Universidade de Aveiro Departamento de Ambiente e Ordenamento
2018

MAX ALBERTO LOPEZ MACIEL

Avaliação dos fatores que influenciam a adoção e difusão de soluções baseadas na natureza em áreas urbanas

Assessment of factors influencing the adoption and diffusion of Nature-Based Solutions in urban areas

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de maestro em estudos ambientais/ JEMES–CiSu sob a orientação científica do Doutor Peter Roebeling, Professor Auxiliar Convidado, Universidade de Aveiro e com apoio de atividades curriculares pelo Dr. Abel Chávez, Western State Colorado University.

This thesis was developed in the context of the UNaLab Project (https://www.unalab.eu/), undertaken by a consortium led by VTT and in which the UA is consortium partner as well as work package leader (Monitoring and impact assessment). The UNaLab Project has received funding from the European Union Horizon 2020 research and innovation programme under Grant Agreement No. 730052, Topic: SCC-2-2016-2017: Smart Cities and Communities Nature based solutions.

I dedicate this work to my father, - you will always be in my heart, papá-.

o júri

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agradecimentos
acknowledgements

I would like to extend all my gratitude to:

All my family, especially to my mother, my brother and my aunt Gladys.

To the JEMES-CISU coordinators Maria Rosa Rovira and Martin Lehman for their support in difficult times. To the JEMES coordinator in UA, Isabel da Silva Nunes, who has always been attentive to the students. To my supervisor Peter C. Roebeling, for his constant guidance through all this process. To Abel Chavez coordinator of the activities in the WSCU, a great example as a person and as an academic, for all his support. To Eva Maria Holzer for her kind support and motivation. To Bauke de Vries, Mayke van Dinter and Luuk Postmes who made possible the realization of the workshops in the city of Eindhoven.
And last, to the JEMES-CISU colleagues and the working group in UA who have been friends and family during these two years.

palavras-chave

Soluções baseadas na natureza, Resiliência, Áreas urbanas, Adoção, Difusão, Telhados verdes, Stakeholders.

resumo

Nas cidades por todo o mundo, há uma tendência geral de aumentar o seu tamanho nas próximas décadas, o que leva a um aumento não só da população, mas também no aparecimento de impactos ambientais urbanos, bem como a probabilidade de se tornarem áreas vulneráveis devido ao efeito do clima. Nesse sentido, é essencial aumentar a sua resiliência, o que lhes permitirá enfrentar os efeitos da mudança do clima. Uma estratégia que permitirá uma adaptação e mitigação é a implementação de soluções baseadas na natureza. No entanto, o seu nível de sucesso como política implementada em comunidades urbanas depende de uma série de fatores relacionados com o seu nível e tempo de adoção. O presente estudo propõe uma metodologia para avaliar esses fatores, através da criação de um workshop participativo e do uso potencial de uma ferramenta, inicialmente desenvolvida para o setor agrícola, conhecida como ADOPT, que pode ser usada para avaliar o nível de adoção e taxa de difusão de soluções baseadas na natureza. Para testar a adaptação desta ferramenta, do governo local, foi usado para o caso de estudo da cidade de Eindhoven, na Holanda, que é uma das principais cidades do projeto UNaLab, patrocinado pela Comissão Europeia, que reúne evidências do nível de eficácia, implementação e replicação de soluções baseadas na natureza em áreas urbanas. Para o caso de Eindhoven, foi medido explicitamente o nível de adoção e taxa de difusão de telhados verdes com a participação de partes interessadas dos setores académico e do governo local. Dando como resultado, cenários de adoção de 12% e 49%, respetivamente, constatando que uma participação diversificada de diferentes partes interessadas influência a percepção da adoção potencial dessa inovação em comparação com uma resposta individual.

keywords

Nature-Based Solutions, Resilience, Urban Areas, Adoption, Diffusion, Green Roofs, Stakeholders.

abstract

In cities around the world, there is a general tendency to increase their size in the coming decades, which leads to an increase not only in population but also in the generation of urban environmental impacts, as well as the probability of becoming vulnerable areas due to the effects of climate change. In this sense, it is essential to increase their resilience, which will permit them to face the effects of climate change. A strategy that allows taking common measures of adaptation and mitigation approaches is the implementation of Nature-based Solutions. However, its level of success as a policy implemented in urban communities depends on a series of factors related to their level and time of adoption. This study proposes a methodology for evaluating these factors, through the creation of a participatory workshop and the potential use of a tool, initially developed for the agricultural sector, known as ADOPT, which could be used to evaluate the level of adoption and rate of diffusion of Nature-based Solutions. In order to test the adaptation of this tool, it was used for the case study of the city of Eindhoven in the Netherlands, which is one of the front-runner cities of the UNaLab project, sponsored by the European Commission, which gathers evidence of the level of effectiveness, implementation and replication of Nature-based Solutions in urban areas. For the case of Eindhoven, it was explicitly measured the level of adoption and rate of diffusion of green roofs with the participation of stakeholders from the academic and local government sectors. Giving as a result, scenarios of adoption of 12% and 49% respectively finding that a diverse participation of different stakeholders influences the perception of the potential adoption of this innovation in comparison with an individual answer.

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List of acronyms and abbreviations

ADOPT	Adoption and Diffusion Outcome Prediction Tool
CSIRO	Commonwealth Scientific and Industrial Research Organization
EU	European Union Commission
GHG	Green House Gases
IDEA	Investigate, Discuss, Estimate and Aggregate protocol
MS-EXCEL	Microsoft Excel
NBS(s)	Nature-Based Solution(s)
Tu/e	Technological University of Eindhoven
UCIR	Urban Community Infrastructure Resilience
UN DESA	United Nations, Department of Economic and Social Affairs, Population Division
UN ENVIRONMENT	United Nations Environnemental Program
UNaLab	Urban Nature Laboratories
US EPA	United States Environmental Protection Agency
USA	United States of America

1 Introduction

1.1 Problem description

The effects of climate change have been widely studied in a global scale, and according to scenarios developed by the United Nations' *Intergovernmental Panel on Climate Change* (IPCC, 2014), their impacts in the natural and urban ecosystems could highly increase in the next years. Moreover, the cities, in general, will also grow. In that sense, it is expected that 68% percent of the global population will live in cities by 2050 (UN DESA, 2018).

Along with a growth of the population in the urban areas, the ecological risk increases too (Luo, Liu, Peng, & Wu, 2018). Heat islands, flooding or water scarcity are some examples of the potential effects that cities could face due to climate change, resulting in alterations on the local energy use, water management, air quality and human health (Fan et al., 2017). For instance, in some countries as the United States of America (USA), it is known that urban heat islands increase the overall and peak electricity demand, occurring especially during the summer afternoons, when the houses and offices run the cooling systems, lights, and appliances. Extreme events of this type of phenomena can cause, rolling brownouts or blackouts to prevent power outages in the community (US EPA, 2014).

In this sense, while urban areas become one of the most vulnerable types of human communities (The World Bank, 2010), on the other hand, urbanization is one of the most significant aspects of human activities that changes the landscape and the weather (Cai et al., 2018). Moreover, along with the increase in the emission of greenhouse gases (GHG) due to the activities within the cities (IPCC, 2014), these means that urban areas become not only receptors but important generators of the climate change impacts. This contrast, allows cities to be the places were a significative response to reduce the global warming effects can be done (The World Bank, 2010).

As stated before, climate change can affect the local infrastructure of the cities and put into risk to their inhabitants (Rosenzweig et al., 2015). In the case of Europe, from 1980 to 2010, more than €300 billion have been lost due to storms, floods, mudflows, and landslides, 75 000 deaths due heatwaves moreover, it is losing €50 million per year as a cost of not halting biodiversity loss and degradation of ecosystem services (European Commission,2016). Furthermore, more than 700 000 people resulted directly affected by urban heat islands in 2003, and 70% of the larger cities in the continent have vulnerable areas to sea level rising (The World Bank, 2010).

As a response to this situation, the cities must become more flexible in their dynamics within and with the external environment by improving their resilience. Brown et. al (2018) (secondary source) cite the concept from several sources highlighting the ones by Maru et al. (2014); Meerow et al. (2016); Mock et al. (2015); Moser and Boykoff (2013) (primary sources), whom define resilience as all the systems that gives to the city the capacity to anticipate, absorb and reorganize due a known or unknown threat.

Also, Aruchamy (2016) (primary source) analyses a series of literature definitions, which consider the major principles of urban resilience, which are:

"Urban Governance, Infrastructure Services and Accessibility, Urban Planning and strategy, Environmental Sustainability, 4-Rs (Robustness, Redundancy, Resourcefulness, and Rapidity (Tierney and Bruneau, 2007) (secondary source), Vulnerability analysis, Disaster preparedness, response and awareness, Economy and wellbeing of the citizens, Uncertainty oriented planning and Flexibility to deal with wide range of risks" (Aruchamy, 2016, pp.11).

As seen before, it is important to highlight that *infrastructure* either in the means of services or accessibility, can be considered one of the basic sub-systems that take part into the urban resilience scheme (Aruchamy, 2016).

Following the importance of the *infrastructure*, Aruchamy (2016) proposes a specific definition *for Urban Community Infrastructure Resilience* (UCIR), which can be stated as the ability that *infrastructure* (as a system) has to:

i) Deal and restore its functions quickly, avoiding adverse impacts to the inhabitants of the city, ii) Provide the expected services with minimal environmental impact, and iii) Adapt and manage processes related to future environmental uncertainties, such as climate change and rapid urbanization.

In addition to the importance of the UCIR, two general concepts divide the actions taken to improve the resilience to climate change in cities: *Mitigation* and *Adaptation*. The first one is related to the efforts to decrease the emission of GHG and the exposure to climate change (UN Environment, 2018). The second one defined as an adjustment from the social, ecological and economic view in response to climate change effects, in order to reduce the negative impacts or take advantage of new opportunities created (Raymond, et al., 2017). Furthermore, even though *Mitigation* and *Adaptation* might have different based goals and approaches to resilience, there are common drivers of application, that can be definitive to make cities more resilient (Rosenzweig et al., 2015).

1.2 Nature-based Solutions

In that sense, one option that integrates these concepts in the UCIR context could be the use of Nature-Based Solutions (NBSs) as one of the means to improve the resilience in cities (Raymond, C.M., et al., 2017). However, to make a successful implementation of joint *Mitigation* and *Adaptation* strategies as part of the urban infrastructure policies; synergies have to be addressed with a cost-efficiency context and a political view that allows to strength the frameworks used by the decision-makers in the cities with a proper scale (Landauer, Juhola, & Klein, 2018). Including the willingness of the community to accept them as a new implementation (Tri-Ethnic Center for Prevention Research, 2014). Then, to improve the rate of success, it is essential to assess the probability of the adoption of NBSs in each city context, by addressing the different factors that influence its adoption and diffusion.

According to Raymond et al. (2017) and Kabisch et al. (2016), NBSs are defined in a general context, as actions taken in a systemic view, which use concrete implementations as solutions to diverse societal challenges, inspired, supported or copied by nature. Those can include climate change mitigation, adaptation and disaster risk reduction. As seen in figure 1, some examples of these actions are carbon sequestration and storage, local climate and air quality, slopes and shoreline stabilizations, flood control, erosion prevention; etcetera (Seddon, 2018).

Figure 1. Diagram of Nature-based solutions (source: Seddon, 2018).

Some other concepts that are closely related to NBSs are: “ecosystem-based adaptation,” “green infrastructure,” “ecosystem-based disaster risk reduction,” and “natural water retention measures.” (Kabisch et al., 2016 pp 3).

Hence, being specific with the urban communities, the natural areas of public value in the land , as well as rivers, canals, lakes and reservoirs, among others (natural or man-made); which offer recreation, sports, and other services to the cities can be defined as *green spaces* and *blue spaces* (San Martin-Feeney, 2014). These areas can support the local biodiversity conservation, but also give economic, environmental and social benefits to the population (Kabisch et al., 2016). If the *green* and *blue spaces* are promoted and managed consciously for these objectives, they can be considered as NBSs.

1.3 State of Knowledge

NBSs is relatively a new term. Since 2013 the European Commission (EU) grounded the use of the concept, and started to consolidate a defined spectrum of ecosystem-based approaches, including activities such as the promotion of research (Faivre, Fritz, Freitas, de Boissezon, & Vandewoestijne, 2017) for generating evidence of the functionality and (co-) benefits regarding its implementation.

The table 1, shows some examples of NBSs for urban areas (Nature4cities EU, 2017, p. 4):

Table 1. Examples of urban NBSs implemented at different levels

At the building or plot level:	At a district/ city level:
Green roofs.	Ecological corridors.
Combined solution: green roofs/renewable energy.	Urban forests.
Green walls.	Urban farming.
Bio-retention cells.	Constructed wetlands.
Shelter for auxiliary fauna - insect hotel.	Stormwater planters.
Sustainable urban drainage system.	Green street network.
Use of auxiliary fauna - Earthworms.	Urban planning related to NBSs

In that sense, evidence of its implementation and benefits in urban areas it is already started to be demonstrated. For instance, in the city of Barcelona, Spain. In 2009 the municipal government implemented a series of measures with the objective of reducing the emissions of GHG, one of them focused on the conversion of courtyards into green spaces through initiatives like "*Pocket Gardens*" or "*Green 5 minutes from Home*" (Raymond et al., 2017 pp. 36). This strategy involved local citizenship participation in the creation of new green zones in Barcelona (Figure 2). Today green spaces represent a 36.8% of the city, more than the double of the amount 30 years earlier (Raymond et al., 2017).

Figure 2. Urban Garden, Barcelona, Spain (source: Raymond et al., 2017, pp. 36).

Furthermore, in the East of London; the Queen Elizabeth Olympic Park had a significant urban regeneration before the Olympic Games in 2012. According to the Directorate-General for Research and Innovation of the European Commission (2015), this type of actions contributed not only to a resilient urbanization but to produce benefits to the wellbeing and health of the people. In that sense, *green spaces* can lower the costs related to some illnesses, such as depression, obesity, and heart disease. In England, by 2010 it has been estimated that green spaces have reduced treatment costs of these type of illnesses by £2.1 billion (Directorate-General for Research and Innovation-European Commission, 2015, pp 8-9).

Figure 3. The Queen Elizabeth Olympic Park, before and after its regeneration (source: Directorate-General for Research and Innovation-EC, 2015, pp 9).

Another example of NBSs implementation, now in a large-scale range, can be found in the city of Vienna in Austria. With more than 20 years of implementation, it focuses in a series of small to large projects related to the adoption, recovering or restoration of existing: parks, green bridges, green roofs, green walls, trees, rivers and streams, and a whole natural protected area. These policies are stipulated in different levels, from the *Local Urban, Heat Island Strategy Plan, the City Development Plan 2025, to the National Biodiversity Strategy of Austria, the Netzwerk Natur* (Nature network) and *Natura 2000* (Raymond et al., 2017, pp. 32). The objectives vary according to the plan; some examples are the recovering of *green spaces* coverage, energy efficiency or the increase of the biodiversity in the city, among others (Raymond et al., 2017).

Figure 4. Panoramic view of some green and blue spaces in Vienna, Austria (source: Raymond et al., 2017, pp. 32).

On the other hand, even NBSs can be a good option for improving the UCIR, it is important to notice that the governments manage most of the green and blue spaces in the cities. One of the approaches for the successful implementation of NBSs depends on tackling the barriers that

governments, especially in the local level-, face to adopt them. From the green infrastructure view the United States-Environmental Protection Agency (US EPA, 2010) highlights some of the main adoption barriers which are:

- Funding
- Lack of political support/leadership
- Resistance to change
- Coordination of multiple stakeholders and partners
- Legislative action
- Conflicting regulations
- Need for technical information and training
- Nascent market
- Misunderstanding about land use issues
- Cost concerns

If these aspects are not taken into account, the success rate of the implementation can be reduced considerably. Consequently, it is important to have a structured planning before adopting NBSs, which at the same time is a concept that is still constantly developing itself.

Kabisch et at. (2016), explains four significant gaps in the knowledge related to NBSs (Figure 5): Effectiveness, Society relations, Design, and Implementation:

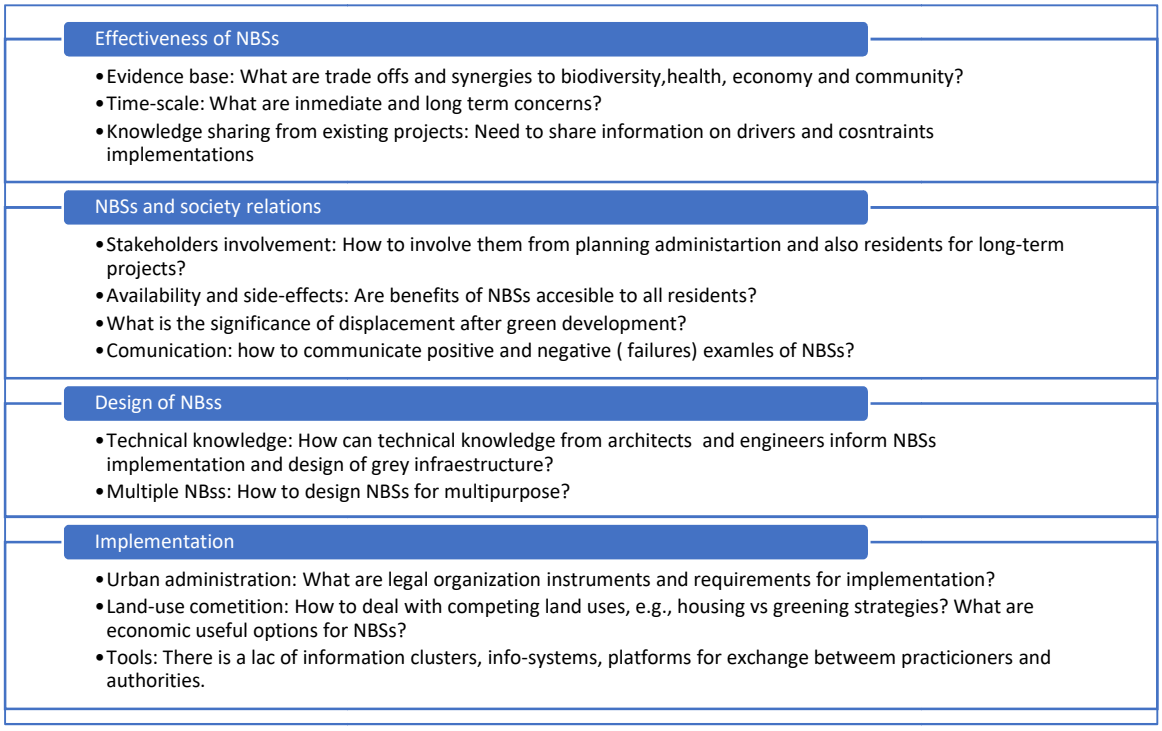

Figure 5. Gaps in the knowledge related to NBSs (Adapted: Kabisch et al., 2016, pp. 6).

This study focuses in the NBSs and the society relationships gap, by searching methods to promote the involvement of the different stakeholders, and the evaluation for the potential adoption of NBSs in their communities.

1.4 Objectives

The scope of this work is focused on the implementation of NBSs, through the application of a tool that allows improving the stakeholder participation in the decision making when adopting NBSs, making a more inclusive and diverse consensus for generating possible scenarios for their level of adoption and the opportunity areas implicated for these means. Hence, the overall objective of this thesis is to use qualitative and quantitative methods to assess the factors that influence the adoption and diffusion of Nature-Based Solutions in Urban Areas. To this end, the adoption and diffusion theory (E., Rogers, 1983) is used, adapting the ADOPT tool (CSIRO, 2017a) to the case of NBSs in urban areas, resulting in ADOPT-NBSs.

Specific Objectives:

- Identify the general factors that influence that adoption and diffusion of innovations.
- Analyze ADOPT as a potential tool for the assessment of the level of adoption and rate of diffusion of NBS.
- Adaptation of ADOPT for the NBS context.
- Creation of a methodology for the implementation of workshops oriented to the assessment of the level of adoption of NBSs in urban areas.
- Implementation of a workshop in the city of Eindhoven, the Netherlands assessing the factors that influence the adoption and diffusion of green roofs in its urban area.

1.5 The UNaLab project

Urban Nature Laboratories (UNaLab) is a project that aims to foster the development of an European Reference Framework for NBSs. It is funded under the Grant Agreement No. 730052 Topic: SCC-2-2016-2017: *Smart Cities and Communities Nature-based solutions from the European Union´s (EU) horizon 2020 research and innovation programme* (UNaLab, 2017).

Its goal is to provide quantitative evidence of NBS efficacy, applicability, cost-effectiveness, and to apply it to regional and local authorities, communities, enterprises and other stakeholders to enable the development of smart, inclusive, resilient and sustainable urban communities (UNaLab, 2017)

UNaLab is integrated by a consortium of 28 partners from 10 cities across Europe and beyond, form the governmental, academic and private sector. It possesses three front-runner cities for the implementation of the project: Eindhoven, Geneva, and Tampere. Also, a diverse group of seven follower cities (Cannes, Prague, Başakşehir, Castellón and Stavanger, Buenos Aires and Hong Kong), with the intention of replicating the solutions generated (UNaLab, 2017). Figure 6, describes the general approach of the project:

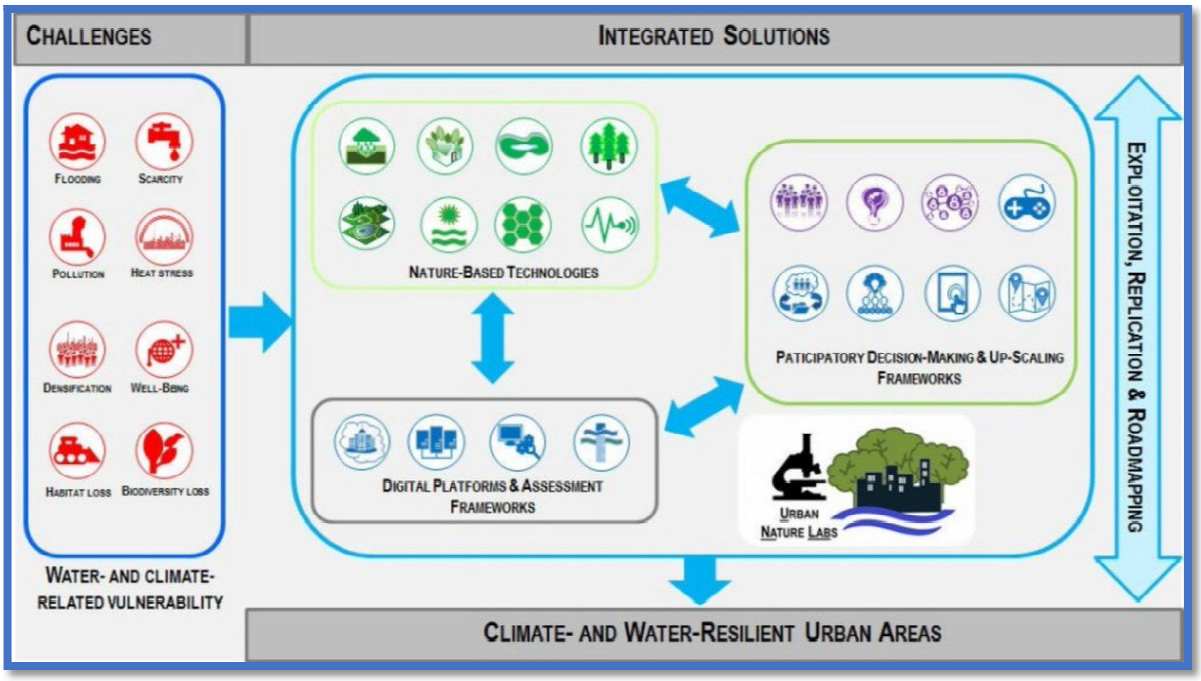

Figure 6. UNaLab project approach (Source: https://twitter.com/UNaLab_EU/media, 2017).

1.6 Thesis Outline

Thesis: The assessment of the factors that influence the adoption and diffusion of NBSs, can allow to the primary stakeholders in a determined urban area, to make better decisions in the selection and successful implementation of these type of innovations in their communities.

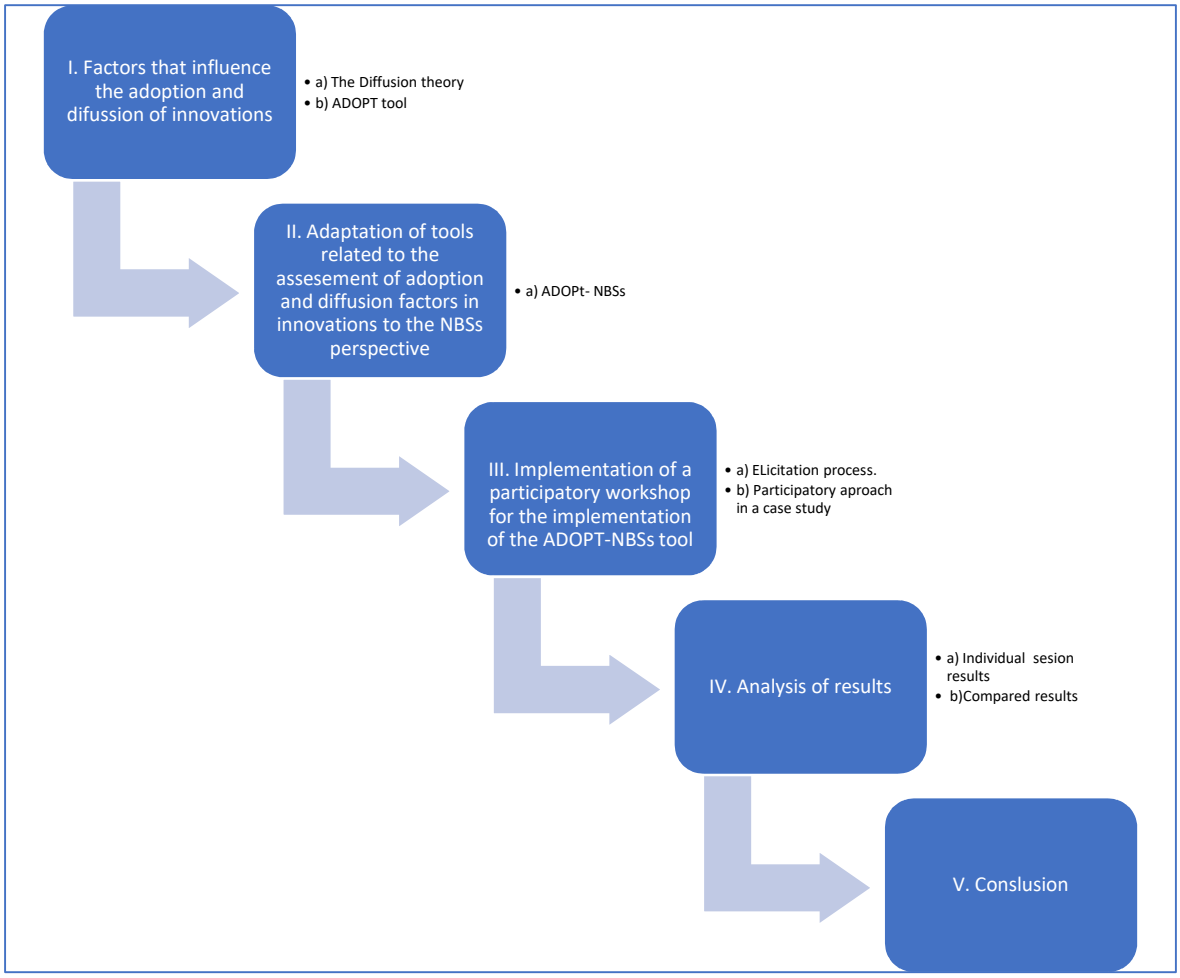

Figure 7. Thesis outline diagram.

2 Adoption and Diffusion Theory and Applications

2.1 Theory of adoption and diffusion of innovations

The *Diffusion of innovations* is a social science theory, developed first in 1962 by E.M. Rogers (Rogers, 1983), that describes how over time an idea or product gains momentum and spreads through a specific population or social system.

In that sense the people from a specific social system, adopt a new idea, behavior or product at the end of the adoption and diffusion process.

The theory states that an innovation can be considered as any practice, idea or object that can be perceived as new either by an individual or any other adoption unit (Rogers, 1983, preface xvii). In this context, the diffusion becomes a process in which the innovation is communicated through specific channels over time among the members of a social system. Those are defined as communication Channels.

Furthermore, Rogers (1983), refers to adoption as a decision to use and implement a new idea, considering it as a dependent variable. In order to adopt innovations, five variables, determine the rate of adoption (Figure. 8).

