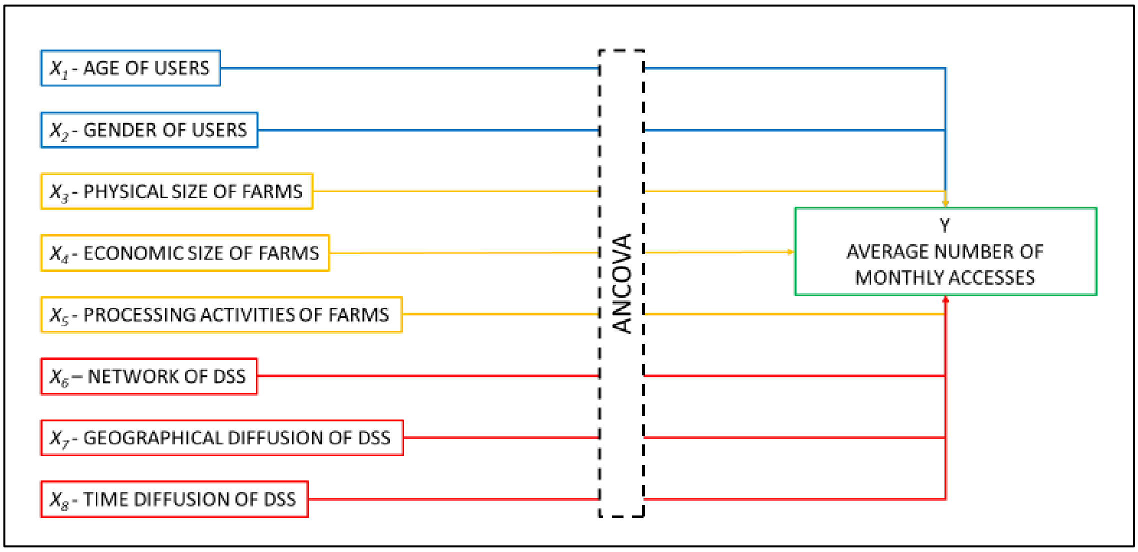

Figure 38: The structure of the covariance analysis (Ancova) model

Results and discussion

Table 6 shows the first general results about the model validity.

R^2	0.098
GDL-Regression	9
GDL-Residual	176
GDL-Total	185
F	2.134
F significance	0.029
F confidence	97.1%

Table 6: ANCOVA analysis results (1)

Given the R^2 value, the independent variables (x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8) explain the 10% of the whole variability of dependent variable (Y), namely the AVERAGE NUMBER OF MONTHLY ACCESSES. Otherwise, considering that the *F* confidence value is over the 97%, the model seems to show a good predictive capacity.

Table 7 shows the regression results in terms of independent variables.

Variables	Typology	Coefficients	Standard error	Stat t	Significance
Intercept		0.159	21.707	0.007	0.994
1. Age of user	Quantitative	0.355	0.272	1.304	0.194
2. Gender (0)	DUMMY	2.140	13.457	0.159	0.874
Gender (1)					
3. Physical size of farms	Quantitative	0.113	0.049	**2.322**	**0.021**
4. Economic size of farms (0)	DUMMY	3.988	10.161	0.392	0.695
Economic size of farms (1)		-1.562	8.379	-0.186	0.852
Economic size of farms (2)					
5. Processing activities (0)	DUMMY	-6.281	10.345	-0.607	0.544
Processing activities (1)					
6. Network (0)	DUMMY	28.258	9.632	**2.934**	**0.004**
Network (1)					
7. Geographical diffusion (0)	DUMMY	-8.525	6.609	-1.290	0.199
Geographical diffusion (1)					
8. Time diffusion	Quantitative	-0.219	0.252	-0.870	0.385

Table 7: Ancova analysis results (2)

Given such results, the final regression function becomes:

$$Y = 0.159 + 0.355\ x_1 - 2.140\ x_2 + 0.113\ x_3 - 3.988\ x_4 + 6.281\ x_5 - 28.258\ x_6 + 8.525\ x_7 - 0.219\ x_8$$

In absolute terms the more impacting variable is NETWORK (6) followed by GEOGRAPHICAL DIFFUSION (7), PROCESSING ACTIVITIES (5) and ECONOMIC SIZE OF FARMS (4). Later, GENDER (2), AGE OF USER (1), TIME DIFFUSION (8) and PHYSICAL SIZE OF FARMS (3) are found.

Each coefficient explains how much the variables influence the dependent one increasing the number of accesses when the sign is positive (+) or, conversely, reducing this value whether the sign is negative (-). Therefore, about the way the variables effect on the dependent variable, higher age, larger farms, presence of processing activities and the localization in the Northern part of Italy lead the users to use more the DSS. On the contrary, a female gender, the presence of the intermediary and an early adopter situation lead to a reduction in DSS utilization.

Figure 39 shows how much each independent variable affects the dependent in standardized terms. In the case of the dummies variables, the incidence has been calculated for the first category, namely the 0 value. It means: male gender (GEN-0), location of farms in the Central and Southern Italian regions (GEO-0), low (ECO-0) and medium (ECO-1) slot of farm sales - as such variable counts three categories -, no processing activities right inside (PRO-0) and no intermediary (INT-0).

