Sustainable innovations in horticultural production systems

– evaluating the decision-making process of the adoption of new practices

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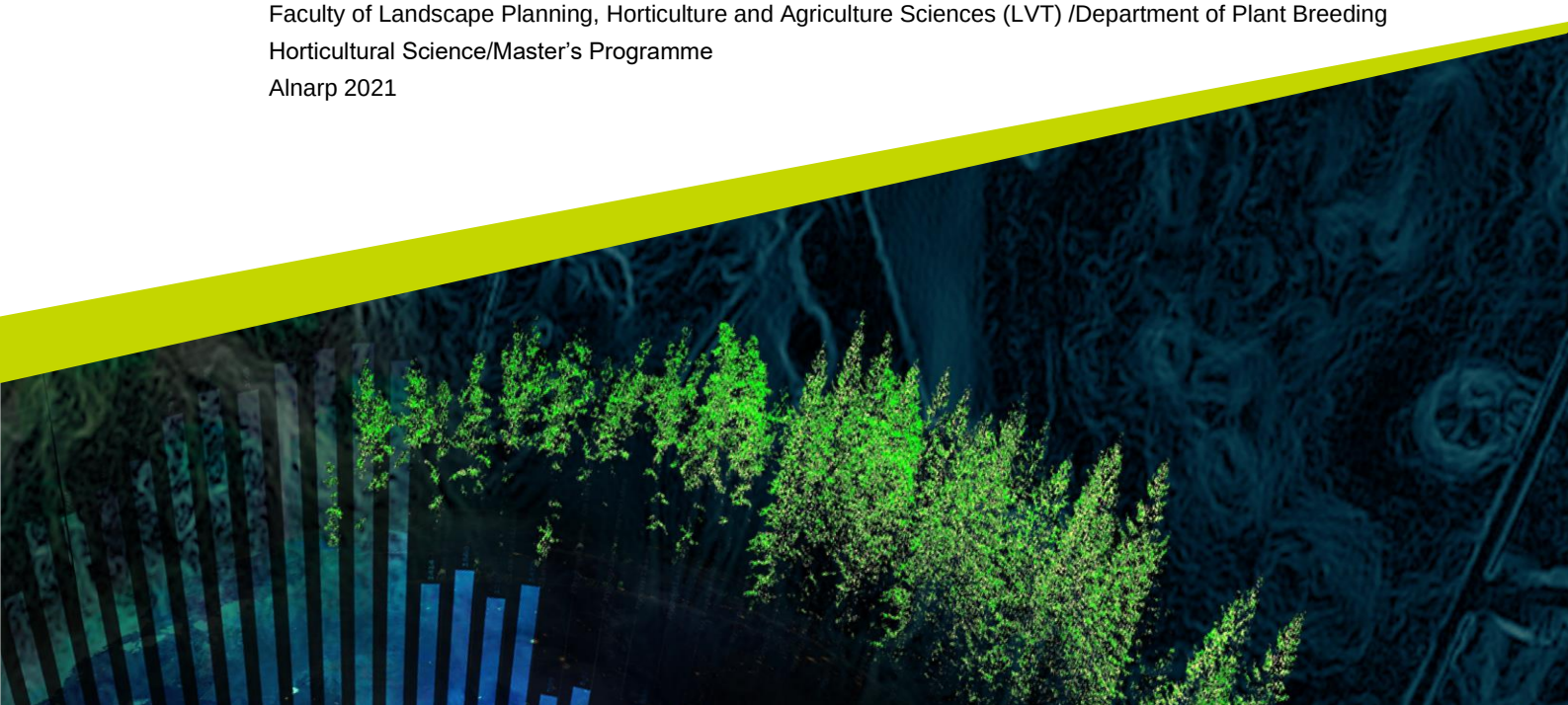

Sustainable innovations in horticultural production systems – evaluating the decision-making process of the adoption of new practices

Hållbara innovationer i hortikulturella produktionssystem - en utvärdering av adoptionsprocessen

Loriène Borderie

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Abstract

In this report, horticultural growers' behaviour towards innovations in relation to sustainability are assessed through a literature review combined with empirical research conducted on the field.

Designing innovations to face the sustainable challenges of modern agriculture is a complex process which has been thoroughly analysed in previous scientific papers. However, it is less common to find the horticultural growers' own perspective included in the assessment of sustainable innovation's adoption, whereas they can be considered as the main stakeholders of the horticultural sector.

This thesis gathers information found about growers' subjective evaluation of innovations in recent scientific publications, their relationship to the sustainability dimension of new practices and technologies and the factors potentially influencing their decision-making process. The most recurrent decisional factors found in the papers are sorted out in a matrix which applicability is tested in the second part of the thesis during several interviews of French horticultural growers. Some correlations are found between the literature and field results, especially about the decision-making pattern growers follow when considering adopting a sustainable innovation. The importance the interviewees bring to social and economic decisional factors also correlate with the ones found in the literature review. The current COVID-19 pandemic has however been added to the matrix due to its exceptional impact on global production systems. The final updated matrix can be used as a guide for researchers or professionals aiming to design sustainable innovations better adapted to growers' demands and expectations.

Keywords: Sustainable innovations, horticulture, new practices, horticultural production systems, decision-making process, adoption of innovation

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Abbreviations[1]

HACCP	Hazard Analysis Critical Control Point
FAO	For the Attention Of
SDD	Sustainable Development Department
WCED	World Commission on Environment and Development
UN	United Nations
IFOAM	International Federation of Organic Agriculture Movements
EC	European Commission
R&D	Research and Development
PROSUIT	PROspective SUstaInability Assessment Technologies
SAFA	Sustainability Assessment of Agriculture Systems
AIS	Agricultural Innovation Systems
LCA	Life Cycle Assessment
SDG	Sustainable Development Goals
SMART	Sustainability Monitoring and Assessment RouTine
OECD	Organisation for Economic Co-operation and Development
INRAE	Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (*National Research Institute for the Agriculture, Food and Environment*)
ISHS	International Society for Horticultural Science
BTS	Brevet de Technicien Supérieur (*Advanced Technician's Certificate*)
HVE	Haute Valeur Environnementale (*High Environmental Value*)
AB	Agriculture Biologique (*Organic Farming*)
IPM	Integrated Pest Management

[1] An English translation of abbreviations referring to French organism has been added for better understanding.

1. Introduction

As consumer society evolves considerably fast, new ideas regularly rise in the agricultural world to answer the evolving demands. Whether it is to try providing local food to urban areas with vertical farms and rooftop gardens, or to grow products in arid lands where food is lacking (Kassie et al., 2008), growers are globally turning more to sustainable innovations. Combined with their agricultural knowledge, the aim of new technologies and practices is often expected to boost their productivity and competitivity without jeopardizing their durability (Almukhambetova et al., 2017). The growing concern about climate change having pushed collective consciousness to work on technologies more respectful of the environment (Smith et al., 2010), most strategies such as organic farming, permaculture and more are also in favour of innovative opportunities; they are often explored by researchers and academic knowledge to the farmer's advantages (IFOAM, 2008). Although lots of studies on the innovation design process were conducted before, fewer of them focused on how growers apprehend and integrate them into their systems. Consequently, some ideas failed to integrate the horticultural market because of a lack of available information about innovation compatibility with farmers' systems (Rogers et Shoemaker, 1971 ; Bangura, 1983). Thus, it seems essential to know how they, as the key stakeholders in horticultural production, perceive new strategies in a time where sustainable development is on the rise; a better understanding of their decision-making process could help researchers and firms offering innovations better adapted to both growers and global challenges.

The aim of this thesis will be to establish and evaluate the decision-making pattern horticultural growers follow when considering the introduction of sustainable innovations to their systems. At the outcome of the thesis will be presented a matrix sorting out the most recurrent decision factors influencing the adopters' choices in relation to the sustainability of new practices. Drawing up a list of subjective decisional factors, the aim of the matrix will thus be to help researchers and professionals designing innovations better adapted to growers' needs and reduce the risk of market failure.

To conduct this thesis methodically and organise the research process as thoroughly as possible, the story arc will follow two research questions :

<u>Research question 1 :</u> Which pattern follows the process of adopting innovation in horticultural systems ?
<u>Research question 2 :</u> Which main factors growers consider when then decide to adopt or not an innovation in their systems ?

To answer those questions, a literature review will be first done to list the key stages of the decision-making process regarding the adoption of innovations in horticulture. More research papers will then be browsed to consider the complexity of evaluating the sustainable dimension of new strategies and/or technologies, and more precisely in the horticultural sector. Afterwards, will be identified the decisional factors influencing the adoption of sustainable innovations; the most recurrent ones will be sorted out in a relevant matrix table. The matrix will then be put into practice by testing its relevance on the field; using a questionnaire designed thanks to the literature review, local French growers will be interviewed to evaluate their apprehension of sustainable innovations and the main factors influencing their choices. The results will be compared to the ones sorted in the matrix to find out any correlation between them and potentially identify factors which haven't been mentioned in the scientific publications before. Depending on the results, the decision matrix could eventually be updated.

Before starting the research process, a short introduction about horticultural innovations' background has to be done to better understand the context of this study.

1.1. The "green revolution" and its limits

Conventional agriculture today has certainly reached its thresholds. The booming of mechanised and treated monocrop fields not only changed our landscapes, but also our relation to the environment. The agro-industrial production system kept developing advanced tools to maintain a high productivity level despite the multiplication of biological breaks at the cost of ecosystems health. The introduction of genetically engineered crops in the 1970s (Altieri, 2009; Rangel, 2015) also revealed its limits on both economic and environmental sides. On top of that, more scientific publications progressively gave rise to a global public concern for health and environment and called the agro-industrial strategies into question. Rapidly, not only chemicals were showed to contaminate non-targeted organisms (Van der Werf, 1996 ; Cope, 1965) but heavy mechanization was also proven to be a threat to soil biota, essential for plant growth (Bardgett, 2005).

1.2. A global shift in agriculture priorities

Thus, the increasing concern for future generations gave rise to more demanding agriculture policies set by governmental organizations. To try to preserve natural ecosystems, new legislations are regularly updated; agrochemicals proven to be highly toxic to humans and environment are banished (Ingram et al., 2015), farming inputs are monitored by counsellor organisms and end products are submitted to stricter food quality control policies such as Hazard Analysis Critical Control Point (HACCP) (Betts et de Blackburn, 2009). However, tightening policies and controls did not really change the farming systems themselves, and nowadays intensification remains the credo of most agricultural production leaders. Such massive production phenomenon and increased food control stringencies in developed countries where people require "premium" products consequently leaded to a high amount of food waste. In 2020, Europe alone threw away more than 88 million tons of products per year on all the production levels (Balan et al., 2020) whereas paradoxically at least 4 countries (Sudan, Yemen, Nigeria and Somalia) are still seriously impacted by famine with more than 30 million people starving every day (Bongaarts, 2021). Alongside food waste, the global overload of products and imports on the market provoking high price volatility forced growers to produce even more to limit their economic losses. Although the Green Revolution has been proven to successfully increase global food production, it doesn't vindicate the economic collapse of small-scale farming systems and populations facing famine because of uneven food distribution.

1.3. The emergence of the "sustainable development" concept

Clearly, worldwide food distribution remains unbalanced today. In a growing dynamic to try to eradicate famine in the world, the concept of "food security" was introduced during the first World Food Conference held in Rome on the 5th to the 16th of November 1974 (World Food Conference, 1974) and its definition has been updated several times until today's version stated by the FAO : "*Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life*" (FAO and Sustainable Development Department, 2003. Retrieved from https://www.fao.org/3/y4671e/y4671e06.htm). Imagining more environmentally friendly strategies in agriculture and food distribution could thus help reverse destructive phenomenon such as soil salinization and thinning out, diversity collapse and more before they reach the point of no return.

The concept of sustainable development is the result of decades of scientific and ecological introspective. It however rapidly became obvious that a restructuration of conventional farming alone would not meet the rising problematics of environment preservation and food security. Thus, the principle of sustainability slowly interrogated not only farming practices, but all sectors involved in the food production channel as well.

The name "sustainable development" originates from the Brundtland Commission Report "Our Common Future" published after the World Commission on Environment and Development (WCED) held in 1987 (Mitcham, 1995). This report underlines the worldwide rising crises resulting from intensive production disequilibrium and their impact on the economic, social and environmental levels. It defined the concept of sustainable development as "[...] *a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations*" (Imperatives, p.43, 1987). The definition is still regularly updated, incidentally revealing a growing craze for a more sustainable world; different movements, politics, industrials and professionals adapted their strategies to face the challenges highlighted by the WCED, consequently making the concept of sustainable development itself very unclear (Keiner, 2005). In 2015 however, the United Nation (UN) member states introduced the 2030 "Agenda for Sustainable Development", giving the involved countries and states 15 years to reach 17 specific goals to restore the balance between environment conservation and human global needs. A parallel can be clearly drawn between each one of the 17 Sustainable Development Goals (SDG) and the production channel dynamic; because modern agriculture is accused of negatively impacting the three pillars of sustainable development, the SDGs are also aiming to transform its dynamic.

1.4. Attempting to produce more sustainably

Fortunately, other farming strategies following the lines of sustainability exist to try to counter the infatuation of agro-industrial lobbies. Organic farming for example existed long before the Green Revolution, but it was then dramatically blotted out by the development of agroindustry. Permaculture is another movement which appeared in the 70s and keeps developing today. Whether it is about organic farming, permaculture, biodynamic agriculture, agroecology and more, they are all interdisciplinary fields aiming to offer good quality products while reasonably using natural resources and preserving local biodiversity by limiting the use of destructive inputs. Furthermore, adopting these strategies must not threaten the farmer's quality of life by remaining profitable (Poincelot, 2004). As opposite to conventional agriculture, any system considering the growth of sustainable

products has then to prioritize environment and grower's wellbeing, resource conservation and biodiversity balance. Although there is no existing label available on the market for "sustainable products", several countries established food "standards" to raise consumers' awareness to sustainable practices and processes through the whole production channel (Meybeck et Redfern, 2014).

1.5. Agriculture and innovation : nothing new !

To better grasp the complexity growers must cope with when considering sustainable innovations, it is important to understand where the concept of innovation itself comes from. New strategies in mankind history aren't new; the very first traces of human innovativeness were dated from the prehistorical age, although they were rare and mostly influenced by climate change. The apparition of agriculture is probably the most famous innovation identified, and it brought its own challenges. To learn to grow food and raise cattle, humans had to be much more imaginative than when they were hunter gatherers (Dow et Reed, 2011). The concept of "incremental innovation" appeared with agriculture itself, where humans learnt to observe, select and improve their products (Gremmen et al., 2019).