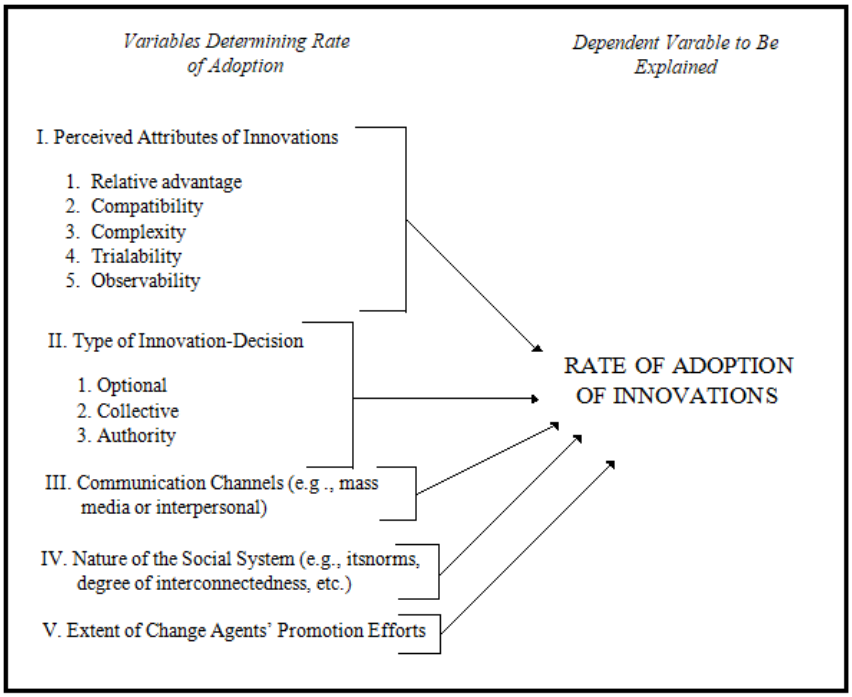

Figure 8. Variables that are measuring the rate of adoption of an innovation (Adapted: Rogers, 1983, p.233).

The *perceived attributes* of the innovations include the *relative advantage*, which measures the degree in which an innovation is seen as better as the product, service or idea that replaces. The *compatibility,* related to acceptance level with the values, needs, and expectations of potential adopters. The *complexity* to use or learn about the innovation. The extent to which it can be tested before there is a commitment to adopt it, known as *trialability* and the tangible results obtained through the *observability* (Rogers, 1983).

The way it is decided, when adopting an innovation is also important, either an arbitrary selection to a collective one that includes the specific weight of the authorities, could lead to a rejection or a later adoption of the innovation.

The communication channels such as the *mass media* or an *interpersonal* setting are forms to measure the rate of adoption too, as well as attributes such as the knowledge related to the innovation, the capacity of persuasion over the potential adopters, the decision about the innovation and its confirmation of the adoption or rejection of it (Rogers, 1983).

Furthermore, the nature of the social system can affect the level of adoption. Depending on the target population, their tolerance of deviancy and communication integration can increase or decrease the successful adoption of the innovation (Rogers, 1983).

Consequently, during the adoption process, the primary stakeholders are the *opinion leaders*, who introduce the knowledge and persuade potential adopters to decide on adopting an innovation, followed by the *change agents* and *change aides*, that through their efforts can broaden the range of adoption between the citizenship (Rogers, 1983).

There are different categories of people that adopt an innovation through time (Figure 9). The *innovators* are the pioneer percentage of the population that can take risks when adopting an innovation. Followed by the *early adopters* that are influenced by *opinion leaders* and *change agents*, in general terms they adopt the innovations as long as someone has adopted them before them, to decrease the risk. The *early majority* represent the gross of the population that accepts innovations, then the *late majority* that adopts it by the inertia of the social behavior and finally the *laggards* that are the sector more resistant to adopt the innovations (Rogers, 1983).

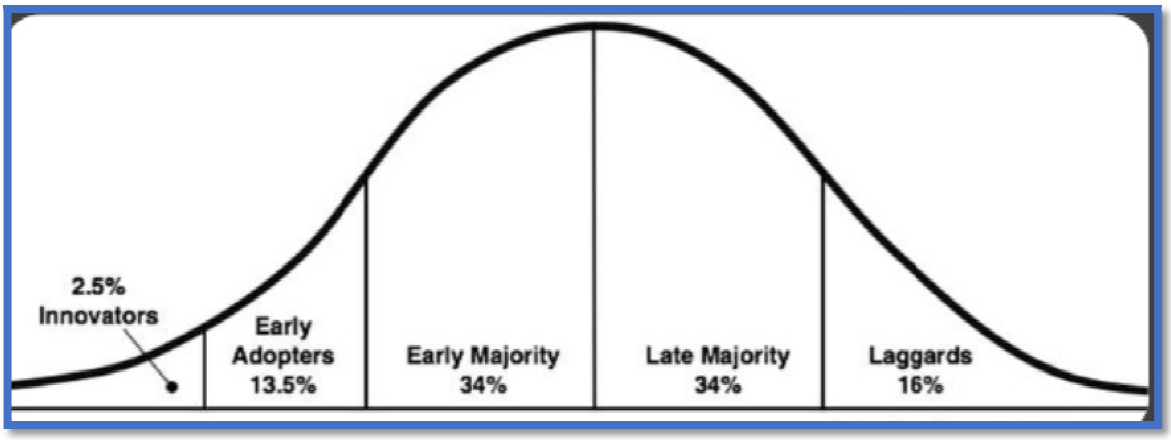

Figure 9. Diagram of the adopter categories (Source: Rogers, 1983, p. 247).

The consequences or final results of the *innovation-decision* process (Figure 10), are the implementation of the innovation in a target sector, as well as its later continuance or discontinuance by the action of replacement. On the other hand, the rejection as a concept can be a result of the prolonged delay in the adoption process (Rogers, 1983).

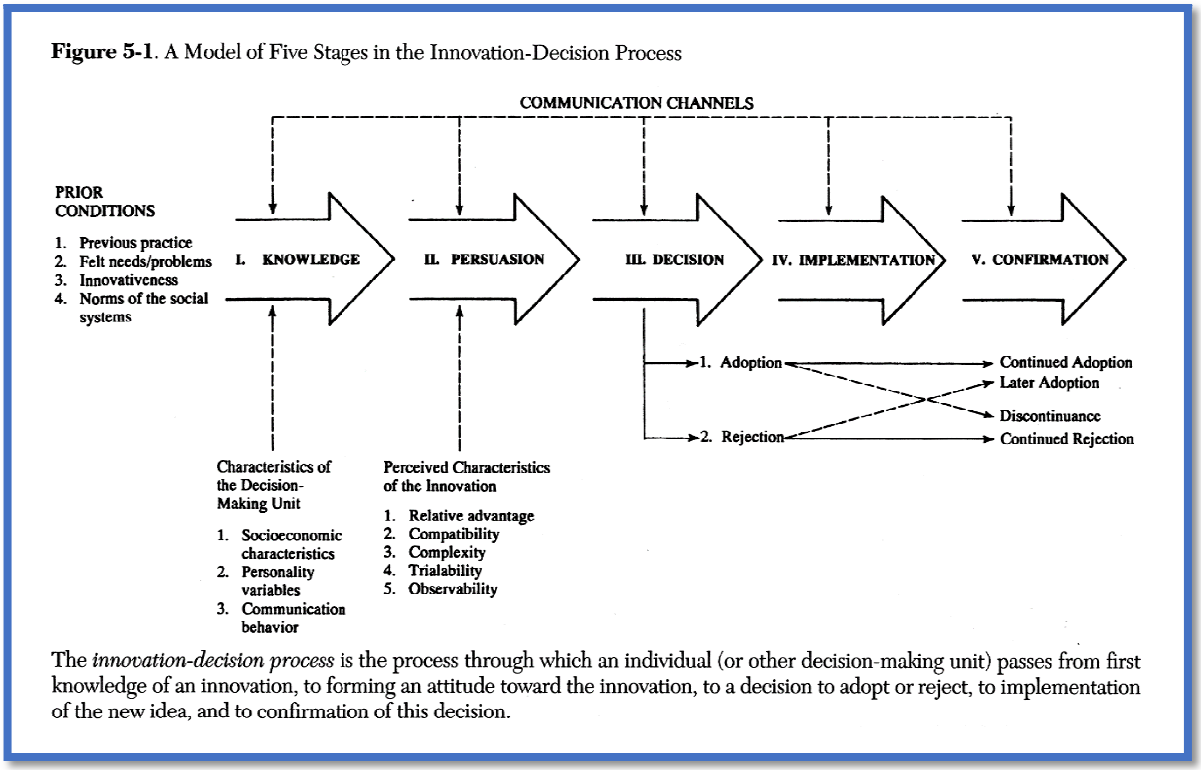

Figure 10. Innovation-Decision process (Rogers, 2003 p. 170)

2.2 Applications of the adoption and diffusion theory.

The adoption and diffusion theory has many applications in diverse fields; one example is the local transport policies in cities as Leeds (Marsden, 2011). Another one in the health sector, allowing to understand the factors impacting patients acceptance and use of consumer e-health innovations (Zhang, Yu, Yan, & Ton A M Spil, 2015).

This theory is also an important part of the technological adoption model (Atkin, Hunt, & Lin, 2015), described ad Atkin (2015) as “a system’s level framework focused on the adoption of emerging media channels and contents“.

Moreover, regarding this thesis project, part of this theory was implemented in the development of ADOPT, which is mainly a tool used to make prosecutions regarding the adoption of innovations in the agricultural sector in Australia (CSIRO, 2017a).

2.3 Evolutions of the adoption and diffusion theory.

Dearing (2018), explains that the diffusion theory has been traditionally applied to different sectors such as the agricultural one, international development, public health, and educational interventions.

However, the central evolution of the theory is related to its conversion into a science of dissemination, concluding three main changes in how it is conceived (Dearing, 2008):

“Changes (1) The social systems from a perspective on physical communities to one on societal sectors and social networks. (2) The nature of the diffusion systems we create to interface with social systems where we want to intervene, which have become more decentralized, multifaceted in some instances, and yet retained elements of centralized efficiency. Also, (3) the strong relevance for public health innovation dissemination of attending to what goes on inside organizations where we may want to intervene upstream to affect change” (p.9).

On the other hand Atkin et al, (2015)(primary source), express that the Rogers theory in this lattes version (2003) challenges to the scholars to make a more complex understanding of the theory ang gives some examples of various authors, such as the development of a convex curve when interpersonal channels impact instead of an S-curve (Vishwanath and Barnett’s 2011) (secondary source)) or the importance of active adopter activity during diffusion Dearing and Meyer (2011)(secondary source).

3 Methodology

Being this thesis project a combination of documentary research and a practical application in a specific case study; its goal was to create a procedure that could also be used in a general context for urban areas. For this purpose, the methodology was developed under quantitative and qualitative research methods. The first approach is mainly focused in determining prospection scenarios measuring the probability and time of adoption for NBS in a specified region; and the second one in developing the means to assess the perception of the stakeholders involved in the decision making concerning the adoption of green infrastructure focused in improve the resilience conditions in their communities.

As seen in figure 11, the procedure consisted in seven chronological phases: Literature review, comprehensive analysis of the ADOPT tool, adaptation of the ADOPT tool for the NBS context, development of a structured elicitation process, implementation of a participatory workshop, results and data analysis; discussion and conclusions.

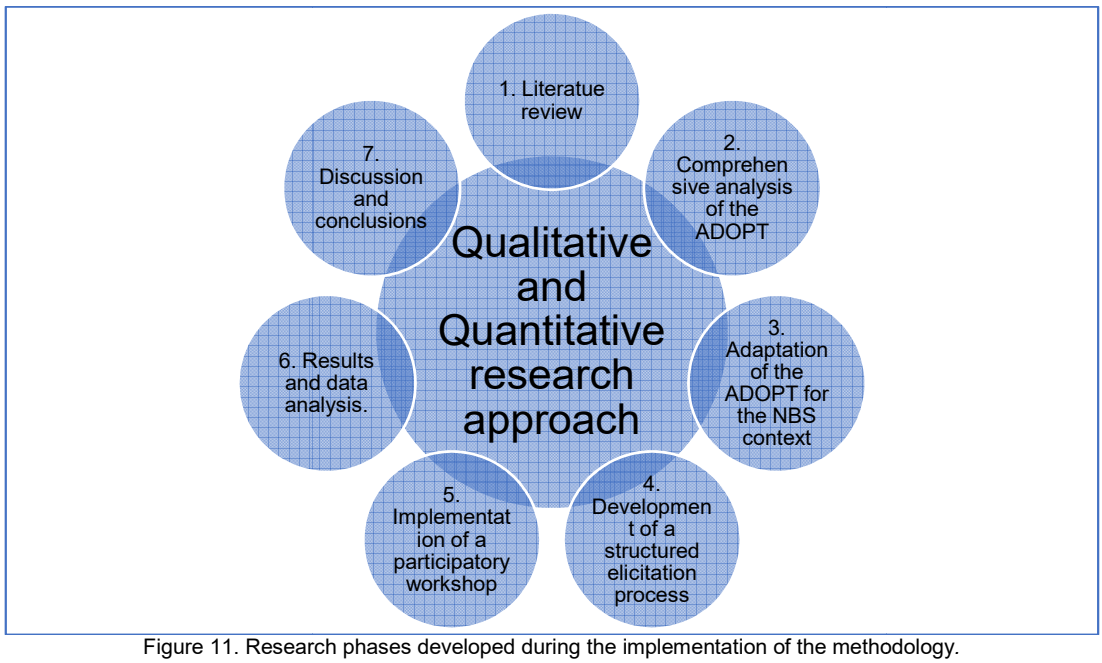

Figure 11. Research phases developed during the implementation of the methodology.

3.1 Literature review

The literature review consisted in a bibliographic analysis of documents related to the basic concept of the NBS, its relationship with climate change, urban processes and its efficacy level proved until now as resilience infrastructure in cities facing the climate change effects.

Furthermore, some practical cases of interest, as well as examples of success and failure during the adoption of green infrastructure in urban areas.

On the other hand, it was examined the *adoption and diffusion theory,* developed by E.M. Rogers (2003), which is one of the essential social methods related to this specific area (Sahin, 2006). As a complement to this theory, it was analyzed information about the concept of community readiness, which as the name indicates, it measures the level of preparedness that a community has to adopt a substantial change or take action into a determined issue (Tri-Ethnic Center for Prevention Research, 2014).

This *adoption and diffusion theory* was, in turn, the primary development source for a predictive tool, used for measuring the adoption rate scenarios oriented to the agricultural sector called *Adoption and Diffusion Outcome Prediction Tool* (ADOPT), which was also analyzed.

Finally, a literature review was performed related to the process for obtaining information from groups of experts on a determined topic; known as structured elicitation (Aspinall, 2010), as well as methodologies used to conduct participatory workshops with this approach.

3.2 Comprehensive analysis of the ADOPT tool

As stated before ADOPT is an *MS-Excel* based tool that was developed and promoted mainly by the *Commonwealth Scientific and Industrial Research Organisation* (CSIRO) in Australia, its primary objective is to create scenarios for measuring the level of adoption and diffusion of innovations in the agricultural sector (CSIRO, 2017b). An informative analysis was performed to understand how the tool could be applied.

The conceptual framework of the tool focuses on the interrelationships between a targeted population and innovation which influences the adoption and diffusion rate. The interaction variables that ADOPT uses are: networks, profit expectations, property size, the short-term costs of adoption, the innovation´s impacts on profits, impacts on riskiness of production, the complexity of the innovation, perceived environmental credibility of the practice, able to be trialled on a small scale, able to be observed and readily apparent effects (Kuehne et al., 2017).

In that sense, according to Kuehne et al. (2017), ADOPT was implemented in a series of workshop settings with specific sectors of farmers in Australia. Then it works is by answering a survey of 22 questions related to four main areas or quadrants. As seen in figure 12, the first two correspond to the relative advantage for the population and the learnability characteristics of the innovation; the

third and fourth quadrants are associated with the specific influences on the ability of the community to learn about the innovation and its relative advantage (Geoff Kuehne et al., 2011).

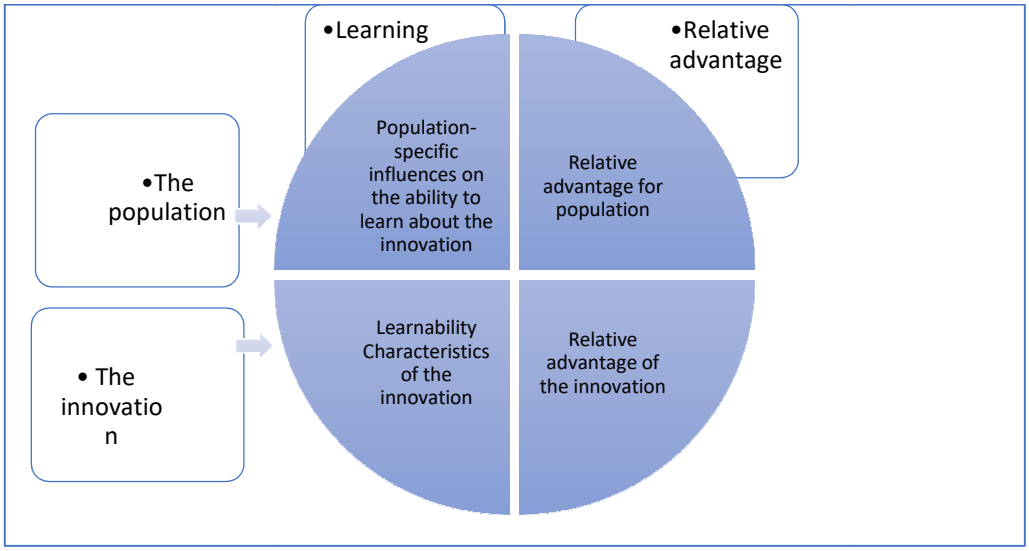

Figure 12. Connections between learning, relative advantage, the population and the practice in the ADOPT (Geoff Kuehne et al., 2017).

The four interconnected quadrants follow multi-directions lines related to each one of the questions of ADOPT (Figure 13):

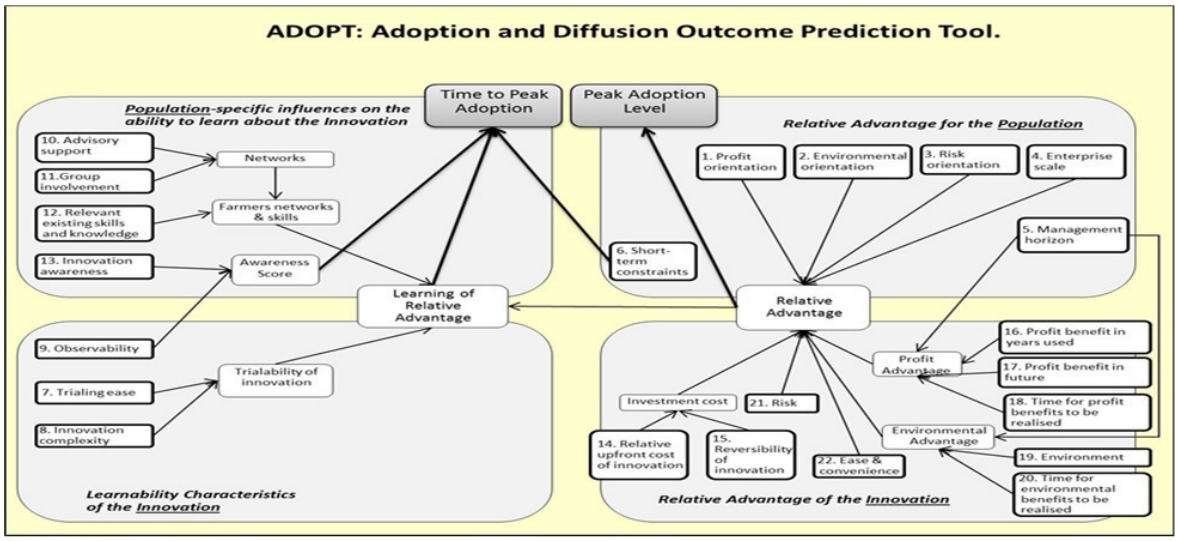

Figure 13. Different quadrants that ADOPT evaluates (source: CSIRO, 2017b).

To know if the potential advantage gained from adopting the innovation is enough to convince the population for the adoption of a particular innovation, the first six questions of ADOPT are organized as part of the *relative advantage for the population* quadrant. These aspects are the profit, environmental and risk orientation, the enterprise scale, the management horizon with profit

and environmental advantages of the innovation incorporated and the possible short-term constraints (Kuehne et al., 2017).

Some innovations will be challenging to adopt in comparison to others. *The learnability characteristics of the innovation* quadrant consider the innovation-specific influences on the ability to learn about the innovation, the three subsequent questions of the survey are expressed in topics of observability, trialing ease and innovation complexity, the two last questions are directly related to the trialability of the innovation. (Kuehne et al., 2017).

The population-specific influences on the ability to learn about the innovation quadrant include questions 10 to 13 and measures the learnability of the population. This situation includes the learning process of gathering information, reassessment of the beliefs of the target population and the review for adopting or not the innovation. Constraints in the learning process could reduce the adoption time possibility. The *networks* of the target population are evaluated through *advisory support* and *group involvement*. Also, the *relative skills and knowledge* are assessed to the *farmers' network* and *previous skills*, and the last question related to the *innovation awareness* (Kuehne et al., 2017).

The more significant quadrant is the *relative advantage of the innovation* quadrant, includes nine questions, focused on the *relative advantage of the innovation* characteristics, specifically in how the target population perceives them. The *profit advantages* are measured by the questions related to the *future benefits* and *in the years used*, also the time for profits the realized. The *environmental advantage* is also incorporated including the *time for the environmental benefits* are going to be realized. Also, the *investment costs* with questions focused on the *upfront costs* and the *reversibility* of the innovation. The *risk* and *ease and convenience* of the innovation are also included.

Even do all the quadrants are interconnected, the *relative advantage for the population* and the *relative advantage of the innovation* influence directly the peak adoption level. Meanwhile, the time to peak adoption is directly influenced by the short terms constraints, the awareness score and the learning of relative advantage. The rest of the variables have a participation in the intermediate equations of these concepts.

After completing the questionnaire, the result of using the software is an adoption curve that displays the number of years and the percentage of adoption of an innovation related to the target population. Along with a sensitivity analysis that helps to point out the opportunity areas for the improvement of the adoption of the innovation.

The outcome is the generation of a report. It includes a table containing the years and the predicted pick level of adoption, the expected adoption level at five and ten years from the start; and optionally if it was inputted in the tool, the set year of the innovation to be adopted and the adoption level at that year. It also includes a series of graphs representing the adoption level, the sensitivity analysis to step change for response in peak adoption level and in the time to peak adoption level (CSIRO, 2017c).

The informatics use of ADOPT is described in the next steps:

1.- The downloadable version must be signed by an agreement of copyright protection before accessing to it. After the registration as a user, one copy of the software can be downloaded onto one single computer. An Excel file is then available, to open the tool. The agreement can be found in Appendix A.

2.- A window will appear, it is essential to select the option USE ADOPT, and select a new or old project to work (Figure 14):

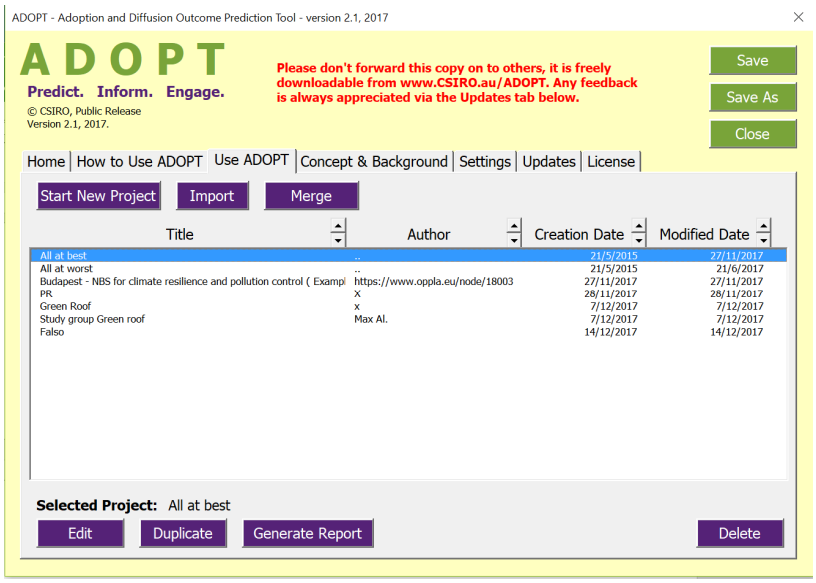

Figure 14. Access window to ADOPT (CSIRO, 2017b)

3.- A second screen will appear, to fill in the general data of the project (Figure 15).

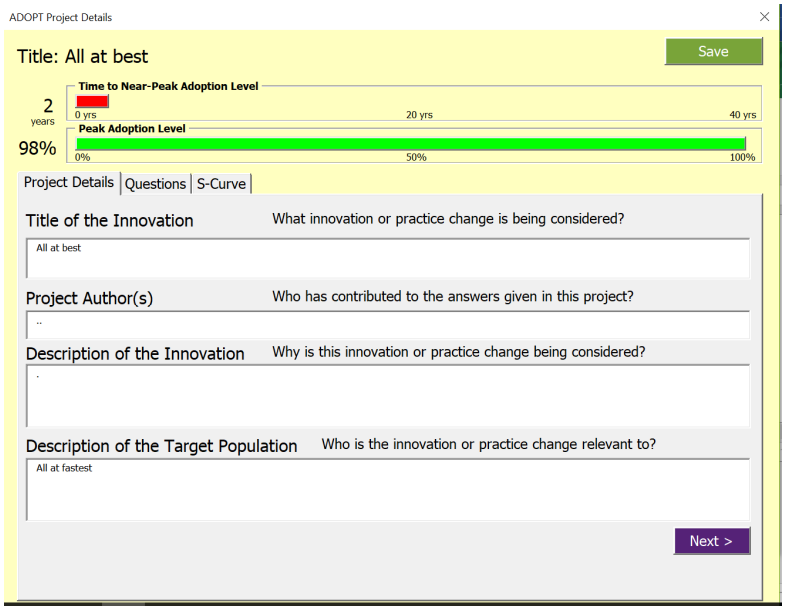

Figure 15. General information of the project and results displayed in the ADOPT tool (CSIRO, 2017b).

4.- After pressing the 'Next' button, the first question will be displayed (Figure 16), with several multiple-choice answers. It is essential to ask the interviewer the reasons for its answer. As mentioned before, the number of questions is 22, those are divided into different topics related to the four quadrants that the tool is based on (relative *advantage for the population quadrant, learnability characteristics of innovation quadrant, population-specific influences on the ability to learn about the innovation quadrant and relative advantage of the innovation quadrant*). The content of each original question, the possible answers and the explanation of each of them, can be found in the Appendix B. It is important to recall that the program is first developed for the farming sector.

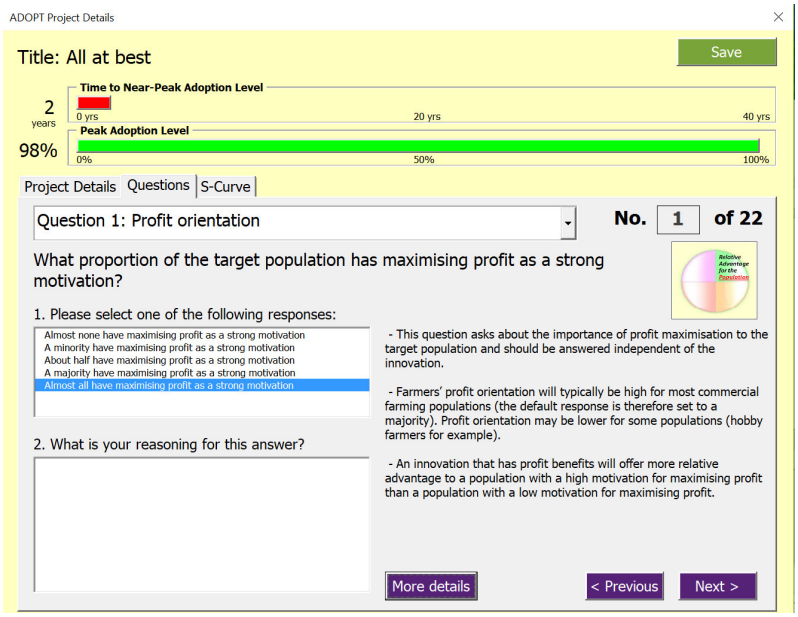

Figure 16. Questionnaire window displayed in the ADOPT tool (CSIRO, 2017b).

5.-afterward, the last window will generate the preliminary adoption curve (Figure 17).