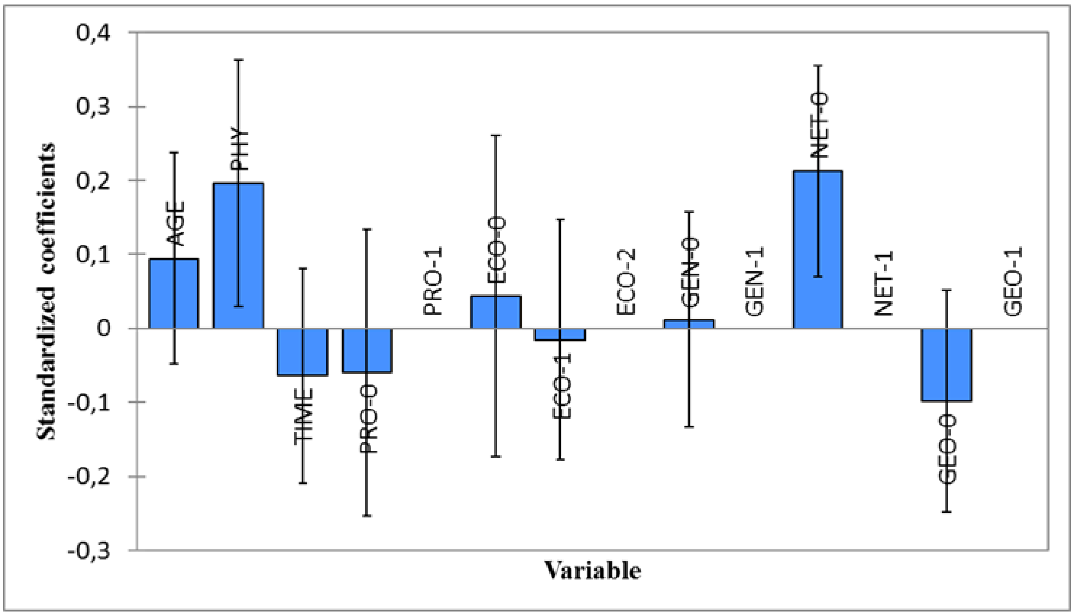

Figure 39: Standardized influence of the independent variables on the dependent one (confidence interval 95%)

Focusing on single variables, the more impacting is the NETWORK followed by the PHYSICAL SIZE OF FARM. Then GEOGRAPHICAL DIFFUSION, AGE OF USER, PROCESSING ACTIVITIES, TIME DIFFUSION and ECONOMIC SIZE OF FARM follow. Finally, GENDER is the less impacting one.

Nevertheless, as the figure 40 highlights, the significant variables are only NETWORK and PHYSICAL SIZE OF FARMS with a significance value of 0.004 and 0.021 respectively.

The influence of GEOGRAPHICAL DIFFUSION and AGE OF USER variables on the dependent variable emerges, but their low confidence values prevent the consideration of these data. However, in the first case the variable coefficient means that farms located in the Northern part of Italy use more the DSS than those located in the Center or in the South. This evidence could be due to many and different factors, but the location of the Horta offices in the Northern part of the Country maybe strengthen the use of the DSS by the farms of such area. Looking at the second variable, older farmers use more often the DSS than younger farmers. The explanation of this result could be a potential incorrect use of *vite.net* by older users with respect to the younger ones who may be more aware and trained about the correct use of this instrument. In general, literature about innovation in the agricultural sector confirms such evidence. Indeed, older farmers usually have shorter planning horizons and are expected to be less innovative whereas it is a stable opinion that younger farmers have an increased innovativeness and a higher likelihood of adoption. Nevertheless, as it has already been said, both variables cannot be considered for the following analysis. Moreover, for the specific case of DSSs and, in general, of eco-innovations different analysis should be done.

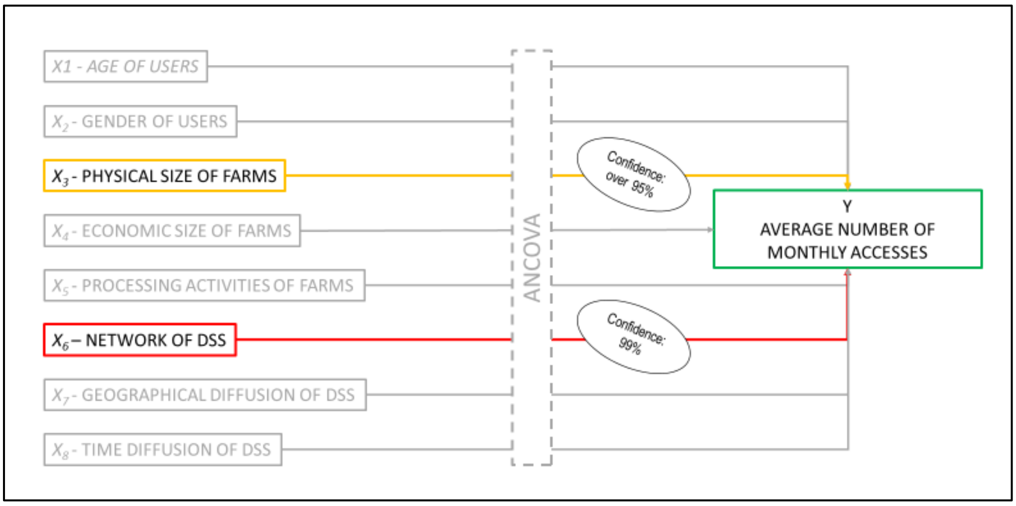

Figure 40: Significant explanatory variables

In order to understand how variables relate each other, an attempt of interaction analysis has been done. Except the interactions AGE-SEX of users (confidence value over 95%) and TIME DIFFUSION-PROCESSING ACTIVITIES (confidence value over 90%), others were not significant. However, as the significant relations refer to not significant variables and the analysis aims to investigate only a general trend, they have not be considered at all.

Therefore, looking at the model results shown in Tables 6 and 7, some primary outcomes emerge:

I. The chosen variables explain only the 10% of the variability of dependent variable (Y), which is consequently influenced by other, maybe subjective, factors not available and hence not considered in the analysis.

II. As the model has a good predictive value (with a confidence value of 97%), Horta could estimate the potential AVERAGE NUMBER OF MONTHLY ACCESSES of a new user according to the eight explicatory variables considered in the model.

III. The NETWORK variable of the *vite.net* diffusion, considerably influence the dependent variable. It means that when the intermediary is present the NUMBER OF MONTHLY AVERAGE ACCESSES made by users to the DSS is lower. About this evidence two possible considerations can be made. The first could see the intermediary's role as negative because it decreases the NUMBER OF MONTHLY AVERAGE ACCESSES. But the same data could be interpreted under a completely opposite perspective, as the intermediary could have a positive role in avoiding a potential incorrect use of *vite.net*, with an excessive number of accesses to the DSS.