The word "innovation" appeared lately between the 17th and the 18th centuries and was firstly used for political and judicial purposes only, which gave it a negative connotation; in 1740, the French Academy even considered innovations as a threat to the divine's natural order. It wasn't until the 19th that the word and context slowly became an ideology (Faure et al., 2018). Progressively, the concept of innovativeness extended to industrial progress, and then to the agricultural sector with the development of farming research programs to increase productivity (Donnan, 2021). The first radical innovations in agriculture quickly followed, with the creation of the first hybrid corn in Iowa in the late 50s (Ghadim et Pannell, 1999; Rogers, 2010). From there, agricultural innovation research skyrocketed with the development of transgenic crops and more aggressive pesticides which unfortunately had irreversible consequences on the ecosystems; the disappearance of plant and insect species, chemical run offs and human health damages being the most common ones (Gremmen et al., 2019). The resulting global loss of trust leaded to a change in the innovation goals, which progressively turned to more sustainable and ethical ones (Pardey et al., 2012). In 2014, the FAO even encouraged the expansion of a movement called "smart agriculture" to help farmers facing global challenges by encouraging the development of innovations and aiming for a sustainable growth. The United Nation explained that the aim of a "sustainable growth" was to meet "[…] *the needs of the present without compromising the ability of future generations to meet their own needs*" (UN, p.41, 1987).

2. Material and methods

This thesis is composed of two distinctive sub-studies. The first one aims to review the available literature to 1) explore the theoretical frameworks available about the decision-making process of adoption of new technologies and strategies, 2) identify the variables used to evaluate the complexity of innovations' sustainable dimension in the horticultural sector and 3) propose a matrix of related decisional factors influencing grower's decision of adoption.

For the second sub-study, interview research is done with local growers to 1) compare their decision-making process to the one previously built up through the literature review and 2) evaluate their relationship to the sustainable dimension of innovations by testing the applicability of the decisional matrix established beforehand thanks to the literature search.

2.1. Literature review and construction of an evaluation matrix

2.1.1. The objectives of the literature review building

To better understand growers' apprehension of the sustainable dimension of innovations, a theoretical background divided into three different steps is done through a relevant literature review (see figure 1).

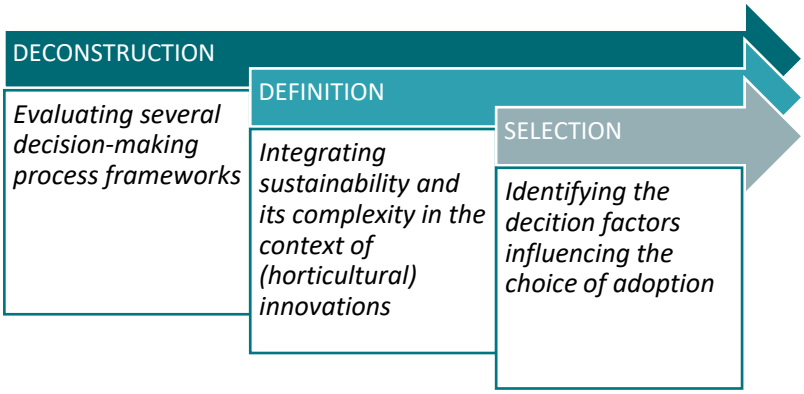

Figure 1. *The literature review breakdown process*

The first objective of the review is to propose a detailed **deconstruction** of the decision-making process growers go through when they are planning to adopt new strategies. The objective there is to identify and understand the different stages and behaviours involved in the whole process. Secondly, a thorough research about the complexity of evaluating the sustainable dimension of horticultural innovations is done to start **defining** the main drivers of innovation adoption. The final part of the literature search aims to identify and **select** subjective decisional factors growers commonly consider when evaluating a sustainable innovation.

2.1.2. The literature search process

To build up the theoretical background, a non-exhaustive list of keywords is established to prepare the resource browsing without digressing from the main problematic. The most recurrent keywords used are : “innovation in agriculture”, “innovation in horticulture”, “innovation failure”, “adoption process”, “sustainability”, “new practices”, “decision-making”, “technology adoption”, “adoption drivers”, “adoption factors”, “decision of adoption”, “horticultural/agricultural innovation system(s)”, “new technologies in agriculture”, “innovation risks”.

The research literature search is conducted on several online sources including Google Scholar, Web of Science, SLU Library website, Science Direct, Research Gate and Springer. Very little sources are collected in public places as the current Covid-19 health crisis limits the access to public libraries and universities. Using keywords only isn’t enough, thus the research is narrowed down to online peer-viewed English articles, not older than 10 years old if possible.

Some articles listed however don’t respect all the criteria; Some older papers are kept because they are still used as recurrent models in today’s literature, and some French ones contain important information difficult to find somewhere else. Articles published for 2022 are ruled out as most of them haven’t been officially reviewed yet. The same phenomenon sometimes applies to articles published in 2021 which were then put aside as well.

Very often, some articles are found by reading through the references used by another. In this situation, they are first selected by the relevance of their titles then the date of their publication. If they are respecting those criteria, the selection process can start, following the stages mentioned in figure 2.

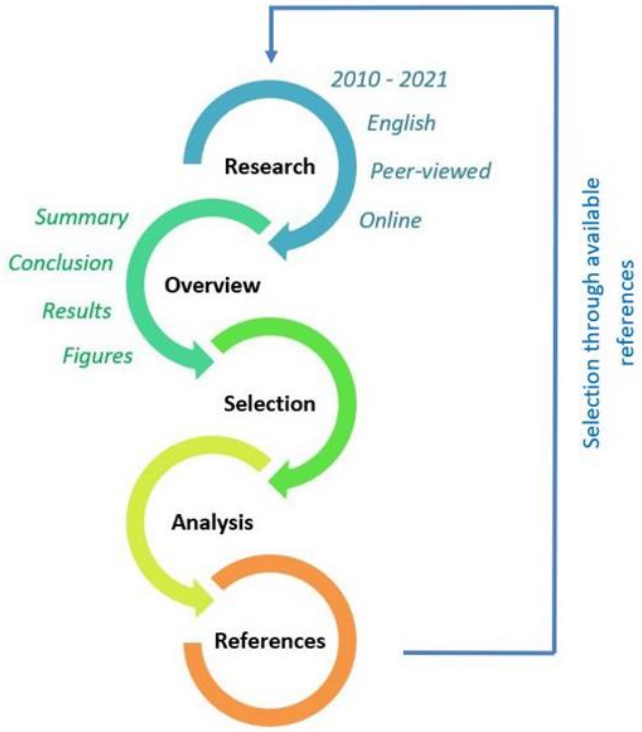

Figure 2. *The research process through the available scientific literature*

2.1.3. Organising the literature research

Once relevant articles are selected, they are sorted out into three different categories related to the three objectives previously set for the literature review search : subsection 1)Decision-making process deconstruction, subsection 2) Sustainable innovation guidelines and subsection 3) Decisional factors (see appendix 1). Some authors and papers can be found several times in the table as they offered information adapted to more than one subsection used in the literature review study. The data selected is then summarized following a narrative literature review strategy (Grant & Booth, 2009).

2.2. Interview study with horticultural growers

For this second sub-study, a questionnaire adapted from the information previously gathered in the literature review is designed to interview local growers; the aim of this questionnaire is to collect qualitive data during interactive exchanges to verify 1) the applicability of the decision-making frameworks found in the literature and 2) the feasibility of the decision matrix created at the end of the literature review. As the whole process is conducted with French growers, the

original questionnaire is in French, but an English translation has been added for better understanding.

This part explains the process of searching for local horticultural firms and the creation of the questionnaire.

2.2.1. Searching for horticultural firms

When looking for local growers, two different research strategies are used. Firstly, keywords are entered in the online Google Maps research toolbar to find nearby horticultural firms. The keywords used are : "horticulture," "*maraîcher*" (="market gardener"), "*pépinière*" (="plant nursery"), "*arboriculteur*" (="fruit tree grower"), "*serre*" (="greenhouse"), "*exploitation viticole*" (="vineyard"), "permaculture", "*apiculteur*" (="beekeeper"), "fruits et legumes" (="fruits and vegetables"), "aquaculture" and "*hydroponie*" (="hydroponics"). Among the results proposed by Google Maps, only the firms mentioning those keywords in their presentations are selected. Afterwards, a thorough exploration of their website (or social media pages) helps determining if their production systems are fitting to the thesis project : firms like retailers, garden shops and botanical conservatories are excluded as they do not produce the crops themselves. Finally, the end selection of growers is contacted either by phone or via email/social medias (in case of no phone number found) and asked if they want to answer a few questions for a master thesis project.

Another strategy to find existing horticultural firms is word of mouth exchanges through a local social network. Some acquaintances working in the agricultural and/or horticultural sectors either offer to participate to the project by doing the survey or give information and contacts of local firms which could be interested to participate as well. The selection of potential "candidates" is then done by asking acquaintances about the firm's activities and by searching for more information on the internet. At last, the growers are mostly contacted by telephone.

Among the existing production activities found in the department, the interviews are proposed to growers focusing on: fruits and/or vegetables production, greenhouse production, hydroponics, fruit trees, vineyard, flowers and plant nurseries, beekeepers and all other production systems included in the official "horticulture" definition given by the International Society for Horticultural Science (ISHS)[2].

Remark : A lot of people contacted admitted they recently had to stop their activities due to the ongoing COVID crisis.

[2] According to the ISHS, the horticultural crops include : "[…]*tree, bush and perennial vine fruits, perennial bush and tree nuts, vegetables,* […] *aromatic and medicinal foliage, seeds and roots,* […] *cut flowers, potted ornamental plants, and bedding plants,* […] *trees, shrubs, turf and ornamental grass*" as well as edible mushrooms and animal products obtained from plants such as honey and maple syrup. Source extracted from https://www.ishs.org/defining-horticulture

2.2.2. The different types of surveys

Because of the COVID-19 health crisis and current restrictions, other alternatives to face to face interview are systematically offered to growers when reaching for them for the first time. If they accept to be interviewed, they have the choice to :

- Meet and go through a face-to-face meeting,
- Do the interview by telephone,
- Fill up the questionnaire online (Google Docs).

Before exchanging in real life or by telephone, the growers are asked for permission to record the exchanges. They then must sign a compliance form (see appendix 3), agreeing they got informed about the interview purposes, that their accounts will remain anonymous and only be used for academic purposes with a right to withdraw at any time (see English version in appendix 3). The compliance forms are sent (Word and/or PDF file) to growers who choose to do the interview via internet or phone. Printed versions are given to others who accept to directly meet on their firms. Any refusal is respected and automatically dismisses the interview.

2.2.3. The questionnaire

The questionnaire inspired from the literature review results is a semi-constructed questionnaire favouring dialogue (DiCicco-Bloom & Crabtree, 2006) with a set of 27 questions including :

- 1 question with multiple choices
- 5 questions with single answer choice
- 3 questions with short open-ended answers only
- 18 questions with open-ended long answers.

The full questionnaire is attached in Appendix 2.

The questions firstly are about the non-variable factors mentioned earlier such as the education, age bracket and past experiences. It then turns to the firms' activities and geographical location. The rest of the questionnaire focuses on growers' potential past experiences with new practices in horticulture, whether they consider innovations as an opportunity/threat, if they already adopted some in the past and for what purposes. A close attention is brought to their social network and where they go search for information when they decide to try something new. Those questions allow to learn more about their adoption strategy process and identify the key factors influencing their decisions.

The growers have the liberty to skip a question if they don't consider it relevant to their motives or current production systems.

Remark : Some of them expressed the interest to get a summary of the answered gathered through the interviews and will be individually informed by email at the end of the thesis.

Orally, the questions are asked in a logical order to maintain a rich exchange with the growers while the discussions are conducted following the central theme of sustainable innovation' perceptions.

2.2.4. Relevant and/or new qualitative data

At the outcome of the interviews, the recordings are translated to small written summaries to perform a thematic analysis related to the former qualitative literature review (Neuendorf, 2018). The results identified in the summaries are then used to 1) compare the decision-making process of horticultural growers to the ones outlined in scientific papers and 2) to verify (and potentially supplement) the list of key factors influencing their choice to adopt an innovation.

3. Results

In this chapter, the results are divided into two sub-studies echoing the ones set in the material and methods part. The first section gathers the information found in relevant papers during the literature search to 1) define the global decision-making process growers go through when considering an innovation, 2) give an overview about the complexity of the evaluation of the sustainability of new practices and 3) design a matrix of subjective decisional factors influencing the decision-making process of horticultural growers.

After a short description of the interviewee's characteristics, the second part of this chapter focuses on the questionnaire's results gathered on the field during the interviews; the data collected is divided into two parts : 1) the individual decision-making processes and 2) the decisional factors identified during the surveys.

3.1. Literature review search

3.1.1. The decision-making process of innovation adoption in horticulture

Although innovation was considered as a "top-down" vertical process in the past (Chambers, 2014; Darré, 1993), it is now well identified as a collective collaboration where growers often reach for external support to create new strategies adapted to their objectives (Faure et al., 2018). It is thus logical that the scientific community started considering the adoption process as a dynamic multi-stage decision from the growers' perspectives (Ghadim & Pannell, 1999). The number of stages involved in the process of adoption itself varies from a scientific paper to another, but the common thread remains the same; it is considered as a dynamic learning process where each stage is reached only if the previous one has been successfully fulfilled (Wilkinson, n.d.; Weersink & Fulton, 2020). Evenson and Biswanger (1978) identified three different types of adoption strategies in agriculture which can still be observed today: "Direct transfer" happens when a foreign but well-known innovation is directly introduced to a farming system without preliminary trial. Such phenomenon mostly happens when farmers have been able to observe the efficiency and ergonomics of the innovation in another

farm (Feder et al., 1985). Another common process observed is the adaptation of new strategies to the farming system. In this situation, farmers transform the innovations or adopt only parts of it so it meets their demands and expectations better. The last type of adoption process is considered as a more collaborative one where the innovations are designed thanks to a strong collaboration between the end stakeholders (e.g., the growers) and the scientific knowledge (e.g., research institutes, universities and firms). Such process is expanding in the horticulture sector and is considered as the best solution to reshape food production systems efficiently and face todays and tomorrow's global challenges.

No matter the stages approached in the adoption process, all studies agree that the result is always dichotomous : a grower will choose to adopt an innovation or not (Feder et O'Mara, 1982; Dimara & Skuras, 2003; Wersink & Fulton, 2020). The steps however vary from a paper to another, as they are non-exhaustive and can even be skipped depending on the situation. Lindner (1980) originally divided the adoption process into two stages: 1) the "discovery stage" which can be more or less short or even skipped if the growers are already aware about the innovation's perks then 2) the "evaluation" one where they test the innovation on their own systems. On the other hand, Ghadim and Pannell (1999) deepened the process into six related stages : 1) the awareness, 2) the non-trial evaluation based on observation, 3) the trial evaluation "on the field", 4) the adoption, 5) the revision and 6) the dis-adoption. Step 1) could be considered as part of the "awareness" process Lindner previously identified whether the growers know the innovation already or not, and steps 2) to 3) could represent the "evaluation" part. Lindner however didn't include the revision and mis-adoption stages in his analysis whereas those are very important nowadays where the horticultural and agricultural sectors struggle to adapt to fast evolving technologies. An innovation can be abandoned if it ends up not meeting the growers' demands or if they find other tools better adapted to their objectives (Wilkinson, n.d).