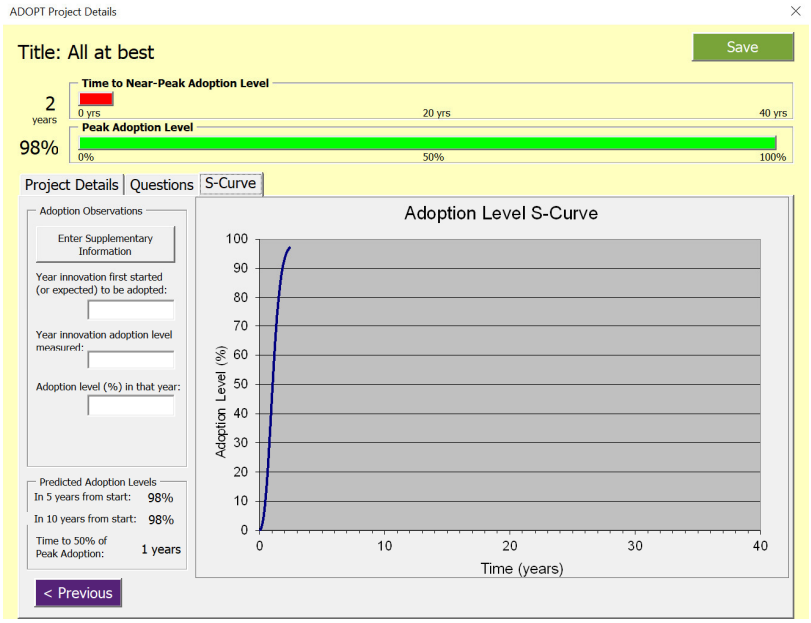

Figure 17. Adoption curve display in the ADOPT tool (CSIRO, 2017b).

6.- A report of the summited data can be generated in the main window, including information on the adoption level, rate of adoption and a corresponding sensitivity analysis of both factors.

3.3 Adaptation of the ADOPT to the NBS context

Understanding that NBSs is a relatively new concept (Eggermont et al., 2015), an adjustment of ADOPT was necessary to give to the first scenarios created, a more aligned sense of adoption respecting not only the possible profits given to the population, but to the different environmental and wellbeing benefits too. This as part of the main intentions that go along with the implementation of NBSs for improving the resilience in the communities.

3.4 Development of a structured elicitation process

Following the structured workshop setting explained by Kuehne et al. (2017), as part of the ADOPT implementation; the next stage of the thesis consisted in the development of a structured elicitation process as a complement of the application of ADOPT.

The structured elicitation process was proposed considering general concepts explained by Aspinall and Cooke (2013), the community readiness handbook from the Tri-ethnic Center for

Prevention Research (2014) from the Colorado University and a structured expert elicitation protocol developed by Hemming et al. (2018) called the IDEA protocol.

Elicitation is the process of getting information (Macmillan Dictionary, 2018) directly from experts instead of searching for it in documents, for scientific (and planning) purposes in the decision-making context (Aspinall, W., & Cooke, R. 2013). It can be divided into two types: i) unstructured elicitation that depends in the single opinion of an expert, and ii) structured elicitation that combines the expert elicitation of various participants through a methodology that weights the opinions of each expert, giving a rational consensus that allows reducing uncertainty in the decision-making process (Aspinall, W., 2010). Aspinall, W. and Cooke, R. (2013: p.11), explain that for structured elicitation there are weights that can be assigned by experts views. One way is related to the appraisal of performance by one or more technical facilitators, on the other hand, the weights can be determined by applying a scoring rule measure to an empirical test of judgment skill, these are the two more significant differences in the weighting scheme.

The IDEA protocol (Hemming, Burgman, Hanea, McBride, & Wintle, 2018) it is an acronym, that describes the steps to follow in the elicitation protocol: "Investigate," "Discuss, "Estimate" and "Aggregate" (Figure 18). The protocol starts with a Pre-elicitation phase where the background information and the previous contact with the potential participants takes place. Next, the Elicitation phase consists of three steps. Investigation refers to the own reasoning and compilation of answers of each expert. Then the Discuss dynamic, with shares in an anonymous way the opinions with the rest of the experts. Estimate, which focuses in the second round of questions after the discussion. Finally, in the Post-elicitation phase, which coincides with Aggregate, where the experts review, discuss and correct their answer for a having some conclusions of the process.

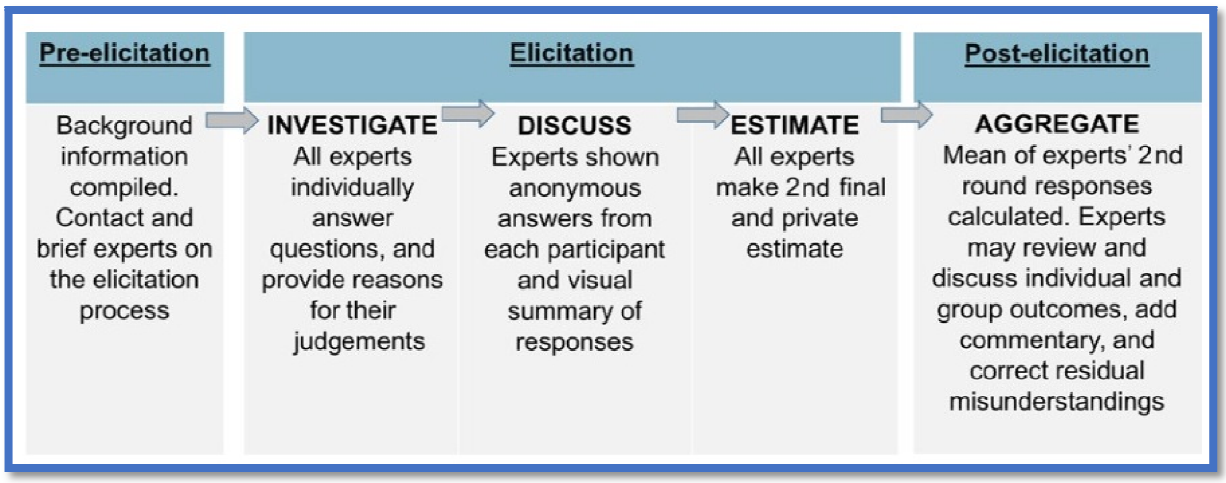

Figure 18. IDEA protocol, from Hemming, et al. (2017).

The third factor that was considered into the workshop methodology preparation was the idea of *community readiness*. According to the Tri-Ethnic Center for Prevention Research (Tri-ECPR) from the Colorado University, “community readiness is the degree to which a community is willing and prepared to take action on an issue” (Tri-ethnic Center for Prevention Research 2014).

The concept was first applied in the Kentucky Conference for Prevention Research1991 by the head of the Midwest Prevention Project (MPP), Mary Ann Pentz (Edwards, Jumper-Thurman, Plested, Oetting, & Swanson, 2000). This program was aimed at the prevention of substance use among middle school students. In this context, "If a program was started even though the community was not ready, initiation was likely to lead only to failure" (Edwards et al., 2000).

Therefore, although the term was used first in the health sector, the basis of the concept allows it to be used in other areas of society. Consequently, community readiness can be applied to the sustainable development of communities, to measure if they are prepared for the transition to technologies and programs that allow them to be more resilient to climate change.

With all these bases, an inclusive methodology was developed for a participative workshop setting for the different types of stakeholders. The performing steps in the case study were the following ones:

1. For the thesis purposes, the participants from the academic and governmental sectors were contacted and invited beforehand by email, with a date proposed for each workshop (see Appendix E). And for establishing the general logistics for realizing the workshops in the city (but depending on the NBSs context also representatives for the private sector and the citizenship organizations could be added).

2. During the workshops, an introduction of the general topic to the audience was performed along with the delivery of an implicit consent letter for the participation in the workshop (see Appendix C) in which the participants agreed to contribute with the study.

3. The workshop was divided into two rounds. The first round was performed with the participants filling the survey of twenty-two questions -adapted for ADOPT-NBSs- and giving a brief explanation of the reasons for setting the score they chose (see Appendices D and F). On the other hand, the second round, consisted of a similar activity. But this time the participants were conformed into heterogenic discussion groups, giving them the possibility to exchange different types of opinions; with the purpose of determining if their view changed or not respecting their first individual answers about the perception in the

adoption of *green roofs* in the city of Eindhoven. The time invested in each activity is described in appendices E and D.

4. After that activity, the answers of all the participants were calculated as an average per question and then set into the ADOPT for their analysis, resulting in the level of adoption and rate of adoption graphs.

5. A group presentation and discussion about the results was conducted.

6. In the end, the participants filled a feedback form, with their comments for the continuous improvement of this type of workshops (see Appendix G).

3.5 Implementation of a participatory workshop

The application of this methodology was made in the city of Eindhoven in the Netherlands, which is one of the participant cities of the UNaLab project. The workshop setting had two sessions orientated to the assessment of the possible adoption of green roofs in the city. The first one was performed in the *Technical University of Eindhoven* (TU/e), with postgraduate students holding a background orientated to urban planning and architecture and the second one took place in the Municipality of the city with personnel of the *Urban Planning* department.

3.6 Results analysis

The results were described regarding the two participatory workshop sessions in Eindhoven, in the forms of tables and graphs created by ADOPT.

As stated before the individual results of each session were evaluated along with the comparison of the answers of both groups that participated; the analysis was done per question and in a global form, this action allowed to have an average result that was used to have a generalization of the view of the participants.

3.7 ADOPT-NBSs

This section reconstructs the equations that compose ADOPT (see Table 2 and 3). Also, it is described the content adapted from the questions of ADOPT into the NBSs context (green roofs in particular).

One of the main objectives of this process is to understand how the responses to individual questions affect the level and rate of adoption of assessed innovations by the tool. Paying more attention to the specific positive or negative impact in the adoption graphs, rather than in the detailed values generated in the MS-Excel scenario, this because the level and rate of adoption could change depending on the scenario created. Another specific aspect is the adaptation of the questions to focus the tool to the right audience by making the survey more practical for NBSs purposes.

In that sense, organized by innovation quadrants, this section describes the questions related to the "Relative advantage for the population" quadrant (Section 3.7.1), the 'Learnability characteristics of innovation' quadrant (Section 3.7.2), the "Population-specific Influences on the Ability to Learn About the innovation" quadrant (Section 3.7.3) and the "Relative Advantage of the Innovation" quadrant (Section 3.7.4). For understanding the influence of each question in the peak adoption and time to peak adoption levels, graphs per question were created combining the different possible responses based on a scenario created with middle level answers of ADOPT. The individual analysis is explained in the next sections.

Table 2. Peak Adoptions equations (Geoff Kuehne et al., 2017)

Peak adoption
Profit advantage = (Profit benefit in years used + Profit benefit in future*(1 + Discount rate)$^{-\text{Years to Future Profit Benefit}}$)/2
Environmental benefit (advantage) = w_{eb}*Environmental benefit*(1+Discount rate)$^{-\text{Years to environmental benefit}}$
Discount rate = 0.02 if Almost all have a long-term management horizon; 0.04 if A majority have a long-term management horizon; 0.06 if About half have a long-term management horizon; 0.08 if A Minority have a long-term management horizon; 0.1 if Almost none have a long-term management horizon.
Relative advantage = [(1 + w_p*Profit orientation) *Profit advantage + (1 + w_r*Risk orientation)*Risk + Ease & convenience + (1 + w_e*Environmental orientation)*Environmental advantage]*(1 + w_{es}*Enterprise scale) + w_{ic}*(Investment cost – Max investment cost)
Peak adoption = P_{min} +(P_{max}- P_{min})/(1+EXP(c_c – Relative advantage*c_p))

Table 3. Time to peak adoption equations (Geoff Kuehne et al., 2017)

Time to Peak Adoption
Trialability of Practice (innovation)= (Trialing ease + Practice complexity)/2
Networks = Min (w_{gi}*Group involvement + Advisory support, 7)
Learning of Relative Advantage = Trialability of practice + Farmer networks skills + w_{RA}*Relative advantage
Awareness Score = A_{min}+ Practice awareness + Observability − A_o*Practice awareness*Observability
Farmer networks and skills = F_a + F_b*Relevant existing skills & knowledge + F_c*Networks + F_d*Relevant existing skills & knowledge*Networks
Time to peak adoption = MAX (T_{max} − Learning of Relative Advantage*L_m + IF (UpfrontCosts ≥ 4, 0, T_{min} − UpfrontCosts) + (C_{max} − ShortTermConstraints) *ShortTermConstraints − AwarenessScore, 3)

As stated before, to develop graphs that show a general influence of each question in the *peak adoption* and time to *peak adoption* values empirically, a scenario was created in MS-Excel, with fixed values close to the intermediate answer of each question (based on ADOPT). For this purpose, each question was assessed individually with the different possible answers, leaving the rest of the questions with the fixed value of the scenario (see table 4).

Table 4. Values used for the MS- Excel scenario created.

QUESTION	SCENARIO FIXED VALUES
1: Profit orientation	3
2: Environmental orientation	3
3: Risk orientation	3
4: Enterprise scale	3
5: Management horizon (discount rate)	0.06
6: Short term constraints	3
7: Trialing ease	3
8: Innovation complexity	3
9: Observability	3
10: Advisory support	3
11: Group involvement	3
12: Relevant existing skills & knowledge	3
13: Innovation awareness	3
14: Relative upfront cost of innovation	3
15: Reversibility of innovation	3
16: Profit benefit in years that it is used	1
17: Future profit benefit	1
18: Time until any future profit benefits are likely to be realized	4
19: Environmental costs & benefits	1
20: Time to environmental benefit	4
21: Risk exposure	1
22: Ease and convenience	1

The intermediate equation *investment cost* was not found directly with the rest of the equations in Table 2. As a result, it was determined as an average of the values of the question 14 and 15 respectively following the definition and relationship of both questions found in ADOPT. In the same way, the table 5, shows the parameters used in the different equations developed by Kuehne et al.(2017), for the scenario purposes, the rescaling parameter “Wra”, was developed empirically following its general definition in ADOPT by obtaining the average value of *triability of practice* with *farmer networks and skills* and then dividing it with the *relative advantage* value. In the same context “Wo” and “Wia” were settled with the value of *one*.

Table 5. Parameters for the peak adoption and time to peak adoption equations (Geoff Kuehne et al., 2017).

PARAMETERS			
w_p	Profit orientation weight (0.4)	C_{max}	Maximum time added due to short-term constraints (4)
w_r	Risk orientation weight (0.2)	w_{ia}	Practice awareness weight (0.)
w_e	Environmental weight (0.4)	w_o	Observability weight (0.)
w_{ic}	Investment cost weight (0.33)	A_{min}	Minimum level for awareness score (-1.25)
w_{es}	Enterprise scale weight (0.4)	A_o	Weight on interaction between practice awareness and observability (0.15)
w_{re}	Risk effect weight (0.6)	w_{eb}	Environmental benefits weight (0.6)
T_{max}	Maximum time to adoption (50)	w_{RA}	Rescales RA (Relative Advantage) score to have equal influence on learning as do Trialability and Farmer Networks & Skills
T_{min}	Minimum time to adoption (3)	w_{gi}	Group involvement weight (0.7)
P_{min}	Minimum adoption rate (1)	c_c	Peak adoption curve parameter (3)
P_{max}	Maximum adoption rate (98)	c_p	Peak adoption curve parameter (0.3)
F_a	Intercept term for Farmer networks and skills (-0.63)	F_b	Weight on existing skills and knowledge (1.13)
F_c	Weight on networks (0.63)	F_d	Weight on interaction between networks and skills (−0.13)
L_m	Scalar of Learning of Relative Advantage Score (3.0)		

3.7.1 Relative advantage for the population

This quadrant comprises six questions (see Table 6), associated with *profit, environmental and risk orientation* (Questions 1 to 3), *enterprise scale* (Question 4), *management horizon* (Question 5) and *short terms constraints* (Question 6). All the questions affect directly or indirectly the intermediate equation known as *relative advantage,* except for Question 6 which affects the calculations directly for the time to peak adoption value (see Table 3). It is important to notice that

the relative advantage equation is related to the *peak adoption and time to peak adoption* equations (see Figure 13).

Table 6. ADOPT questions related to the 'Relative Advantage for the Population' Quadrant.

Quadrant	Question (Variable to evaluate)	Question Associated (original)	Question Associated for NBSs
Relative Advantage for the Population Quadrant	**1.-Profit/utility orientation.**	What proportion of the target population has maximizing profit as a strong motivation?	What proportion of the target population (governments, private sector and/or property owners) has maximizing profit/utility as a strong motivation for implementing Green roofs?
	2.- Environmental orientation.	What proportion of the target population has protecting the natural environment as a strong motivation?	What proportion of the target population (governments, private sector and/or property owners) has protecting the natural environment as a strong motivation for implementing Green roofs?
	3.-Risk orientation	What proportion of the target population has risk minimization as a strong motivation?	What proportion of the target population (governments, private sector and/or property owners) has risk minimisation as a strong motivation for implementing Green roofs?
	4.-Enterprise Scale.	What proportion of the target farms is there a major enterprise that could benefit from the innovation?	What proportion of the target population (governments, private sector and/or property owners) could benefit from the Green roofs?
	5.- Management Horizon.	What proportion of the target population has a long-term (greater than 10 years management horizon from their farms?	What proportion of the target population (governments, private sector and/or property owners) has a long-term (more than 10 years) planning horizon?
	6.-Short terms constraints.	What proportion of the target population is under conditions of severe financial constraints?	What proportion of the target population (governments, private sector and/or property owners) is under conditions of severe financial constraints?

Note: The description of the answers to each question were also changed on the basis of the application of ADOPT to NBSs. See Appendix F for the full description.

The first three questions are related to comprehending which are the strongest motivations for the target population for adopting an innovation, either maximizing profit, environment protection, or minimizing the risk (CSIRO, 2017c). The answer to them will influence systematically the values of the intermediate equations linked to the *environmental advantage, profit advantage* and *risk*

(Kuehne et al., 2017), which in turn affects the *relative advantage* dependent variable (see Table 2).

As seen in Figure 19, the different answers related to question number 1 (*profit orientation)*, influence the level of adoption in a linearly increasing way (see Figure 19a), on the other hand, the rate of adoption is linearly decreasing (see Figure 19b). In this sense, this question measures the influence of another factors influencing the profit expected due adopting the innovation (CSIRO, 2017c).

Figure 19. Influence of 'Profit orientation' on a) the level (in %) and b) rate (in years) of adoption of the innovation.

Question 2 highlights the importance of the environment protection in a broad way for the target population, in a management context independently of the innovation (CSIRO, 2017c). The level of adoption is linearly increasing in the *environmental orientation* (see Figure 20a), and the rate of adoption is linearly decreasing (see Figure 20b).

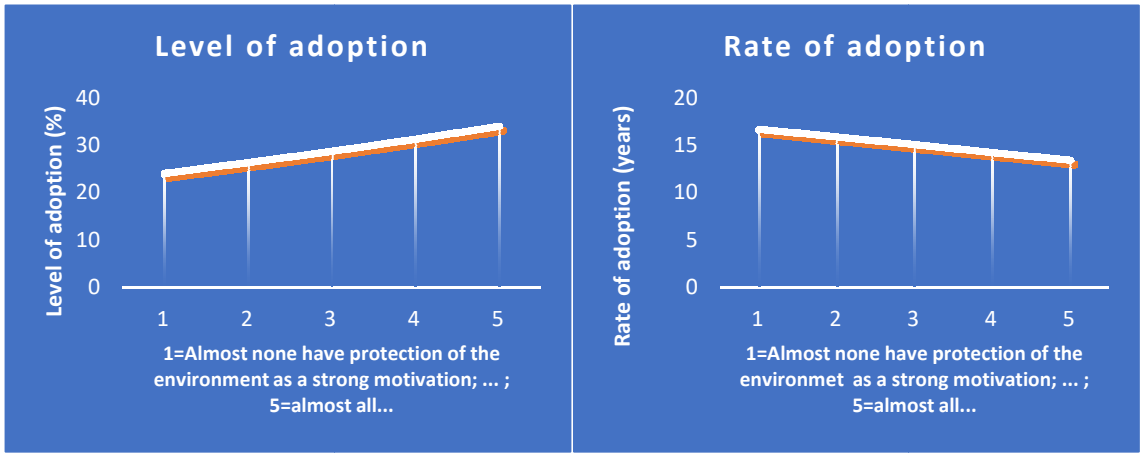

Figure 20. Influence of 'Environmental orientation' on a) the level (in %) and b) rate (in years) of adoption of the innovation.

Question number 3 is the independent variable related to *risk orientation.* In that way, in this context *risk,* it is understood as the uncertainty of a having positive or negative outcomes due to the implementation of an innovation (CSIRO, 2017c). Then, it measures the level of riskiness the target population is willing to accept (CSIRO, 2017c). It can be observed that the level of adoption is linearly increasing (see Figure 21a) and the rate of adoption is linearly decreasing (see Figure 22b).

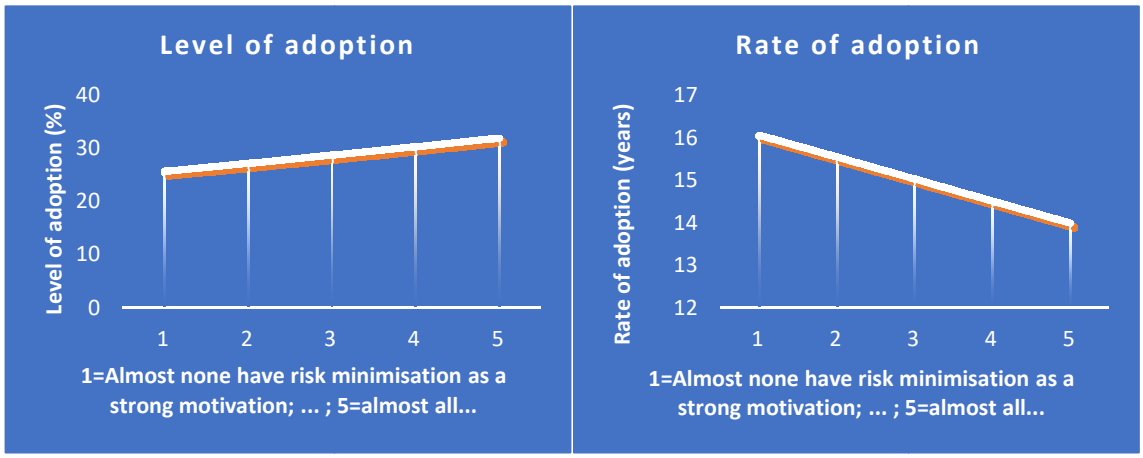

Figure 21. Influence of 'risk orientation' on a) the level (in %) and b) rate (in years) of adoption of the innovation.

The Question number 4, refers to the *enterprise scale,* the concept is related to the number of people of the target population that could benefit from adapting an innovation, this aspect is important specially in the early adoption process (CSIRO, 2017c). The level of adoption is exponentially increasing (see Figure 22a), and the rate of adoption is linearly decreasing (see Figure 22b).

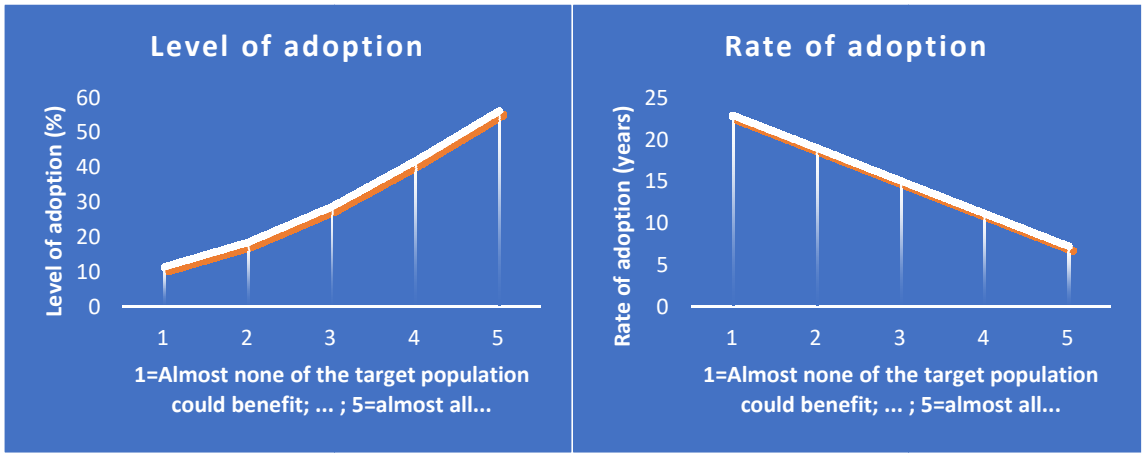

Figure 22. Influence of 'enterprise scale' on a) the level (in %) and b) rate (in years) of adoption of the innovation.

The independent variable *management horizon* is determined in Question 5. This question identifies the planning horizon of the target population. The effect on the outputs will have a bigger weight for innovations requiring a longer time for benefits to be appreciated or higher upfront costs in the form of capital and learning (CSIRO, 2017c). It can be observed that the level of adoption is linearly increasing (see Figure 23a) on the other hand the rate of adoption is linearly decreasing depending on the answer given (see Figure 23b).

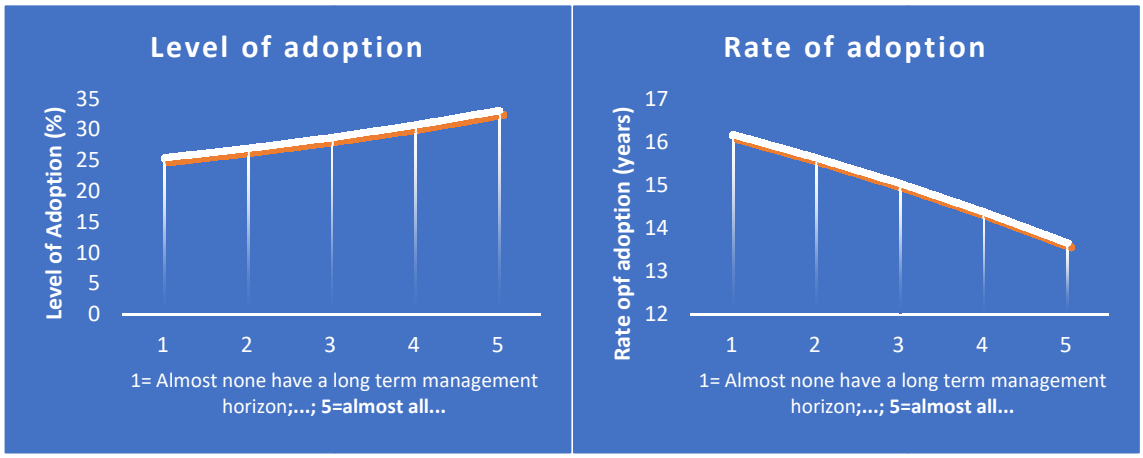

Figure 23. Influence of 'management horizon' on a) the level (in %) and b) rate (in years) of adoption of the innovation.

Question 6 is referred to the *short-term constraints*. Those are temporary constraints, due circumstances like social, economic or any natural phenomena in the short term that could delay de adoption of the innovation (CSIRO, 2017c). In that sense, innovations with a bigger upfront investment will be more affected. The level of adoption is not affected (see Figure 24a), but the rate of adoption is exponentially decreasing depending on the answer (see Figure 24b).

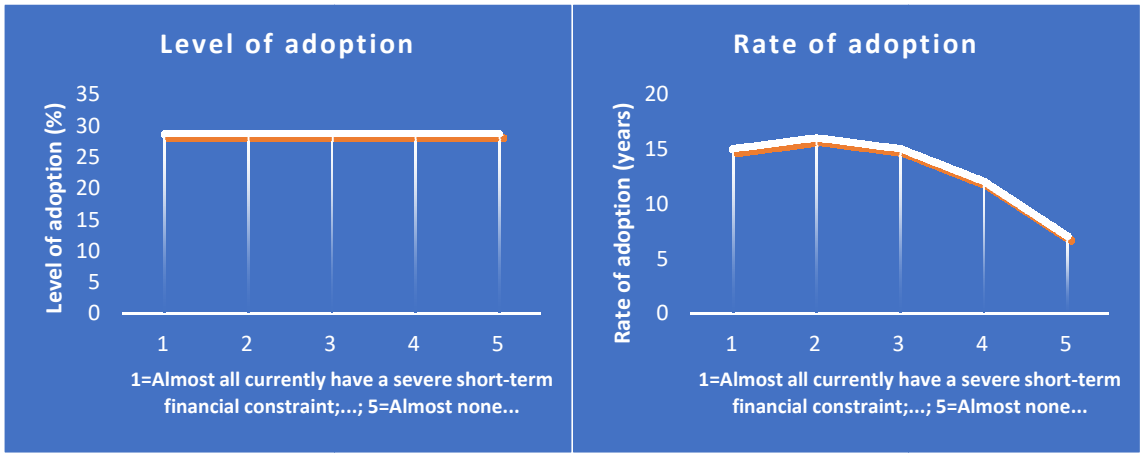

Figure 24. Influence of 'short-term constraints' on a) the level (in %) and b) rate (in years) of adoption of the innovation.