IV. The PHYSICAL DIMENSION OF FARM variable is also significant in explaining the NUMBER OF MONTHLY AVERAGE ACCESSES; indeed, the owners of larger farms use more often *vite.net* than those of smaller farms. This suggests that the first, managing larger vineyards, need to enter the DSS more often.

V. The remaining explanatory variables, because of their low confidence value, do not seem to influence the AVERAGE NUMBER OF MONTHLY ACCESSES.

Innovator's perspective

After getting the result from the analysis of empirical data, and before defining the propositions, the primary outcomes were discussed with an Horta expert in order to test whether they fit with the innovator's perspective of the reality. Indeed, as the *Ancova* analysis is not a properly inductive instrument, to avoid the risk of an excessive estrangement from the peculiarity of the case study, which is one of the distinguishing features of the TBFC research approach, this secondary discussion phase was considered as necessary.

In general, the supply chain manager of *Horta* confirmed all the primary outcomes. Despite it is not significant, he confirmed also that *vite.net* is more and better used in the Northern part of Italy, rather than the Center and the South: «*This is because the closer relations with the Northern farms, while in the South relationships are more complicated for many reasons.* »

In particular, when he focused on the outcome I, namely to all factors affecting the use of the DSS which have not been considered in our analysis, the role of the sustainable awareness was underlined according to a double perspective, internal and external. From the first point of view, the personal inclination of the farmer toward sustainable production affects the decision to adopt and especially to correctly use the DSS and, in general, an eco-innovation. Focusing on the second perspective which can be defined as a market awareness and, in general, seems to be predominant than the first one, other two categories of external influences can be identified: direct market influences and indirect market influences. In the first case, the sustainability demand of the downstream consumers affects also the upstream farms, their owners, the way to produce and, consequently the inclination to adopt and use an eco-innovation. This is the specific case of the farms adopting *vite.net* embedded in a supply chain which directly connects grapes and wine grapes producers with their final consumers. Otherwise, the indirect market influences effect on farms which belongs to supply chains where some innovation stakeholders, as the manager defined them the «*great moms*», mediate between single farms and final consumers. Such stakeholders could be other farms, or multinationals, categories association, elevators, etc. However, in a system like this, such subjects can request the use of guidelines or the adoption and the use of innovations to the farms that provide their products. This is the case of other DSS proposed by Horta, as *granoduro.net* and *orzobirra.net,* as their adoption and use is required by Barilla and Heineken, important companies which produce pasta and beer, to the farms producing durum wheat and barley respectively.

Always focusing on the I outcome, another issue which emerged is the role of communication. Indeed, in the Horta opinion, farmers seem to have «*a real need to communicate the sustainability of their farms*» reached through the correct use of *vite.net* as it allows an efficient and optimized management compared to a classical one. Moreover, in some cases, such communication need can be the first stimulus to adopt and use in an efficient way the DSS, mainly for farms belonging to a supply chain where they directly relate with the final consumer. In this perspective, Horta considers that communicate the -correct- use of the DSS is more powerful than the simple adoption, as the manager said «I*t's not important to have it but use and communicate it*».

Focusing on outcome V, namely the positive role of the network, the manager of Horta found this result confirming his empirical experience. Indeed, he also assigns to this factor a fostering role in the diffusion of the DSS and, above all, of its correct use. As he argued, the network factor give the opportunity to face problems in a standardize way, «*stopping a situation to deal it together. It gives everyone the same pair of lenses. In a sense, it is a way to standardize the knowledge*». Moreover, the staff of Horta is arranging some new activities with the aim to support such aspects of the innovation process: they are committed to the realization of digital communicative platforms (blog and forum) or real meetings where users and technicians can share their ideas, their questions and he1p each other in the daily cropping management.

At this point of the analysis, since the primary outcomes can be confirmed as first evidences, the answer to the third research question (RQ3) aiming to identify the characteristic influencing the diffusion process of the eco-innovation *vite.net* has been reached.

II.2.4 From evidences to propositions

As the RQ3 has been answered, the next and last RQ4 must be faced. Starting from such first evidences, the propositions about the characteristics affecting the diffusion of a general eco-innovation can be identified and confirmed or not through a specific literature review (Figure 41). After this generalization and conceptualization phase, if the results allow it, the primary formulation of a new theory became possible.