What all scientific papers highlight in the adoption process, is that it often occurs after a successful learning and information acquisition period (Feder & O'Mara, 1982; Dimara & Skuras, 2003). It has also been showed that the reasoning process is different between genders, countries and cultural backgrounds (Kassie et al., 2008; Tiffin & Balcombe, 2011; Llewellyn & Brown, 2020). Thus, the available frameworks can vary greatly in recent literature. Figure 3 summarizes the recurrent stages to give an overview of how the adoption process is globally shaped.

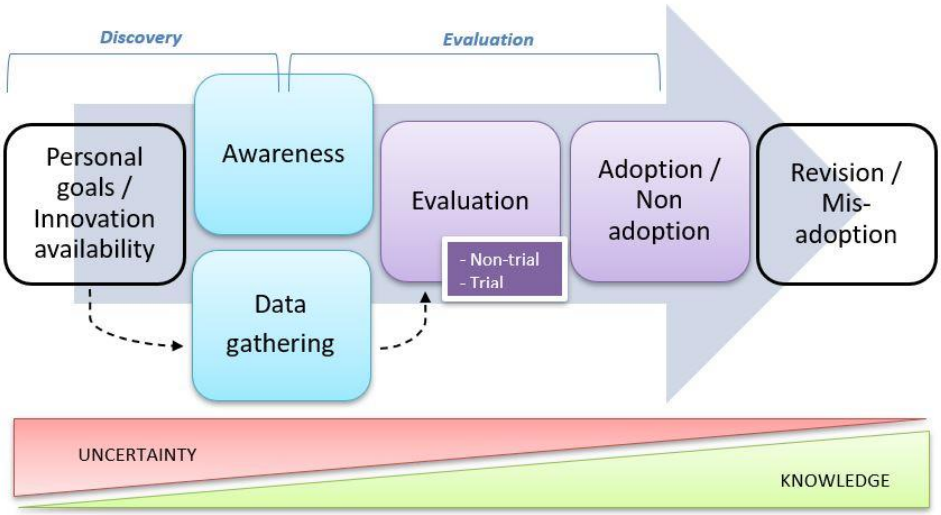

Figure 3. *Overall framework reviewing the several decision-making processes identified in the literature (own elaboration).*

Following the figure chronology, the beginning of the process of adoption is set when growers get informed about an innovation which could potentially help them reach their goals (Wilkinson, n.d). They can sometimes skip this awareness step and move to the data gathering one if they knew about the innovation already (Dimara & Skuras, 2003). Generally, farms are at the centre of strong social networks (Weersking & Fulton, 2020); the data gathering step relies strongly on it. It can be formal (external information sharing) or informal (internal exchanges). Access to formal innovation is mostly done through professional exchanges with academic knowledge, scientific community, governmental counselling agencies, training activities, seminars and more. On the contrary, informal information includes social sources such as the growers' families and close communities (Jean, 2014; Weersink & Fulton, 2020). The social capital of horticultural professionals is essential and proven to highly influence their adoption behaviour. A high access to information through efficient data gathering increases the chances of growers to adopt an innovation in their systems. Cognitive perception can also influence the rate of adoption; depending on their beliefs, past experiences or level of risk aversion, some growers will remain reluctant to introduce a new strategy into their firms even with a good access to information (Weersking & Fulton, 2020).

Once enough information has been gathered, growers can move to the next step, which is the subjective evaluation of the innovation they consider. Following Ghadim and Pannell (1999), the evaluation process can be divided into two parts: the non-trial and the trial evaluations. The non-trial phase includes all the information the growers gathered and reflected on as well as external experiments they have witnessed without participating. For instance, those who participated to seminars introducing an innovation, its advantages and results from previous experimentations will get a better grasp of its applicability and form their own opinion about it (Weersink & Fulton, 2020), like a passive evaluation. Very often,

growers get to witness the action of an innovation on a nearby farm which already adopted it (Smith & Ulu, 2017). Such life-size demonstration is also considered as a non-trial evaluation as they get to see what it can do in a real-life scenario without having to do the experiment themselves. It has been showed that those having witnessed the use of an innovation at a colleague's place were more willing to try it as well (Feder & O'Mara, 1982). Nonetheless, relying on non-trial observation only can be a risk as the growers don't have the complete technical knowledge they could earn through a real trial.

After the passive evaluation comes the trial stage. There, the innovation is introduced to the system and often tried on a small field part. Trying a new strategy on their own system essentially helps growers decide if it will indeed help them meet their goals and be profitable to the firm (Dimara & Skuras, 2003). By experimenting and observing, they progressively do less errors until they reach a process called "learning-by-doing" (Feder et al., 1985; Rogers, 2010; WilkinsonC, n.d). where they progressively get to grips with the innovation to the point of sometimes creating heuristic rules and better adapt it to their needs (Pannell et al., 2006; Weersink & Fulton, 2020). To summarize, non-trial and trial evaluations help growers shape their own opinion about an innovation and highly influence their adoption behaviour.

After an innovation has been tested properly, the process continues with a dichotomous result : the adoption or the non-adoption. Using the example of chickpea trial in a farm system, Ghadim and Pannell (1999) concluded that the choice to adopt a new strategy relied on subjective evaluation of the potential profitability growers could obtain from it on both short and long term. Regarding the rate of adoption, the same behaviour can be observed in horticulture and agriculture like any other sectors. The pattern follows a S curve divided into several categories: 1) the innovators, 2) the early adopters, 3) the early majority, 4) the late majority, and 5) the laggards (Rogers, 2010; Weersink & Fulton, 2020). Past studies underlined that "early adopters" mostly included professionals having economic advantages over the others (high benefits, large firms…) and so had less risk to upset their systems in case of non-adoption (Feder & Slade, 1984). This heterogeneity between growers illustrates the S shape of the innovation diffusion curve as a gradual movement (Pannell & Zilberman, 2020; Heiman et al., 2020). Early adopters noticing positive results after having introduced the innovation into their systems are most likely to spread the information in their social networks, which participates in increasing the number of firms adopting it over the long run. This phenomenon often decreases the innovation's investment costs and can then allow even more growers to get it; it is when the curve reaches its peak. Then when most of the concerned population has adopted it, the curve decreases again. The "late majority" and "laggards" include very late adopters who were either very reluctant to try or unable to afford it. Those categories reveal that hesitation towards

change can remain even once it has been proven to be helpful. Individual background such as education, age, firm's location and previous experiences can also influence the risk aversion behaviour (Hall et al., 2009; Pignatti et al., 2015; Weersink & Fulton, 2020). The new generation of farmers tend to be more open to innovative strategies and show less risk-aversion behaviours. When the diffusion of an innovation is particularly fast, smaller firms can feel pressured to reach for it as well to not risk being outshone by local competitors having adopted earlier (Fuglie & Kascak, 2001).

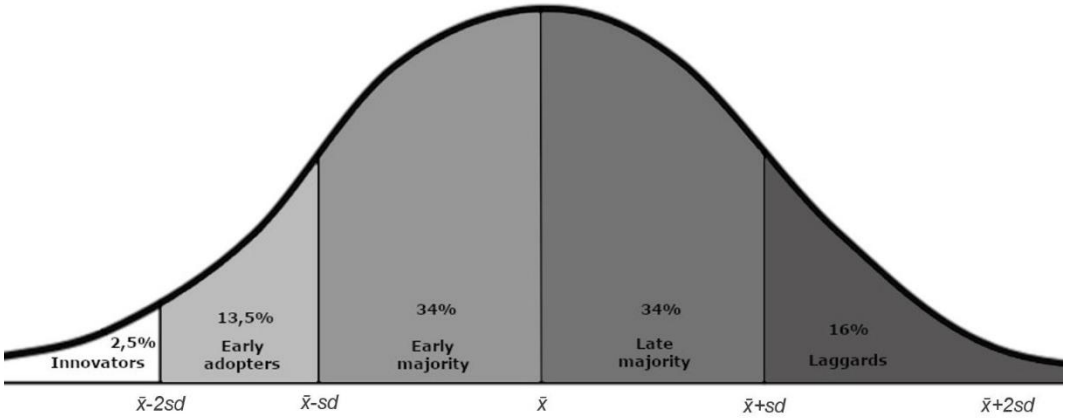

Figure 4. *The different categories of adopters, adapted from Rogers (2010).*

Also, growers can decide to dis-adopt or adapt an innovation after having used for some time. Has we mentioned earlier that the evaluation of an innovation was mainly subjective, the factors likely to determine if the new strategy will be kept or go through changings are the long-term profitability and trialability (Dimara & Skuras, 2003). An ergonomic innovation could be easily adjusted by the growers themselves while a more complex one could discourage them to the point of complete dis-adoption (Weersink & Fulton 2020). Very often though, an innovation is abandoned because a newer model has been introduced to the market; in that case, we talk more about "updating" instead of "dis-adoption."

3.1.3. Evaluating the sustainable innovation model

This part will help better grasp the design process and involved complexity of sustainable innovations in the horticultural sector. Firstly, will be introduced the various factors considered when the sustainability of a horticultural innovation is evaluated, to better understand the involvement of sustainable development in the horticulture sector. The second step will introduce the complexity and hurdles commonly faced when comes the process of monitoring the sustainability of an innovation throughout the whole creation process, the latter being presented and developed in the last part of this chapter.

Sustainable innovations properties in horticulture

When a sustainable innovation is created for the horticultural sector, it must follow the guidelines of the three pillars of sustainable development. The importance of each variable will depend on the project and its main objectives. Most studies focus on the R&D process when evaluating the sustainability of a new product or service on a global scale. The resulting frameworks are useful toolboxes for any firm investigating to design an innovation. No evaluation process specifically designed for innovations in horticulture production systems has been found, but a thorough browsing of recent publications showed that the drivers and factors to be evaluated are similar, no matter which market innovations are aiming for.

Globally, new strategies destined to the horticultural (or agricultural) sector are influenced by social and governmental demands; they must focus on reducing their negative impact on both human and environmental health while trying to feed a quickly growing population (Palombi & Sessa, 2013; Montero et al., 2017). Sustainable innovations in horticulture globally follow the same specifications as other sectors set by the sustainable development pillars. The Earth Security Group (2018) for example proposed a detailed framework for sustainable agri-business investments following the guidelines of the 17 Sustainable Development Goals (SDGs) which could be adapted to innovations. The Sustainability Monitoring and Assessment RouTine (SMART) is another tool built from SAFA guidelines which allows to assess the sustainability of firms from the agricultural and food sectors (Foresi et al., 2016). It doesn't specifically focus on the evaluation of horticultural innovations, but the objectives remain closely related to the SDGs.

As mentioned before, the evaluation of sustainability whether it is for an innovation or for an already existing system adds up the environmental and social part to the economic one. The latter has been well studied already the past decades, with most research articles focusing on profitability. With a raising consciousness about climate change and resources rarefaction, firms wishing to design sustainable innovations must limit their impact on the environment (Scialabba, 2014). It can be done with a better production management; supporting local primary products instead of imports, using natural resources more responsibly or replacing them with renewable ones (OECD, 2019) and a better waste valorisation (Nwosisi & Nandwani, 2018; Calik, 2014) are great examples of actions that would considerably decrease the global carbon footprint (Palombi & Sessa, 2013) of an innovation design process. Depending on the locality, environmental policies sometimes lead companies to revamp their production systems to meet governmental demands. End consumers are sensitive to the environmental impact a product or service might have, which also strongly influences the firm's willing to reorganise their production management systems.

Besides the need to increase productivity and benefits, firms designing innovations commit to equilibrate the distribution of their capital. From the actors' perspective, companies must consider a fairer investment in both human and material capacities. Again, the use of local primary products instead of imported ones would support local economy by financing small firms and retailers with decent contracts (Earth Security Group, 2018; FAO and INRAE, 2020). When explaining their frameworks, the SAFA and the OECD give weight to a global demand for better transparency; all actors involved in the innovation creation process (including the stakeholders) must know what they are investing their time and fundings into. However, many firms are still nowadays lacking transparency and can trigger investment reluctance among potential customers (OECD, 2019), A better transparency could also help evaluating the justness of the shares' distribution between the different actors involved (Scialabba, 2014). From an employee's perspective, a fairer capital management also must include the distribution of equitable salaries, regardless of social situation and gender. This socio-economical factor has an important place in the SDGs as it remains a highly debated topic nowadays in both developed and developing countries.

The social dimension is inextricably tied up to the other two pillars, especially when an innovation is considered. The design process must for instance be closely controlled to ensure employees' and users' health (FAO & INRAE, 2020). Adapted knowledge is then required to set an ergonomic and safe creation process (Calik, 2014; Palombi & Sessa, 2013). Thus, a good access to education and information should be encouraged and helped thanks to a strong collaboration between the different actors involved. Sometimes, an innovation (especially disruptive ones) requires specific skills which a firm might not possess yet; ideally, it then expands the job market by adding or creating more employments (Nwosisi & Nandwani, 2018; Earth Security Group, 2018). Employee's wellbeing covers many parts of the social challenges mentioned in the SGDs. Besides the need for gender equity as mentioned above, a better consideration for traditional and cultural values must progressively enter collective consciousness (FAO & INRAE, 2020). By better respecting social equity, we progressively get away from the model of Fordism; employees must be considered as individuals with different needs and ways of thinking, which can often bring new ideas and concepts to the firms willing to take time for their workers.

Table 1 is a non-exhaustive list summarizing the factors mentioned above which can be considered when evaluating the sustainability of an innovation, all types/kinds of sectors included. Globally, one could refer to the SGD's guidelines to tell if their new strategy is respecting the pillars of sustainable development. However, evaluation frameworks available in previous research studies can show some weaknesses. They very often focus on only one variable at the cost of the other two (Faure et al., 2018). The table has thus been created by crossing several

structural frameworks found in the literature to at least highlight the most important drivers of sustainability one could follow when thinking about creating an innovation. The choice to consider all sectors likely able to innovate has been done to avoid overlapping the chapter dedicated to factors influencing growers' decisions to adopt an innovation.

Table 1. *Most recurrent factors determining the sustainability of an innovation in the horticultural sector*

Environmental	**Economic**	**Social**
Responsible use of natural resources	Fair investments and primary products costs	Employee's well-being
Low impact on local ecosystems	Fair share between the actors	Access to information and knowledge
Responsible disposal of chemical substances	Fair salaries for employees	Actors' collaborations
Respecting global policies	Favouring local market opportunities	Ergonomic
Favouring local production of primary products	Feasibility	Product safety
Better waste valorisation	Affordability	Crease/develop employment
Use of renewable energies	Transparency	Adapt to increasing population
		Gender and social equity
		Human health
		Tradition and culture values

The complexity of the sustainable dimension

Innovations were originally destined to increase productivity, very often to the detriment of ecosystems and people (Gremmen et al., 2019) and were then not seen as sustainable solutions for newly rising problems (Tidd & Bessant, 2009). A growing pressure from governmental policies, consumers and global challenges however forced firms to progressively change their policies by incrementing a sustainable dimension into their innovation research strategies (Röling & Wagemakers, 1998; Donnan, 2021). In 2011, the European Commission (EC) referred to sustainable innovations through this definition : "*Eco-Innovation is any form of innovation resulting in or aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment, enhancing resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources*" (EC, 2011). Some industries successfully made the transition to eco-friendlier products and services such as reusable and cleaner energies, recycling materials, reducing waste and carbon footprint.