3.7.2 Learnability characteristics of innovation

The *Learnability characteristics of innovation* quadrant comprise three questions (see Table 7), associated with *trialability* (Question 7), *innovation complexity* (Question 8) and *observability* (Question 9). Question 7 and 8 compose the intermediate equation for obtaining the value of *trialability of innovation/practice,* and Question 9 comprises the *awareness score* equation (see Table 3). This quadrant is particularly connected to the *time to peak adoption* equation (see Figure 13).

Table 7. ADOPT questions related to the 'Learnability characteristics of innovation' quadrant.

Quadrant	Question (Variable to evaluate)	Question Associated (original)	Question Associated for NBSs
Learnability characteristics of innovation	**7.-Triable**	How easily can the innovation (or significant components of it) be trialled limited basis before a decision is made to adopt it on a larger scale?	How easily can the Green Roof (or significant components of it) be trialled on a small scale before a decision is made to adopt it on a larger scale?
	8.-Innovation complexity	Does the complexity of the innovation allow effects of its use to be easily evaluated when it is used?	Does the complexity of Green Roofs and its components allow effects of their use to be easily evaluated when they are used?
	9.- Observability	To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their districts?	To what extent would Green Roofs be observable to those in the target population (governments, private sector and/or property owners) who are yet to adopt them when they are used in their urban area?

Note: The description of the answers to each question were also changed on the basis of the application of ADOPT to NBSs. See Appendix F for the full description.

Question number 7 is related to the *'Triability'* of innovations. Rodgers (2003: p.258), defines *triability* as "the degree to which an innovation may be experimented with on a limited basis." This concept is, in turn, divided into two components – the first one related to the usage of the innovation and the accumulation of experience called *skill development*, and the second one related to the reduction of *uncertainty* (Feder & Umali, 1993) (primary source). This question aims to assess how easy it is for the target population to test the innovation before implementing it at a larger scale (CSIRO, 2017b). The level of adoption is neutral in the ease of *trialability* (see Figure 25a). The rate of adoption is linearly decreasing in the ease of *trialability* (see Figure 25b).

If small scale trials are not possible, the possibility of adopting the innovation will be most likely be reduced (CSIRO, 2017b) (secondary source).

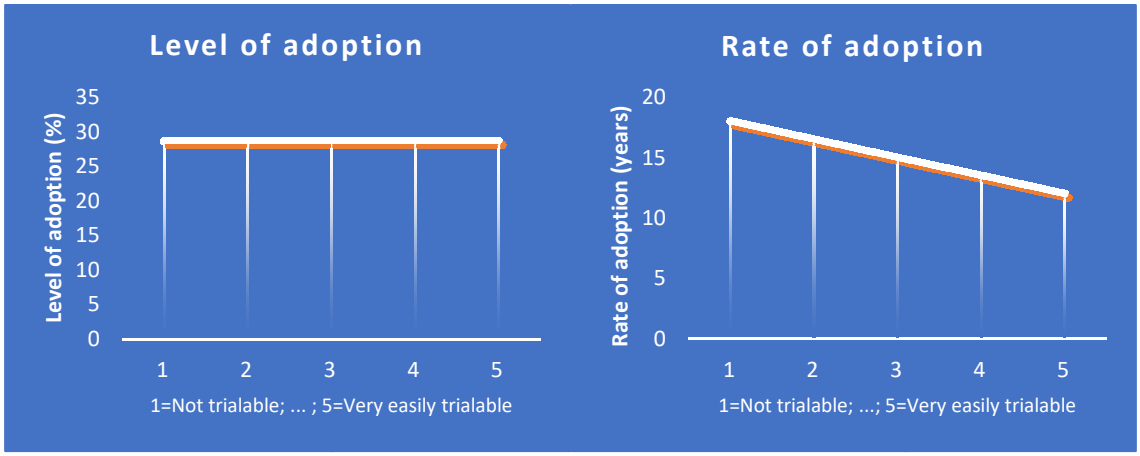

Figure 25. Influence of 'Trialability' on the a) level (in %) and b) rate (in years) of adoption of the innovation

Question number 8 is related to the *innovation complexity;* this concept is the complementary part of the *trialability of innovation* equation. Described as the degree in which an innovation can be perceived as difficult to understand or use (Rogers, 2003, p. 257). The more complex an innovation is, the more the resources needed to implement it successfully (CSIRO, 2017b) (secondary source). Complexity can be comprehended not only in the biology of the innovation but in the management, social and economic impact (Pannell, 1999; Vanclay, 1992) (primary source). The level of adoption is neutral (see Figure 26a), and the rate of adoption is linearly decreasing (see Figure 26b).

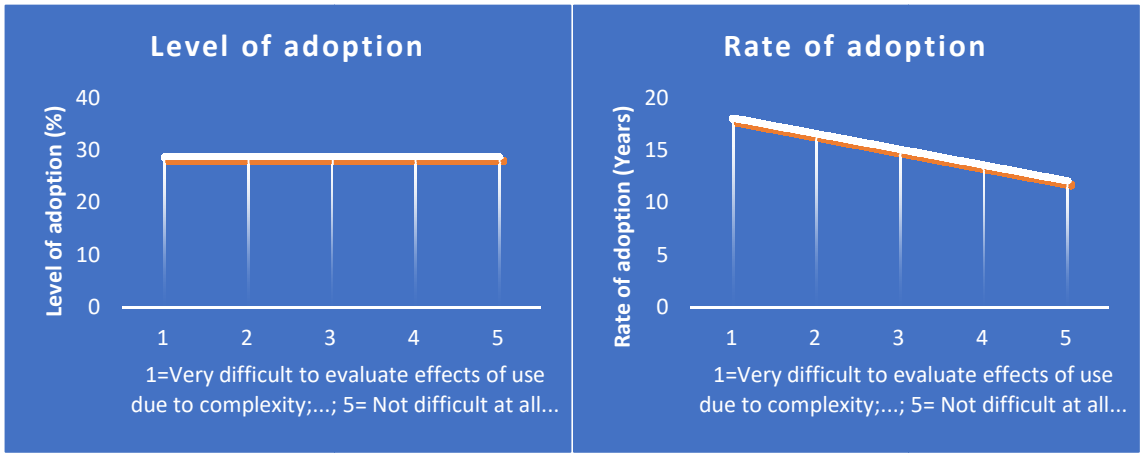

Figure 26. Influence of 'Innovation complexity' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question number 9, is referred to the *observability*, in the context of the innovation results that are visible to others (Rogers, 2003, p. 258). The rate of adoption is higher when the innovation has characteristics easily observable to the target population. In this sense, the recognizing of an innovation enables more the awareness of it and its local use (CSIRO, 2017b). Regarding Question

9, the level of adoption is not affected by the different answers (see Figure 27a) and the rate of adoption is linearly decreasing (see Figure 27b).

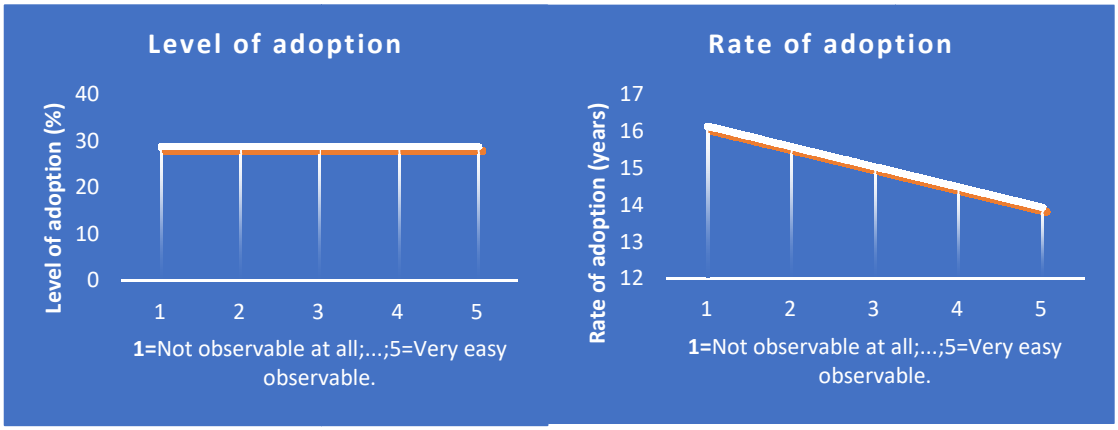

Figure 27. Influence of 'Observability' on the a) level (in %) and b) rate (in years) of adoption of the innovation

3.7.3 Population-specific Influences on the Ability to Learn About the innovation

There are four questions related to this quadrant (see Table 8). These questions are associated with a*dvisory support* (Question 10), g*roup involvement* (Question 11), *relative existing skills and knowledge* (Question 12), and *innovation awareness* (Question 13) independent variables. The first two questions compose the intermediate equation of *networks,* which in turn with the Question 12 conforms the equation of *farmers networks and skills,* the Question 13 along with the previous Question 9 are part of the *equation* for obtaining the *awareness score value* (see Table 3). All these questions and equations related affect particularly the *time to peak adoption* value (see Figure 13).

Table 8. ADOPT questions related to the 'Population-specific Influences on the Ability to Learn About the innovation' Quadrant.

Quadrant	Question (Variable to evaluate)	Question Associated (original)	Question Associated for NBSs
Population-specific Influences on the Ability to Learn About the innovation Quadrant	**10.-Advisory support.**	What proportion of the target population uses paid advisors capable of providing advice relevant to the innovation?	What proportion of the target population (governments, private sector and/or property owners) uses paid advisors capable of providing advice relevant to the implementation of Green roofs?
	11. - Group Involvement.	What proportion of the target population participates in the farmer-based groups that discuss farming?	What proportion of the target population (governments, private sector and/or property owners) participates in groups that discuss this type of NBS (Green roofs)?
	12. - Relevant existing skills and knowledge.	What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?	What proportion of the target population (governments, private sector and/or property owners) will need to develop substantial new skills and knowledge to use the Green roofs?
	13.- Innovation awareness	What proportion of the target population would be aware of the use of trailing or innovation in their district?	What proportion of the target population (governments, private sector and/or property owners) would be aware of the use or trailing of Green roofs in their urban area?

Note: The description of the answers to each question were also changed on the basis of the application of ADOPT to NBSs. See Appendix F for the full description.

Question number 10, focuses on to the *advisory support* the target population could have and that is relevant to the innovation itself. It is important to notice that this question is not referred to 'over-the-counter advice' (CSIRO, 2017b) but an objective innovation analysis. *Advisory support* is part of the *networks* intermediate equation (see Table 3). It is observed that the level of adoption of the innovation is not affected (see Figure 28a) and the rate of adoption is slightly linearly decreasing (see Figure 28b).

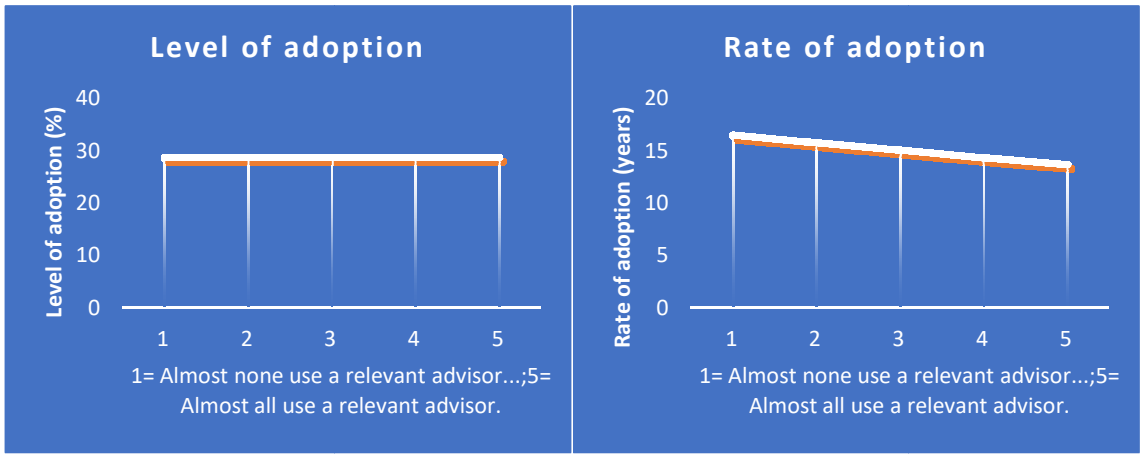

Figure 28. Influence of 'Advisory support' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

The *group involvement* independent variable is analyzed in Question 11. This question focuses on groups that could be relevant to the innovation, which in turn uncovers if the target population is involved with at least one relevant group (CSIRO, 2017b). Moreover, this is important because the *awareness* and *learning of the innovation* will be increased proportionally to the level of group involvement (CSIRO, 2017b). This question is the second conforming the *networks* intermediate equation (see Table 3). It is observed that the level of adoption of the innovation is not affected (see Figure 29a) and the rate of adoption is linearly decreasing (see Figure 29b).

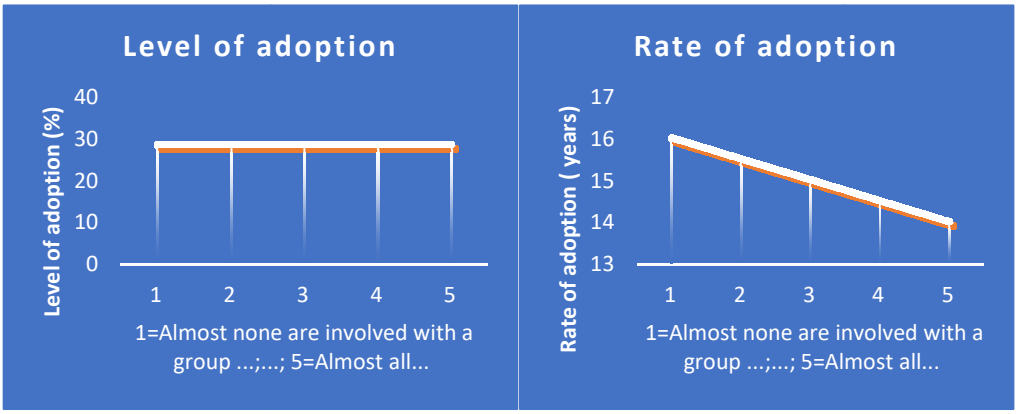

Figure 29. Influence of 'Group involvement' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question 12 is about the *relevant existing skills and knowledge* required to use the innovation. The objective of the question is to determine if the target population (the potential adopters) will need to develop substantial new skills and knowledge before having a real advantage from the use of the innovation (CSIRO, 2017b). This value will determine part of the dependent variable *farmers networks and skills* (it is important to notice that the word *farmers* in the equation is related to the original ADOPT target population) (see table 3 and Figure 12). It is observed that the level of adoption of the innovation is not affected (see Figure 30a) and the rate of adoption is linearly decreasing (see Figure 30b).

Figure 30. Influence of '*relevant existing skills and knowledge*' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question 13 is related to the *innovation awareness*. In that context, it allows evaluating if the target population is aware of the use and information related to the innovation in their area or if time will be needed in order to make them aware if it (CSIRO, 2017b). This question helps to obtain the value of *awareness score* along with the variable *observability* (Question 9) (see Figure 12). As the rest of the quadrant questions, the level of adoption of the innovation is not affected (see Figure 31a) and the rate of adoption is linearly decreasing (see Figure 31b).

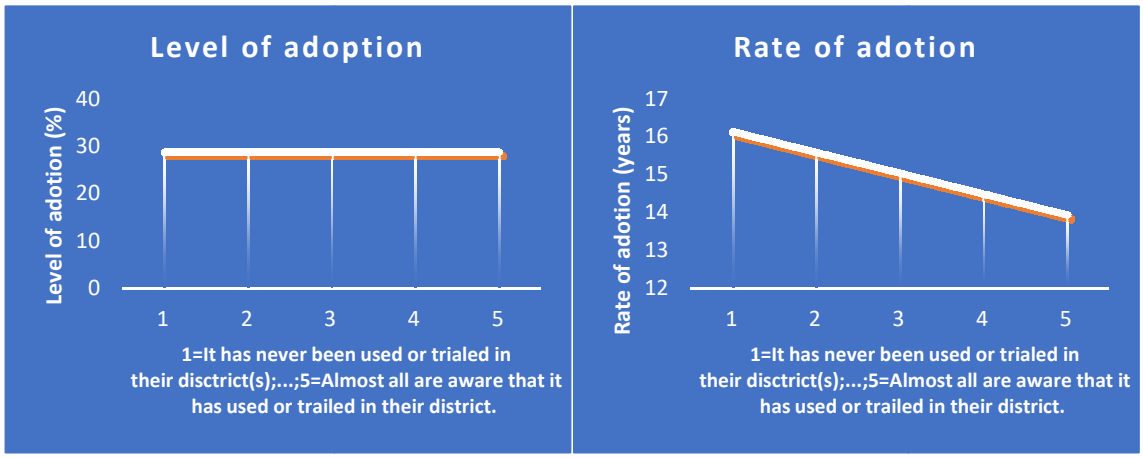

Figure 31. Influence of 'innovation awareness' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

3.7.4 Relative Advantage of the innovation.

This quadrant is the biggest one in the ADOPT scheme, all the questions as independent variables, are connected directly or indirectly to the intermediate equation *relative advantage.* As stated before, this dependent variable can affect as the *peak adoption* as the *time to peak adoption* values of the innovation assessed (see Figure 12). This section comprises the variables of *relative upfront cost of innovation* (Question 14), reversibility of innovation (Question 15), *profit benefit in the years that it is used* (Question 16), *future profit benefits* (Question 17), t*ime until any future profit benefit are likely to be realized* (Question 18), *environmental costs and benefits* (Question 19), *time to environmental benefits* (Question 20), *risk exposure* (Question 21) and *ease and convenience* (Question 22).

Table 9.Questions of the ADOPT software from Relative Advantage of the Innovation Quadrant.

Quadrant	Question (Variable to evaluate)	Question Associated (original)	Question Associated for NBSs
Relative Advantage of the Innovation Quadrant	**14.-Relative upfront cost of innovation**	Is it the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?	What is the size of the initial investment relative to the implementation of Green roofs?
	15.-Reversibility of Innovation	To what extent is the adoption of the innovation able to be reversed?	To what extent is the adoption of Green roofs able to be reversed?
	16.-Profit Benefit in years that it is used	To what extent is the use of the innovation likely to affect the profitability farm business in the years used?	To what extent is the use of Green roofs likely to affect the profitability of the target population (governments, private sector and/or property owners) in the years during its implementation and use?
	17.- Future profit benefit	To what Extend is the use of the innovation likely to have additional effects in the future profitability of the farm business?	To what extent is the use of Green roofs likely to have additional effects on the future profitability of the target population?
	18.-Time until any future profit benefits are likely to be realised	How long after the innovation is first adopted would it take for effects on future profitability to be realised?	How long after Green roofs are first adopted would it take for effects on future profitability to be realised?
	19.- Environmental costs and benefits	To what extent would the use of the innovation have net environmental benefits of costs	To what extent would the use of Green roofs have net environmental benefits or costs?
	20.-Time to environmental benefit	How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?	How long after the Green roofs are first adopted would it take for the expected environmental benefits or costs to be realised?
	21.-Risk exposure	To what extent the use of the innovation affects the net exposure of farm business risk?	To what extent would the use of Green roofs affect the net exposure of the owners' properties to risk?
	22.- Ease and convenience	To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?	To what extent would the use of Green roofs affect the ease and convenience of the management of the properties where they are applied, during the years that they are used?

Note: The description of the answers to each question were also changed on the basis of the application of ADOPT to NBSs. See Appendix F for the full description.

The Question 14 is referred to the *relative upfront costs* of the innovation. In this sense, the size of upfront investment when adopting an innovation could determine its rate of adoption (CSIRO,

2017b). This question is part of the intermediate equation called *investment costs*. It can be seen that the different answers affect the level of adoption in a linearly increasing way (see Figure 32a) and the rate of adoption is slightly linearly decreasing until the middle answer and then decreasing linearly again (see Figure 32b).

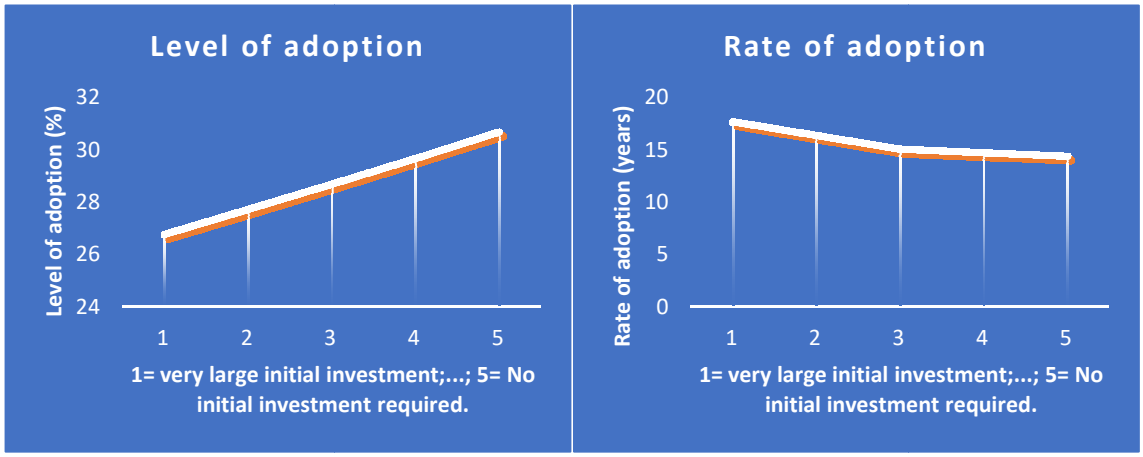

Figure 32. Influence of 'relative upfront cost of innovation' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

The *reversibility of the innovation* (Question 15), conforms the second part of the *investment cost* intermediate equation (see Figure 13). This variable affects the cost of adoption directly. Consequently, if an innovation is not able to be reversed when implemented it, it can create a lower rate of adoption, due to the fact that the decision of adopting it can limit any other future innovation in the target area (CSIRO, 2017b). It is observed that the level of adoption is linearly increasing (see Figure 33a) and the rate of adoption is linearly decreasing depending on the answer given (see Figure 33b).

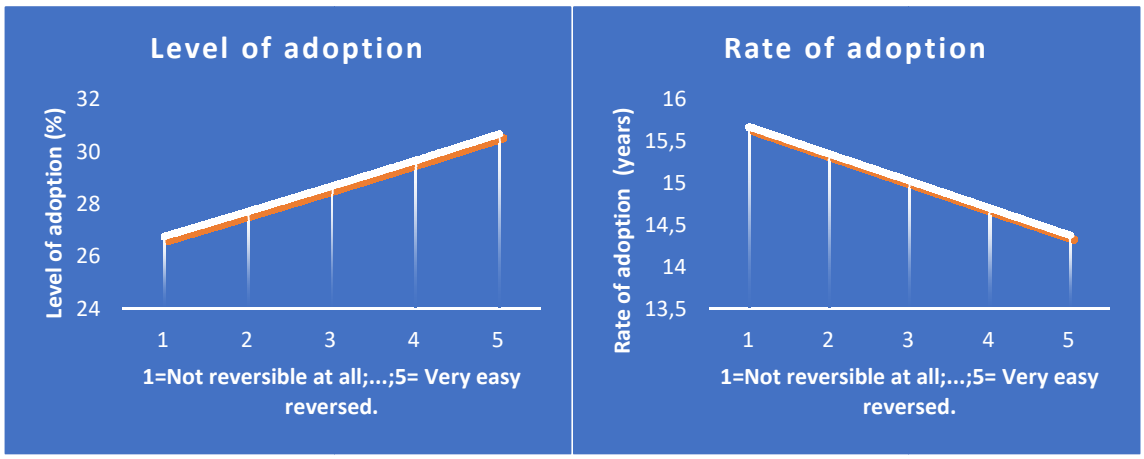

Figure 33. Influence of 'Reversibility of innovation' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question 16 is related to *profit benefits in years that it is used*. This variable is focused only on financial profit derived from the use of the innovation (CSIRO, 2017b). Moreover, this question conforms partially the intermediate equation *profit advantage*. It is noticeable that the level of adoption is exponentially increasing (see Figure 34a) and the rate of adoption is linearly decreasing depending on the answer given (see Figure 34b), it is important to notice that this question has eight different possible answers.

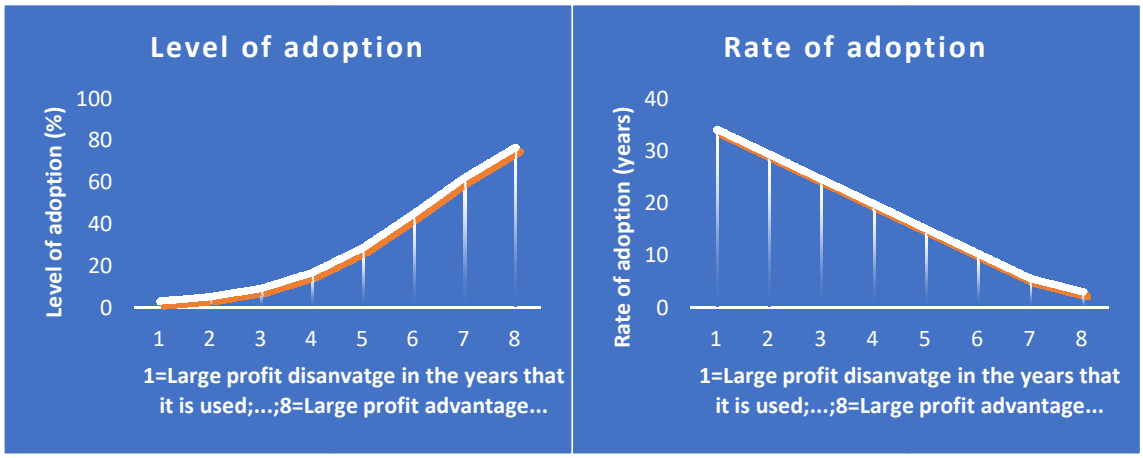

Figure 34. Influence of 'Profit benefit in the years that it is used' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question 17 is *future profit benefit*. This variable is related to innovations that offer profit or loss of profit after the time they have been used. If there is only profit during the time it is used, then there is not future profit benefit (CSIRO, 2017b). Along the eight different possible answers, it can be seen that the level of adoption is exponentially increasing (see Figure 35a) and the rate of adoption is linearly decreasing (see Figure 35b).

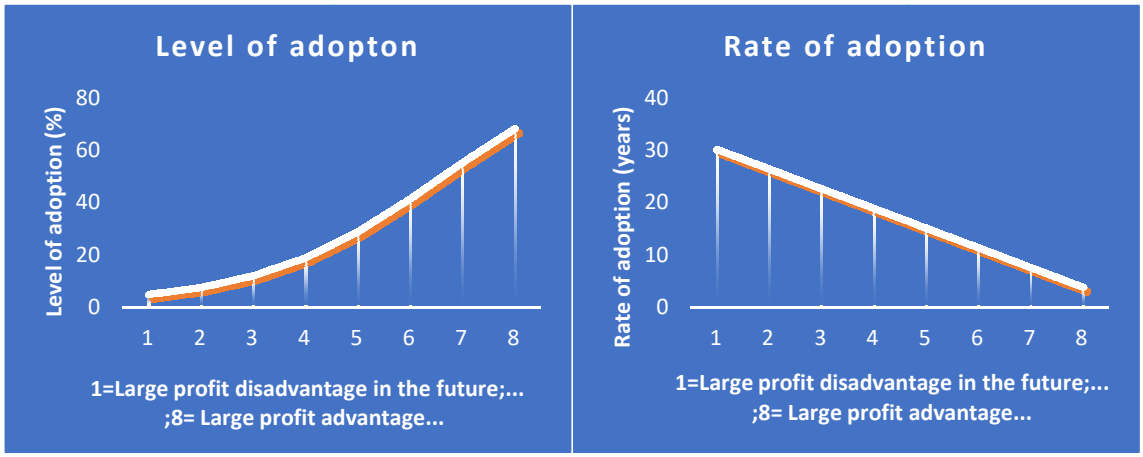

Figure 35. Influence of 'Future profit benefit' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

The question 18 is related to the *time until future profit benefits are likely to be realized.* It is directly related to the previous question, and it also influences the intermediate equation *profit advantage* (see Figure 13). The six different answers affect the level of adoption which is linearly increasing (see Figure 36a), and the rate of adoption is slightly exponentially decreasing (see Figure 36b).