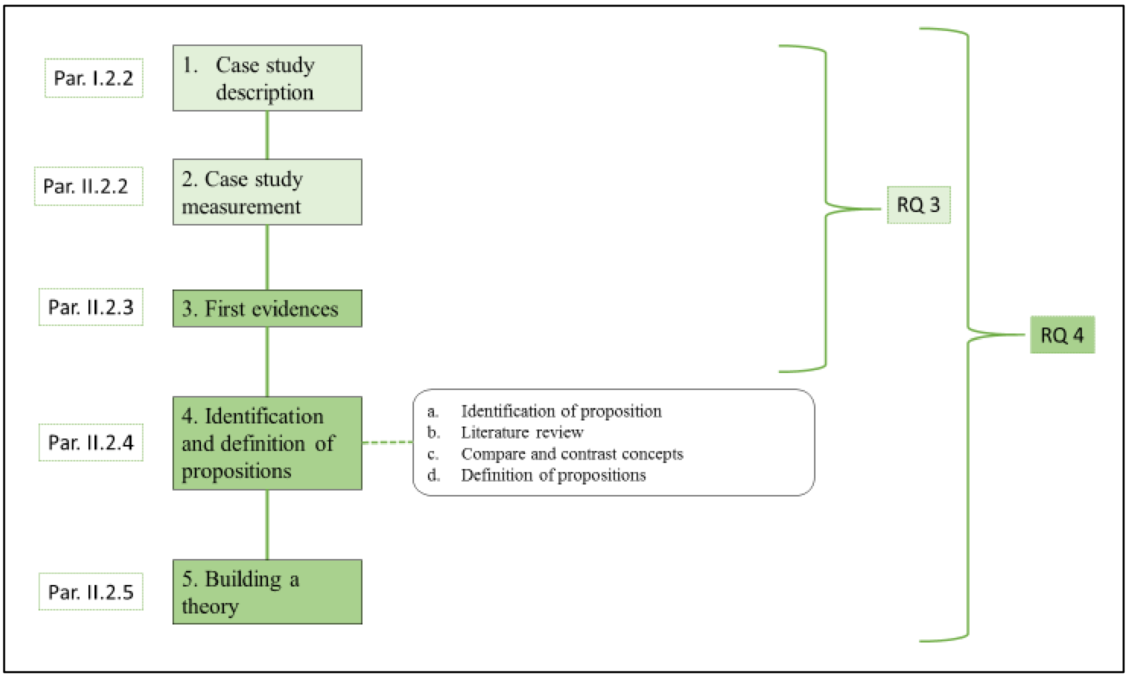

Figure 41: Detailed methodological framework (2)

In order to understand (i) whether the characteristics affecting the use of the DSS *vite.net* are the same which influence the diffusion and utilization process of a general eco-innovation according to existent literature and (2) whether the construction of a theory about eco-innovation within the agricultural sector is possible, in this paragraph, starting from the first evidences about the DSS vite.*net* which have just been identified, three main propositions (P1, P2, P3) about the eco-innovation have been defined.

To correctly define such propositions and before going into their detail, an introducing proposition (P0) have been defined.

- P0: Within the general eco-innovation diffusion process, the adoption phase and the use phase of the eco-innovation must be distinguished.

Then, given such premise proposition, the main three ones (P1-P2-P3) have been identified:

- P1: in a broad sense, the use of an eco-innovation is strongly influenced by not easily identifiable and maybe subjective multiple factors;
- P2: the use of an eco-innovation is related to the physical size of the farms and not to the economical one;
- P3: the efficient use of an eco-innovation is influenced by the network.

Once the propositions have been identified, the next phase consists of a punctual analysis of the eco-innovation literature to understand whether they can be generalized.

In general, the objectives of a TBFC literature review are deeply anchored to the propositions and to the issues they concern. Therefore, such review aims to compare and contrast the concepts expressed by the propositions to the existent literature in order to understand whether they could be a potential starting point to develop a theory, in our case about eco-innovation in agriculture.

According to the specific propositions the main concepts concern:

- (P0) the identification of the distinct phase of the use of eco-innovation;
- (P1) from a general point of view, the role of the subjective and not easily identifiable multiple factors and, trying to go more deeply, the role of communication and personal farmers inclinations, as highlighted by the innovator.
- (P2) focusing on the factors related to the characteristic of the farm, the role of the physical and economic size;
- (P3) focusing on the factors related to the characteristic of the innovation itself, the role of the network, interpreted as a factor fostering an efficient use of the co-innovation.

Once the concepts have been stated, it should be define how to conduct the literature review.

First, as the main result of the first part of the thesis led to the identification of the DSS *vite.net* as an eco-innovation, the search will focus on papers relating to such research topic. Second, *vite.net* is definitely a technical innovation. The introduction of a computer-based software that helps farmer in taking its cultivation decisions involves a technological change in its production scheme. At the same time, it has to be considered that product innovations involve the creation of new products or services through a redefinition of standard processes. So, *vite.net*, and in general any DSS, could be seen under both perspectives. According to the first point of view, the focus is put on the technology and hence can be seen as a process innovation able to reduce costs and increase the quantity produced; the second perspective looks at the DSS as a way to improve the quality (both material and environmental) of the production and, for this reason, can be seen as a product innovation. Unfortunately, the literature on innovation is not focused on specific typology of innovation and hence it is not possible to address adequately this discussion.

More in general, it would be interesting to compare the propositions with the eco-innovation literature (even non strictly scientific) focused on agricultural sector, on the implementation phase of the diffusion process, on the different aspects of eco-innovation or, also, with not scientific documents. Unfortunately, as such topics are still largely unexplored from both a research and practical point of view, an effort in this direction does not appear promising enough.

Therefore, the analysis has been focused on the concepts resulting from each proposition compared to scientific literature about the topic of eco-innovation in general terms.

P0 - *Within the general eco-innovation diffusion process, the adoption phase and the use phase of the eco-innovation must be distinguished*

This preliminary assumption emerged, first of all, from the literature analysis carried out in the first part of the thesis. This proposition was also confirmed by empirical evidences and, in particular, by the final considerations of the innovator which indicates the crucial phase of the innovation utilization completely different from the adoption one.

Indeed, as it was already argued in the introduction, according to the Schumpeter's model, the innovation process starts when an idea reaches the market becoming a true innovation and ends when it turns out in normal practices and procedures (Schumpeter, 1939). So, the innovative process can be ideally divided in two phases, the first from the innovation birth to its early adoption and the second from the adoption (and the use) to the normal practice. In general, differently from the ample discussion existing about innovation diffusion processes, the literature about this second phase is very poor. Moreover, Chen and Shiu (2012) highlighted the under investigated theme of the use of an eco-innovation arguing that Arundel and Kemp (2009) is the unique study which try to fill the gap. Moving from such considerations, it can be said that this proposition seems to be confirmed.

P1 - *The general use of an eco-innovation depends by not easily identifiable and subjective multiple factors*

This proposition focuses on the role of multiple and subjective factors which seem to influence the diffusion process of the eco-innovation, as confirmed by the empirical evidences from both external (e.g. the Ancova analysis) and internal (e.g. the innovator' final comments) perspectives. Scientific papers facing this issue are not so many. They faced the immaterial and subjective characteristics of the eco-innovation process focusing on different aspects.