According to Tidd and Bessant (2009), four different forms of sustainable innovations exist and specifically rely on two factors: knowledge and application (Figure 5). Exploiting an already existing knowledge can lead to the development of incremental innovations such as the democratisation of solar panels for private individuals or the creation of new niches (the development of electric cars being one example).

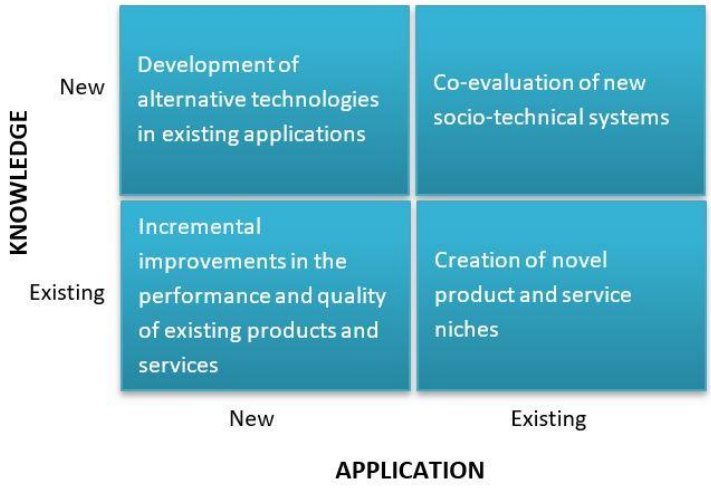

Figure 5*. The relationship of knowledge and application regarding sustainable innovations, adapted from Tidd and Bessant (2020)*

However, incremental development sometimes isn't enough to meet environmental demands and firms thus must turn to more radical innovations (Boons et al., 2013 ; Wagner, 2017). On top of that, a frenzy for "greener" industry became very controversial in terms of what they advert and what they truly offer (Marcus, 2015) and for some products, the sustainability guidelines sometimes haven't been fully respected in the production channel. This is where the limits between responsible R&D and "green washing" businesses can be difficult to draw. Overall, the concept of sustainable innovation is still perceived today as a blur without structural definitions. Werbach (2009) underlined that to offer true sustainable innovations, a company should give as much importance to the environmental and social factors as the economic one. The potential challenge then is to offer relevant and easily applicable models for any kind of sustainable innovation; according to the EC, the traditional linear model of innovation is now obsolete (EC, 2006) and must be considered as a tree view of different collaborations and strategies. The FAO pinpointed that an "*innovation needs to be considered in its broadest sense including innovation on technology, management, business models, and enabling policies*" (FAO, p.20, 2021).

The diversity of sustainable innovation evaluation frameworks

Although innovations take more factors in account to be considered as effectively sustainable, their design process globally remain the same as the conventional ones. Lee and al. (2006) decomposed the innovation design process into a circle of three connected phases (Figure 3). Firstly, a social demand for a product or a service must be clearly identified through a thorough market analysis. Secondly, the firm must search for a solution to fulfil that demand as best as possible with an adapted solution. The final step is then the evaluation of the newly designed product or service by either field tests, its introduction to the market or a combination of both. If the result is satisfactory, the design process is over. If it is however non adapted or need some improvement, the design management adapts itself and loops back to Phase 1 (’Connell et al., 2013).

Between the first and second phases, the firms wanting to design an innovation must consider the demands set by not only potential customers but also governmental policies (Marxwell & Van der Vorst, 2003). During the R&D process, the firm’s technological and knowledge capacities play an essential role and can become either considerable assets or strong hurdles depending on their availability. The consequences of lacking either/or both would mainly be serious deficits by offering unsuitable end products. Thus, the potential investments to develop the industrial and education capacities must be precisely estimated before even starting the R&D process. A continual market analysis is also vital to apprehend the impact of possible competitors and target the right group of customers (Köhler et al., 2013; De Medeiros et al., 2014). In the end, the design process of sustainable innovations is mainly influenced by social, environmental, economic, and institutional demands (Saulina et al., 2018).

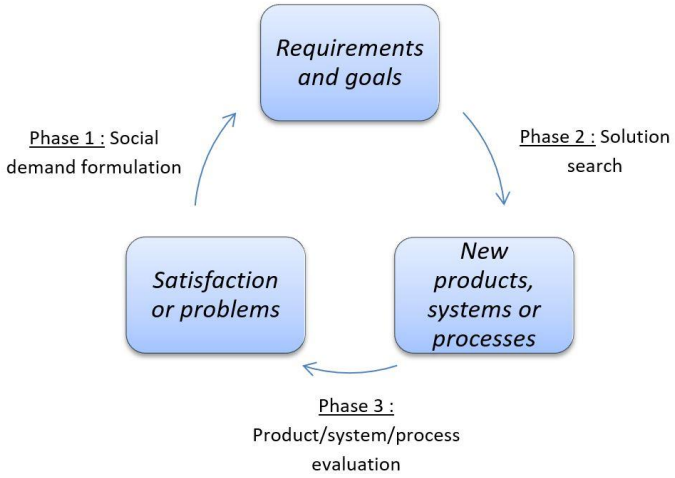

Figure 6. *The information and knowledge flow during the development stages, adapted from Lee and al., (2006)*

If it is well established that sustainability can be achieved by fulfilling the social, economic and environmental requirements, the subject remains vague and can vary

greatly from an individual to a national scale (Cinelli et al., 2014). Thus, recent studies offered more multi-criterial evaluation frameworks regarding innovations and the redundancy of several factors can help grasping which ones seem essential when assessing new strategies. PROspective SUstaInability Assessment Technologies (PROSUIT), a project reuniting European researchers, offered for instance five main factors to evaluate when assessing the sustainability of a new technology: the use of limited natural resources, the impact on the close environment, the respect of human health and social well-being and the stakeholder's prosperity (Blok et al., 2013). On an agricultural perspective, the Sustainability Assessment of Food And Agriculture Systems (SAFA) considers four main themes to consider when involved systems turn to sustainable innovations: good governance, environmental integrity, economic resilience and social well-being (Scialabba, 2014).

A wide range of frameworks can be found in literature; some evaluate the sustainability of a product only through its life cycle and others cover the whole research and collaboration process. It is important to remember that sustainability evaluation frameworks are often multi-criterial (Van der Vliet et al., 2018): The main focuses are non-exhaustive and can vary depending on the firm's objectives. Some innovations will be more socially oriented while others will focus on reducing their environmental impact as much as possible. The interactions between the different actors involved can also vary. Thus, there could be as many evaluation models as many innovations designed. The data gathered in various frameworks found in the literature is summarized in Figure 7. The sustainable development pillars are represented here as variables as their importance and sub-categories can change, as mentioned earlier. As famous examples, we can mention the Agricultural Innovation Systems (AIS) approach as a fair framework evaluating innovations in agriculture through a strong network of actors and thus reconsidering the conventional linear innovation model set during the green revolution (Aerni et al, 2015). The Life Cycle Assessment (LCA) is another well-known framework found in literature which evaluates innovation's sustainability through the whole design process (from Phase 1 to Phase 3 (Figure 2)). It specifically focuses on the quantity of energy and materials used to create a product or an innovation and the direct global footprint it has on the environment (Blok et al., 2013; Foresi et al., 2016).

At the same time, all actors, stakeholders involved and their interactions and global impacts are also evaluated (OECD, 2019).

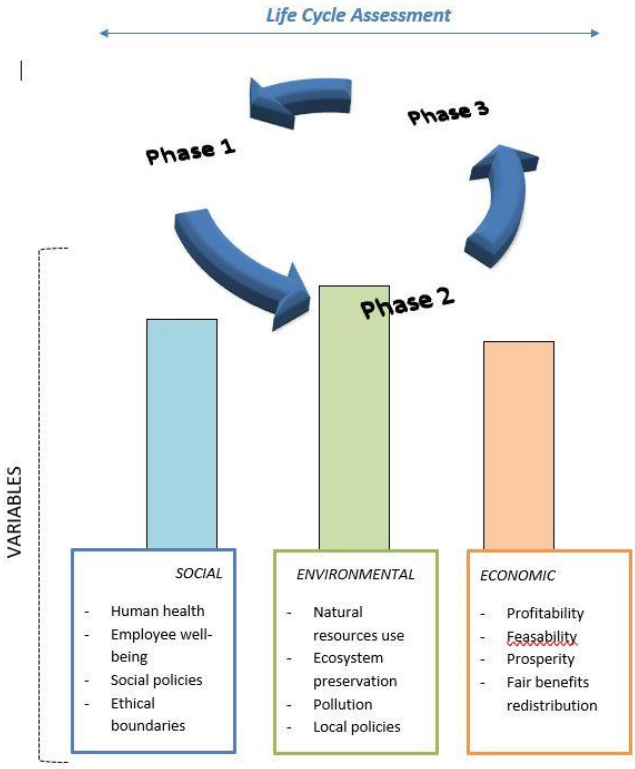

***Figure 7**. A global overview of evaluation frameworks for innovation sustainability*

3.1.4. Factors influencing the adoption process

Identifying recurrent decisional factors

Growers' main motives to adopt an innovation are mostly economical (Mansfield, 1961; Dimara & Skuras, 2003). Recent research papers revealed however that their decisions to adopt new practices could also be influenced by social, environmental, and psychological factors as well as their access to both knowledge and technology (Mankad et al., 2017; Serebrennikov et al., 2020).

From an economical perspective, what regularly appears in the literature is growers' reluctance to invest in innovations with no clear sights on return of investment (Marra et al., 2003). Such uncertainty is showed to be higher among those relying on their farms' activities only; compared to others having also external incomes (e.g. second activity/work), they aren't often economically able to wait for long term benefits (Matata et al., 2010). Conversely, growers having comfortable wealth show less reluctance to try new strategies as they can cover potential money losses in case of trial failure. The irreversibility of the investment is also considered as a hurdle for smaller firms as any problem could jeopardize their systems (Weersink & Fulton, 2020). Thus, the opportunity to see positive results before investing in the innovation itself showed how it could comfort growers in their

decisions to integrate it to their own farms (Ghadim & Pannell, 1999). Collecting such information and other feedbacks is indeed proven to decrease grower's uncertainty as well as risk-aversion towards innovation (Marra et al., 2003). Uncertainty is a variable difficult to evaluate as it may change from a grower to another and can be influenced by several factors. In her famous book "Diffusion of innovations", Rogers defined uncertainty as "[…] *the degree to which a number of alternatives are perceived with respect to the occurrence of and event and the relative probabilities of these alternatives. Uncertainty implies a lack of predictability of the future [and] motivates an individual to seek information*" (Rogers, p.XVIII, 2010). When the uncertainty is high, growers might show more reluctance to take any economic risks (Hall et al., 2009). Past studies found that aversion of risk (and investment) was correlated to social factors such as the age and experience of the people involved. Globally, older growers comforted by their traditional way of handling their firms don't necessarily have to anticipate the future by disrupting their systems with new practices (Tey & Brindal, 2012), while others who previously had negative experiences with innovations will most likely refuse to take risks again (Ghadim & Pannell, 1999; Barr & Cary, 2000). Besides, some can lack experience with new technologies and thus be unable to use it or be unaware of what is available on the market. Innovation complexity is indeed another factor of risk-aversion, which can drastically restrict its integration to a firm if it is difficult to use. When the complexity level is too high, the level of uncertainty and risk of failure increase proportionally. However, recent studies highlighted that the younger population of growers liked taking risks (Kassie et al., 2008; Serebrennikov et al., 2020). It can be assumed that their education, youth, long term plans and greater motivation to preserve the environment push them to try new strategies. No matter the ages and objectives, many growers still rank economics above the other two pillars of sustainability when they consider new strategies because having a good capital can help them improving both the social and environmental parts in their firms (Da Silva & Forbes, 2016). All in all, when growers consider an innovation, they want to know about its "relative advantage" (Rogers, 2010), if the resulting incomes would quickly pay their investment off and then bring concrete and higher incomes compared to their original systems (Pannell et al., 2006; Pignatti et al., 2015). Logically, even farms interested in turning to more sustainable practices will not likely adopt one if it implies important economic losses (Panell et al., 2006). In the end, profitability has an important weight in the decision-making process of adoption and growers' uncertainty can decrease if they get a clear perspective of the global costs and net incomes promised by the innovation itself (Weersink & Fulton, 2020).

On a social scale, growers' demands about innovations have changed since the green revolution. Indeed, the level of acceptation was proven to vary between social groups, historical times, traditions and ethics (Mankad et al., 2017; Faure et al.,

2018). The example of GM crops remains a good example; even though it was appreciated by farmers when it came out, genetically modified organisms became strongly controversial and rejected by customers. Consequently, innovations in the biotechnology sector globally lost people's trust (Gremmen et al, 2019). Some growers thus rejected those practices to keep their customers and competitiveness on the market. We can observe here that ethical belief is a common factor influencing the adoption behaviour in horticulture, where growers concerned about environment health are more likely to get an innovation if it has positive impacts on the ecosystems (Marra et al., 2003; Pannell et al., 2006; Serebrennikov et al., 2020). Previous studies pointed out the influence of the consumers' demands on farmers willing to adopt sustainable practices (Weersink & Fulton, 2020) while paradoxically some instead admitted they didn't grant importance to it (Hall et al., 2009); the decision-making process then depends more on their culture and personalities (Panell et al., 2006). Retailers can however often pressure the growers to respect their bills of specifications (Da Silva & Forbes, 2016). This phenomenon is quite common nowadays where environmental policies keep evolving incredibly fast. For instance, new regulations can push retailers to be more uncompromising towards growers; in such scenario, some of the latter may have to change their strategies and consider sustainable innovations to keep up. This situation can be seen as a threat to those who lack interest in new strategies and technologies in general and prefer to keep their traditional systems. Here again, the economic aspect plays an unavoidable role, as upsetting a viable system for a more sustainable one can be costly and unaffordable for some firms. Some growers may also show reluctance to adopt an innovation if it subsequently increases their workload, especially when they must replace chemicals by more time-consuming alternatives (Röling & Wagemakers, 1998; Weersink & Fulton, 2020). Paradoxically, some confessed they were ready to adopt non-profitable innovations if it stabilized their work-life balances. Ghadim and Pannell (1999) and Kassie et al. (2008) found out that family farms or firms having enough employees were less worried to try new practices as they would have enough extra hands in case of work-load peaks. A well-established connection with experts such as professional counsellors, researchers and other consultants can also deepen the growers' personal skills and change their point of view about an innovation (WilkinsonC, n.d.; Ghadim & Pannell, 1999; Serebrennikov et al., 2020; Streletskaya et al., 2020). To counter the risk of aversion towards especially complex innovations, many studies mentioned the need for growers to have a stronger social network. They can seek social support from their own families, employees and farmer neighbours, especially if the innovation would ask them to begin important and stressful changings in their farms (Panell et al., 2006). Weersink and Fulton (2020) pinpointed that firms having an important human capital (employees, interns…) were willing to adopt complex innovations as they would be able to split the tasks more easily in case of an increase

workload. Globally, growers require proofs that an innovation works before considering adopting it, and the sources can either be official (forums, counsellors and consultants) or non-official (family, neighbours, employees, social networks.) Lately, the expansion of communication technologies (internet) also helped growers having a better access to information (Pierpaoli et al., 2013; Campos, 2021). The more expensive or complex the new practices are, the more information and concrete results growers will ask for (Panell et al., 2006).