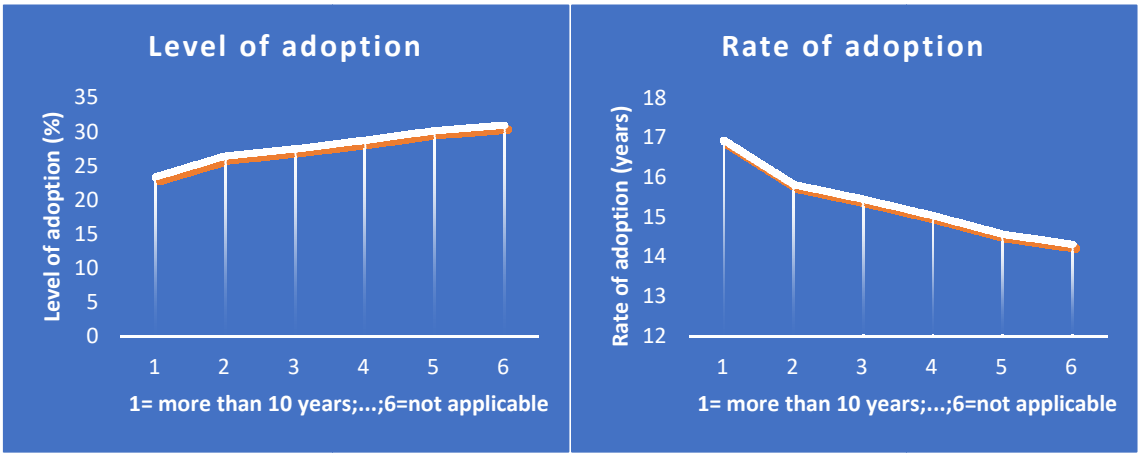

Figure 36. Influence of 'Time until any future profit benefits are likely to be realised' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

The variable *environmental costs and benefits* is represented in Question 19, and it has eight possible answers. The question evaluates the balance between these costs and benefits due to the adoption of the innovation, this variable is part of the *environmental advantage* intermediate equation (see Figure 13). It is observed that the level of adoption is exponentially increasing (see Figure 37a) and the rate of adoption is linearly decreasing (see Figure 37b).

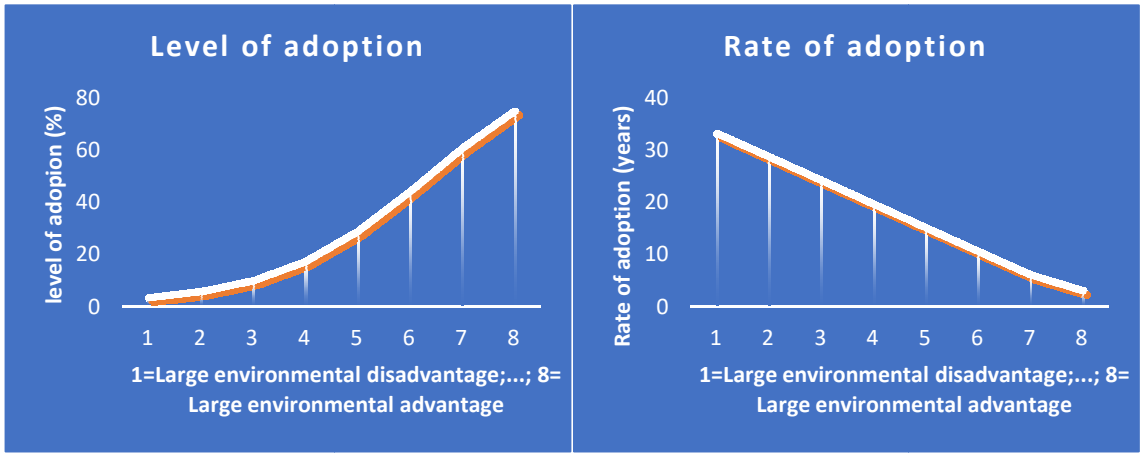

Figure 37. Influence of 'Environmental costs and benefits' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

The Question 20, is related to the *time to environmental benefit.* This variable is also part of the *environmental advantage* intermediate equation. This question assesses the time for the expected

environmental benefits from the innovation to be realized which are mentioned in Question 19 (CSIRO, 2017b). It is observed that the level of adoption is exponentially increasing (see Figure 38a) and the rate of adoption is slightly linearly decreasing (see Figure 38b).

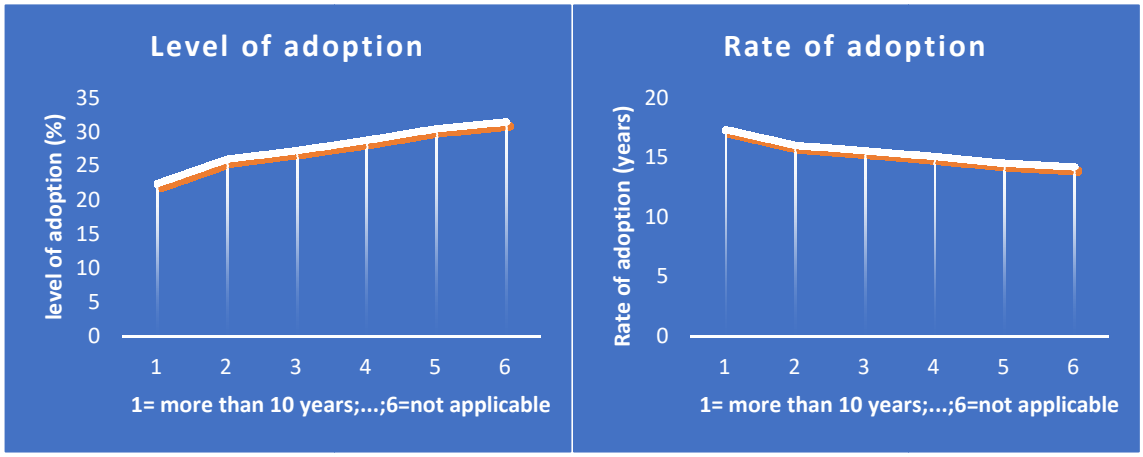

Figure 38. Influence of 'Time to environmental benefit' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question 21 shows the variable *risk exposure*, which analyzes if the adoption of the innovation could increase or decrease the risk exposure of the target population to uncertainty events or performance in the results. This question is one of the components of *the relative advantage* intermediate equation (see Figure 13). Along with the different eight responses, it is observed, that the level of adoption is exponentially increasing (see Figure 39a) and the rate of adoption is slightly linearly decreasing (see Figure 39b).

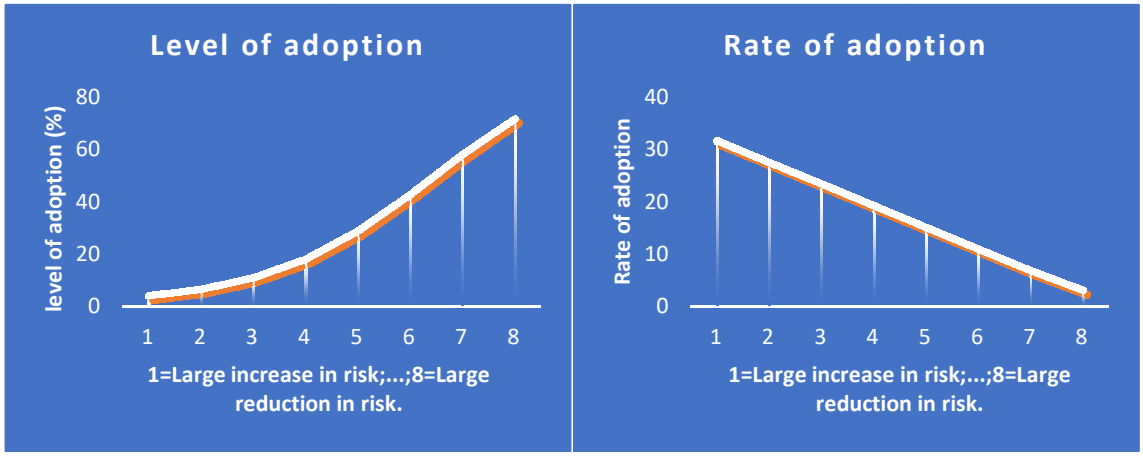

Figure 39. Influence of 'Risk Exposure' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

Question 22 is the last one of the survey, it evaluates the *ease and convenience* of the innovation, from a management perspective in the area where the innovation is adopted (CSIRO, 2017b). It

also affects the dependent variable *relative advantage*. It is observed that the level of adoption is exponentially increasing (see Figure 40a) and the rate of adoption is slightly linearly decreasing (see Figure 40b).

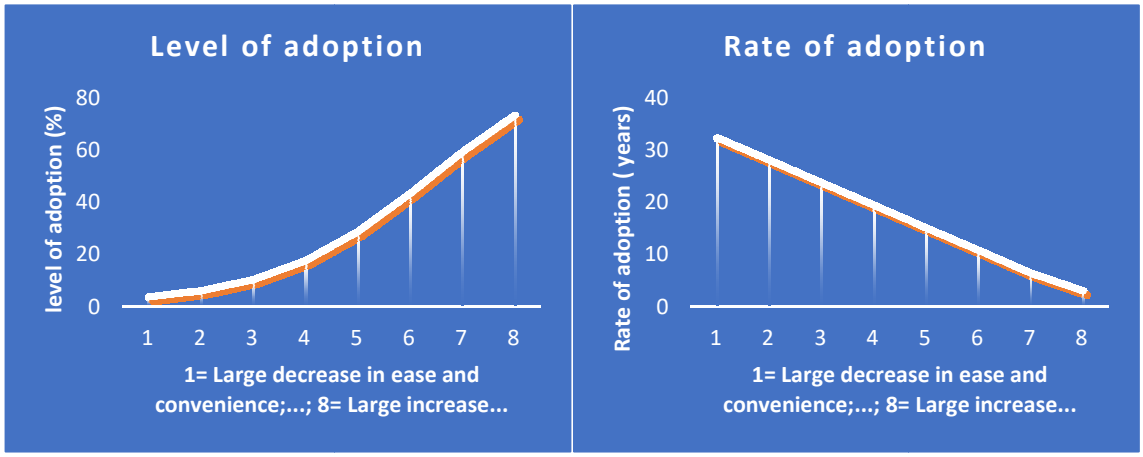

Figure 40. Influence of 'Ease and convenience' on the a) level (in %) and b) rate (in years) of adoption of the innovation.

4 Results

As it was explained in the last chapter, two workshops were performed in the city of Eindhoven. The first one with nine participants, all Ph.D. students of the *Technological University of Eindhoven* (Tu/e) with an urban planning and architecture background and the second one with seven members of the *Urban Planning Department* of the municipality. Both workshops with the objective of assessing the probability of adoption of *green roofs* in the city urban area. For this purpose, it was employed the methodology proposed in this thesis work and the ADOPT software version 2.1 (CSIRO, 2017b). The duration of the workshops was an average of two and a half hours per session (see Appendix E).

The data was divided into the analysis of the two rounds in the Tu/e and the two rounds with the municipality of Eindhoven. It is shown separately in the next sections.

4.1 Results from the first round in the Tu/e.

The following table shows the responses of each participant to the filling survey given (Appendix D) and the average answer per question.

Table 10. Answers are given per participant in the first workshop round (Tu/e).

Question	Participant:									Average rounded answer
	1	2	3	4	5	6	7	8	9	
1: Profit orientation	4	2	5	3	2	3	4	2	4	**3**
2: Environmental orientation	5	2	4	4	4	4	5	4	3	**4**
3: Risk orientation	2	5	3	3	3	3	3	3	3	**3**
4: Enterprise scale	4	5	4	2	5	2	4	4	4	**4**
5: Management horizon (discount rate)	2	2	3	3	2	4	2	4	4	**3**
6: Short term constraints	1	5	3	2	3	4	3	4	3	**3**
7: Trialling ease	5	3	3	4	5	3	5	4	4	**4**
8: Innovation complexity	3	1	2	3	3	3	1	3	3	**2**
9: Observability	1	4	3	3	3	5	4	5	4	**4**
10: Advisory support	3	2	1	2	3	4	5	2	4	**3**
11: Group involvement	2	4	1	4	4	3	4	3	3	**3**
12: Relevant existing skills & knowledge	2	1	2	1	2	4	1	4	2	**2**
13: Innovation awareness (practice)	3	5	2	3	2	4	4	4	3	**3**
14: Relative upfront cost of innovation	3	4	2	3	2	2	1	2	3	**2**
15: Reversibility of innovation	3	4	3	2	3	3	3	4	3	**3**
16: Profit benefit in years that it is used (profit benefit now)	4	5	5	5	7	3	6	2	6	**5**
17: Future profit benefit (profit benefit later)	6	6	5	7	7	6	5	3	7	**6**
18: Time until any future profit benefits are likely to be realized	3	3	4	2	3	4	4	4	4	**3**
19: Environmental costs & benefits	7	6	6	7	7	6	7	7	1	**6**
20: Time to environmental benefit	1	2	4	2	3	4	4	4	4	**3**
21: Risk exposure (effect)	6	4	3	3	5	3	4	3	6	**4**
22: Ease and convenience	6	3	3	4	3	2	3	2	3	**3**

With the information given, the level and rate of adoption of *green roofs* for the city of Eindhoven was calculated in ADOPT. For this round, there was a probability of 25% of peak adoption in about 18 years (see Table 11).

Table 11.Predicted Adoption levels, first round Tu/e.

Predicted peak level of adoption[1]	25%
Predicted years to peak adoption[2]	18
Predicted years to near-peak adoption[3]	14
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	8.3%
Predicted adoption level in 10 years from start	21.7%

NOTE: 1. The predictions of 'Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 2. The prediction of 'Time to Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 3. 'Time to Near Peak Adoption' represents the time to 95% of the maximum predicted adoption level (CSIRO, 2017b).

Figure 41, shows the curve of adoption graphically for the *green roofs* in the first round:

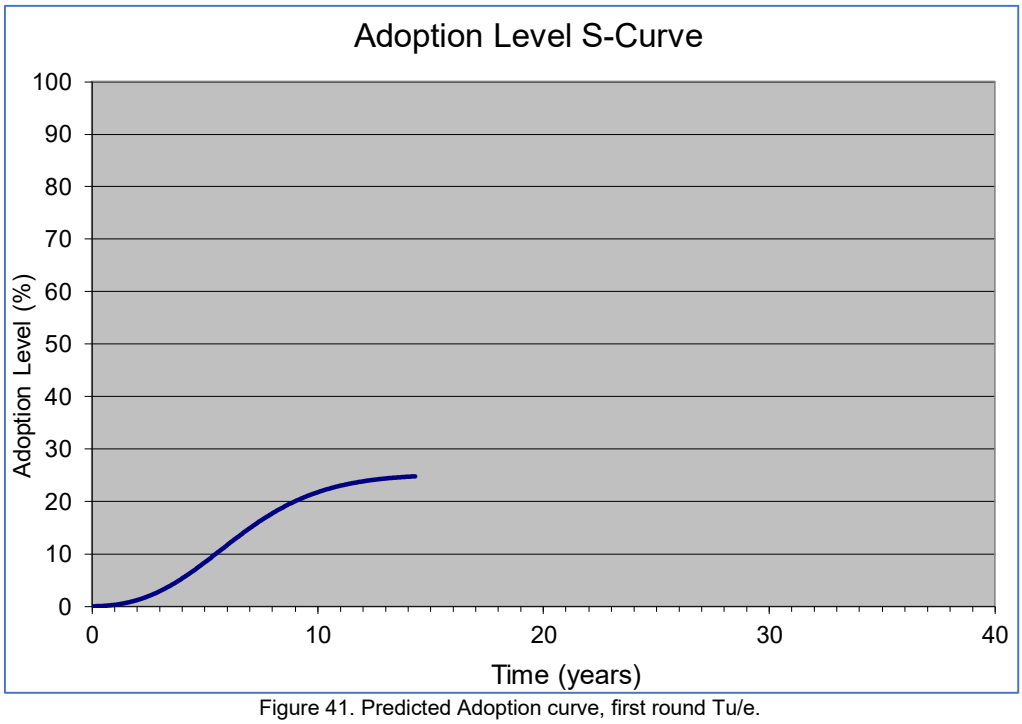

Figure 41. Predicted Adoption curve, first round Tu/e.

The next figures, show the sensitivity analysis of the adoption of *green roofs*, moved by possible changes in the individual answers per question. Regarding the level of adoption (see Figure 42), the variables with a possibility of improving it, if the perception improves are questions 1,2,4 and 5 for the first quadrant, none of the second and third quadrant, and due a change in the innovation design all the questions of the fourth quadrant (from 14 to 22). It is important to notice that the questions related to the design of the innovation are the ones with the biggest impact in a possible change, either positively or negatively. Specifically, Question 19, related to the *environmental benefits and costs* generated by the *green roofs*.

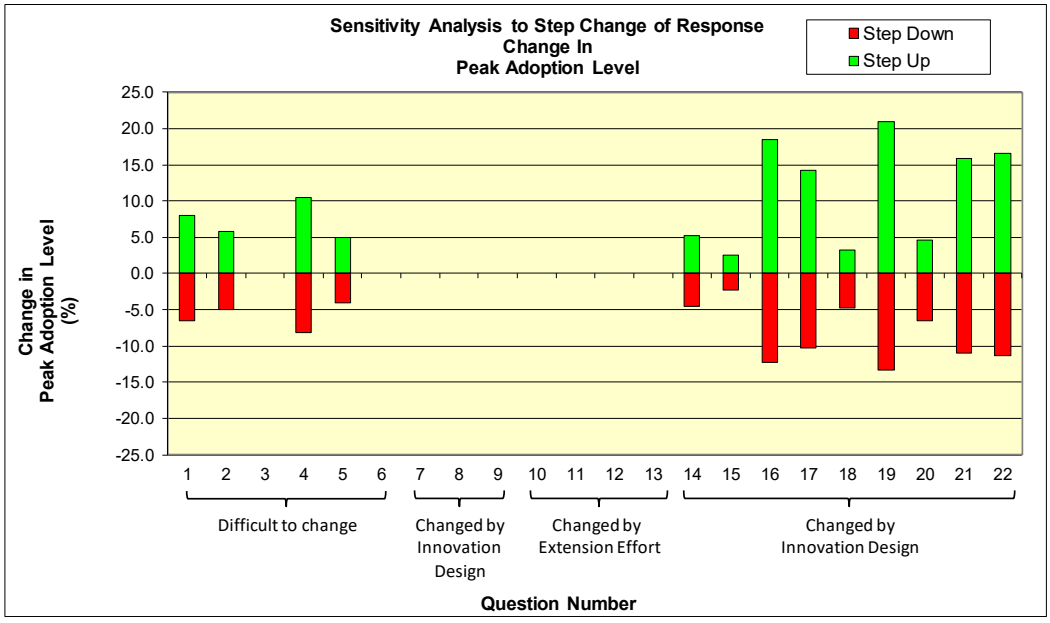

Figure 42. Peak adoption sensitivity analysis, first round Tu/first round Tu/e.

Respecting the time to peak adoption (see Figure 43) the questions with possible changes in the adoption rate, are from the first quadrant question 1,2,4,5 and 6, this last one on a larger scale. 7,8 and 9 in a significative way in the second quadrant. 10,11,12 and 13 in the third quadrant and 14,15,16,17,18,19,20,21 and 22 in the last quadrant. Changes in the *innovating design* and the *extension effort* for the promotion of the adoption of the innovation could change relevantly the rate of adoption, in that sense the Questions 7, 8 (which conform the *intermediate equation trialability of innovations*) and 12 (*relevant existing knowledge and skills*) are the ones with the bigger change potential.

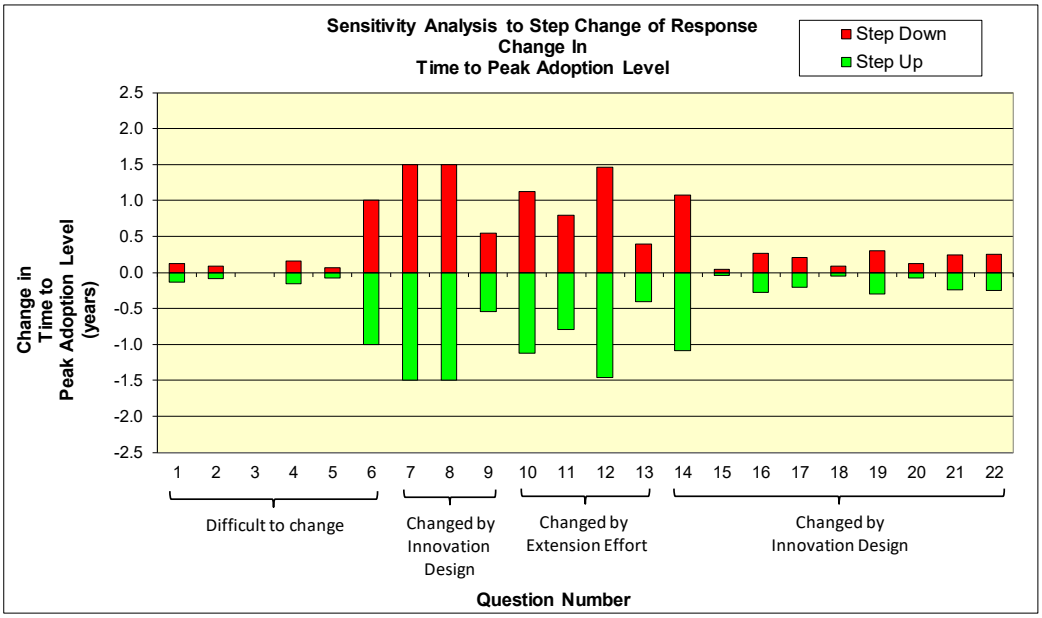

Figure 43. Time to peak adoption sensitivity analysis, first round Tu/e.

4.2 Results from the second round in the Tu/e.

The next table shows the answers given after making two discussion groups for the analysis of the survey. Each group had up to two minutes per analyzing each question (appendix D).

Table 12.Answers are given per participant in the second workshop round (Tu/e).

Question	Participant:									Average rounded answer
	1	2	3	4	5	6	7	8	9	
1: Profit orientation	4	3	5	3	2	3	3	3	3	**3**
2: Environmental orientation	4	2	4	4	4	4	2	2	2	**3**
3: Risk orientation	2	4	3	3	3	3	3	3	3	**3**
4: Enterprise scale	4	5	4	3	5	3	4	4	4	**4**
5: Management horizon (discount rate)	2	3	3	3	2	4	4	4	4	**3**
6: Short term constraints	2	4	3	2	3	2	3	3	3	**3**
7: Trialling ease	5	4	3	4	5	3	4	4	4	**4**
8: Innovation complexity	3	2	2	3	3	3	3	3	3	**3**
9: Observability	3	4	3	3	3	4	4	5	4	**4**
10: Advisory support	3	2	3	2	3	3	3	3	4	**3**
11: Group involvement	3	4	3	4	4	3	4	3	3	**3**
12: Relevant existing skills & knowledge	2	1	2	1	2	4	1	2	2	**2**
13: Innovation awareness (practice)	3	5	2	3	3	4	4	4	4	**4**
14: Relative upfront cost of innovation	3	3	2	3	2	2	2	2	2	**2**
15: Reversibility of innovation	3	4	3	3	3	3	3	4	3	**3**
16: Profit benefit in years that it is used (profit benefit now)	7	5	5	5	7	3	2	2	6	**5**
17: Future profit benefit (profit benefit later)	6	6	5	7	7	6	3	3	6	**5**
18: Time until any future profit benefits are likely to be realized	3	3	4	2	3	4	4	4	4	**3**
19: Environmental costs & benefits	7	6	6	7	7	6	7	7	1	**6**
20: Time to environmental benefit	2	2	4	3	3	4	4	4	4	**3**
21: Risk exposure (effect)	5	4	3	3	5	3	4	4	4	**4**
22: Ease and convenience	3	3	3	4	3	2	3	2	3	**3**

The table 13, shows the predicted level of adoption which is 12% in approximately 16 years.

Table 13.Predicted Adoption levels, second round Tu/e.

Predicted peak level of adoption[1]	12%
Predicted years to peak adoption[2]	16
Predicted years to near-peak adoption[3]	13
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	5%
Predicted adoption level in 10 years from start	11.1%

NOTE: 1. The predictions of 'Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 2. The prediction of 'Time to Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 3. 'Time to Near Peak Adoption' represents the time to 95% of the maximum predicted adoption level (CSIRO, 2017b).

Figure 43, shows the curve of *green roofs* adoption in Eindhoven, for the second round in the Tu/e.

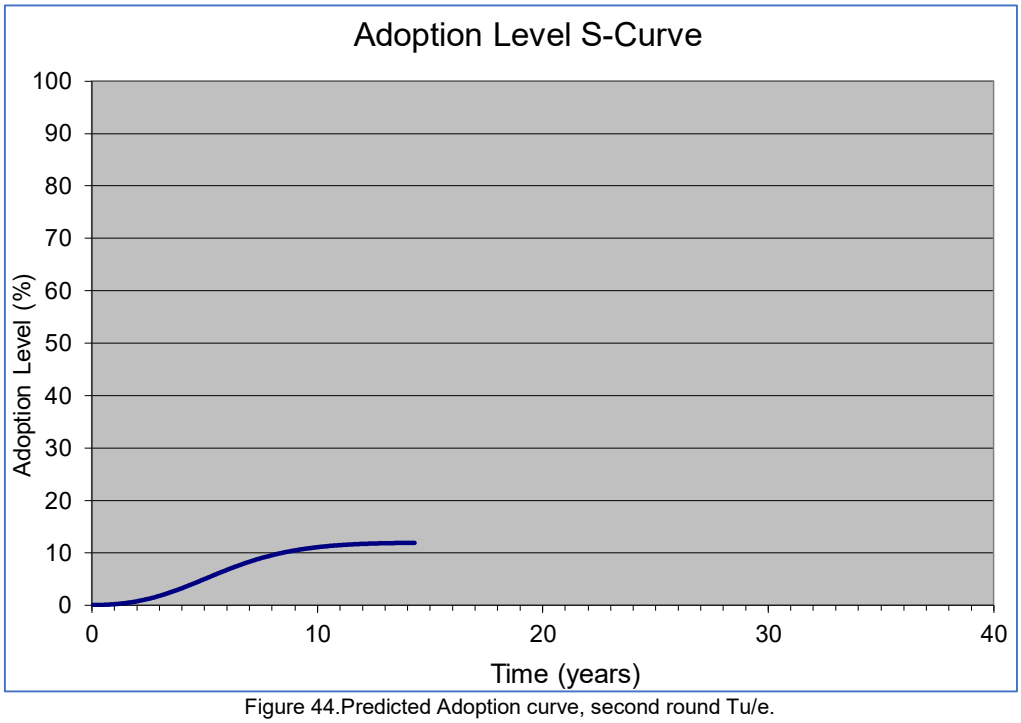

Figure 44.Predicted Adoption curve, second round Tu/e.

The sensitivity analysis in the second round of the Tu/e (Figure 45), showed that the variables with a possibility of improvement or decrement, are questions 1,2,4 and 5 for the first quadrant, none for the second and third quadrant, and all the questions of the fourth quadrant (from 14 to 22). It is

important to observe that the difference with the first round is the capacity for improvement in the questions. The independent variable *profit benefit in years that it is used,* which is the question 16 is the one with the biggest potential of change in the level of adoption.