Horbach *et al.* (2012) argued that the subjectivity of the eco-innovation relies within some of its definitions where innovation has been considered to be new for the firm deviating from the traditional economic notion of innovation proposed by Schumpeter (1934) which regards innovation as the first introduction of a new product, process, service or organizational structure into the market. Moreover, Kemp and Martens (2007) examining the notion of sustainable development that has emerged in the western society, argued that the number of its definitions is estimated to run into the hundreds because it is an inherently subjective concept. Therefore, a precise definition of the concept would say of excluding the views, which were not expressed in that definition (Robinson, 2004). Indeed, as these authors argued:

- different actors belonging to various sectors may have different ideas regarding sustainable development;
- existing solutions tend to be sustainable within some sectors rather than across the whole of society;
- new developments bring new risks that cannot be anticipated;
- sustainable development is a long-term, open-ended project that precedes and supersedes limited term, democratically elected governments;
- sustainable development involves making choices, and perhaps trade-off decisions, on highly contested issues (Farrell *et al.* 2005).

They finally highlighted the sustainable development, and eco-innovation too, derives from what it has been considered unsustainable or, conversely, what constitutes progress. This is the result of a social consensus, which differs across nations and localities. In the authors' opinion, such themes «*cannot be scientifically determined as "objective knowledge," but will always incorporate normative valuations that only become ascertained in the process of social interaction*» (Kemp and Martens, 2007: 7).

Sheng Tey and Brindal (2012) argued that farmer perception refers to their personal subjective evaluation of innovation attributes, such as relative advantage and profitability. In Carillo-Hermosilla *et al.* (2010) the authors noted that albeit the method they formulated can be applied to different eco-innovation types, it may not be applicable to all eco-innovations because subjectivity of the assessment of changes occurring in the eco-innovation process.

Finally, some authors also focused on the role of communication (Arnold and Hockerts, 2011) arguing that a good communication strategy represent an optimal starting point to foster the adoption and, it adds, the efficient use of eco-innovations.

As this proposition is quite general, it is also the more easily generalizable one. Indeed, authors which faced the subjectivity of the factors affecting the eco-innovation process in their studies mainly refer to literature about innovation in general (e.g. Schumpeter, 1934). In addition, focusing on the specific agricultural sector, the subjectivity of the innovation process is even more emphasized (Crossan and Apaydin, 2010).

In conclusion, the P1 has been largely confirmed by literature.

<u>P2</u> - *The use of an eco-innovation is related to the physical size of the farms and not to the economical one*

Such proposition affirms the significant role of the firm size, rather than the economical one, in the eco-innovative process. In different studies, the physical size of firms has been widely considered as a factor which is likely to positively effects environmental activities in general (Triguero *et al.*, 2013;) and the eco-innovation process (Berrone *et al.*, 2013; Chen, 2008; De Marchi, 2012; Demirel and Kesidou, 2011;) with distinct influence on firms with different characteristics (del Rio *et al.,* 2016).

Moreover, results provided by the literature reviews conducted by Bossle *et al.* (2016), del Rio *et al.*, (2016) and Hojnik and Ruzzier (2016) on the drivers affecting the eco-innovation process confirmed the significant role of this factor, otherwise it seems less frequently reported (Hojnik and Ruzzier, 2016). Results of such literature reviews showed that papers where this evidence has been confirmed are many (Kesidou and Demirel, 2012; Kammerer, 2009; Rehfeld *et al.*, 2007; Rennings *et al.*, 2006; Wagner, 2007; Veugelers, 2012; Ziegler and Rennings, 2004; Borghesi *et al.*, 2012; Borghesi *et al.*, 2015; Triguero *et al.* 2013) nevertheless some exceptions (Demirel and Kesidou, 2011; Mazzanti and Zoboli, 2009; Frondel *et al.*, 2007; Wagner, 2008; Cainelli *et al.*, 2012;) and mixed result (Cleff and

Rennings, 1999). In particular, eco-product innovation, eco-process innovation, organizational eco-innovation and environmental R&D investments have been found all positively associated with company size (Hoynik and Ruzzier, 2016; Triguero *et al.*, 2013). Moreover, it positively influences the eco-innovation process in all its stages (Hoynik Ruzzier, 2016).

Focusing on the way size of farm affects the eco-innovation process, it has been found that large companies tend to develop and adopt more eco-innovations (Kesidou and Demirel, 2012; Triguero *et al.*, 2013; del Rio *et al.*, 2016; Hojnik and Ruzzier, 2016;). Moreover, Triguero *et al.*, (2013) argued that size of firm is a potential barrier for eco-innovation, as small companies can face more difficulties to apply environmental innovations although firm size is not found to effect on the probability of a firm carrying out environmental innovations.

Other examples are provided by the PA literature, which have been already considered as an eco-innovation subcategory, where Roberts *et al.*, (2004) argued that PA is more feasible when the farmland is larger. Indeed, as smallholders know their land, they also know which activities are best for farming (Galindo et al 2012). Moreover, Sheng Tey and Brindal, (2012) in their analysis about the drivers of adoption of PA technologies considered both variables, namely physical and economical size of farms. Together, represents an important consideration to acquire high level technologies. Because uncertainty, investment and informational costs given by the eco-innovation adoption they argued that larger farms and farms with greater capital have much capacity to absorb costs even in the case it became unfavorable Therefore, PA technologies are more likely to be adopted on large farms and farms with greater financial capital. However, the authors finally affirmed that the economic size of farms has proved insignificant results (e.g. Larson *et al.* 2008; Roberts *et al.* 2002) or mixed results (e.g. Daberkow and McBride 1998; Isgin *et al.* 2008) in most cases.

Focusing on the literature about general eco-innovation, the role of the economic size of firms within the eco-innovation diffusion process it seems to be not adequately considered and investigated. In some studies, (Rio *et al.*, 2016; Hojnik and Ruzzier, 2016;) this factor has been considered as embedded within the physical size without analyze it separately.