Among all the papers read for this thesis, environmental concern appears to be mostly influenced by growers' own perception of environmental problematics (Weersink & Fulton, 2020). On one hand, there is the need to preserve soil and ecosystem's health to both increase and homogenise the quantity of crops cultivated in their fields. Although the main objective of using more respectful practices is to preserve the environment, the growers' end goals often remain to increase profitability. Cullen et al (2013) for instance demonstrated that among several types of sustainable innovations proposed, wine producers in New Zealand mostly chose the cheapest and riskless one to limit any potential economic loss (flora and fauna conservation). The second category was mentioned before and includes those feeling pressured to turn to more responsible production strategies. On top of the customers, policies and/or retailers demands (Da Silva & Forbes, 2016; Llewellyn et al., 2020), the geological location of a farm can become a challenge growers have to face by changing their goals or ways of thinking. It was previously demonstrated that firms located in uneven lands (mountains, stony soils and scarce access to lands) limiting mechanical interventions negatively impacted the decision to adopt new strategies, as those offered on the market aren't often adapted to rough lands (Kassie et al., 2008; Weersink & Fulton, 2020; Marescotti et al., 2021). Climate change and natural disasters also have repercussions on the decisions to adopt innovations. Arid or submersible locations require growers to use twice as much imagination than the others to preserve their productions and secure their incomes (Kassie et al., 2008; Serebrennikov et al., 2020). Thus, the number of scientific studies in developing countries sensitive to drought, famine, and other recurrent concerns is increasing every year, as it is vital to find new solutions to cope with climate change. Another category of adopters is about growers ready to turn to sustainable innovations to preserve the ecosystems even if it means to reasonably reduce their profitability (Weersink & Fulton, 2020). Such behaviour is correlated with the farmer's own concern about environmental health (individual perception) and/or capacity to pay off the potential income decrease it would trigger. Thus, sustainable strategies uptake is not only influenced by the environmental challenges or concern, but also by the financial, infrastructural and social context of the firms.

Farm geographical location is another recurrent factor which raised in previous papers under the name "environment", which can be confusing. For better understanding, it will be separated here from geological location. Globally, farms

located closer to important urban areas showed more openness to sustainable innovations (Dimara & Skuras, 2003; Hall et al, 2009). It is explained by a better access to information sources (research institutes, counsellors and academics) and a closer proximity to potential customers (Koesling et al., 2008; Serebrennikov et al., 2020). Very often, growers living close to residential developments must also follow stricter policies to reduce chemical or noise pollutions. On the other hand, growers' choices to innovate can be reduced if their location limits their access to the informational and material resources required (Marra et al., 2003). Indeed, a large distance between a farm and a city negatively impacts the access to materials by increasing the transport costs and times of delivery, which very often discourages the growers to innovate (Dimara & Skuras, 1998). It is thus not uncommon to find mainstream horticultural systems in isolated locations, where the growers' only access to information and materials relies on rare neighbours and small villages' proximity. Depending on the countries' geographical coverages, some remoted firms sometimes don't even have access to the internet, which makes it even more difficult to keep oneself updated about the new strategies available on the market. Theoretically, horticultural growers would be more willing to adopt sustainable innovations if they live closer to urban areas, have a good access to information, are sensitive to environmental challenges or at worst compelled to adapt to tighter policies and demands.

Summarizing the drivers influencing the decision-making process and adoption/non-adoption of an innovation, they are correlated to the guidelines it must follow in order to be considered as sustainable : the environmental, social and economic drivers are recurrent concerns for growers. Now they are properly identified, it is possible to sort them out in a relevant decisional matrix.

Designing a decisional matrix

The factors previously identified in the literature can now be organised into a relevant matrix table. A thorough analysis of the data collected in several scientific papers helped dividing the factors into five distinctive categories; four of them follow Rogers' reasoning about the drivers influencing new strategies adoption from the growers' perspectives : their "compatibility", "complexity", "trialability"/"observability" and "relative advantages" (Rogers, 2010). The "compatibility" of an innovation determines its suitability to the growers' systems and geographical demands, whereas its "complexity" is evaluated by the capacity of the growers to apprehend it efficiently. The "trialability"/"observability" category can be related to the "evaluation" part of figure 3, where it is highly influenced by external feedbacks and field observations. "Relative advantage" mostly includes the potential benefits one could get when adopting a sustainable innovation, which can be estimated through an efficient data-gathering and evaluation process. A fifth category focusing on individual's background is added

to the list as many factors identified during the review relied on the growers' past experiences and subjective perceptions of an innovation.

At the outcome of the literature review, a matrix of 43 different decisional factors is built (see table 2). With a total of 30 factors involved, economics came out as the most important pillar of sustainable development considered when growers evaluate the potential of an innovation. It is closely followed by the social dimension with 28 factors found, or 20 without counting the non-changeable "individual background" category. The environmental pillar comes last with only 7 factors counted, more than 85% of them relating to innovation's compatibility with production systems and global challenges. Some factors can also correspond with more than one pillar. For instance, external feedbacks and consumers' needs can convince growers to safely invest into effective innovations to meet local demands. On the other hand, national and/or local laws can be seen as an opportunity to get governmental fundings to invest into costly strategies. Likewise, growers showing high environmental concerns will more likely turn to sustainable innovations than others.

Apart from the individual backgrounds, most of the social factors can be seen as variables; knowledge, skills and awareness may change throughout the decision-making process depending on their behaviour and investment in information search and networking.

Some factors summarized in table 2 can be correlated to the ones mentioned in table 1 such as the feasibility of an innovation and its relationship to global policies or individual cultural values. However, table 1 gathers the general guidelines to follow when evaluating the sustainability of an innovation while table 2 summarizes the various decisional factors considered from a grower's perspective when they consider introducing a new sustainable practice to their systems. Only the matrix created in table 2 will be thus used for the following parts of the report.

Table 2. *Factors influencing the adoption of innovations from the growers' perspectives based on the literature review (inspired from Rogers' (2010) work)*

Decisional factors			Sustainable development pillars		
			Social	Economic	Environmental
Individual background		Age	X		
		Experience	X		
		Culture	X		
		Tradition	X		
		Education	X		
		Technology awareness	X		
		Environmental involvement	X		X
		Innovation acceptance/aversion	X		
Relative advantage		Productivity		X	
		Profitability		X	
		Clear economic perspectives		X	
		Clear investments		X	
		Available fundings		X	
		Net incomes		X	
		Clear maintenance costs		X	
		Affordability		X	
Trialability/observability		Non-official sources' feedback	X	X	
		Technology awareness	X		
		Technology access	X	X	
		Neighbours' trials	X	X	
		Human capital	X	X	
		Management organisation	X	X	
Compatibility	System	Available market	X	X	
		Labels		X	X
		Geographical location	X	X	X
		Work-life balance	X		
		Workload	X		
		Infrastructure		X	
		Hand work skills	X	X	
	Global challenges	Local/national policies		X	X
		Consumers' demands	X	X	
		Stakeholders' pressure	X	X	
		City closeness	X	X	X
		Local climate		X	X
		Market demand	X	X	
		Geological location		X	X
Complexity		Adapted infrastructure		X	
		Information access	X		
		Technology knowledge	X		
		Autonomy		X	
		Potential alternatives awareness	X	X	
		Management skills	X	X	
		Knowledge access	X	X	

3.2. Interview search results : assessing the decision-making process and decisional factor “matrix”

In this section, the interview results are sorted out into three parts : 1) The interviewees’ background and main characteristics, 2) their decision-making process followed when facing an innovation and 3) their main decisional factors potentially influencing the outcome of the decision process itself.

3.2.1. Interviews and description of the sample

For this report, a total of six growers with various activities were interviewed, including :

- Garden crop production
- Flower production
- Wine production
- Herb production
- Fish and garden crop production (aquaculture)
- Fruit tree production.

Their main characteristics such as the age, field experience and education are summarized in table 3.

Table 3. *Details and characteristics of the interviewees*

Firm	**Status**	**Type of production**	**Sales channels**	**Proximity to city (km)**	**Owner/manager characteristics**			
					Age	Field experience (years)	Education	Professional background
1	Owner	Organic herbs	Direct selling, anti-food waste apps	20 - 50	35-45	4	Agronomist Computer degree	Horticultural woofing abroad, bank adviser, data analyst
2	Owner	Organic wine	Direct selling	> 50	35 - 45	6	BTS agriculture	Commercial
3	Manager	Organic fruit trees	Direct selling, retailers, industry	< 5	25 - 35	14	BTS agriculture	-
4	Owner	Market gardening crops	Direct selling, municipality	< 5	> 55	26	BTS agriculture	Accountant
5	Owner	Aquaculture and hydroponics (fruits and vegetables)	Direct selling, retailers, supermarkets, hospital	< 5	25 - 35	3	BTS agriculture	-
6	Owner	Fruit trees	Direct sales, retailers	5 - 20	> 55	40	BTS agriculture	-

3.2.2. Firms' locations

All the interviewees are in the Nouvelle-Aquitaine region, in the Southwest of France. For information, Nouvelle-Aquitaine is the largest region of France and hosts various landscapes, from mountains to Atlantic coasts. The climate is mostly oceanic and the main productions found in the area are vineyards, pine trees and garden crop productions (mostly flowers and vegetables) due the high content of sand found in the soil.

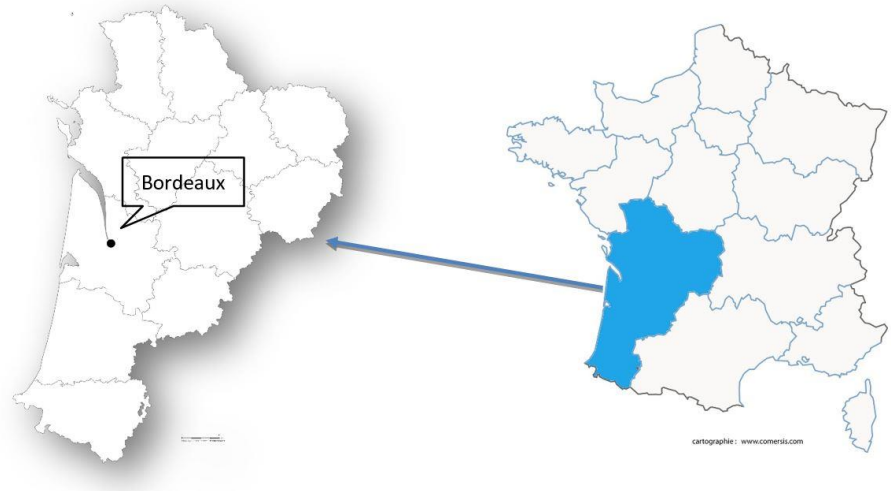

***Figure 8**. Firms' location on the French territory. All growers live in Nouvelle-Aquitaine, south west of France (the region coloured in blue). Source ©comersis.com*

The location is limited to Nouvelle-Aquitaine to facilitate face-to-face interviews. As a result, five interviews were conducted directly on the firms and one was done by telephone. Globally, three growers live between 20 and 50km away from the nearest city centre, one between 5 and 20km and one less than 5km.

3.2.3. Growers' background

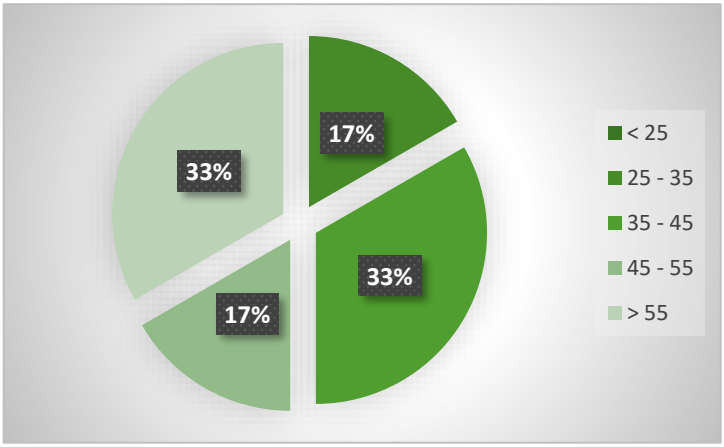

***Figure 9** - Age distribution of the growers interviewed*

In the sample of growers interviewed, 50% are over 45 years old while only 17% are under the age of 35. None of them are younger than 25 years old. Five of them own the firms and one is the manager.

The average work experience in the same firm is 16 years, with an important standard deviation of 14,8 as the shortest experience registered is 3 years against 40 for the longest one.

Most growers had related education backgrounds; five of them graduated after a "BTS" (French bachelor's degree achieved in two years to obtain an "advanced technician certificate") specialized in agricultural production systems, which is the classical education students follow when they want to become farmers. One of them said their current associate however graduated from a local business school. The last grower graduated from an engineering school in horticulture then supplemented their knowledge in computer engineering by graduating in informatics. All interviewees remained in the agricultural sector since they graduated except one who used to be an accountant and another who has worked in horticultural firms around the globe, then settled as bank adviser for a few years before turning back to plant production.

Field experience (years)					
3	4	6	14	26	40
				Average :	**15,8**
				Standard deviation :	14,8

Table 4. *Field experience distribution*

All growers interviewed dedicate their production to direct sales with local customers, followed by retailers for 23% of them. 15% of them also sell their products to more targeted audiences (category "others") including hospitals and local municipalities (schools, city halls…)

Three of the firms visited possess the "*AB*" label ("*Agriculture Biologique*", French equivalent of "organic farming"), one is registered to the "*HVE*"[3] ("*Haute Valeur Environnementale*"), which can be translated to "High Environmental Value") technical specification and one possesses the label "*verger eco-responsable*" [4] (="eco responsible orchard.")

[3] The HVE certification requires firms to respect very strict technical specifications such as preserving local ecosystems, limiting chemical and organic inputs, and using natural resources reasonably. The quantity of inputs and resources used is monitored annually by governmental agencies.

[4] Eco responsible orchards follow technical specifications similar to the HVE certification. Conventional practices must be replaced by more responsible ones, natural resources must be used reasonably and ecosystems must be preserved. This label can only be given to firms selling crops produced in France.