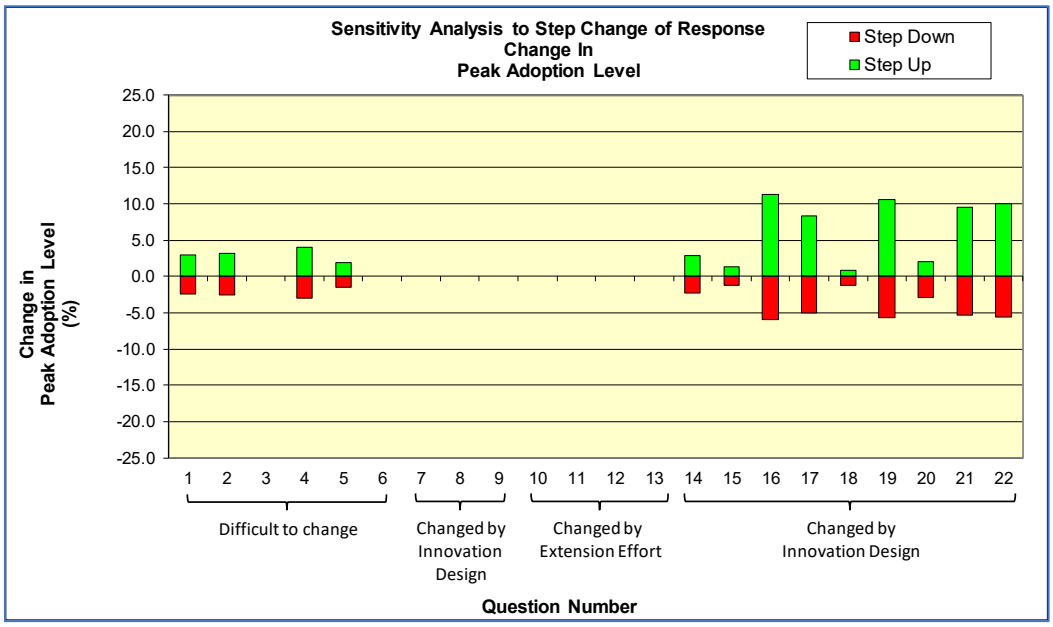

Figure 45. Peak adoption sensitivity analysis, second round Tu/first round Tu/e.

Similarly, to the first round, changes in the time to peak adoption (see Figure 46) are related to the questions 1,2,4,5 and 6 in the first quadrant and all the questions for the rest of the quadrants. The Question 7,8 and 12 are also the ones with the biggest potential for changing the rate of adoption.

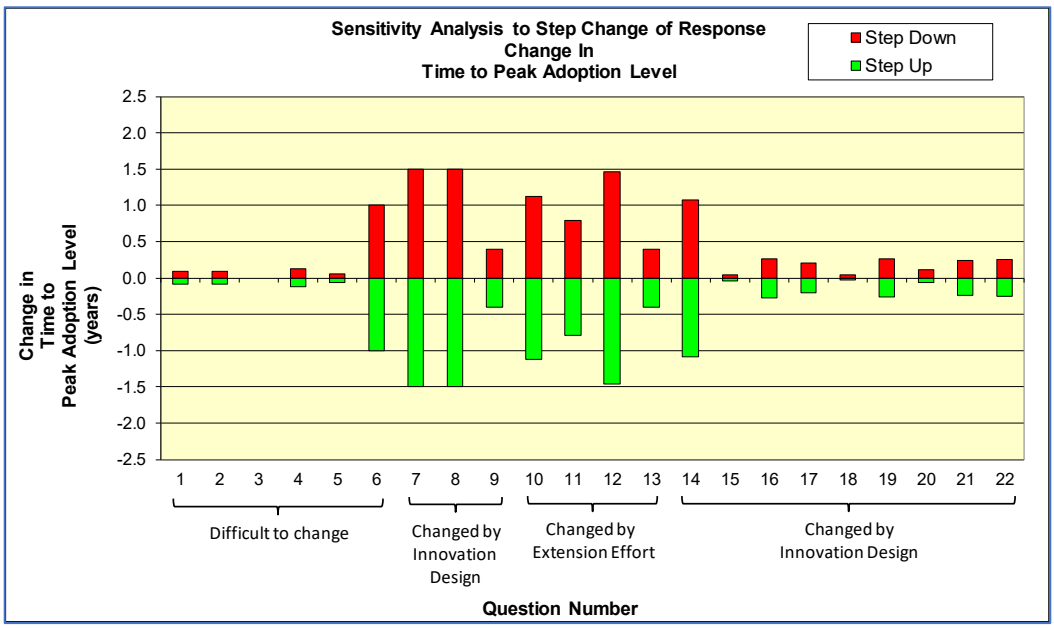

Figure 46. Time to peak adoption sensitivity analysis, second round Tu/e.

4.3 Question values that changed from round 1 to round 2 (Tu/e).

The average value of four questions changed between the first and the second round (see Table 14), the effect of this changes reduced the rate of adoption by 13%, but positively the perception in the rate of adoption was also reduced in the time to peak adoption by two years. It is also important to notice that even the questions in the sensitivity analysis are the same, the difference is on the potential of change in the curve of adoption because during the second round it was reduced considerably.

Table 14. Differences in responses between the first and second round Tu/e

Question	Total 1st round	Total 2nd round	Difference in the average result
2: Environmental orientation	4	3	-1
8: Innovation complexity	2	3	1
13: Innovation awareness (practice)	3	4	1
17: Future profit benefit (profit benefit later)	6	5	-1

4.4 Eindhoven Municipality first round:

The workshop with the personnel of the municipality of Eindhoven had seven participants from the planning department, and the setting was similar to one employed in the Tu/e. It is observed in Table 15, the answers given by the participants.

Table 15. Answers are given per participant in the first workshop round (Municipality of Eindhoven).

Question	Participant:							Average rounded answer
	1	2	3	4	5	6	7	
1: Profit orientation	3	2	4	2	3	3	3	3
2: Environmental orientation	2	3	3	5	2	2	2	3
3: Risk orientation	4	3	3	2	4	4	4	3
4: Enterprise scale	5	4	5	3	5	4	4	4
5: Management horizon (discount rate)	1	3	2	3	2	3	2	2
6: Short term constraints	3	3	2	4	4	3	3	3
7: Trialling ease	3	3	5	4	5	5	5	4
8: Innovation complexity	1	2	5	1	3	5	2	3
9: Observability	5	4	5	2	2	2	4	3
10: Advisory support	4	1	3	4	2	2	3	3
11: Group involvement	2	4	3	2	1	2	2	2
12: Relevant existing skills & knowledge	4	2	1	1	1	4	2	2
13: Innovation awareness (practice)	2	4	1	2	2	2	3	2
14: Relative upfront cost of innovation	3	2	2	2	1	3	2	2
15: Reversibility of innovation	2	3	4	2	3	5	4	3
16: Profit benefit in years that it is used (profit benefit now)	8	5	5	6	4	6	3	5
17: Future profit benefit (profit benefit later)	6	5	6	5	7	5	5	6
18: Time until any future profit benefits are likely to be realized	1	3	1	3	1	5	1	2
19: Environmental costs & benefits	7	6	7	7	7	6	7	7
20: Time to environmental benefit	5	3	3	3	5	5	3	4
21: Risk exposure (effect)	4	3	6	3	4	6	2	4
22: Ease and convenience	5	3	6	4	4	3	3	4

The first round gave, as a result, a scenario of 49% percent of adoption with 18 years to peak adoption (see Table 16).

Table 16. Predicted Adoption levels, first round Municipality of Eindhoven.

Predicted peak level of adoption[1]	49%
Predicted years to peak adoption[2]	18
Predicted years to near-peak adoption[3]	14
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	16.3%
Predicted adoption level in 10 years from start	42.6%

NOTE: 1. The predictions of 'Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 2. The prediction of 'Time to Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 3. 'Time to Near Peak Adoption' represents the time to 95% of the maximum predicted adoption level (CSIRO, 2017b).

A graphic description of these results can be seen in Figure 47.

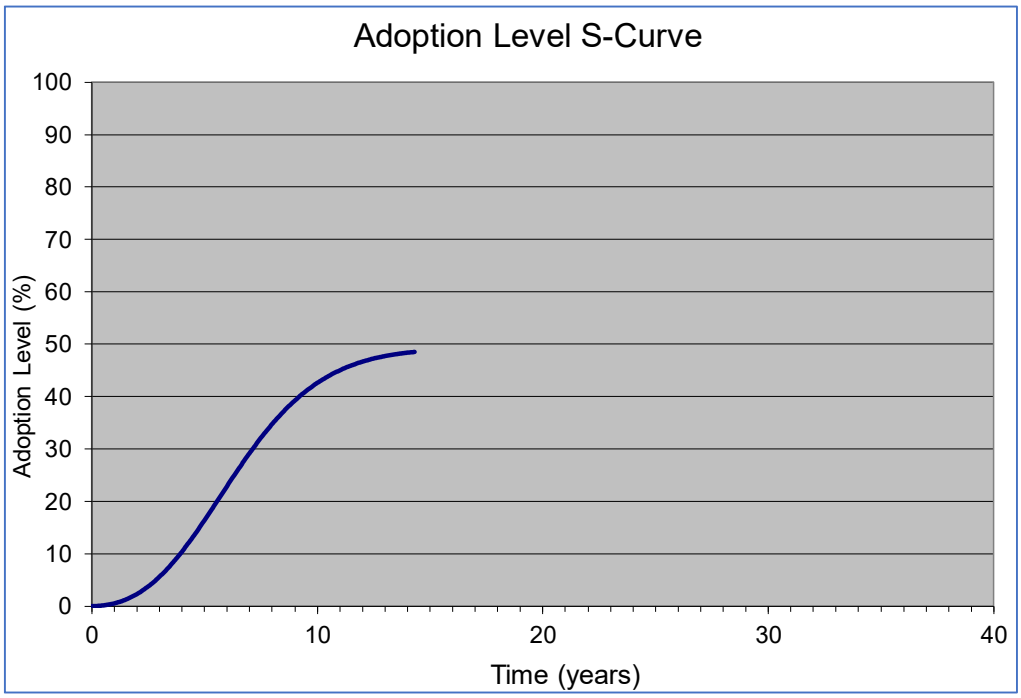

Figure 47. Predicted Adoption curve, first round Municipality of Eindhoven.

Regarding the sensitivity analysis of *green roofs* adoption (Figure 48). It is observed that just as with the Tu/e, in the workshop realized in the municipality the questions with the potential of generating a change in the level of adoption are the ones from the first and fourth quadrant except for the Question 3, and the quadrants two and three are neutral to any change. Question 16 and 19, have the most relevant impact and are related to the improvement of the *green roofs* as innovations.

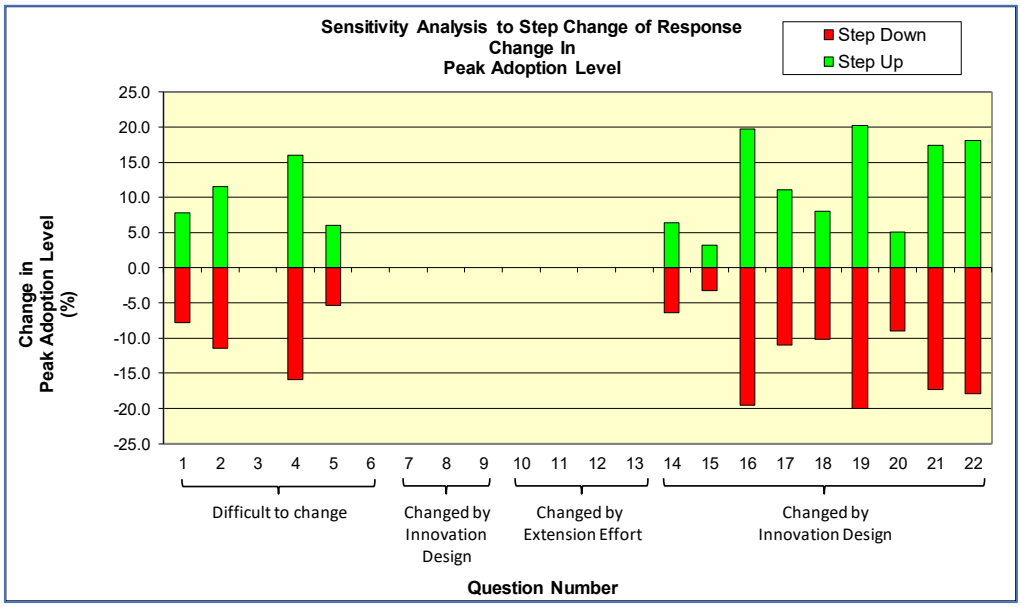

Figure 48. Peak adoption sensitivity analysis, first round Municipality of Eindhoven.

In the same sense, the time to peak adoption includes the potential to change in all the questions but the third one. The second and third quadrants, representing the *innovation design* and the *extension effort*, are the most relevant for changing the rate of adoption. The most relevant question is number 12, which is the independent variable e*xisting knowledge and skills* (see Figure 49).

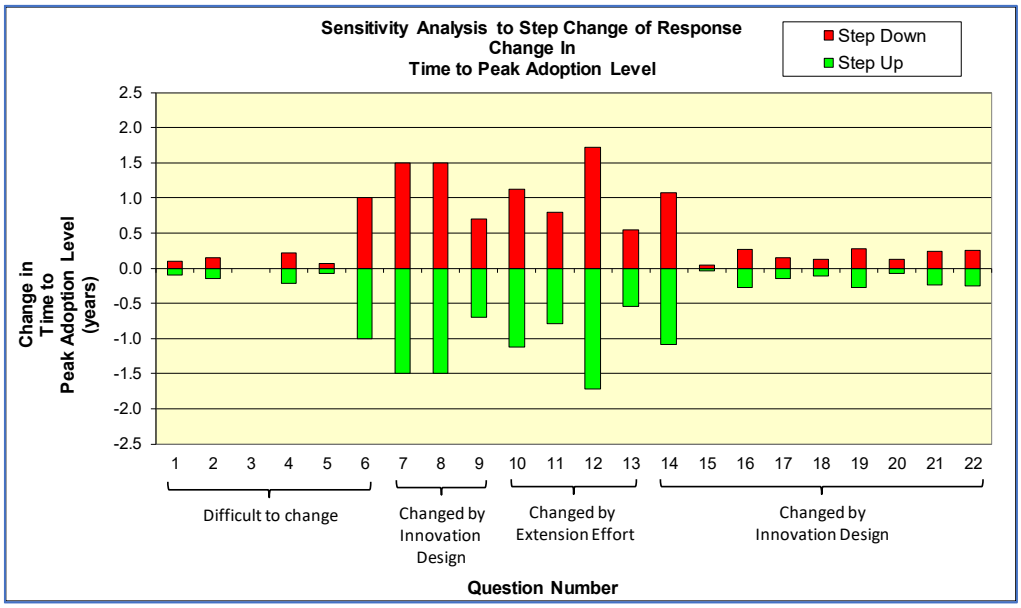

Figure 49. Time to peak adoption sensitivity analysis, first round Municipality of Eindhoven.

4.5 Eindhoven Municipality second round

After the discussion session in the groups conformed, a new series of results was generated it is shown in Table 7.

Table 17. Answers given per participant in the second workshop round (Municipality of Eindhoven).

Question	Participant:							Average rounded answer
	1	2	3	4	5	6	7	
1: Profit orientation	3	3	3	3	3	3	3	3
2: Environmental orientation	2	2	2	3	2	2	2	2
3: Risk orientation	4	4	4	4	4	4	4	4
4: Enterprise scale	5	4	5	5	5	4	4	5
5: Management horizon (discount rate)	2	3	2	2	2	3	3	2
6: Short term constraints	4	3	3	4	4	3	3	3
7: Trialling ease	3	5	5	4	4	5	5	4
8: Innovation complexity	3	5	5	2	3	5	5	4
9: Observability	5	3	5	2	3	3	3	3
10: Advisory support	2	2	3	2	2	2	2	2
11: Group involvement	2	2	1	2	1	2	2	2
12: Relevant existing skills & knowledge	1	2	1	1	1	2	2	1
13: Innovation awareness (practice)	2	2	2	2	2	2	2	2
14: Relative upfront cost of innovation	1	2	2	2	1	2	2	2
15: Reversibility of innovation	2	5	4	3	3	5	5	4
16: Profit benefit in years that it is used (profit benefit now)	8	4	5	5	4	4	4	5
17: Future profit benefit (profit benefit later)	6	5	6	6	7	5	5	6
18: Time until any future profit benefits are likely to be realized	1	6	1	1	1	6	6	3
19: Environmental costs & benefits	7	6	7	7	7	6	6	7
20: Time to environmental benefit	5	5	5	5	5	5	5	5
21: Risk exposure (effect)	4	3	4	4	4	3	3	4
22: Ease and convenience	5	3	5	4	5	3	3	4

As seen in Table 18, the rate of adoption after the second round in the municipality of Eindhoven, was of 68% with ta time to peak adoption of 19 years.

Table 18. Predicted Adoption levels, second round Municipality of Eindhoven.

Predicted peak level of adoption[1]	68%
Predicted years to peak adoption[2]	19
Predicted years to near-peak adoption[3]	15
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	20.4%
Predicted adoption level in 10 years from start	56.8%

NOTE: 1. The predictions of 'Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 2. The prediction of 'Time to Peak Adoption Level' is a numeric output that is provided to assist with insight and understanding and like any forecasts should be used with caution. 3. 'Time to Near Peak Adoption' represents the time to 95% of the maximum predicted adoption level (CSIRO, 2017b).

The adoption curve can be observed in Figure 50; it measures the level of adoption versus time of adoption.

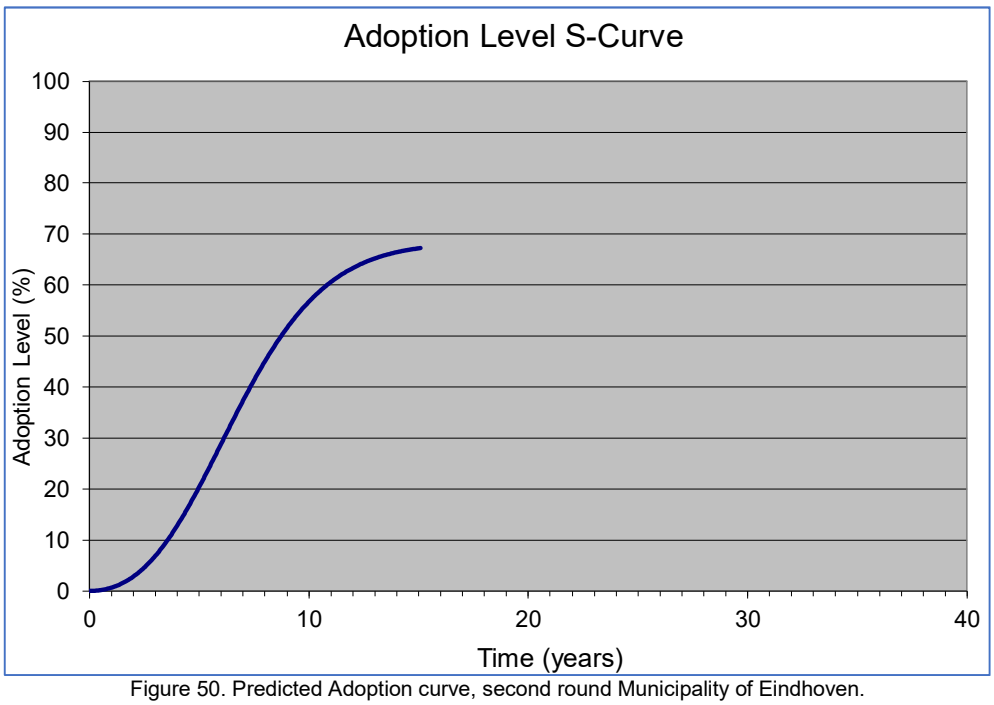

Figure 50. Predicted Adoption curve, second round Municipality of Eindhoven.

The peak adoption sensitivity analysis shows similar results with the questions tested in round one. (see Figure 51) However, the potential for change is different, question 16 (*profit benefit in years that it is used*) and 21 (risk *exposure*) are the ones with the most relevant change potential. It is relevant to point out that Question 4 can only generate negative impacts to the level of adoption if there is any change in the *enterprise scale* of adoption.

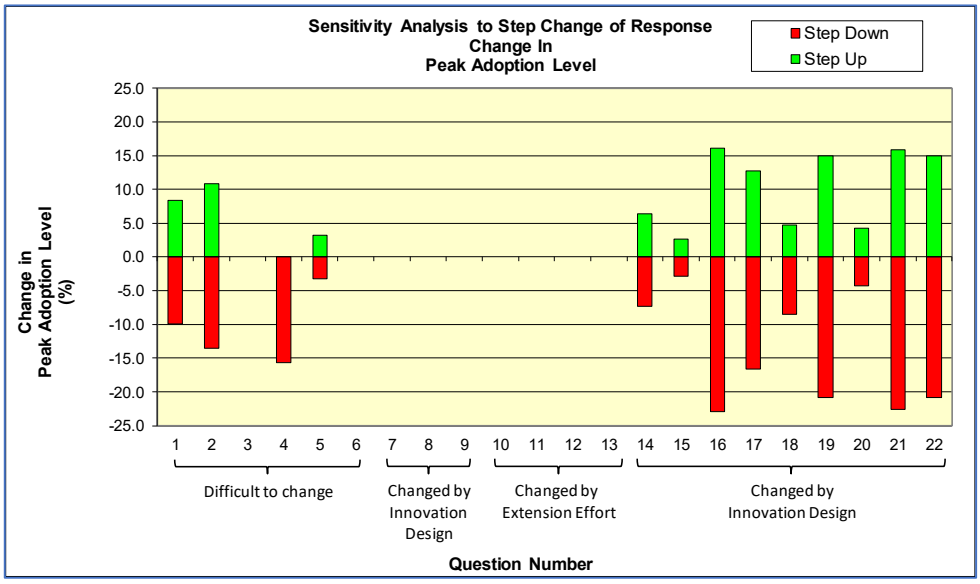

Figure 51. Peak adoption sensitivity analysis, second round Municipality of Eindhoven.

All the questions except for Question 3, generate some impact on the time to peak adoption according to the sensitive analysis. Figure 51, shows that Question 12 (relevant *existing skills & knowledge*) is the one with the biggest potential to make a change, in this case only a positive one (Figure 52).

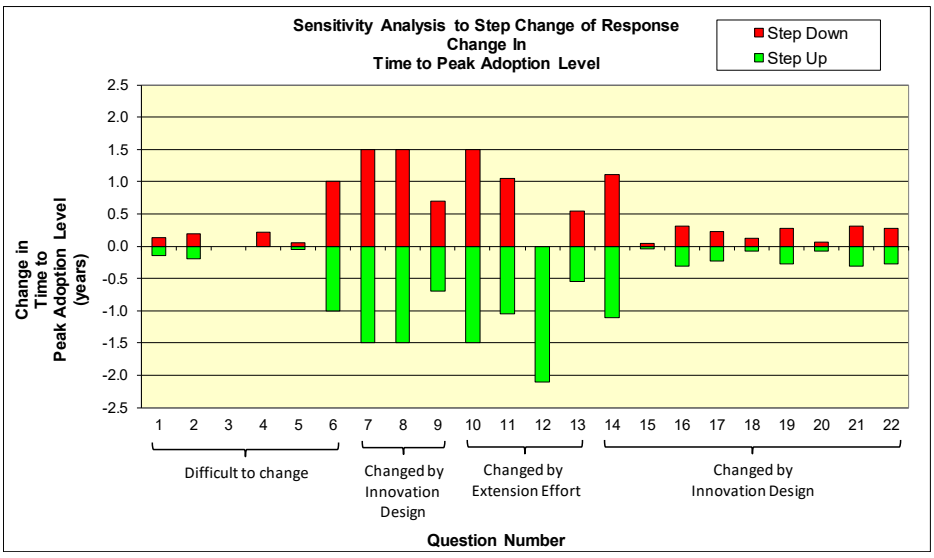

Figure 52. Time to peak adoption sensitivity analysis, second round Municipality of Eindhoven.

4.6 Question values that changed from round 1 to round 2 (Municipality of Eindhoven)

As shown in Table 19, nine questions changed after the second round of the workshop; the result was an increasing in the level of adoption by 19. On the other hand, the rate for adoption increased by one year. Another effect is a change in the potential of change in the sensitive analysis for the level of adoption and time to pea adoption.

Table 19. Differences in responses between the first and second round, Municipality of Eindhoven.

Question	Total 1st round	Total 2nd round	Difference in the average result
2: Environmental orientation	3	2	-1
3: Risk orientation	3	4	1
4: Enterprise scale	4	5	1
8: Innovation complexity	3	4	1
10: Advisory support	3	2	-1
12: Relevant existing skills & knowledge	2	1	-1
15: Reversibility of innovation	3	4	1
18: Time until any future profit benefits are likely to be realized	2	3	1
20: Time to environmental benefit	4	5	1

5 Discussion

The ADOPT transforms qualitive knowledge into quantitative scenarios that can help the decision makers to take better choices when investing in innovations for their communities, with a relatively fast result, being important for the resilience scheme in the urban areas. However, as part of an elicitation process, even with the use of equations and parameters for calculating the scenarios (CSIRO, 2017b), the use of this tool has a significative subjective element that could give results depending on the view of the stakeholders that participate in the process.

The experiment for the adaptation of ADOPT for the use of NBSs revealed two different views in the adoption of green roofs in the city of Eindhoven. Even when the time to peak adoption was slightly different (16 and 19 years respectively), the level of adoption in the first workshop gave a result of 12% of adoption and the second one 68%. In this sense, the results that the different workshops had, must be analyzed in their respective context. It is important to express that in the workshop realized in the Tu/e, the participants were all foreign people. In that sense, their opinion is the view for specialists that are outsiders to the city, and their perception of green roofs adoption is the result of their expectations with their knowledge of the city. On the other hand, the personnel interviewed in the municipality corresponds to participants that work from the public sector and are more related to the context and capabilities of the city from the local governments perspective.

The elicitation process resulted in a more inclusive exercise, allowing to reduce the degree of uncertainty when making decisions due to consensus generated (Aspinall, W., & Cooke, R. 2013). With the case study, it was confirmed that a change really happened in the individual answer of the participants after the ideas interchange for the adoption of green roofs in Eindhoven, and the result was the decreasing of the general perception of adoption (Tu/e workshop) or the increasing of it (Municipality of Eindhoven) depending on the stakeholders reunited.

In order to improve the methodology of the workshop setting and following the comments in the feedback survey (Appendix G). It was suggested to set the answers in the local language of the participants to make it easier to them to understand the content, in the same way making the question less technical was also a suggestion to reach a broader level of participants.

For future studies, it is recommended to involve an even more diverse group in the same workshop to have a complete answer and make a comparison of those scenarios with the separated scenarios created. In this case with the information generated, it is possible to make an average of the results of both workshops, giving a general value of 40% of adoption in 17 years for the city of Eindhoven. This type of result does not represent a negative or positive value. The case study

survey was broad, intending to show the potential of the whole city. But the adoption of NBSs such as *green roofs*, will depend in the intentions and planning of the decision makers, a project in a neighborhood could have an objective of 100% of adoption, but NBSs introduced to a bigger urban area such as the whole metropolitan area of the city could have a low level of adoption proportionally to the size of the urban area required, for instance, the creation of specific green or blue spaces for enhancing the resilience in strategic areas of the city.

It is important to say, that being NBSs a relatively new concept, in order to calibrate an adaptation of ADOPT for NBSs, it is important to continue with future comparison studies between the adoption of NBSs in the next years and the scenarios generated in the tool, this could give a higher rate of confidence in the results given.

Another aspect related to the use of ADOPT was the sensitive analysis of the answers. The recreation of the equations confirmed which quadrants in the survey were more related with the level of adoption and the time to peak adoption, which is the reason why in the sensitivity analysis the same questions where reacting to the different answers, the only difference was the potential of change in each question. This is also an important part of the tool. Because once the stakeholders have a result of adoption level and time to peak adoption, then they can identify in which of the 22 independent variables should put more effort in order to improve the probability of adoption and consequently the rate of success when implementing a new NBSs. Which could be improving the design of the innovation, making more extension effort (in the promotion of the implementation) or checking the orientation of the target population (which is difficult to change) .

This methodology could serve as a first filter to the decision makers in urban areas to differentiate projects related to NBSs, before taking an investment decision, an also promotes the citizen participation which allows having a better idea of the expectations and acceptance level of the population to the potential strategy.

6 Conclusions

Following the adoption and diffusion theory (Rogers, 1983, and Rogers 2003), the main factors that influence the adoption of innovations are related in general terms to the learnability and the relative advantage that the NBSs as a type of innovation could give in comparison with other types of infrastructure.

The ADOPT has a good potential for the assessment of the level of adoption of NBSs (it is important to remind that the use of the tool, will need the permission of the developers, along with the acceptance of the terms and conditions it has). However, taking into account that it is a scenario generator tool, it is essential to be cautious when reviewing the results. Since the scenarios do not represent an absolute truth but a prospection and are generated through an elicitation process that could be more or less subjective depending in the type of participants, this means that diverse participation is vital to have a more objective type of responses when analyzing a determined urban area.

Nevertheless, if it is considered as a pre-filter that gives the first approach to decision makers when thinking in adopting NBSs, the answers using ADOPT can give to the stakeholders a good idea on which type of NBSs could be easier to implement in a particular urban community. Also, to now which opportunity areas they should tackle for improving the rate of success when implementing them. Furthermore, the workshop setting methodology, it gives a fast track response; this makes ADOPT a practical tool for improving the rate of success when analyzing potential adoption of NBSs, saving time and resources for the NBSs promoters and enchasing the citizen participation in the decision making. The case study in Eindhoven represented the first approach in the use of this tool for NBSs along with the methodology proposed for assessing its potential.