In conclusion, the relation between the physical size of farms and the eco-innovation process has been confirmed by literature. However, the lacking relation between the economic size and the eco-innovation process cannot be completely confirmed as well, as not many studies adequately analyze this factor. Therefore, P2 has been considered as partially confirmed by literature and more case studies are needed to definitely prove such proposition.

P3 - *The efficient use of an eco-innovation is influenced by the network*

Even the relational role of the network in the eco-innovation diffusion process has been considered by many studies. According to the empirical evidence and, in particular, to the innovator perspective, it was a very interesting result. Networking has been proved as a highly relevant factor to explain the decision of firms to eco-innovate as it has been seen as a response to stimulus and incentives from different actors and factors (Del Rio *et al.*, 2016; Del Rio, 2005).

In Carillo-Hermosilla *et al.* (2010) a distinction between networks of incremental and radical innovations have been made: in the first case innovation are defined by existing networks whereas in the second one new ones are build.

In Bossle *et al.* (2016) the cooperation between both stakeholders and external entities has been faced. Indeed, as the role of the network has been related to the information flows (Horbach, 2016), the systemic and complex characteristic of eco-innovation require cooperation (Bossle *et al.*, 2016; Carrillo-Hermosilla *et al.*, 2010; Geffen and Rothenberg, 2000; Verghese and Lewis, 2007) and interdependency between firms (De Marchi, 2012; Horbach, 2008), customers, distributors, suppliers (Buttol *et al.*, 2012; Green *et al.*, 1994), universities, research institutes and agencies (Triguero *et al.*, 2013; Cainelli *et al.*, 2012). In particular, collaborative network with such research entities resulted in Triguero *et al.* (2016) as essential to drive all types of eco-innovation. Moreover, some authors argued that, in practice, relations between different actors created added value in products, processes and services. Therefore, they all can be characterized as value networks rather than value chains (Könnölä and Unruh, 2007).

However, other studies categorize such factor as one of the less relevant drivers affecting eco-innovation (Hojnik and Ruzzier, 2016) or the less investigated by empirical studies (Oltra, 2007).

Anyway, the importance of the network has been also proved by a study totally centered on this issue (Roscoa *et al.*, 2016). Indeed, the authors developed a conceptual framework for eco-innovation supply networks where they advanced that three typologies of supply network designs can differently build eco-innovations: strong ties between firms and strategic suppliers foster incremental innovation; multiple weak ties between firms and non-strategic suppliers increase the opportunities for finding innovations; and weak ties between firms and suppliers gain access to innovations.

Finally, from a practical point of view, as Tingru et al, 2015 showed in their study, nowadays firms often rely on online communities to actively search for potential external knowledge (Di Gangi and Wasko, 2009), and the virtual environment of knowledge transfer and integration is supported by collaborative innovation systems or communication tools (Zammuto et al, 2007).

In conclusion, P3 has been confirmed by literature.

II.2.5 Building the theory?

The research approach adopted in this thesis recalls the great importance of the case study and the induction process. Indeed, in the TBFC perspective, theory is emergent from the case study and from the real-world context in which the phenomena occur (Eisenhardt and Graebner, 2007). Therefore, starting from the analysis of the specific case study of the eco-innovation *vite.net*, a preliminary proposition (P0) and three general propositions (P1-P2-P3) about factors affecting the eco-innovation diffusion process in agriculture have been identified:

- P0: Within the general eco-innovation diffusion process, the adoption phase and the use phase of the eco-innovation must be distinguished.
- P1: in a broad sense, the use of an eco-innovation is strongly influenced by not easily identifiable and maybe subjective multiple factors;
- P2: the use of an eco-innovation is related to the physical size of the farms and not to the economical one;
- P3: The efficient use of an eco-innovation is influenced by the network;

According to the P0, such propositions focused on the implementation/utilization part of the eco-innovation process. Except for the P1, which is quite general, the others concern factors related to the characteristics of the farm (P2) and the diffusion process itself (P3).

In order to finally confirm them, such propositions have been compared with the existent literature about eco-innovation. The results of this analysis, namely the answer to the RQ4, show that three propositions have been proved (P0-P1-P3) while one needs additional case studies and investigation to be totally confirmed (P2).

Focusing on the single propositions, although literature about the use of the eco-innovation is lacking, P0 has been confirmed. Indeed, as the first part of the thesis showed, the most part of literature is strictly focused on the phase that ends with the adoption of the eco-innovation. General drivers and determinants, specific characteristics of innovator, adopter and innovation itself are often used by researchers to understand how to foster innovation and which factors influence its adoption or reject.

Surely, understanding how to promote eco-innovation is an important factor, but it could be also a good point to begin to make other questions about this issue. Indeed, given the general aim of the eco-innovation, namely to reduce the environmental impact of the human activities, the adoption itself is not sufficient to reach this sustainability goals.

Given this preliminary consideration, the main propositions (P1-P2-P3) focused on this side of the eco-innovation diffusion process. P1 has been totally confirmed by literature, as the important role of the subjective factors is acknowledged by many studies about eco-innovation and general innovation too. Moreover, this proposition fits well with the peculiarities of the agricultural sector, which, by its nature, is strongly influenced by the specific features of the context where the innovation is spread.

P2 has been partially confirmed by literature. Indeed, while the physical size of the farm is very recognized as a factor influencing the eco-innovation diffusion process, the economic size of firms has not been adequately investigated.

Finally, the last proposition (P3) has been confirmed by literature, as there is a large agreement on the idea that networking is one of the most important factors affecting the eco-innovation diffusion process.

In conclusion, despite such positive results, the opinion is that, to completely confirm such propositions and, therefore, to build a general and well-founded theory about the eco-innovation diffusion process in agriculture many case studies are needed. Indeed, during this analysis, many problems and obstacles have been faced. As stated in the thesis background, beside the typical research difficulties of the agricultural sector, literature about eco-innovation is generally fragmented and no theoretical framework exists (Rennings, 2000; Rio *et al.*, 2016; Hojnik and Ruzzier, 2016; Bossle *et al.*, 2016; Carillo-Hermosilla *et al.*, 2010). Moreover, more specific aspects, such the eco-innovation use (Cheng and Shiu, 2012), different types of eco-innovation (Hojnik and Ruzzier, 2016), sectorial and national studies (Rio *et al.*, 2016) have not been addressed.