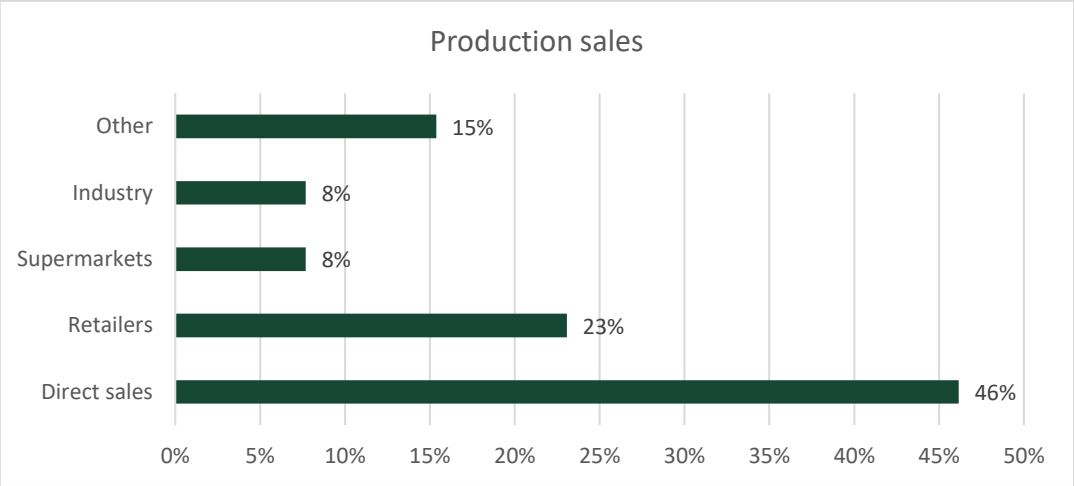

***Figure 9**. The different sales distribution networks*

3.2.4. Projects and objectives

Among the growers interviewed, the main objective identified for most of them is to develop direct sales to private individuals and thus reduce third parties' commissions. Two of them are hoping to extend their farm network outreach by encouraging the creation of local cooperatives or developing their social network. Another goal observed is the desire to pull away from conventional monoculture production systems by diversifying the crops grown on the firms. All interviewees wish to decrease or stop the use of chemical inputs on the long run by replacing them with more sustainable practices such as the use of biodegradable materials.

3.2.5. Sustainable practices previously adopted in the firms

Although their activities are diverse, all growers presented more respectful practices they already have adopted in their firms. Three of them have never used chemicals since they created or took the farms over while one progressively stopped using synthetic products a few years later. Two interviewees turned to natural predators for integrated pest management while two others replaced herbicides by mechanical weeding. Three firms also use organic filters and rainwater tank for better water recycling management. On a more social note, two firms recently developed their farm network; one of them participated in the creation of cooperative of farmers to encourage local sales and attract more clients. The second one created a new market during the first health crisis lockdown by being the first one in the country to sell their products via a take-away app to prevent plant waste.

Globally, all growers affirmed they remained opened to any available strategy which would match both their systems and objectives.

3.3. Identification of the decision-making process

3.3.1. Innovation awareness and/or data gathering

As mentioned above, all growers interviewed already adopted sustainable practices in the past. The objective of this part is to summarize the decision-making process they went through when considering the adoptions.

Even if the newly adopted practices were often different from a grower to another, they all agreed that gathering information about it before trying it was essential. Thus, most of them turned to official sources such as technicians, counsellors, professional forums to learn more about the innovation's use and perks. All of them admitted they also searched for information near non-official sources including neighbours, local cooperatives, families and employees. A minority mentioned the use of local newspaper as well. Globally, those having access to the internet also browsed information online. One of the growers often finds new ideas when observing other sectors' works such as the construction industry. One of the market gardeners didn't feel the need to learn more about the new tool he wanted to adopt, although they discovered it recently in a professional farming convention (LED lamps).

3.3.2. The evaluation

One grower admitted they didn't need to try the new strategies (in those case, LED lamps and chemical weeding) before adopting it. One fruit tree grower on the other hand conducted life-sized trials in their fields then slowly extended it to the rest of the orchard to anticipate any short- and long-term side effects. One grower experimented the new practice in partnership with the creator, which helped them improve and adapt it to their needs thanks to the growers' feedback. The last grower interviewed was in the middle of the trial/evaluation stage of a new pest management strategy and stated they will need more time to find out if it will be worth adopting or not.

Whether they tried it or not, all growers confirmed they observed the innovation potential efficiency at neighbours' places or in official demonstrations before trying it themselves. Three of them even added that hearing positive feedback from their farm network had a lot of weight in their decision-making, and that it was the main way innovations were diffused in horticulture.

Four of the interviewees collaborated with academics in the past and were globally satisfied by the outcome, although one said it could take a long time before getting any official results once the innovation trials were over.

3.3.3. The adoption/non-adoption

After some time, five of the six growers ended adopting the innovations they were evaluating beforehand. Two of them integrated tools they considered new for their firms, but which already existed on the market for several years already. One market gardener created a niche on the online food saving market and was soon imitated by other growers around the country.

Most of the growers however admitted they had to face various risks when deciding to adopt new strategies or tools in their firms. Economic risk was the most important one mentioned by the interviewees, followed by the fear of failure. Growers having no external income showed greater concerns than the others.

3.3.4. The revision and/or dis-adoption

Only one grower has been through the dis-adoption process, but only to switch the innovation with the latest model released (newest weeding machine) which has been proven to be more respectful towards their tree's roots. One market gardener modified a strategy they adopted in the past to better adapt it to their system, especially after they observed the apparition of new side effects on the long run (wooden tables for pot support quickly defective after bad weather and wood pest invasion). In that case, they did some changing themselves using techniques observed in the construction sector (built tables out of burnt wood treated with turpentine).

Growers were then asked at the given moment if they were satisfied by the new tools and/or practices they integrated to their systems or if they were planning to change it. Four of them said they were pleased with their choices and not planning to change anything while the other two said it was too early to tell.

4. Discussion

In this chapter, the results collected during the literature review and the interview search are put together and compared to identify the possible correlations or differences between the different data. The first part of the discussion focuses on the relevance of the decision-making process between the literature search and the growers' experiences collected while the second one evaluates the applicability of the decisional matrix created in the literature review by comparing it to the factors identified during the interviews conducted with the horticultural producers.

4.1. About the decision-making process

Exchanging with the growers allowed to recognize the different stages involved in the decision-making process of an innovation adoption. The accounts gathered during the interviews reminded more of Ghadim and Pannell's six stages of adoption (1999) : 1) awareness, 2) non-trial evaluation, 3) trial evaluation, 4) adoption/non-adoption, 5) revision and 6) dis-adoption. For this part, the pattern of adoption summarized in figure 4 will be followed.

As all growers interviewed had already adopted a new strategy in the past (or were in the middle of the adoption process), one question in the questionnaire focused on the first stage "awareness" by asking them where they first heard of it. Although they all reached for both formal and informal information sources, most of them gave more importance to the informal ones and discovered the innovation at neighbours' farms or within farmer community meetings. Jean (2014) and Weerskink and Fulton (2020) already highlighted the importance of social capital in the diffusion of innovations in the agricultural/horticultural sectors and such behaviour has been observed with the interviewees as well. Another factor observed was the relationship between the firms' closeness with big cities and the ways of reaching for information. Information given by formal sources such as technicians, counsellors and academics came second. Those living less than 20km away from an urban area added the use of the internet (social media, online newspapers, documentaries) to keep themselves updated about available innovations on the market while those living more than 20km away from a city gave priority to their social network and local press. No matter the farm's location the growers moved to

the data gathering stage once they were comforted that the innovation could potentially help them achieve their main objectives in a near future, as mentioned before by Dimara and Skuras (2003) and WilkinsonC (n.d). One of the growers skipped the information gathering part, a behaviour identified by Dimara and Skuras (2003), as the tool they wanted was already well-known and available on the market for years.

The two different types of evaluation behaviour (Ghadim & Pannell, 1999) were also identified during the interviews. Most growers firstly observed the potential efficiency (non-trial evaluation) in both their social and professional circles and admitted that getting positive feedback from their neighbours had a considerable weight on their decision-making process, more than the official information given by professionals; the trust and strong social connection between growers again plays a very important part in their final decisions (Feder & O'Mara, 1982; Smith & Ulu, 2017). It became apparent that they globally trust their informal network more than the formal one, especially about the unfiltered feedback they could get from their fellow neighbours compared to the limited one given by commercials and traders. Furthermore, those who previously observed the experimentations either at a neighbour's or an official convention for instance, explained they had very little difficulties to set it up for trial because they already had an overview of how it was supposed to be used and thus felt more motivated to try it. We join here Weersink and Fulton's (2020) study where they noticed that such passive observation can indeed improve grower's knowledge and opinion before even starting the real field's trial. However, one of the interviewees underlined that it could be difficult to reach for more information especially when their fellows aren't really open to new strategies/technologies and thus expressed their gratitude towards professionals offering easier access information. It appeared that the activities and commitment of fellow growers in each farm's social network can also have a direct impact on the information access about an innovation.

For the trial part, different types of behaviours were identified. A fruit tree grower planning to adopt mechanical weeding went through a small field trial process, explaining it was the most convenient strategy for their system. Testing and observing the results helped them getting a good grasp of the tool's practical use and adjust their application accordingly without jeopardizing the whole system. We were in accordance there with Feder (1985), Rogers (2010) and WilkinsonC (n.d).'s statements, where producers testing innovations on their firms go through a "learning-by-doing" phase where they acquire more knowledge and experience the more they try it. Another behaviour was observed with the herb grower who decided to replace metal tables with a more local and sustainable material to support plant pots. They invested into wooden tables and observed negative side effects of the local climate on the material itself. To counterbalance that, they investigated and selected turpentine burnt wood ("yakisugi" technique) to design new tables. By

observing and searching for solutions, the grower adapted the innovation to their needs, a behaviour already observed by Pannell (2006) and Weersink and Fulton (2020). Two other growers were at the beginning of the trial stage when they were interviewed, but they both confirmed they were not worried about the outcome. Following Rogers reasoning (2010), the market gardener installing LEDs in their hothouse can be considered as part of the "early majority" because the technique has already been adopted in the past but is still rarely found in conventional hothouses. On the other hand, the wine maker trying salt water as a natural fungicide stated they weren't worried either about the possible outcome for an economic reason; using salt water being cheaper than chemicals, a negative result wouldn't cause them any losses, they would just turn back to the chemicals they used before. It was interesting to observe different types of trials done by the interviewees, and the novelty of the innovation seemed to correlate with the testing strategies. We can refer to the fruit tree grower who took the time to experiment mechanical weeding on their orchard as the product is still considered as a novelty going through a lot of R&D processes, while the market gardener replaced the totality of their lamps by LEDs without going through the trial process. We can follow Smith and Ulu (2017) observation and deduce that it is easier to access available (and especially informal) information about older strategies than new ones, which could explain why growers adopting newer strategies are more cautious when going through the evaluation process.

At the outcome of the evaluation stage all interviewees who tested the innovations decided to adopt them (except two still going through the evaluation process). The herb grower could be seen as an "innovator", as they created a new niche selling potted plants via a take-away app to limit food waste. Such solution came up to limit the number of plants they had to keep or throw away if they didn't meet the customers' demands. As the app was only taking a small percentage when a sale was officially closed, the grower said no economic risk was taken whenever a plant didn't find a buyer, while making a sale was just a bonus. As they quickly noticed some benefits from this new strategy, they shared the information through their social network which consequently increased the number of adopters, a process previously noted by Pannell and Zilberman (2020) and Heiman (2020). Going through several available apps, a few more growers and garden stores now indeed offer the same service and can thus be identified as the "early adopters" category from Rogers' curve (2010). The wine maker could also belong to this category if they happen to adopt the saltwater spraying strategy. They found this technique among those living on a small island along the Atlantic coast and nowhere else; they could be then considered as the "innovators." Finally, the two growers who adopted integrated pest management techniques could belong to the "late majority" of adopters, as IPM isn't really new and appeared in the 50s. However, the technique keeps being improved and new products and natural

enemies are regularly introduced to the market; depending on the novelty of the strategy chosen, the growers can then be considered as part of the early majority.

Only one case of dis-adoption was found, when the fruit tree grower gave up on a weeding machine to buy the latest model; this behaviour mentioned by Dimara and Skuras (2003) happens regularly and is more considered as an upgrade than a dis-adoption because the functionality and purpose remain the same. One grower already went through several revision stages, the most important one being the change of materials used to design biodegradable pots. The pots were created and tested on their firms thanks to a partnership with the designer. In this case, the revision was easily doable for the grower thanks to their strong collaboration with the pots creator. Weersink and Fulton (2020) previously found out that the easiness to adapt an innovation to an existing system was negatively correlated to the extent of its complexity. The grower indeed confessed that without the help of the firm creating biodegradable pots, they would have struggled to find another solution to their problems. Although Ghadim and Pannell (1999) set the dis-adoption" stage after the "revision" one, in this case the grower stopped at the "revision" step; they indeed asked for some changings in the material and design process but eventually adopted it.

4.2. Review of decisional factors

4.2.1. Individual background

Concerning the individual background no correlation between the age and adoption rate has been found, as the age distribution of the interviewees was broad. For instance, two of them over 55 years old possess tools considered as novelty products such as a weeding machine and LED lamps. This behaviour can then be more related to the experience of the growers, as they both worked more than 25 years on the firm. They consequently have more practical and technical knowledge than younger ones, which can, as demonstrated previously by Hall, (2009), Pignatti (2015) and Weersink and Fulton (2020) positively influence the decision-making process. On the other hand, one of the growers interviewed, aged between 25 and 35 years old and currently manager of the farm, explained they went through a lot of trouble to convince the owner to get a new technology (mechanical weeding tool). The owner, close to retirement and not really interested by innovations, showed some reluctance to change the system their family has been taking care of for three generations. In this case, the technology awareness and attachment to tradition, especially in French agriculture, remains strong and can negatively impact growers' relationship with innovations as Mankad (2017) and Faure (2018) previously highlighted. The owner's aversion however decreased after having seen some public demonstrations of the tool (mechanical weeding) and they ended

adopting it after having received positive feedback from fellow growers. Such changing follows Ghadim and Pannell (1999) and Marra (2003) reasoning, where an individual's uncertainty tends to decrease once they have collected more information and positive results about a given innovation.

The herb grower seemed to be the most resourceful one when considering new strategies; they regularly collaborated with local companies to design new products and had the idea to create a new market niche. Although their field experience is less consequent than the older growers, their educational background (Hall et al., 2009, Pignatti et al., 2015) as an agronomist appeared to have not only changed their way to comprehend a problem but also how to methodically try and imagine solutions. At last, although three of the persons interviewed possessed organic farming labels and more respectful practices, all of them agreed that sustainable development was an important factor which should be brought forward in any innovation case. For example, a market gardener who had no label and thus less restrictive policies than the others already introduced two sustainable innovations in the past : IPM and closed water cycle in their hothouses. Furthermore, the owner of the aquaculture market gardening system only uses organic inputs through a closed water cycling system relying on the complementarity between the fishes and the crops, whereas they can't however pretend to official labels as soilless cultivation isn't considered as a form of organic horticulture. The ethics and concerns of growers about the environment health seem to progressively increase in their decision-making process, along with the other more economic factors (Pannell, 2006).