Then, being ADOPT-NBSs an innovative implementation it is suggested for future studies to test the tool in more communities, also with different scales of projects, and in parallel, to follow the implementation of NBSs through the time, to generate a database that could strengthen the credibility and sharpness of the results given in the scenarios, and for possible tool calibration purposes.

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Appendix A

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Appendix B

Transcription of the original questions of ADOPT and detailed information about them

Question 1.

Profit orientation.

What proportion of the target population has maximizing profit as a strong motivation.

Possible answers:

Almost none have maximising profit as a strong motivation
A minority have maximising profit as a strong motivation
About a half have maximising profit as a strong motivation.
Almost all have maximising profit as a strong motivation.

More details.

- This question asks about the importance of profit maximisation to the target population and should be answered independent of the innovation.
- Farmers' profit orientation will typically be high for most commercial farming populations (the default response is therefore set to a majority). Profit orientation may be lower for some populations (hobby farmers for example).
- An innovation that has profit benefits will offer more relative advantage to a population with a high motivation for maximising profit than a population with a low motivation for maximising profit.

Profit orientation mediates the influence of other factors related to the profit expected to be gained from adopting the innovation. Achieving a profit is not the only motive of farm business decision-makers and sometimes not one of the primary motives for decision-makers. An instance where few landholders in a population have profit as a primary motivation are those areas with 'hobby'-sized farms that are supported by off-farm income. In most of Australia's commercial broadacre farming regions it could be assumed that profit maximisation is one of the farmers' primary motives. However, assuming that a farmer focuses on profit for its own sake can be a mistake because profit is often pursued for its role in enabling family goals such as family continuity (Pannell, et al., 2006).

It is not that family farms do not behave in a business-orientated way that sees them striving for profit, but that they are balancing competing influences so "rational decisions are made within a framework that embraces intrinsic values in farm work, the values of autonomy and family continuity as well as maximising profitability" (Gasson & Errington, 1993, p. 112).

Malcolm, Makeham et al. (2005) suggested that farmers seek to make a profit because they wish:

... to be able to improve and develop the farm so as not to have to work so hard in old age ... to acquire extra land or to control a larger business for the future and for heirs ... to have a reasonable but not profligate standard of living which compares reasonably with others in farming and society at large (p. 12).

Profit orientation is complicated and not always easily understood because, although in most cases, profit-maximization would be a prominent goal, the reasons that farmers seek to make a profit are varied and complex.

Question 2

Environmental orientation.

What proportion of the target population has protecting the natural environment as a strong motivation?

Possible answers.

Almost none have protection of the environment as a strong motivation
A minority have protection of the environment as a strong motivation.
About a half have protection of the environment as a strong motivation.
A majority have protection of the environment as a strong motivation.
Almost all have protection of the environment as a strong motivation.

More details.

- This question asks about the importance of environmental motivations (defined broadly so that they also include such things as animal ethics) to the target population independent of the innovation.

- For most commercial farming populations this will be moderately high (the default response is set to about half), but may be higher with populations who own land primarily with the intention of interacting with or improving the natural environment.
- An innovation that has environmental benefits will offer more relative advantage to a population with a high motivation for protection of the environment than a population with a low motivation for protection of the environment.

This question is intended to measure the proportion of the population who has a strong motivation to protect the environment through their management decisions. Although sustainable management of the natural resources of the farm are likely to be very important for a majority of farmers, some populations are likely to contain more people who care for the natural environment as a primary motive, than others. In some regions with less commercially oriented farm production, some target populations may have land managers who own land primarily with the intention of interacting with, or improving the natural environment. Environmental Orientation mediates the influence of the expected environmental impacts of the innovation, relative to other variables in the Relative Advantage quadrant such as Profit and Ease and convenience. A target population with a stronger environmental orientation is more likely to adopt an innovation that provides environmental benefits, even if it does not have profit benefits. In general, pro-conservation attitudes influence the decisions that farmers make about conservation (Lynne, Casey, Hodges, & Rahmani, 1995; Lynne, Shonkwiler, & Rola, 1988), but it is not always the case as:

Many environmental technologies often do not produce immediate financial gain; the perceived benefits (which sometimes may be of an ambiguous nature) accrue in the future. Given the observed importance of perceptions of profitability to farm decision-making, it is not surprising that more general positive environmental attitudes often do not translate into significant environmental behaviour (Cary & Wilkinson, 1997, p. 20).

Willock et al. (1999) also indicates that the influence of environmental orientation is not clear- cut, suggesting that:

... multiple attitudes influence both business and environmentally oriented behaviours, and that some of these attitudes influence behaviour directly, while others are mediated by objectives. Further, behaviour is to some extent influenced by farm structural variables (p. 298).

Like the Profit orientation question, the Environmental orientation question is not simple to understand. This is because people are favorably oriented towards the environment, but other problems and concerns can interfere with their underlying orientation.

Question 3.

Risk orientation

What proportion of the target population has risk minimisation as a strong motivation?

Possible answers:

Almost none have risk minimisation as a strong motivation (risk takers)
A minority have risk minimisation as a strong motivation.
About half have risk minimisation as a strong motivation.
A majority have risk minimisation as a strong motivation.
Almost all have risk minimisation as a strong motivation (risk averse)

More details.

- This question asks about the importance that the target population places on minimising risk. For a typical commercial farming population it is suggested that about half would have minimising risk as a strong motivation (this is the default response), which is intended to reflect studies that suggest the farmers, on average, express slight risk aversion.
- The orientation to risk minimisation may be lower for some populations (e.g. a sub-population of farmers aggressively aiming at high production). Similarly the orientation to risk minimisation may be higher for some populations (e.g. a population particularly known for conservative or traditional management).
- An innovation that minimises risks will offer more relative advantage to a population with a high motivation for risk minimisation than a population with a low motivation for risk minimisation.

This question seeks to uncover the target populations' attitude towards the type of farm business risk which is incurred to reach a particular economic goal in the future (Zaleskiewicz, 2001). Risk is the uncertainty of both negative and positive farm business outcomes, and includes the risk of farm business failure. Farmers vary widely in their tendency to take or avoid risks in their decision making. Risk aversion describes how much an individual avoids risks in their decision-making. The more risk-averse a landholder is, the more likely they will be to adopt an innovation that is

perceived to reduce risk or not to adopt an innovation that is perceived to increase risk. Most populations of farmers should have similar levels of risk aversion although it is commonly assumed that farmers tend toward slight risk aversion. This tendency to risk aversion is likely to occur because although risks do need to be taken in the pursuit of profit, they are felt by the farmer as something that is emotionally bad (Fuglie & Kascak, 2001; Zaleskiewicz, 2001). However, whether through socio-cultural factors or some interaction with environment, some populations or segments of populations are occasionally anecdotally referred to as highly 'conservative' while others are referred to as 'risk-takers'. Because the adoption of something novel usually involves exposure to greater levels of risk, this question focuses on quantifying one part of the distribution—the proportion deemed 'highly conservative' or highly risk averse. This question mediates the influence of the innovation characteristics associated with risk.

Because risk is derived from uncertainty, adoption can be delayed while the potential adopter seeks more information (Jensen, 1982). At its core risk is about farmers concerns, "that capital and other resources invested in adopting the technology will not produce any benefits" (Vanclay, 1992, p. 10). These benefits are not necessarily immediately experienced and can also include the loss of future earnings.

A risk-averse farmer might be motivated to engage in an unfamiliar and risky activity more than a risk neutral one, because of a decrease in future risks as a result of learning that, in turn, depends on present adoption decisions. This means that the greater the risk aversion of the farmer, the greater the appreciation of future declines in risk (Tsur, Sternberg, & Hochman, 1990). Risk aversion leads the decision maker to diversify to reduce undesired income risk. However, in the absence of uncertainty, or risk aversion, and in the absence of economies of scale associated with the innovation there will be no incentive to diversify (Feder & Umali, 1993).

Risk orientation is a question that determines the level of riskiness that the target population is prepared to accept. Mostly the target population will be slightly risk averse.

Question 4

Enterprise Scale.

What proportion of the target farms is there a major enterprise that could benefit from the innovation?

Possible answers.

Almost none of the target farms have a major enterprise that could benefit
A minority of the target farms have a major enterprise that could benefit
About half of the target farms have a major enterprise that could benefit
A majority of the target farms have a major enterprise that could benefit
Almost all of the target farms have a major enterprise that could benefit

More details.

- If very few in the target population make large amounts of hay and the innovation is a hay-making technology then the response should be 'almost none' or 'a minority'.
- If the innovation will benefit farm management in general (e.g. farm finance software) then the response should be 'a majority' or 'almost all'.

This question aims to define the number of farms among the target population who could benefit from adopting the innovation. A large enterprise scale will usually increase the overall attractiveness of adopting the innovation (Hoag, Ascough, & Frasier, 1999). The larger the property is, the easier it is to manage profitably, and the more resources are available for investing in new innovations (Cary, Webb, & Barr, 2002). Some innovations such as reducing seeding rates, or growing something in one place and not another will not require additional investment, however, it is the innovations that require additional investment where this question becomes more difficult to answer. Rogers (2003) suggests that the size of the organisation can be a de facto measure for such things as total resources, free resources and technical expertise.

The adoption of conservation tillage is significantly associated with farm size (Rahm & Huffman, 1984 ; Smit & Smithers, 1992) which could be because of economies of scale or the greater demand for labour-saving technologies on a larger farm (Fuglie, 1999). Much depends on the context because some larger farms are less likely to adopt conservation tillage. The reasons for this is that their land can be less suitable for crop growing and therefore less able to benefit from conservation tillage (Nowak, 1987).

Enterprise scale is important early in the diffusion process but is expected to becomes less so further into the process (Feder & Umali, 1993) as the innovation becomes more commonplace.

Farms smaller than a certain critical level are unlikely to adopt new innovations because of their fixed information costs. However this will not apply in the absence of uncertainty; that is when the innovation is more profitable than what it replaces and when the innovation is not affected by scale (Feder, Just, & Zilberman, 1985).
Enterprise scale influences adoption, not just by making the innovation relatively more affordable, but also because:
... larger farms need to collect less off-farm information to be persuaded to use a scale neutral innovation on a trial basis, and thus larger farms have a shorter evaluation-stage lag as well as a shorter discovery-stage lag (Feder, et al., 1985, p. 265).
Larger farm sizes could improve the scale of economies for information collection and assimilation, making adoption quicker (Lindner, Pardey, & Jarrett, 1982) but this is only when there is a scale bias embodied in the innovation (Lindner, 1987). An example is the purchase of a windrower to prepare canola for harvest, which would not be a justifiable purchase for an infrequent or small grower of canola. Scale bias is only likely to exist in the early stages of diffusion (Dong & Saha, 1998). During the intial stages of diffusion larger enterprises are likely to invest more in information gathering (Feder & Slade, 1984) which could be because they have greater access to financial and human capital.
Only considering information gathering as the reason why Enterprise Scale is important does not cover all the possible reasons that Enterprise Scale affects adoption. Geroski suggests that firm size is commonly used in diffusion studies and thought to be important because larger firms might; be more capable, benefit more from adopting the innovation, have a different attitude to risk and be less financially constrained (Geroski, 2000).
Clay, Reardon, & Kangasniemi (1998) found that the effect of farm size on adoption was ambiguous. Larger farmers had more spare land, were wealthier and could afford to hire labour and buy inputs for land improvements. Whereas small farmers tended to have more labour available per hectare and a greater incentive to improve their land as they depended on it more for an income, and therefore considered intensification a substitute for acquiring more land.

Question 5

Management Horizon.

What proportion of the target population has a long-term (greater than 10 years management horizon from their farms?

Possible answers.

Almost none have a long term management horizon
A minority have a long term management horizon
About a half have a long term management horizon
A majority have a long term management horizon
Almost all have a long term management horizon

More details.

- This affects the potential value of innovations that provide benefits (or costs) in the longer term.
- For a typical commercial broadacre farming population it is suggested that about half could have a long-term management horizon (the default is set at about half).
- For some populations it may be lower e.g. if their industry or region is under threat from external forces such as government reforms, climatic conditions or similar.

Although it is common in adoption studies to include the age of the grower as variable, this tool uses Management horizon instead. The question is included to identify the planning horizon of growers. It is probable that farmers (regardless of their age) who intend to manage the farm business for a longer period, or who have family members who wish to continue operating the business over the longer term, are more likely to consider innovations that require more time before benefits are fully realised, or a larger upfront investment of resources (and thereby more time for the investment to provide a return on costs) (Gasson & Errington, 1993). In those situations where family succession is less likely, landholders may be less likely to invest in adopting new innovations (Curtis, Lockwood, & MacKay, 2001).
The effect of this question on the outputs of the tool is weighted more heavily for innovations requiring a longer time for benefits to be realised or higher upfront costs in the form of capital and learning.
The Management horizon question is, in most cases, likely to be related to the stage of the farmer's career:

Stage in the lifecycle is therefore a complicated variable, but it demonstrates that there are many factors that are involved in decisions about adopting new management practices or new crops, and that adoption is not a simple process of communication (Vanclay, 2004, p. 214).
Older farmers, who are expected to have a shorter time to repay any investments, are less likely to invest in adoption of conservation measures, while corporate farms who are not driven by the complex goals of a family farm are more likely to make that investment (Featherstone & Goodwin, 1993).

Question 6

Short terms constraints.

What proportion of the target population is under conditions of severe financial constraints?

Possible answers:

Almost all currently have a severe short-term financial constraint.
A majority currently have a severe short term financial constraint.
About half currently have a severe short term financial constraint.
Almost none have a severe short term financial constraint.

More details.

- These constraints are temporary and only defer adoption for a short period.
- A high proportion may be affected if a region has been under drought conditions for example.
- For a standard commercial broadacre farming population experiencing 'normal' years it is suggested that almost none would be under conditions of short-term financial constraints.

This question is aimed at determining the proportion of the target population that may be less willing or able to make a capital investment because of their short-term capital constraints. These constraints are considered transitory, but when they are active they are extremely important; they are solved quickly and become immediately unimportant. If the constraint is because of the financial effect from a drought, it would be short-term and less important in the near future. This question has its greatest influence on the likelihood of rapid adoption in the short-term by delaying adoption by several years. It mostly affects adoption of innovations that involve a substantial up-front investment. Innovations with little cost to adopt will not be influenced by the target populations need to restrain spending.

Question 7

Triable.

How easily can the innovation (or significant components of it) be trialled limited basis before a decision is made to adopt it on a larger scale?

Possible answers:

Not trailable at all
Difficult to trial.
Moderately triable.
Easily triable.
Very easily trailable.

More details.

- This identifies whether the innovation can be trialled on a limited basis with low cost to allow some learning about its likely value.
- A new crop variety can usually be very easily trialled.
- A new rotary dairy is not trialable on the farm.
- A new whole-farm paddock layout cannot be easily trialled.

Trialing has two components; skill development and the reduction of uncertainty (Feder & Umali, 1993). Skill development happens by practising the use of the innovation and accumulating experience. Although skill development is an important component of learning about the innovation, it is not always possible (Tsur, et al., 1990). "Trialability is the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003, p. 258). If farmers cannot trial the innovation, so that they can easily and inexpensively gain knowledge and experience about the innovation under their farm conditions, the rate of adoption can be diminished (Pannell, et al., 2006). Differences in trialability exist between 'lumpy' (not divisible) and 'divisible' innovations (Hardin, 1976). Divisible innovations, those innovations that can be trialled on a smaller scale, will not be disadvantaged from being unable to be trialled.
For example a small area of the farm can be easily and inexpensively treated with a new herbicide, which means that the herbiicide is very easily trialable. It is, however, far more difficult or sometimes even impossible to trial a new 'lumpy' technology like a new farm dairy. Adding further

complications, it may be that an innovation is easy to try on a small scale, but that it is not easy to see whether it has had the desired effect on the small scale. The success of a trial of a new animal health treatment might be rapidly and easily observed. On the other hand, the establishment success of a tree plantation intended to reduce the spread of salinity can be observed within a couple of years, but judging the success of the trees in reducing the saline watertable may take a decade or more of monitoring. In this case the overall trialing of the innovation (trees to reduce on-farm salinity) is difficult to achieve. This question aims to measure how easy it is for farmers in the target population to conduct an on-farm trial to tell whether the innovation is likely to be a success.
Trialling is not just about establishing whether an innovation has been successful, but it is also about establishing whether there are disadvantages from adopting it. Nicholson et al. (2003, p. 693) suggest that "the value and importance producers place on being able to discuss the potential negative consequences of adopting a practice and the impact this has on the rate of adoption have not been widely recognised previously" but it is also about the "farmer's potential to learn about risk and reduce uncertainty through trialing the innovation" (Abadi Ghadim, Pannell, & Burton, 2005, p. 1). Skill improvement (dealt with, in part, in the Relevant Existing Skills and Knowledge question) is an important part of trialing and learning about an innovation (Abadi Ghadim, et al., 2005).
Trialing is an important part of the adoption process because after the trial the farmer adjusts the "scale either upwards towards full adoption or downwards towards disadoption as they gain knowledge and confidence in their perceptions about its performance" (Pannell, 2003).
This trial phase is important because:
If small-scale trials are not possible or not enlightening, the chances of widespread adoption are greatly diminished. This is because farmers will be very unlikely to leap to full-scale adoption due to the real risk that the innovation will prove a full-scale failure (Pannell, 2003, p. 69).
Skill development requires information gathering which is a staged process that culminates in trialing. Trialing can take place on or off the farm and is aimed at gathering information about the productivity of the innovation (Lindner, et al., 1982).

Question 8

Innovation complex

Does the complexity of the innovation allow effects of its use to be easily evaluated when it is used?

Possible answers.

Very difficult to evaluate effects of use due to complexity.
Difficult to evaluate effects of use due to complexity.
Moderately difficult to evaluate effects of use due to complexity.
Slightly difficult to evaluate effects of use due to complexity.
Not at all difficult to evaluate effects of use due to complexity.

More details.

- Changing herbicide types is a simple change that is not usually difficult to evaluate.
- Introducing livestock to a crop only farm could be a very complex change to the farming system with far ranging effects that are difficult to evaluate.

Rogers (2003) defines complexity as "the degree to which an innovation is perceived as relatively difficult to understand and use" (p. 257). This means that greater complexity increases the difficulty, required effort and time to learn about the innovation's performance and how best to implement it. With increasing complexity there is a need for more information, meaning that local advisory services become much more important (Llewellyn, 2007). For example a decision to change to a new herbicide or change wheat variety is likely to be a simple process—it is often just a substitution. Other innovations, because of their complexity, may require changes to different components of the farming system. Introducing livestock to what was a crop-only farm involves complex changes to components such as land management, crop rotations, infrastructure and labour management. Introducing precision agriculture and variable rate technologies with soil-specific mapping and data management is likely to involve complex changes which could constrain adoption.
Another important component of complexity is that it may need increased and ongoing attention to management, which also reduces the innovation's relative advantage. This part of complexity is mostly captured by the Ease and Convenience question from the Relative Advantage of the Innovation quadrant.
Innovation complexity is a multifaceted concept. Innovations may be complex not only in their biology, but also in their management, in their economic impacts and in the social attitudes and

perceptions that they generate. If an innovation is complex it means that there are more elements to it than in a simple system. There is more to learn about a complex innovation before the system can be competently managed, and there is therefore a greater chance of problems occurring (Pannell, 1999; Vanclay, 1992).
Complexity can make it difficult for the farmer to evaluate whether the innovation has been successful (Pannell, 1999).

Question 9

Observability.

To what extend would the innovation be observable to farmers who are yet to adopt it when it is used in their districts?

Possible answers.

Not observable at all
Difficult to observe
Moderately observable
Easy observable
Very easy observable

More details.

- Changing to no-tillage or windrow burning is easily observed.
- Using a new farm record keeping system is not easily observed by others.
- Variable rate fertiliser applications are not easily observed.

Rogers (2003) suggests "observability is the degree to which the results of an innovation are visible to others" (p. 258). Innovations with characteristics that allow the target population to easily observe and recognise whether it has, or is, being used by those around them will result in higher rate of adoption than otherwise. This question focuses on observation of the use of an innovation. Being able to observe and recognise the use of the innovation enables more rapid awareness of its existence and local use. For example an easily observable innovation is the adoption of direct-drill or no-till cropping to replace conventional tillage practices. Examples of innovations that are difficult to observe, or not observable at all, include the use of a new farm record-keeping system, decision-making process or financial risk management tools. The use of some technologies such as a new herbicide or high crop seeding rates are easy to observe, but rely on the target population being cognisant that the innovation is under trial before it can influence their adoption.
Concerned by early adoption studies that could only explain 50% or less of the variance of adoption Lindner, Pardey et al. (1982) suggested including previously unconsidered variables, such as location. They found that distance from the innovation (which is a crude and de facto measure of observability) was related to awareness of the innovation. Observability is less important for farmers with higher levels of education because they are likely to be better at information gathering. Shampine (1998) suggests that perfect observability leads to rapid learning about the innovation followed by rapid adoption whereas poor observability leads to an inability to learn about the innovation, and poor levels of adoption.

Question 10

Advisory support.

What proportion of the target population uses paid advisors capable of provide advice relevant to the innovation?

Possible answers.

Almost none use a relevant advisor.
A minority none use a relevant advisor.
About a half use a relevant advisor.
A majority use a relevant advisor.
Almost all use a relevant advisor.

More details.

- These are advisors relevant to the innovation and not advisors who provide over-the-counter advice.

Rapid adoption of some innovations, particularly those that are more information-intensive or complex, is associated with higher levels of on-farm advisory support and access to expertise (Llewellyn, 2007). This question uncovers how much the target population use advisors for advice relevant to the innovation. It is not asking about the use of advisors who are unrelated to the innovation, or those who provide predominantly 'over-the-counter' advice.

Question 11

Group Involvement.

What proportion of the target population participates in the farmer-based groups that discuss farming?

Possible answers.

Almost none are involved with a group that discusses farming.
A minority are involved with a group that discusses farming.
About half are involved with a group that discusses farming.
A majority are involved with a group that discusses farming.
Almost all are involved with a group that discusses farming.

More details.

- These are groups that are potentially relevant to the innovation.
- Greater involvement in groups that discuss farming can increase the rate of awareness and learning about new innovations.

This question is aimed at uncovering whether the target population are involved with at least one group that is relevant to the innovation. It is being used as an indication of farmers use of information networks potentially related to the innovation such as a local farming systems group involving crop-livestock farmers for a grazing-related innovation, as well as a defacto measure of their local learning and development capacity. A positive relationship has been found between farmers' membership of Landcare groups and their adoption of specific conservation practices (Cary et al. 2002; Curtis 1997; Curtis and De Lacy 1996; Mues et al. 1998) although the direction of causality is uncertain.

Question 12

Relevant existing skills and knowledge.

What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?

Possible answers.

Almost all need new skills and knowledge.
A majority need new skills and knowledge.
About half will need new skills and knowledge.
Almost none will need new skills or knowledge.

More details.

- Some target populations will require substantial new skills and knowledge before the full value of the innovation can be realised.
- Cropping farmers would not usually need substantial new skills to change to a new crop variety or fertiliser type, but cropping farmers may need new skills to change to more intensive livestock management.

This question is designed to capture whether potential adopters will need to spend time developing new skills and knowledge before they can gain the expected advantage from the innovation. Adopting an improved wheat variety or new herbicide is unlikely to require any substantial development of new skills and knowledge for a typical wheat grower. On the other hand adopting a precision agriculture technology such as variable rate technology probably requires substantial new skills and learning for the proportion of the population who have not gained experience in precision agriculture technology and data management. The Relevant Existing Skills and Knowledge question is aimed at establishing how much farmers existing knowledge is adequate for adopting the innovation. The complexity of the innovation will affect adoption speed because more complex innovations will often require users to undertake more training or skill development (Rogers 1995).

Question 13

Innovation awareness,

What proportion of the target population would be aware of the use of trailing or innovation in their district?

Possible answers.

It has never been used or trialed in their disctrict(s)
A minority are aware that it has used or trailed in their district.
About a half are aware that it has used or trailed in their district.
A majority are aware that it has used or trailed in their district.
Almost all are aware that it has used or trailed in their district.

More details.

- This question is about whether the target population is likely to recognise that an innovation, and information about it, exists in their district.
This question is intended to capture the target populations' existing awareness of the innovation and whether more time will be needed for the target population to become aware that the innovation exists and is suitable for their local environment. The location of the trial is important because farmers place more value on local trials that are applicable to them than on more remote trials (Marsh, et al., 2000).
Farmers do not need to be trialling the innovation themselves, they just need to be aware that it has or is being trialled. For example, just because they have good existing skills at growing a grain legume does not mean that they are aware of new varieties of grain legume that are soon to be released. Awareness matters to adoption because many innovations have long time lags while awareness develops. On the other hand some innovations, Bt cotton for example, have high levels of existing awareness, and unsatisfied demand, before they are available for adoption.
Awareness is one of the types of knowledge of an innovation that is a prerequisite for adoption (Rogers, 2003). But awareness is:
"... not just awareness that an innovation exists, but awareness that it is potentially of practical relevance to the farmer. Reaching this point of awareness is a trigger which prompts the farmer to open his or her ears and eyes—to begin noting and collecting information about the innovation in order to inform their decision about whether or not to go to the next step of trialing the innovation" (Pannell, 2003, p. 68).

Question 14

Relative upfront cost of innovation.

Is it the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?

Possible answers.

Very large initial investment
Large initial investment
Moderate initial investment
Minor initial investment
No initial investment required

More Details.

- Adopting a new annual animal health treatment requires little upfront investment but can generate a large benefit.
- Adopting a new design of cattleyard require a large upfront investment for a moderate benefit increase.
- Changing crop seeding date requires no upfront investment but can result in large benefits.
- If subsidies or incentives are provided they should be incorporated into your response.

The initial costs of the innovation, relative to the ongoing cost of using the innovation, may affect the rate of adoption (Rogers, 2003). Some innovations require high upfront costs compared with their financial returns; with benefits occurring sometime after the investment is made. For example adopting a new animal health product requires little upfront investment as the required quantities can be purchased for each use. On the other hand livestock handling infrastructure, such as a new design of cattleyard require a large upfront investment and only provide benefits from their use over time. Other innovations, such as changing a grazing strategy, may require no upfront investment. Innovations with higher up-front costs to adopt are perceived as riskier and are less likely to be adopted quickly (Vanclay, 1992).

Question 15

Reversibility of innovation.

To what extend is the adoption of the innovation able to be reversed?

Possible answers.

Not reversible at all
Difficult to reverse.
Moderately difficult to reverse.
Easily reversed.
Very Easily reversed.

More details.

- A different fungicide can easily be used if a newly adopted one fails; therefore it is easily reversed.

- The adoption of clay-spreading over non-wetting sands is not reversible at all.
- The planting of trees or shrubs is difficult to reverse, because they need to be removed and disposed of, taking time and money.

This question uncovers the reversibility of an innovation; a factor that influences the potential cost of adoption. An innovation that is unable to be reversed creates an opportunity cost because the decision to adopt makes it difficult to do something else at a later date. Irreversibility of an innovation can lead to slow rates of adoption (Baerenklau & Knapp, 2007). Most adoption investments, once made, have some degree of irreversibility. Often, the adoption of an innovation can very easily be reversed; for example, a different fungicide can easily be used if the newly adopted one fails. Reversing other adoption decisions can be difficult and costly, such as refencing for livestock after an earlier decision to remove all fences.

Reversibility is the degree to which, and the ease with which, the pre-innovation status quo can be reinstated. It will not always be possible to reverse the adoption of the innovation; for example the adoption of clay-spreading over non-wetting sands is not reversible.

Question 16

Profit benefit in years that it is used.

To what extent is the use of innovation likely to affect the profitability farm business in the years that it is used?

Possible answers.

Large profit disadvantage in years that it is used
Moderate profit disadvantage in years that it is used
Small profit disadvantage in the years that it is used
No profit advantage or disadvantage in the years that it is used
Small profit advantage in the years that it is used
Moderate profit advantage in the years that it is used.
Large profit advantage in the years that it is used.

More details.

- This question is only focused on financial profit; not on any other non-financial benefits.
- The next question asks about innovations that provide additional profit advantage other than just in the years after they are used.
- This question is focused on the profit (or loss) in the years that the innovation is used e.g. extra yield from a new crop variety, reduced labour costs due to new machinery.

Question 17

Future profit benefit.

To what extend is the use of the innovation likely to have additional effects in the future profitability of the farm business?

Possible answers.

Large profit disadvantage in the future
Moderate profit disadvantage in the future
Small profit disadvantage in the future
No profit advantage or disadvantage in the future
Small profit advantage in the future
Moderate profit advantage in the future
Large profit advantage in the future

More details.