In this situation, a single empirical evidence is not sufficient to find a theory which can be generalized to the eco-innovation in agriculture and, in the future, valid for all sectors. Indeed, two levels of generalization can be defined: the first aims to build a theory about the eco-innovation diffusion process in the agricultural sector, which was the objective of such dissertation. To do so, some of the propositions must be tested again and compared to other eco-innovations case studies related to the agricultural sector, as the deductive process side of figure 42 shows (for more detail see chapter II.1.1).

Once these propositions will be tested and the theory about eco-innovation in agriculture can be defined, the second level of generalization became possible, namely the construction of a general framework for eco-innovations, through a new phase of analysis focused on eco-innovation case studies within different sectors.

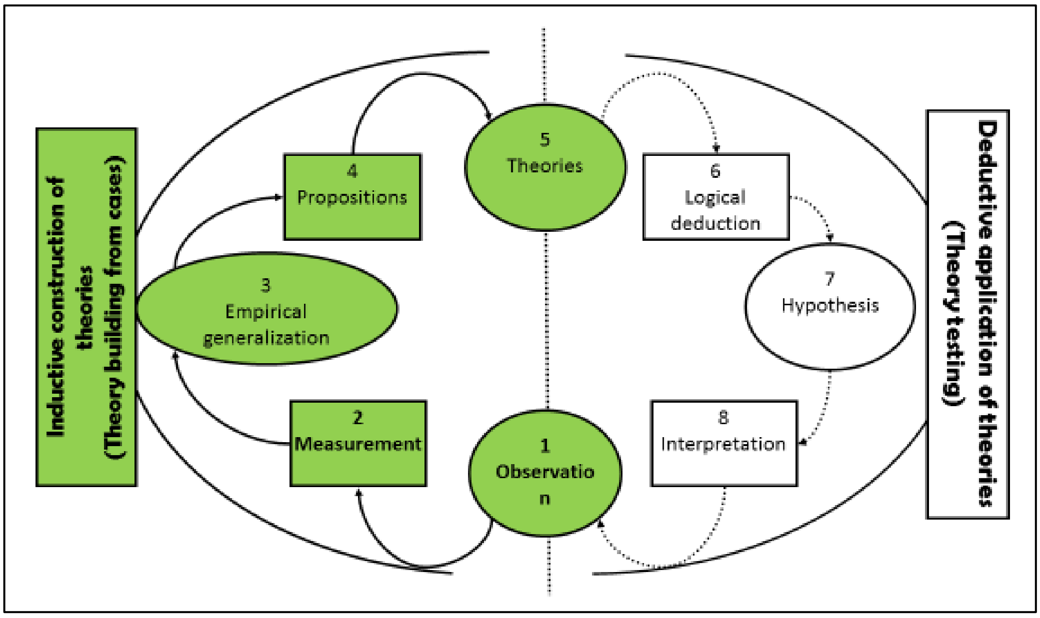

Figure 42: Own elaboration of Wallace representation of "Scientific Process"

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Conclusions

In the last few years, innovation and environmental sustainability has become central concepts from both academic and business perspectives. However, despite this growing interest, a shared theoretical framework about eco-innovation still not exists and literature is very fragmented. Focusing on the agricultural sector, these evidences are especially true.

Therefore, the aim of this thesis was to investigate the research theme of the eco-innovation to understand which factors influence its diffusion process within the agricultural sector. Given this objective and the overall structure of the thesis which highlights, on one hand, the complexity of the discussed argument and, on the other, an attempt of innovative approach, the final outcomes can be seen under two perspectives, contents and methodology.

From the first perspective, to reach the purpose of the thesis, four different research questions have been identified. In order to answer to such questions, as it has just been said, an attempt to carry out a particular path has been done. It consists in the integration of two different research approaches, which have been developed in the two parts of this thesis (Figure 43).

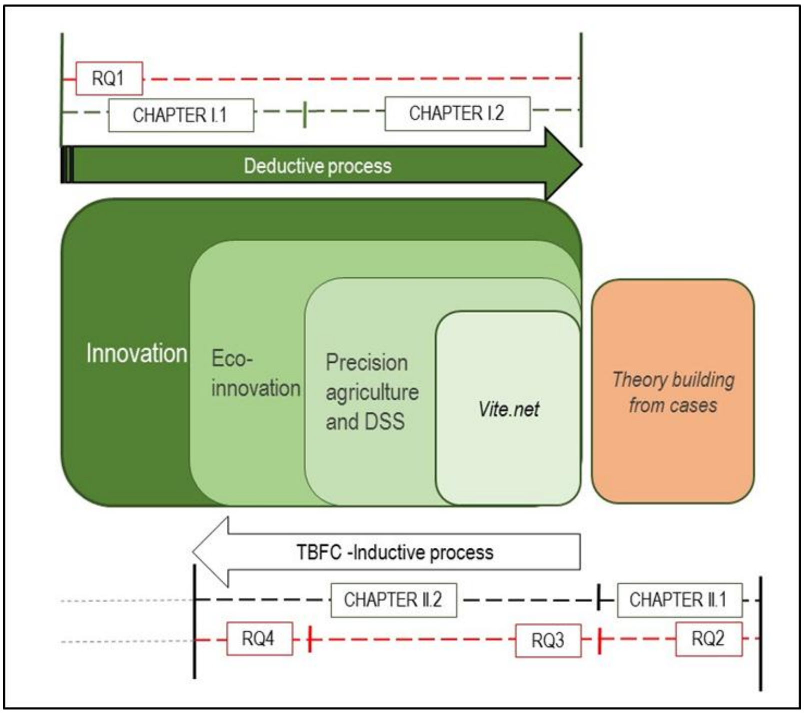

Figure 43: Complete research design of the thesis

In the first one, a classical deductive process has been followed to answer to the first research question (RQ1). Whereas, through the inductive approach proposed by the Theory Building From Cases, object of the second research question (RQ2), the third and fourth research questions have been answered (RQ3-RQ4).