4.2.2. Compatibility

Other variables related to grower's perception of new strategies' compatibility came back very often. The three growers possessing labels admitted that stricter policies influenced their ways to evaluate innovations' applicability. As some products are prohibited in organic farming, they had to be proactive to find tools adapted to their label restrictions, infrastructure and personal objectives without making concessions, which was revealed to be difficult. The young manager who convinced the firm's owner to adopt a weeding machine consequently helped the firm reducing the input costs, but at the cost of a higher workload. Conversely, a fruit tree grower invested a lot of money and effort in creating a collective local product shop; it however allowed them to spend more time with their family, as they no longer had to drive around for customer deliveries. They also explained that the shop took time to become economically viable and, although they had some heavy loans waiting, they enjoyed having a better work-life; such behaviour in a temporary difficult economic situation has already been observed by Röling and Wagemakers (1998) and Weersink and Fulton (2020) before, where growers sometimes prioritise their family lives over economic factors. Another challenging

factor mentioned by a few growers was the geographical location of the firms. Dimara and Skuras (2003) and Hall (2009) pinpointed in their studies, that city closeness is known to influence farms' openness to innovations. Among the two growers living less than 5km away from an urban area, one fruit tree grower felt forced to turn to sustainable innovations due to stronger restrictions. Although they encountered some difficulties during the transition stage, they in return gained a larger clientele as the local market demand for more eco-friendly products is more important in cities and their surroundings. No grower however felt pressure from their other stakeholders (e.g. retailers) as noted previously by Da Silva and Forbes (2016), and four of them actually saw it as an opportunity, as they found more customers from the moment they started producing either organic or more sustainable products. The only firm which had difficulty to set up was the aquaculture and hydroponics one, and for different reasons. As the concept itself is considered as innovative and totally different from a conventional farming system in the eye of novice customers, the owner admitted they struggled to create their clientele, even though the greenhouse is located less than 2km away from the centre of the biggest city of the department.

Concerning geological factors influencing the growers' perception of an innovation compatibility, the local climate came back very often in the interviews. Because of climate change, the Southwest of France must face long rainfall seasons followed by irregular heatwaves in summer. The winemaker's main concern about spraying seawater was unexpected rainfall episodes which could potentially wash the salt off and cause run offs in the soil. Conversely, the herb grower shared their struggle to keep their plants' biodegradable pots moisten during summer heatwaves, even in a closed environment. Finally, the aquaculture firm's owner observed odd behaviours among the fishes when the outside temperature raised over 40 degrees, even if the greenhouse' environment was controlled with AC. The firm's infrastructure itself was also considered as a potential break during the decision-making process, especially among fruit tree growers. Their perennial orchards being difficult to change in a short amount of time, one of them shared the hesitation they felt when they were given the opportunity to try mechanical weeding. The machine being adapted to only certain types of tree layouts, they were unsure about its potential applicability in their system. A long trial period proved them otherwise and comforted them in their decision to adopt the tool (Pannell et al., 2006; Weersink & Fulton, 2020). Regarding personal working skills, the best example found was the farm manager who introduced mechanical weeding to the firm. Although the owner ended accepting the adoption of a new technology, they were not capable to use it properly; the young manager was then personally assigned to the weeding tasks. In this situation, different factors could be indeed involved : the age of the manager influencing their will to take risks (Kassie et al., 2008; Serebrennikov et al., 2020), the owner's attachment to tradition (Tey &

Brindal, 2012) and lack of interest in new technologies and the younger farmer's integration of practical knowledge through a successfully conducted "learning-by-doing" process (Feder et al., 1985; Rogers, 2010).

The current COVID crisis appeared as a significant factor during the interviews and could be sorted into the "global challenges" category. Some of the growers searched for innovations easily applicable by fewer and sometimes less experimented workforces. At the time of the interview, one of the market gardeners was for instance considering trying a salad harvesting machine if the health crisis restrictions were eventually extended, something he would have never considered before the crisis started.

Globally, the influencing factors observed concerning the compatibility of an innovation varied from a grower to another and mainly relied on social demands (better work/life balance and required hand skills), economics (market and customers' demands) and environmental ones (label requirements, local policies, city closeness and local climate).

4.2.3. Trialability and observability

It has been previously observed in the adoption process part that trialability played an important role in the growers' decisions. All interviewees indeed agreed it remained essential to collect as much information as possible to efficiently integrate an innovation into an already existing system (Weersink & Fulton, 2020). The most recurrent factor mentioned was the access to non-official information sources, especially fellow neighbours and other (Smith & Ulu, 2017). Whether they witnessed efficient demonstrations and results in other firms or participated in diffusing positive feedback about a given innovation, all growers gave priority to their social web for the information gathering and non-trial evaluation processes. The herb grower even relied on feedbacks from acquaintances in other sectors (building trades) to try new materials. Globally, the interviewees seemed to put more trust into their close friends and fellows when evaluating a new practice, especially because their feedbacks can be more honest than the ones given by traders. Although neighbours' opinion had a higher impact when evaluating a new strategy's efficiency, the awareness and access to information were also relying on formal sources such as counsellors and official meetings as Weersink and Fulton (2020) previously mentioned. As an example, the market gardener first heard of LED lights for greenhouse production in a professional convention and then gathered more information about it through other specialized sources such as technicians, agriculture press (paper and online) and counselling agencies. They however explained that a lack of fellow plant growers' experiences pushed them into finding information somewhere else. To summarize, all growers interviewed were well informed about the innovations they adopted or were about to adopt; the awareness stage can happen spontaneously when a farmer discovers a new tool at

a forum or a neighbours', while the evaluation process is mainly influenced by 1) a subjective perception of innovation's usefulness and 2) human capital (social networks). In some circumstances, the firm's management also impacted the length and effectiveness of non-trial and trial evaluation processes but revealed to be potentially influenced by demonstrations done by other farmers from the close friend circle. Whether it is subjective perception or social capital impacting the trialability of a sustainable innovation, both drivers can be considered as variables which can be changed throughout the decision-making process.

4.2.4. Relative advantage

Concerning the perceived relative advantages, two different kinds of factors were identified during the interviews. Most growers were considering economical flows both upstream and downstream the innovation adoption. All the interviewees admitted they took the time to properly quantify the investment needed for the introduction of a given strategy to their system, especially if it was unknown to them before (Rogers, 2010; Weersink & Fulton, 2020). Among them, the market gardener calculated it a few years back and had to wait for market prices to decrease before they could finally invest in the LED lamps. Another affordability driver identified was the access to potential fundings; one fruit tree grower explained they would have been able to adopt the weeding machine earlier if the governmental funding policies would have treated their application file faster (Llewellyn et al., 2020). The aquaculture and hydroponics farm also struggled to install their system after their file has been rejected twice, so the owner had to be a creative force and search for other funding sources. Although it was mentioned in the literature that possible fundings could influence the adoption outcome (Llewellyn et al., 2020), we can also observe here that it can slow down the whole process if the innovation cannot be afforded otherwise. When growers adopted a new strategy to either decrease their workload or limit their financial inputs, they tried beforehand to quantify the maintenance costs (e.g., price/km) and sometimes work ratio (e.g., hours/ha) for growers needing extra hands in high seasons. Those potentially costly factors needed to be clearly identified and then compared to the net incomes promised by the innovation itself; one market gardener turned to IPM because it

drastically decreased their expenses without impacting their systems' productivity, just like the one who replaced sodium lamps by energy-saving LEDs.

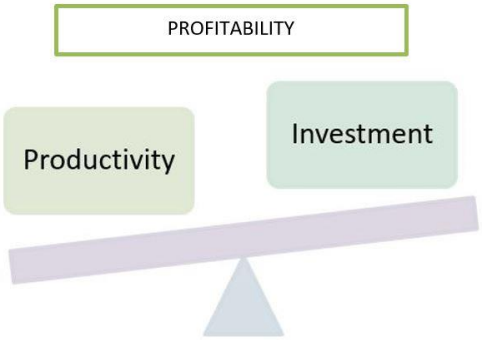

Figure 10. *The expected economic outcome of adopting a new strategy*

Globally, each grower interviewed admitted they first studied the investment/profitability balance of an innovation before deciding to adopt it, to limit any unpleasant surprise which could jeopardize their firms. None of them however had to renounce to it due to a lack of European or national fundings, although they denounced a lack of support from the government regarding sustainable changes.

4.2.5. Complexity

The factors involved in the complexity of an innovation are closely related to the compatibility ones, as the perception of complexity can vary between individuals. Following the decision-making process established in part 5.1, the growers admitted they grew more and more confident about an innovation after having gathered as much knowledge as possible among local and/or professional communities. They considered the access to information extremely valuable, especially when they face something they haven't heard of before. One fruit tree grower called in professional counsellors when they introduced IPM practices to their orchards to go through a thorough field training and become progressively more autonomous and efficient. Another one confessed they haven't reached for enough information when they turned to mechanical weeding and started using the machine while being oblivious to potential side effects. It was once the damaged were done on the tree roots that they reached for professional counsellors who guided them towards a model better adapted to their tree row layouts, which in the end cost them more than they had planned. Indeed, considering complex innovations usually needs growers to reach for more technical knowledge near professionals or "expert" fellows before they gain enough skills to become fully autonomous. It is sometimes necessary to change or upgrade their systems so they

can be compatible with the new strategy; the hydroponic firm had for instance to reconsider their whole water cycling system when they introduced fishes to the plant water trays. Upsetting a system can be perceived as even more difficult than the innovation itself, which can add up to the whole complexity perception and even lead to technology aversion in some cases if the transition isn't efficiently handled.

Complexity perception is difficult to evaluate, as it changes greatly between individuals. It can however be related to the growers' own experiences with new strategies, access to information, adaptability to potential transformations and global openness to change.

4.3. Updating the decisional factor table

The interviews conducted allowed to verify the applicability of the factors previously drawn up into a matrix (cf. "Materials and Method"). Most of them were identified at least once while some came back regularly among the growers. The importance of the social capital was probably the most recurrent driver observed among the six interviewees, whether it was for innovation awareness, data gathering or non-trial evaluation, and was proven to influence greatly the decision-making process to the point of decreasing innovation aversion. Attachment to economic advantages had importance as well, as it has been showed in countless studies beforehand. Globally, the clear insight of the potential profitability a new strategy could bring to a firm indeed carried weight in the growers' subjective evaluation. However, none of the interviewees felt pressured by their customers and/or retailers' demands but considered them more are inspirational sources of constructive feedbacks to improve their products' quality. No correlation has been clearly found between the age and openness to innovations either, as the sample of growers interviewed were from 25 to over 55 years old and all had already adopted new strategies in the past. It appeared that the adoption rate was mostly related to the personal background (education and experience) of the adopters.

Table 5. *Factors influencing the adoption of innovations distributed over the social, economic, and environmental dimensions*

Decisional factors			Sustainable development pillars		
			Social	**Economic**	**Environmental**
Individual background		~~Age*~~	(X)		
		Experience	X		
		Culture	X		
		Tradition	X		
		Education	X		
		Technology awareness	X		
		Environmental involvement	X		X
		Innovation acceptance/aversion	X		
Relative advantage		Productivity		X	
		Profitability		X	
		Clear economic perspectives		X	
		Clear investments		X	
		Available fundings		X	
		Net incomes		X	
		Clear maintenance costs		X	
		Affordability		X	
Trialability/observability		Non-official sources' feedback	X	X	
		Technology awareness	X		
		Technology access	X	X	
		Neighbours' trials	X	X	
		Human capital	X	X	
		Management organisation	X	X	
Compatibility	**System**	Available market	X	X	
		Labels		X	X
		Geographical location	X	X	X
		Work-life balance	X		
		Workload	X		
		Infrastructure		X	
		Hand work skills	X	X	
	Global challenges	Local/national policies		X	X
		~~Consumer's feedback*~~	(X)	(X)	
		~~Stakeholders' pressure*~~	(X)	(X)	
		City closeness	X	X	X
		Local climate		X	X
		Market demand	X	X	
		Health crisis (COVID-19)**	**X**	**X**	
		Geological location		X	X
Complexity		Adapted infrastructure		X	
		Information access	X		
		Technology knowledge	X		
		Autonomy		X	
		Potential alternatives awareness	X	X	
		Management skills	X	X	
		Knowledge access	X	X	

** Non verified factors during the empirical study derived from literature review*

***Factor discovered during the empirical study and non-present in the literature review*

4.4. Implications for horticultural research and practice

All in all, a new factor was identified throughout the interviews, which not only impacted the horticultural market, but also growers' perspectives regarding the potential integration of new strategies in their farms. Indeed, the COVID-19 health crisis forced the growers to innovate more and find new solutions to counterbalance a dangerous slowdown of their activities. Although it is an exceptional and disastrous situation, national lockdown revealed how imaginative and resourceful growers can be. While some investigated for new technologies to overcome the sudden lack of hand work, others created new market niches by expanding their social networks to at least secure some income. The COVID-19 situation thus brought the development of innovative strategies impacting both the social and economic dimensions of crop productions. As such event also pushed the farmers to adapt their infrastructure and ways of thinking, the health crisis factor can be added to the "compatibility" column, on the "global challenges" part.

In table 5, the factors which haven't been verified during the interviews are crossed, but it doesn't mean they were wrong. As the studies' opinions about age influence on the adoption rate are often mixed, it could be possible to find firm cases where the age and adoption rate are correlated; it would be interesting to interview more growers to verify that once the health crisis will allow it again. This also applies to the pressure put by customers and retailers on the growers; such variable could be observed with more interview cases.

5. Conclusion

Although the growers interviewed had various backgrounds and activities, their decision-making processes remained similar to the overall framework established through the literature review research. The adoption stages identified were relevant to the six ones Ghadim and Pannell (1999) previously broke down, although the awareness and data gathering steps revealed to be closely related by the information sources they shared. The decision-making process framework designed in this report was inspired from scientific papers studying different sectors, but it remained easily applicable to the horticultural one, although the chronology isn't set in stone. Some growers indeed had the capability to skip some stages ("data gathering" and/or "trial evaluation") in the decisional process when they were already well-informed about the advantages and utility of an innovation.

Regarding said utility, the factors identified throughout the literature review clearly appeared during the interviews done with the growers. Globally, the economic dimension related to the relative advantage of an innovation remained important for all of them, as frequently mentioned in the papers. However, the social capital appeared to be as important as the capital one, as the diffusion of information, knowledge and feedback kept flowing through the growers' social networks in every cases. All interviewees insisted on the importance of informal information sources to the point of sometimes bringing it before the formal ones. On the other hand, the latter wasn't set aside either, as most of the growers either had or used to collaborate with academic, industrial and scientific branches to conduct innovation experiments on the field. Globally, the observation of this constant exchange of information through the different actors of the horticultural sector proved again that innovation was no longer a top-down process as Carré (1993) and Chambers (2014) previously stated, but as a strong collaborative one (Faure et al., 2018) where growers' opinions are becoming progressively more important.

An important factor which has however been added to the matrix after the interviews was the COVID-19 health crisis, as it strongly impacted every single one of them. This exceptional disaster pushed them to face important income decreases, a lack of workforce, material shortage due to limited transport and more. However, some of them showed a great capacity to handle the crisis thanks to resourceful solutions; replacing the missing workforce with machinery, opening new market

niches or becoming self-sufficient… As difficult as it was and remains, the virus revealed to be an influencing factor in the whole decision-making process but with which inventive people can cope.