- This question is for those innovations that offer profit (or loss) a long time after first use e.g. perennials for salinity prevention.
- A herbicide resistance or salinity prevention strategy may prevent future costs and therefore result in a future profit advantage.
- If the innovation only affects profit in the year it is used there should be no additional Future Profit Benefit.

This question is designed to gauge the profit to the overall farm business from the adoption of the innovation rather than seeking a per hectare or a gross margin figure. It aims to capture the typical expected profit benefit of an innovation once its profit benefits are being fully realised. The next question—Time to Profit Benefit—captures how long after first adoption those profit benefits are fully realised. This question is aimed at identifying the typical level of profitability that would be expected for a normal season. Risk and variability caused by extraordinary seasons is captured by other questions. Few innovations offer a large profit advantage to the farm business, however,

examples do exist such as the dramatic benefits obtained from applying trace element to soils discovered to be highly deficient (Kline, 1954). Often innovations will only offer a small profit advantage, but include other non-profit advantages. For example, a herbicide tolerant crop variety that replaces an established variety may not have large profit advantages but will provide greater management ease and convenience (see the Ease and Convenience question). Some innovations may not increase profit per hectare but may offer whole of farm profit advantages. For example adopting new seeding machinery allows more land to be cropped during years with favourable climate or high commodity prices. Some innovations are not profitable if a single year is considered, but will have substantial profit advantage at the whole-farm level due to flow-on effects. For example a new disease break-crop may not be as profitable as alternative crops but will increase the yield of subsequent wheat crops.

Because farmers maximise profit as much as they can within their constraints such as land and capital (Feder, et al., 1985), the time to adoption will usually be shorter if the innovation is more profitable (Lindner, Fischer, & Pardey, 1979). On the other hand farmers who do not know whether the innovation is profitable could be expected to delay adoption while they gather further information about the innovation (Jensen, 1982). Referring to the adoption of hybrid corn Griliches (1957, p. 522) states “where the profits from the innovation were large and clear cut, the changeover was very rapid ... In areas where profitability was lower the adjustment was also slower”. Others take a more holistic view seeing rates of adoption as related to the benefits that farmer receives with profit being just one part, but an important part, of those benefits (Lindner, 1987).

The adoption of some innovations have specific effects on farm profits. Whether this is important to the farmer and the farm business is determined by enterprise scale (see the Enterprise Scale question), the farmer’s management horizon (see the Management Horizon question), when the profit will be experienced (see the Time to Profit Benefit question), and the farmer’s orientation toward that profit (see the Profit Orientation question).

Question 18

Time until any future profit benefits are likely to be realised.

How long after the innovation is first adopted would it take for effects on future profitability to be realised?

Possible answers.

More than 10 years.
6 to 10 years
3 to 5 years
1 to 2 years
Immediately
Not applicable

More details.

- The response to this question influences the value of the Future Profit Benefit from the previous question.
- For example Future Profit Benefits that take more than ten years to be realised are worth less in current terms than future profit that is realised more quickly.
- Profit Benefits that are gained quickly (see question 16) are not discounted.
- Future Profit Benefit, such as salinity prevention, that is expected in ten years time is converted to an approximate present value through discounting.

This question aims to capture the expected time delay before the future profit benefits measured by the previous question are achieved. The longer it takes to receive profit benefits the lower the net present value of those profits. Landholders who need to focus on profits in the short-term are less likely to adopt innovations with long time to profit benefits. This question mediates the profit benefit response.

Question 19

Environmental costs and benefits.

To what extend would the use of the innovation have net environmental benefits costs.

Possible answers.

Large environmental disadvantage.
Moderate environmental disadvantage.
Small environmental disadvantage.
No net environmental effects.

Small environmental advantage.
Moderate environmental advantage.
Large environmental advantage.

More details.

- This question is not only focused on environmental costs and benefits but could also include allied non-profit concerns such as animal ethics issues.

This question aims to uncover the environmental costs and benefits of adopting the innovation. For example improvements to soil structure would be expected after the adoption of no-till cropping. Illustrating how farmers are not only motivated by profit, unprofitable conservation practices have been adopted by many landholders, encouraged in part by government programs such as Landcare and the Natural Heritage Trust (Pannell & Roberts, 2010).

Question 20

Time to environmental benefit.

How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?

Possible answers.

More than 10 years.
6 to 10 years
3 to 5 years
1 to 2 years
Immediately
Not applicable

More details.

- This question is used to discount the response to the previous question Environmental Costs and Benefits.
- For example the environmental advantages of a tree plantation may take many years to become evident but may be almost immediate for the adoption of no-tillage.

This question aims to capture the expected time delay before the anticipated environmental benefits identified in the previous question are achieved. If environmental payoffs are expected to occur too far into the future, no matter what those payoffs are they will have less current value. For example the success of ameliorative responses to land degradation problems such as dryland salinity, soil acidification, and decline of remnant native vegetation are often long-term, even occurring over decades. The adoption of environmentally beneficial activities such as these often suffer from the problems of high up-front costs and delayed benefits.

The response to this question weights the influence of any environmental benefit identified in the previous question.

Question 21

Risk Exposure.

To what extend would the use of the innovation affect the net exposure of the farm business to risk.

Possible answers

Large increase in risk
Moderate increase in risk
Small increase in risk.
No increase in risk.
Small reduction in risk.
Moderate Reduction in risk.
Large reduction in risk.

More details.

- This question identifies whether the innovation reduces the possibility of the farm business experiencing years of poor performance.
- The adoption of farm insurance reduces exposure of the farm business to risk while the adoption of an innovation requiring higher input costs may increase risk.

This question identifies whether the innovation reduces the possibility of the farm business experiencing years of poor performance. For example a new crop or pasture choice that is more drought tolerant—but not higher yielding—may reduce exposure to downside risk. Some innovations are purely designed to reduce downside risk rather than increase average profit, such as the adoption of crop insurance designed to cover previously uninsured weather related risks. Adoption of anything new is likely to involve some level of risk; however, some innovations are

more likely to expose the farm business to risk of financial failure than others. An example might be an innovation that requires a market to be developed before it can be successful, such as planting trees with the intention of selling carbon credits.
Other components of risk relating to adoption are the variability in performance across seasons that make observation of the 'typical long-term' benefits difficult to assess in a short-period. In this tool, this has also been partly captured by the Trialability concept which reduces uncertainty and therefore risk (Abadi Ghadim, et al., 2005; Marra, Pannell, & Abadi Ghadim, 2003).

Question 22

Ease and convenience.

To what extend would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?

Possible answers.

Large decrease in ease and convenience.
Moderate decrease in ease and convenience.
Small decrease in ease and convenience.
No decrease in ease and convenience.
Small increase in ease and convenience.
Moderate increase in ease and convenience.
Large increase in ease and convenience.

More details.

- This question measures changes to the ease, convenience and management demands on the farm that may result from adopting the innovation.
- Some innovations that offer ease and convenience benefits are pesticide tolerant crops, tractor autosteer, irrigation sensors, while other such as intensive cell grazing greatly increase management demands and inconvenience.

Some innovations do not increase financial or environmental gains, but their value is in improving the ease with which some farming activities can be performed as well as potentially providing lifestyle benefits. This question is aimed at identifying these non-pecuniary costs and benefits. An innovation that increases ease and convenience on cropping farms is the adoption of auto-steering in tractors and harvesters. While it does have a profit benefit through enabling more accurate operations its main advantage is the lifestyle benefit of less driver fatigue. Herbicide tolerant crops such as bromoxynil-tolerant, and Bt and Roundup-ready cotton, even though not always increasing gross margins, were quickly adopted because reduced complexity of insect or weed management resulted in a change to the farmers ease and convenience (Carpenter & Gianessi, 2000). Improving ease and convenience can add substantial value to a farm business. On the other hand, an innovation that introduces more management demands, such as more intense livestock management over the summer holiday period, or a change to irrigation scheduling that requires irrigation management through the night, reduces ease and convenience and is therefore less likely to be adopted.

Appendix C

Implicit Consent Letter

Date: Location:

_____

Dear Participant,

You are invited to participate in a study for measuring the factors that determine the adoption and diffusion of Nature Based Solutions (NBS) in the city of Eindhoven, Netherlands. Conducted by researchers of the UNaLAb project from the University of Aveiro. It is expected to learn about the level and time of adoption of green roofs in established urban areas of the city. The group of participants was proposed from three different types of areas related to the city and the NBS (Government, academia and local residents), in order to have a diverse and inclusive view regarding the study.

If you decide to participate, please complete the attached survey as part of the workshop activities. Your return of this survey is implied consent. The survey is designed to evaluate different questions regarding the relative advantage for the population due the adoption of green roofs, its learnability characteristics, learnability of the population and the relative advantage of green roofs as a NBS. The participatory workshop including the filling of the survey will take about two hours. No benefits accrue to you for answering the survey, but your responses will help and be used to create a virtual scenario for the assessment of the level of adoption of this NBS. Any discomfort or inconvenience to you derives only from the amount of time taken to complete the activities during the participatory workshop.

The results of this research will be presented at the University of Aveiro as part of the results of an academic thesis, along with possible reports regarding the UNaLab project activities. While individual responses will be kept in the strictest confidence, aggregate data will be presented representing averages or generalizations about the responses as a whole. No identifiable information will be collected from the participant and no identifiable responses will be presented in the final form of this study. All data will be stored in a secure location accessible only to the researchers coordinating this workshop. The researcher retains the right to use and publish non-identifiable data.

Your decision whether or not to participate will not prejudice your future relationships with the University of Aveiro or the UNaLab project. If you decide to participate, you are free to discontinue participation at any time without prejudice.

If you have any questions, please ask. If you have additional questions later, contact:

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+355912813412
Master student in Environmental Studies - Cities & Sustainability, University of Aveiro.

Thank you for your time.

Sincerely,

UNaLab Team, University of Aveiro.

Appendix D

FILLING SURVEY

Date:
Location: Eindhoven, Netherlands.
Participant origin/department:_____

1. Answer sheet.

1.i. Write-down individual answers to each question in the *1st answer* column. (<1 minute).

2.ii.Create groups of at least 3 people from different backgrounds, departments, etc.

3.iii.Discuss each question in group and write-down individual answers in the *2nd answer* column. (<2 minutes).

4.iv.At the end of the activity return the feedback form to workshop organizers.

Question	Question Associated	Range of possible answer from lower (-) to higher (+).	1st Answer	Reasoning for the answer	2nd Answer	Reasoning for the answer
1. Profit/utility orientation.	What proportion of the target population (governments, private sector and/or property owners) has maximizing profit/utility as a strong motivation for implementing Green roofs?	1 to 5				
2. Environmental orientation.	What proportion of the target population (governments, private sector and/or property owners) has protecting the natural environment as a strong motivation for implementing Green roofs?	1 to 5				
3. Risk orientation	What proportion of the target population (governments, private sector and/or property owners) has risk minimisation as a strong motivation for implementing Green roofs?	1 to 5				
4. Enterprise scale.	What proportion of the target population (governments, private sector and/or property owners) could benefit from the Green roofs?	1 to 5				

Question	Question Associated	Range of possible answer from lower (-) to higher (+).	1st Answer	Reasoning for the answer	2nd Answer	Reasoning for the answer
5. Management horizon.	What proportion of the target population (governments, private sector and/or property owners) has a long-term (more than 10 years) planning horizon?	1 to 5				
6. Short terms constraints.	What proportion of the target population (governments, private sector and/or property owners) is under conditions of severe financial constraints?	1 to 5				
7. Triable.	How easily can the Green roof (or significant components of it) be trialled on a small scale before a decision is made to adopt it on a larger scale?	1 to 5				
8. Innovation complexity	Does the complexity of Green roofs and its components allow effects of their use to be easily evaluated when they are used?	1 to 5				
9. Observability.	To what extent would Green roofs be observable to those in the target population (governments, private sector and/or property owners) who are yet to adopt them when they are used in their urban area?	1 to 5				
10. Advisory support.	What proportion of the target population (governments, private sector and/or property owners) uses paid advisors capable of providing advice relevant to the implementation of Green roofs?	1 to 5				
11. Group Involvement.	What proportion of the target population (governments, private sector and/or property owners) participates in groups that discuss this type of NBS (Green roofs)?	1 to 5				
12. Relevant existing skills and knowledge.	What proportion of the target population (governments, private sector and/or property owners) will need to develop substantial new skills and knowledge to use the Green roofs?	1 to 5				
13. Innovation awareness	What proportion of the target population (governments, private sector and/or property owners) would be aware of the use or	1 to 5				

Question	Question Associated	Range of possible answer from lower (-) to higher (+).	1st Answer	Reasoning for the answer	2nd Answer	Reasoning for the answer
	trailing of Green roofs in their urban area?					
14. Relative upfront cost of innovation	What is the size of the of the initial investment relative to the implementation of Green roofs?	1 to 5				
15. Reversibility of innovation	To what extent is the adoption of Green roofs able to be reversed?	1 to 5				
16. Profit benefit in years that it is used	To what extent is the use of Green roofs likely to affect the profitability of the target population (governments, private sector and/or property owners) in the years during its implementation and use?	1 to 8				
17. Future profit benefit	To what extent is the use of Green roofs likely to have additional effects on the future profitability of the target population?	1 to 8				
18. Time until any future profit benefits are likely to be realized	How long after Green roofs are first adopted would it take for effects on future profitability to be realised?	1 to 6				
19. Environmental costs and benefits	To what extent would the use of Green roofs have net environmental benefits or costs?	1 to 8				
20. Time to environmental benefit	How long after the Green roofs are first adopted would it take for the expected environmental benefits or costs to be realised?	1 to 6				
21. Risk exposure	To what extent would the use of Green roofs affect the net exposure of the owners' properties to risk?	1 to 8				
22. Ease and convenience	To what extent would the use of Green roofs affect the ease and convenience of the management of the properties where they are applied, during the years that they are used?	1 to 8				

Appendix E

ADOPT-NBSs Participative Workshop Agenda

Date: October 22nd and 23rd
Location: Eindhoven (Netherlands)

Introduction

The implementation of nature-based solutions (NBS) in urban areas requires the involvement of different stakeholders that will provide, utilize and/or manage this type of infrastructure. To obtain key information for measuring the level (peak) and rate (diffusion) of adoption of NBS in different target areas, an elicitation process is proposed through a workshop session that will involve not only experts in the topic but also other stakeholders that directly or indirectly could have a stake in the adoption process.

For this purpose, the workshop will be performed along with a survey and data analysis of the ADOPT software (Kuehne et al, 2017), which is the tool that will provide in the factors influencing the level and rate of adoption of NBS.

Objective

To assess the factors that influence the adoption and diffusion of nature-based solutions (NBS) in the city of Eindhoven (Netherlands), focusing on the case of green roofs.

The workshop

The participatory workshop will entail an elicitation process, which will include individual and group scoring of 22 questions regarding the possible adoption of green roofs, their relative advantage for the population, learnability characteristics, learnability of the population and the relative advantage of green roofs as NBS. A general introduction to these concepts will be given at the start of the main activity.

The information obtained during the workshop will be entered in the ADOPT-tool, which will calculate an adoption rated scenario based on the final answers. In turn, a general session of results discussion and conclusions will take place. The participatory workshop will take between 2 and 2.5 hours.

Agenda

Activity	Duration
Registration to the event	20 min before the start of the event
Welcome	5 min
Informative Presentation including the concepts of: UNaLab project, Nature-based solutions and ADOPT-tool.	15 min
First part of the workshop.	30-40 min
Second part of the workshop.	40-60 min
Coffee-break.	15 min
Results discussion and conclusions.	20-40 min
Closure.	5 min

If you have any questions, please contact:

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Appendix F

WORKSHOP COMPLEMENTARY INFORMATION

Question	Question Associated	Details	Possible Answers
1. Profit/utility orientation.	What proportion of the target population (governments, private sector and/or property owners) has maximizing profit/utility as a strong motivation for implementing Green roofs.	○ This question asks about the importance of profit/utility maximisation to the target population and should be answered independent of the innovation. ○ An innovation that has profit/utility benefits will offer more relative advantage to a population with a high motivation for maximising profit than a population with a low motivation for maximising profit. ○ For example, to have monetary savings due energy consumption, Improvement of the wellbeing or an impulse to local companies related directly or indirectly with green roofs.	1. Almost none have maximising profit/utility as a strong motivation 2. A minority have maximising profit/utility as a strong motivation 3. About a half have maximising profit/utility as a strong motivation 4. A majority have maximising profit/utility as a strong motivation 5. Almost all have maximising profit/utility as a strong motivation
2. Environmental orientation.	What proportion of the target population (governments, private sector and/or property owners) has protecting the natural environment as a strong motivation for implementing Green roofs?	○ This question asks about the importance of environmental motivations (defined broadly) to the target population in general. ○ Green roofs or innovations in general that have environmental benefits will offer more relative advantage to a population with a high motivation for protection of the environment than a population with a low motivation for protection of the environment.	1. Almost none have protection of the environment as a strong motivation 2. A minority have protection of the environment as a strong motivation. 3. About a half have protection of the environment as a strong motivation. 4. A majority have protection of the environment as a strong motivation. 5. Almost all have protection of the environment as a strong motivation.
3. Risk orientation	What proportion of the target population (governments, private sector and/or property owners) has risk minimisation as a strong motivation for implementing Green roofs?	○ This question asks about the importance that the target population places on **minimising risk**. ○ Risk takers (answer 1), are keener to try new type of innovations, risk aversion (answer 5) would mean the target population is worried to decrease the possible risk the most they can, before adopting Green roofs.	1. Almost none have risk minimisation as a strong motivation (risk takers) 2. A minority have risk minimisation as a strong motivation. 3. About half have risk minimisation as a strong motivation. 4. A majority have risk

Question	Question Associated	Details	Possible Answers
			minimisation as a strong motivation. 5. Almost all have risk minimisation as a strong motivation (risk averse)
4. Implementation scale.	What proportion of the target population (governments, private sector and/or property owners) could benefit from the Green roofs?	○ If very few in the target population benefit directly from the Green roofs, then the answer should be 'almost none' or 'a minority'. ○ If the Green roofs will benefit the target population in general, then the response should be 'a majority' or 'almost all'. ○ For example, if only one property in a neighbourhood could implement green roofs the answer should be 1, on the other hand if the whole neighbourhood could implement green roofs in their properties the answer should be 5.	1. Almost none of the target population could benefit. 2. A minority of the target population could benefit. 3. About half of the target population could benefit. 4. Most of the target population could benefit. 5. Almost all the target population could benefit.
5. Management horizon.	What proportion of the target population (governments, private sector and/or property owners) has a long-term (more than 10 years) planning horizon?	○ This affects the potential value of Green roofs that provide benefits (or costs) in the longer term. ○ For some populations it may be lower e.g. if their property, enterprise or region is under threat from external forces such as government reforms, climatic conditions or similar.	1. Almost none have a long-term planning horizon 2. A minority have a long-term planning horizon 3. About a half have a long-term planning horizon 4. A majority have a long-term planning horizon 5. Almost all have a long-term planning horizon
6. Short terms constraints.	What proportion of the target population (governments, private sector and/or property owners) is under conditions of severe financial constraints?	○ These constraints are temporary and only defer adoption for a short period. ○ A high proportion may be affected if a region has been under disaster conditions (e.g. economic, social or natural phenomena).	1. Almost all currently have a severe short-term financial constraint 2. A majority currently have a severe short-term financial constraint 3. About half currently have a severe short-term financial constraint 4. A minority currently have a severe short-term financial constraint 5. Almost none have a severe short-term financial constraint

Question	Question Associated	Details	Possible Answers
7. Triable.	How easily can the Green roof (or significant components of it) be trialled on a small scale before a decision is made to adopt it on a larger scale?	○ This identifies whether the Green roof can be tested (in the target urban area) on a limited basis with low cost to allow some learning about its likely value, before implementing it on a larger scale.	1. Not trailable at all 2. Difficult to trial 3. Moderately triable 4. Easily triable 5. Very easily trailable
8. Innovation complexity.	Does the complexity of Green roofs and its components allow effects of their use to be easily evaluated when they are used?	○ New social behaviours or wellbeing due to Green roof implementation may be difficult to evaluate. ○ Energy savings due to Green roof implementation may be moderately difficult to evaluate ○ Changing materials is a simple change that is usually not difficult to evaluate.	1. Very difficult to evaluate effects of use due to complexity 2. Difficult to evaluate effects of use due to complexity 3. Moderately difficult to evaluate effects of use due to complexity 4. Slightly difficult to evaluate effects of use due to complexity 5. Not at all difficult to evaluate effects of use due to complexity
9. Observability.	To what extent would Green roofs be observable to those in the target population (governments, private sector and/or property owners) who are yet to adopt them when they are used in their urban area?	○ Green roofs on low-rise residential housing are easily observed. ○ Green roofs on high-rise or factory buildings may not be easily observed.	1. Not observable at all 2. Difficult to observe 3. Moderately observable 4. Easy observable 5. Very easy observable
10. Advisory support.	What proportion of the target population (governments, private sector and/or property owners) uses paid advisors capable of providing advice relevant to the implementation of Green roofs?	○ These are advisors relevant to Green roofs processes and not advisors who provide over-the-counter advice.	1. Almost none use a relevant advisor 2. A minority none use a relevant advisor 3. About a half use a relevant advisor 4. A majority use a relevant advisor 5. Almost all use a relevant advisor

Question	Question Associated	Details	Possible Answers
11. Group Involvement.	What proportion of the target population (governments, private sector and/or property owners) participates in groups that discuss this type of NBS (Green roofs)?	○ These are groups that are potentially relevant to the innovation. ○ Greater involvement in groups that discuss NBS can increase the rate of awareness and learning about NBS (Green roofs).	1. Almost none are involved with a group that discusses NBS 2. A minority are involved with a group that discusses NBS 3. About half are involved with a group that discusses NBS 4. A majority are involved with a group that discusses NBS 5. Almost all are involved with a group that discusses NBS
12. Relevant existing skills and knowledge.	What proportion of the target population (governments, private sector and/or property owners) will need to develop substantial new skills and knowledge to use the Green roofs?	○ Some target populations will require substantial new skills and knowledge before the full value of Green roofs can be realised.	1. Almost all need new skills and knowledge 2. A majority need new skills and knowledge 3. About half will need new skills and knowledge 4. A minority will need new skills and knowledge 5. Almost none will need new skills or knowledge
13. Innovation awareness.	What proportion of the target population (governments, private sector and/or property owners) would be aware of the use or trailing of Green roofs in their urban area?	○ This question is about whether the target population is likely to recognise that Green roofs, and information about it, exists in their urban area.	1. It has never been used or trailed in their urban area 2. A minority are aware that it has been used or trailed in their urban area 3. About a half are aware that it has been used or trailed in their urban area 4. A majority are aware that it has been used or trailed in their urban area 5. Almost all are aware that it has been used or trailed in their urban area
14. Relative upfront cost of innovation.	What is the size of the of the initial investment relative to the implementation of Green roofs?	○ If subsidies or incentives are provided they should be incorporated into your response.	1. Very large initial investment 2. Large initial investment 3. Moderate initial investment 4. Minor initial investment 5. No initial investment required

Question	Question Associated	Details	Possible Answers
15. Reversibility of innovation.	To what extent is the adoption of Green roofs able to be reversed?	○ Structural adjustments to roofs are more difficult to reverse ○ Trees are moderately difficult to reverse ○ Shrubs are easily reversed ○ Plants and grasses are very easily reversed	1. Not reversible at all 2. Difficult to reverse 3. Moderately difficult to reverse 4. Easily reversed 5. Very easily reversed
16. Profit benefit in years that it is used.	To what extent is the use of Green roofs likely to affect the profitability of the target population (governments, private sector and/or property owners) in the years during its implementation and use?	○ This question is only focused on financial profit. ○ This question is focused on the profit (or loss) in the years that the innovation is used. ○ The first 3 answers are related to disadvantages, one neutral answer and 3 positive answers related to advantages.	1. Large profit disadvantage in years that it is used 2. Moderate profit disadvantage in years that it is used 3. Small profit disadvantage in the years that it is used 4. No profit advantage or disadvantage in the years that it is used 5. Small profit advantage in the years that it is used 6. Moderate profit advantage in the years that it is used 7. Large profit advantage in the years that it is used 8. Very large profit advantage in the years that it is used
17. Future profit benefit.	To what extent is the use of Green roofs likely to have additional effects on the future profitability of the target population?	○ If it is believed that Green roofs offer loss a long time after first use, then the response should be 'disadvantage'. ○ If it is believed that a Green roof only affects profit in the years it is used, then there is no 'advantage' or 'disadvantage'. ○ If it is believed that Green roofs offer profit a long time after first use, then the response should be 'advantage'. ○ The first 3 answers are related to disadvantages, one neutral answer and 3 positive answers related to advantages.	1. Large profit disadvantage in the future 2. Moderate profit disadvantage in the future 3. Small profit disadvantage in the future 4. No profit advantage or disadvantage in the future 5. Small profit advantage in the future 6. Moderate profit advantage in the future 7. Large profit advantage in the future 8. Very large profit advantage in the future
18. Time until any future profit benefits are likely to be realised.	How long after Green roofs are first adopted would it take for effects on future	○ The response to this question influences the value of the Future Profit Benefit from the previous question.	1. More than 10 years. 2. 6 to 10 years 3. 3 to 5 years 4. 1 to 2 years

Question	Question Associated	Details	Possible Answers
	profitability to be realised?	○ For example, Future Profit Benefits that take more than ten years to be realised are worth less in current terms than future profit that is realised more quickly. ○ Profit Benefits that are gained quickly (see question 16) are not discounted. ○ Future Profit Benefit are converted to an approximate present value through discounting.	5. Immediately 6. Not applicable
19. Environmental costs and benefits.	To what extent would the use of Green roofs have net environmental benefits or costs?	○ This question is not only focused on environmental costs and benefits but could also include allied non-profit concerns. ○ The first 3 answers are related to disadvantages, one neutral answer and 3 positive answers related to advantages.	1. Large environmental disadvantage 2. Moderate environmental disadvantage. 3. Small environmental disadvantage 4. No net environmental effects 5. Small environmental advantage 6. Moderate environmental advantage 7. Large environmental advantage 8. Very large environmental advantage
20. Time to environmental benefit.	How long after the Green roofs are first adopted would it take for the expected environmental benefits or costs to be realised?	○ This question aims to capture the expected time delay before the anticipated environmental benefits identified in the previous question are achieved. ○ For example, the environmental advantages of a tree plantation may take many years to become evident but may be almost immediate for the adoption of no-tillage in farming.	1. More than 10 years 2. 6 to 10 years 3. 3 to 5 years 4. 1 to 2 years 5. Immediately 6. Not applicable
21. Risk exposure.	To what extent would the use of Green roofs affect the net exposure of the owners's properties to risk?	○ Risk is defined here as the uncertainty of having positive or negative possible outcomes related to the implementation of Green roofs in the buildings. ○ Examples of increases in risk include, for example, possible structural issues, infiltrations and short-circuits in buildings. ○ Examples of reductions in risk include, for example, possible structural improvements, sealing and safety in buildings. ○ The first 3 answers are related to disadvantages, one neutral answer and 3 positive answers related to advantages.	1. Large increase in risk 2. Moderate increase in risk 3. Small increase in risk 4. No increase in risk 5. Small reduction in risk 6. Moderate reduction in risk 7. Large reduction in risk 8. Very large reduction in risk

Question	Question Associated	Details	Possible Answers
22. Ease and convenience.	To what extent would the use of Green roofs affect the ease and convenience of the management of the properties where they are applied, during the years that they are used?	○ This question measures changes to the ease, convenience and management demands on the property that may result from adopting the Green roof. ○ The first 3 answers are related to disadvantages, one neutral answer and 3 positive answers related to advantages.	1. Large decrease in ease and convenience 2. Moderate decrease in ease and convenience 3. Small decrease in ease and convenience 4. No decrease in ease and convenience 5. Small increase in ease and convenience 6. Moderate increase in ease and convenience 7. Large increase in ease and convenience 8. Very large increase in ease and convenience

Appendix G

Participatory Workshop Feedback Form- *Green Roofs level of adoption*, Eindhoven

Date:
Location: Eindhoven, Netherlands.
Please take some minutes to answer this feedback form.

1.- How would you rate the workshop:

Very useful/Interesting	
Useful/Interesting	
Moderately useful/interesting	
Not very useful/Interesting	
Disadvantageous	

2.- What did you find more useful from the workshop.

3.-What did you find less useful from the workshop.

4.- Would you consider that this type of workshops could help to the different stakeholders in urban areas to make better decisions when adopting Nature Based Solutions in their communities?

Yes_____ No_____

3.-Suggestions and comments for improving the workshop process in the future.

Thank you for your participation.