As the RQ1 aimed to choose a suitable eco-innovation to analyze, the Decision Supporting System (DSS), a specific typology of process eco-innovation developed to help farmers take their decision, has been chosen. Following a "classic" deductive process, this part has been focused on the theoretical analysis of the innovation diffusion process, first from a general perspective and then within the agri-food context. In this wide research theme, the eco-innovation has been pinpointed, considering in such definition all innovations aiming to promote sustainable development. In the composite framework of the different eco-innovation categories and typologies, the precision agriculture was selected. Precision agriculture is a way for farmers to make more correct decisions helped by a technology, or a set of technologies, to reach an increasing quantity and/or quality production and, simultaneously, by means of the inputs reduction, some environmental benefits. Then, the DSS has been chosen to practically represent all such theoretical orientations, as this tool aims to help farmers in reducing the environmental impact of agricultural activities and, at the same time, in improving the quantity or the quality of the production. Finally, the case study of *vite.net*, a specific DSS developed for the vineyard management has been identified and described.

Then, given the purpose of the RQ2, which deals with the identification of an adequate research approach able to analyze such eco-innovation case study, the attention has been focused on the Theory Building From Cases. This approach, which aims to construct or modify theories starting from the case studies analysis, seemed to offer an efficient way to face the study of eco-innovation in agriculture, considering the absence of a shared framework able to explain its single and diversified realities. Therefore, the inductive approach offered by the TBFC is very helpful to highlight the peculiarities of each case study in order to finally generalize them through a comparison with the existent literature.

In the second part of the thesis, following this process, the eco-innovation case study of *vite.net* been described and measured: data about users from the launch of this DSS in 2013 to November 2016 and their characteristics have been collected. As the number of rejected adoptions or abandons are quite inexistent and specific data about the adoption starting phase were not available, the analysis has been focused on the stage following the adoption, which identifies represents the phase of utilization/implementation of the eco-innovation. Once the key variables have been identified, they have been "read" using a general statistical instruments, namely the multivariate covariance analysis, in order to understand their relations with the intensity of DSS utilization, measured by the number of software accesses. In this way, the third research question (RQ3), aiming to understand which characteristics affect the innovation process of the specific DSS *vite.net*, has been answered. Results show that the effective use of the DSS is influenced, in general, by subjective factors and, in particular, by age of users, physical size of farm and the presence of a network supporting the DSS diffusion process.

According to this answers, the last question (RQ4), which aimed to generalize such first empirical evidences to eco-innovation processes in agriculture, have been solved through the identification of four propositions. Among those, three have been confirmed by existent literature on eco-innovation, while one needs additional case studies to be confirmed.

Considering these evidences, it is possible to assert that singles empirical evidences are not sufficient to build a well-founded theory about the eco-innovation diffusion process in agriculture. Indeed, only once the propositions will be tested according with different case studies, an exhaustive theory about eco-innovation in agriculture could be defined. Moreover, whether a new phase of analysis focused on different eco-innovation case studies within different sectors will be conducted, also the definition of a general framework for eco-innovations became possible.

Finally, trying to understand which factors affect a correct eco-innovation implementation, one of the main contributions which has been tried to give in this works is to stimulate the reflections among the many and different agri-food operators within the political and decisional process about eco-innovations. Indeed, beside the clear benefits on the environment, eco-innovations can produce many other positive effects also for the actors of the chain, from farmer to final consumer by way of the other multiple subjects, as innovations promoters, universities and research entities, category associations and other agri-food firms. The final goal to achieve is to foster eco-innovation in the agri-food sector by setting a conscious win-win interaction among the actors of the supply chain, their business and the environmental, economic and social context where they operate.

For what concerns the limits of the research, always according to the contents point of view, the analysis of an eco-innovation case study in a single agri-food supply chain is the main one. Indeed, this limitation prevents the final generalization of the empirical evidences. Second, the exclusive focus of the analysis on the implementation phase of the eco-innovation, rather than on the whole diffusion process, has not allowed drawing a complete panorama of the whole eco-innovative process. In general, to overcome this limits and reach the definition of a theory about eco-innovation in agriculture additional studies must be done. From another point of view, the innovative structure of the whole thesis which combines deductive and inductive approaches and qualitative and quantitative researches, sometimes shows some critical issues: for example, the scientific accuracy and the explanation of results are not uniform among the first and the second part of the works and single chapters.

The second perspective through which the final outcomes can be seen, is focused on the research approach which has been proved in this dissertation. Independently from the analysis which has been conducted, which presents some critical points and limits, also in this case, an attempt to stimulate national and international scientific community has been made. Indeed, the TBFC approach is likely to have potential to develop the methodological research on eco-innovation and, also, of general innovation. Even more for the agricultural sector where the inherent features which identify such context make the analysis hard to generalize. Indeed, the debate on innovation in this context remains contradictory or under investigated and literature is very fragmented. This research methodology seems able to represents a useful approach to investigate all innovation processes in agriculture overcoming the peculiarity of specific situations, actors or areas.

From a wide perspective, the TBFC approach can be applied to all contradictory research fields where shared opinions and theories have not been already reached. The relevant role that it confers to the empirical evidences is combined to a rich literature review direct to confirm or reject what is emerged by the single case studies.

Despite this vast potential, the efforts to conduct a research following the TBFC approach are greater, in both phases of identification of the case studies and, successively, of their analysis. It is a riskier, tiring and long way to define a new theory. Indeed, especially during the selection of the case studies, some eventual evaluation mistakes could affect in a significant way the final result. Anyway, whether no error is committed, the risk of achieving not completely satisfying outcomes must not been underestimated. But, at the same way, also some unpredictable and unexpected results may be revealed which following a classical research approach would not have been considered at all.

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