It could be however interesting to interview a higher number of growers to get more accurate results concerning the matrix of factors previously set. Some of them couldn't indeed be properly confirmed, like the age for instance, which is still strongly debated in today's literature. It was also very difficult to meet at the time of the interviews (fall 2021) because of the health crisis; the related policies tightened while a "fifth wave" was overrunning France and neighbouring countries. Some meetings got cancelled or postponed until further notice once the contamination peak will be gone.

The matrix of subjective decisional factors designed through this thesis could be used as a non-exhaustive checklist for any researcher or professional aiming to design sustainable innovations better adapted to horticultural growers' demands. The list of factors may of course be updated and/or completed as needed; more interviews and research could be done in future works to explore better the applicability of the matrix once the health crisis will allow it.

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Appendix

Appendix 1. *List of articles selected for the literature review*

	Author(s)	Article title	Date
Sustainable innovation guidelines	Calik	Multi-Criteria Scale Development for Sustainable Innovation Performance Evaluation	2014
	FAO & INRAE	Enabling sustainable food systems: Innovators' handbook	2020
	Faure et al.	Innovation et développement dans les systèmes agricoles et alimentaires	2018
	Foresi et al.	Sustainability assessment tools for organic greenhouse horticulture	2016
	Montero et al.	Innovative systems for sustainable greenhouse production	2017
	Nwosisi & Nandwani	Urban horticulture: overview of recent developments	2018
	OCDE	Innovation, Productivity and Sustainability in Food and Agriculture	2019
	Palombi & Sessa	Climate-smart agriculture: sourcebook.	2013
	Scialabba	SAFA Guidelines: Sustainability Assessment of Food and Agriculture Systems	2014
Decision-making process	Chambers	Rural development: Putting the last first	2014
	Dimara & Skuras	Adoption of agricultural innovations as a two-stage partial observability process	2003
	Evenson & Biswanger	Technology transfer and research resource allocation	1978
	Faure et al.	Innovation et développement dans les systèmes agricoles et alimentaires	2018
	Feder et al.	Adoption of agricultural innovations in developing countries: A survey	1985

	Feder & O'mara	On information and innovation diffusion: A Bayesian approach	1982
	Feder & Slade	The acquisition of information and the adoption of new technology	1984
	Fuglie & Kascak	Adoption and diffusion of natural-resource-conserving agricultural technology	2001
	Ghadim & Pannell	A conceptual framework of adoption of an agricultural innovation	1999
	Hall et al.	Factors affecting growers' willingness to adopt sustainable floriculture practices	2009
	Heiman et al.	Marketing and technology adoption and diffusion	2020
	Tiffin & Balcombe	The determinants of technology adoption by UK farmers using Bayesian model averaging: The cases of organic production and computer usage	2011
	Jean	A new paradigm of rural innovation: learning from and with rural people and communities	2014
	Kassie et al.	Adoption of organic farming technologies: Evidence from semi-arid regions of Ethiopia	2008
	Lindner	The time to adoption	1980
	Llewellyn & Brown	Predicting adoption of innovations by farmers: What is different in smallholder agriculture?	2020
	Pannell et al.	Understanding and promoting adoption of conservation practices by rural landholders	2006
	Pannell & Zilberman	Understanding adoption of innovations and behavior change to improve agricultural policy	2020
	Pignatti et al.	What really matters? A qualitative analysis on the adoption of innovations in agriculture	2015
	Rogers	Diffusion of innovations	2010
	Smith & Ulu	Risk aversion, information acquisition, and technology adoption	2017
	Weersink & Fulton	Limits to profit maximization as a guide to behavior change	2020
	WilkinsonC	Understanding and promoting adoption of conservation technologies by rural landholders	n.d.
Factors influencing adoption decision	Barr & Cary	Influencing improved natural resource management on farms	2000
	Campos	The innovation revolution in agriculture: a roadmap to value creation	2021
	Cullen et al.	Non-adoption of environmental innovations in wine growing	2013
	Da Silva & Forbes	Sustainability in the New Zealand horticulture industry	2016
	Dimara & Skuras	Adoption of new tobacco varieties in Greece: Impacts of empirical findings on policy design	1998

Dimara & Skuras	Adoption of agricultural innovations as a two-stage partial observability process	2003
Faure et al.	Innovation et développement dans les systèmes agricoles et alimentaires	2019
Ghadim & Pannell	A conceptual framework of adoption of an agricultural innovation	1999
Gremmen et al.	Responsible innovation for life: five challenges agriculture offers for responsible innovation in agriculture and food, and the necessity of an ethics of innovation	2019
Hall et al.	Factors affecting growers' willingness to adopt sustainable floriculture practices	2009
Kassie et al.	Adoption of organic farming technologies: Evidence from semi-arid regions of Ethiopia	2008
Koesling et al.	Factors influencing the conversion to organic farming in Norway	2008
Llewellyn & Brown	Predicting adoption of innovations by farmers: What is different in smallholder agriculture?	2020
Mankad et al.	Psychosocial barriers and facilitators for area-wide management of fruit fly in southeastern Australia	2017
Marescotti et al.	Smart farming in mountain areas: Investigating livestock farmers' technophobia and technophilia and their perception of innovation	2021
Marra et al.	The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve?	2003
Matata et al.	Socio-economic factors influencing adoption of improved fallow practices among smallholder farmers in western Tanzania	2010
Pannell et al.	Understanding and promoting adoption of conservation practices by rural landholders	2006
Pierpaoli et al.	Drivers of precision agriculture technologies adoption: a literature review	2013
Pignatti et al.	What really matters? A qualitative analysis on the adoption of innovations in agriculture	2015
Rogers	Diffusion of innovations	2010
Röling & Wagemakers	Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty	1998
Serebrennikov et al.	Factors Influencing Adoption of Sustainable Farming Practices in Europe: A Systemic Review of Empirical Literature	2020
Streletskaya et al.	Agricultural adoption and behavioral economics: Bridging the gap	2020
Tey & Brindal	Factors influencing the adoption of precision agricultural technologies: a review for policy implications	2012
Weersink & Fulton	Limits to profit maximization as a guide to behavior change	2020
WilkinsonC	Understanding and promoting adoption of conservation technologies by rural landholders	n.d.

Appendix 2. *Questionnaire used for the growers' interviews (English translation in Italic)*

Title : Les nouvelles pratiques agricoles et horticoles dans un contexte de développement durable / *New agricultural and horticultural practices in relation to sustainable development*

Introduction : Afin d'illustrer mon mémoire dont le sujet est l'adoption de nouvelles pratiques durables en agriculture et horticulture, j'ai besoin de vos connaissances et expériences envers les innovations agricoles ! (au sens très large du terme, ce qui n'inclue pas uniquement la technologie mais toute pratique ou processus nouveaux pour l'exploitant "dans un contexte spécifique, afin d'accroître l'efficacité, la compétitivité et la résilience dans le but de résoudre un problème" (FAO, 2020). Exemples d'innovations : lutte intégrée ou raisonnée, mise en place d'un système de compostage, une nouvelle stratégie de communication et publicité, etc.

Tous les témoignages seront bien sûr anonymes et dédiés uniquement à la rédaction de mon mémoire ; vous aurez si vous le souhaitez un droit de regard sur le résumé rédigé à partir de vos réponses (les adresses emails ne sont demandées que pour cela et pour m'aider à recenser tous les témoignages).

Merci à vous ! / *As part of my thesis research which subject is the adoption of new sustainable practices in agriculture and horticulture, I need your knowledge and experience about innovations! (broadly speaking, which does not only include technology but also any practice or process perceived as new to the operator "in a specific context, in order to achieve efficiency, competitiveness and resilience in the but to solve a problem" (FAO, 2020). Examples of innovations: integrated pest management, establishment of a composting system, a new communication and advertising strategy, etc. Every accounts will of course remain anonymous and used for the redaction of my thesis only; you will have the right to verify the information summarized in my project (which can later be sent to your email address).Thank you very much !*

Questions

1. Quelle est votre tranche d'âge ?/ *How old are you ?*

- < 25 ans/*years*
- 25 – 35 ans/*years*
- 35 – 45 ans/*years*
- 45 – 55 ans/*years*
- > 55 ans/*years*

2. Quel rôle jouez-vous au sein de l'exploitation ?/*What is your position in the firm ?*

3. A quelle distance ce situe la ville la plus proche de votre exploitation ?/*How far do you live from the closest city ?*

- < 5km
- 5 – 20km
- 20 – 50km
- > 50km

4. Quel a été votre parcours scolaire initial ?/*What is your educational background ?*

5. Depuis combien de temps travaillez-vous sur l'exploitation ? Avez-vous vécu d'autres expériences professionnelles auparavant ?/*How long have you been working on the firm ? Do you have any other professional experiences beside it ?*

6. Quelles sont les activités principales de votre exploitation ?/*What are your main producton activities ?*

7. Possédez-vous un label ?/*Do you own any label ?*

8. A quel type de clientèle vous adressez-vous ?/*Which type of customers does your firm have ?*

- Particuliers/ Direct selling
- Distributeurs/Retailers
- Supermarchés/Supermarkets
- Industrie/Industry
- Autres/Others

9. Quels sont vos objectifs principaux sur le long terme ? (Développer l'entreprise, proposer plus de produits à la vente, réduire les intrants, etc)/*Do you have any objectives on the long run ? (Expand the production system, develop the products grown on the firm, reduce the inputs, etc)*

10. Exercez-vous déjà des pratiques respectueuses de l'environnement sur votre exploitation ? Si oui, lesquelles ?/*Do you already use sustainable practices on your firm ? If yes, which ones ?*

11. Le développement durable est-il un enjeu important pour vous ?/*Is sustainable development an important stake for you ?*

- Oui/*Yes*
- Non/*No*
- Je ne sais pas/*I don't know*

12. L'avis de votre clientèle influence-t-il vos choix de productions ?/Are customer reviews important to you ?

13. Que vous inspire l'innovation en agriculture/horticulture ? Voyez-vous cela comme une opportunité, une nécessité, une contrainte ?/*How do you perceive innovation in agriculture/horticulture ? Is it an opportunity, a necessity, a growing pressure ?*

14. Avez-vous changé ou adopté une nouvelle pratique/nouvel outils dernièrement, ou par le passé ? Si oui, laquelle ? (système d'irrigation différent, nouveau substrat, nouvelle stratégie de communication, rénovation…)/*Did you adopt new tools, technologies or practices in the past ? If yes, what was it ? (e.g. new irrigation system, new advertising startegy, renovations..).*

15. Si oui, d'où vous est venue l'idée ? (Voisins, publicité, forums, conseillers…)/*If yes, where did the idea come from ? (neighbours, adverts, meetings, counselors..).*

16. Avez-vous testé la nouvelle pratique avant de l'adopter définitivement ? Si oui, comment ?/*Did you try the new practice before adopting it ? If yes, how ?*

17. Avez-vous eu l'impression de prendre des risques (physiques, financiers…) lors de ce changement ? Si oui, lesquels ?/*Did you feel like you were taking some risks (physical, economic..). while adopting it ? If yes, which ones ?*

18. Qu'attendiez-vous de ce changement ? (Allégement de la charge de travail, moins de pertes, augmentation de la productivité…)/*What were you expecting to change or improve ? (lighter workload, less production losses, increased productivity..).*

19. Avez-vous rencontré des obstacles ou des inconvénients lors de la mise en place de cette nouvelle pratique/nouvel outil ? Si oui, lesquels ?/*Did you identify any hurdles when you integrated the practice/technology to your system ? If yes, which ones ?*

20. Lorsque que vous envisagez quelque chose de nouveau, est-il important pour vous de recueillir plus d'informations à ce sujet avant de le tester ?/*When you consider adopting something new, do you think it is important to gather as much information as possible before testing it ?*

- Oui/*Yes*
- Non/*No*
- Je ne sais pas/*I don't know*

21. Si oui, auprès de qui/quoi allez vous chercher l'information ? (famille, voisins producteurs, conseillers agricoles, conférences, magasines etc)./*If yes, with what/whom do you collect the information ? (family, fellow neighbours, counselors, professional conferences, newspaper..).*

22. Pensez-vous que la collaboration entre les producteurs et les équipes scientifiques/universitaires est importante lors de la création d'innovations agricoles ?/*Do you think partnership between growers and academic/scientific knowledge is important during the innovation design process ?*

23. Avez-vous vous-même collaboré avec des chercheurs ou universités auparavant ?/*Have you worked with researchers or universities yourself ?*

- Oui/*Yes*
- Non/*No*

24. Que pensez-vous de la réglementation environnementale française imposée aux agriculteurs ? L'avez-vous ressenti comme une menace ou une opportunité de s'adapter pour rester compétitif ?/*What is your opinion about French environmental policies ? Do you consider it as a threat or an opportunity to adapt and remain competitive on the market ?*

25. Pensez-vous être assez accompagné et/ou renseigné à propos des innovations disponibles en agriculture/horticulture ? Que changeriez-vous ?/*Are you feeling informed enough regarding the innovations available for the horticultural sector ? What would you change ?*

26. Ces dernières années, avez-vous ressenti une augmentation de l'importance du développement durable et des pratiques plus respectueuses de l'environnement dans votre branche professionnelle ?/*Have you felt the past few years an increasal of the sustainable development and respectful practices importance in your sector ?*

Appendix 3. *Compliance form signed by the interviewees*

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of People and Society
Loriène Borderie, MSc student

Date

Compliance form: Privacy policy for student research project

When you participate in a student research project, some of your personal information will be handled. Your approval to handle this information is necessary for the completion of the project. This form gives you the information necessary for you to decide whether you approve that the student handles the information given in the interview/survey. The university complies with the General Data Protection Regulation (GDPR) in accordance with regulation (EU) 2016/679 of the European Parliament and of the Council.

You will always have the possibility to withdraw your approval without giving any reasons. Your contact person for this project is Loriène Borderie (MSc student, horticultural science): leie0001@stud.slu.se, +33659027298. Supervisor of the project is Dr. Fredrik Fernqvist, Department of People and Society, SLU (Fredrik.fernqvist@slu.se).

The title of the project is ”*Evaluating the process of adoption of new practices in horticultural/agricultural production systems*”. Questions asked regard: Your name, education, experiences, type of producing and firms’ goals, distribution and views on innovation, the adoption of innovations and new practices, and views on measurements of sustainability. The interview will be recorded, summarised and analysed by the student. The summary of the interview will be saved and archived following the university’s policies. You will get the opportunity to read through the summary and approve it. All results will be anonymous in any form of publication: the student thesis and possible academic papers.

The purpose with the handling of the given information from interviews in this study is to conduct a student thesis and also has the aim for writing an academic paper. You can read more on SLU’s processing of data here: https://www.slu.se/en/about-slu/contact-slu/personal-data/

I hereby give consent for handling the information for the purposes mentioned given in the text above.

Name and signature Place, date