Strategies for Sustainable Farming in the Mediterranean: Lessons from Argolida, Greece.

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Declaration of Authorship

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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ABSTRACT

The agricultural sector faces challenges in achieving sustainable food production, such as climate change, soil erosion, and biodiversity loss. The importance of access to agronomic information and relevant knowledge for farmers to make informed decisions towards sustainable farming practices is crucial. An in-depth and comprehensive investigation of the various, multifaceted ways and strategies through which the management and sustainability performance of farming systems can be bolstered and fortified within the context of a typical Mediterranean area is attempted.

The methodology followed consisted of a mixture of qualitative and quantitative methods and primary and secondary data. Thematic analysis and content analysis were used to reveal themes and patterns of behaviours while the sustainability assessment performed a quantitative analysis of the data entered in the program during the interviews. Finally, the Q-methodology performed a quantitative Q-factor analysis and a qualitative factor interpretation analysis.

The research presents the results of a study that aimed to explore the perceptions of farmers on decision-making, farm sustainability, and digital technologies, the perceptions of farmers and advisers on the use and adoption of planning and control methods and identify the needs and requirements of end-users for the design of an effective Decision Support Tool (DST). The research concludes that there is a gap in the understanding of wider sustainability issues within the context of farm decision-making. The educational, technological, and consultancy framework needs to be reformed to address the challenges indicated previously. The findings of the study illustrate the need to encourage farmers and advisers to change their actions to enhance wider agricultural sustainability. The research recommends a review and update of the educational framework for both farmers and advisers to tackle the challenges of sustainability awareness and performance, and technology uptake.

The study concludes that the adoption of DSTs in agriculture can contribute to farm sustainability and that understanding farmers' perceptions of DSTs is crucial for successful adoption. Finally, there is a number of recommendations for farmers, advisers, researchers and policymakers regarding the future action needed to take place in order to improve the sustainability performance of farming systems in the area.

OUTLINE OF PUBLICATIONS

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Praedes sacramenti

Όταν ο άνεμος σε σπρώχνει
προς τα μπρος
να ξέρεις
πως θα σ’ ακολουθούν πάντοτε
οι σκιές όσων έμειναν πίσω
για να βλέπουν
αν άξιζε τον κόπο
που άδειασαν τα πνευμόνια τους
φυσώντας δυνατά
τόσα χρόνια
για ν’ ανοίξουν
τα πανιά της μοίρας σου.

When the wind pushes you
forward,
you should know
that they will always follow you,
the shadows of those who were left behind
to see
if it was worth it
emptying their lungs,
blowing loud,
so many years
to open
the sails of your fate.

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CAP:	Common Agricultural Policy
CI:	Composite Indicators
CO_2:	Carbon Dioxide
CPD:	Continuing Professional Development
CTV:	Citrus Tristeza Virus
DSSs:	Decision Support Systems
DSTs:	Decision Support Tools
EU:	European Union
EV:	Eigenvalues
FADN:	Farm Accountancy Data Network
FAO:	Food and Agriculture Organization
GHG:	Greenhouse Gas Emissions
IDEA:	Indicateur de Durabilité des Exploitations Agricoles
IOC	International Olive Council
IoT:	Internet of Things
IT:	Information Technology
MAP:	Mediterranean Action Plan
MCA:	Multi Criteria Assessment
MOAN:	Mediterranean Organic Agriculture Network
NVZ:	Nitrate Vulnerable Zone
PA:	Precision Agriculture
PCA:	Principal Component Analysis
PG:	Public Goods
PPP:	Plant Protection Products
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
P-set:	Participants in Q-methodology
Q-set:	Statements to be ranked in Q-methodology
Q-sort:	Grid with ranked statements in Q-methodology
RISE:	Response-Inducing Sustainability Evaluation
SA:	Sustainability Assessment
SAFA:	Sustainability Assessment of Food and Agriculture systems
SDGs:	Sustainable Development Goals
TA:	Thematic Analysis
TRA:	Theory of Reasoned Action
UN:	United Nations

CHAPTER 1. Introduction

1.1 Background and problem statement

The traditional structure and the organisational form of the agricultural and food production systems in the Mediterranean basin have been challenged by the changing political, economic and technological environment (Iakovidis et al., 2023). The undesirable trajectory of the current agri-food production systems has become a driving factor in the transition to more sustainable systems in order to cope with the increasing demand for environmental awareness and at the same time ensuring sufficient access to food and fibre (Borsellino et al., 2020).

The economic, environmental and social context have been influencing this transition towards sustainability. Climate change and the more frequent appearance of severe weather phenomena, land degradation, natural resources scarcity, population growth and biodiversity loss have led in many cases to increased production costs, decreased quality and quantity of production and/or even farmland abandonment in some cases. In the Mediterranean basin, a range of factors potentially undermine farm sustainability:

- small size of agricultural holdings,
- spatial characteristics of the area,
- dependency on CAP subsidies for small and medium holding farms,
- an ageing rural population,
- farmers' low level of education, and
- land fragmentation.

The agricultural sector in the Mediterranean region is facing several challenges that threaten its sustainability (Iakovidis et al., 2023). To ensure the future sustainability of these systems it is important to explore the strategies through which the agricultural sector can overcome these challenges, enhance the managerial competencies of farmers for improving their businesses and finally, identify the needs and requirements of stakeholders towards sustainable farming. This is necessary as agriculture is the primary source of food production for the population. Sustainable agricultural practices ensure that food production is maintained in the long run without depleting natural resources or causing environmental harm. Additionally, conventional agricultural practices have often led to environmental degradation, such as soil erosion, water pollution, and loss of biodiversity (Muhie, 2022). By adopting sustainable agricultural strategies, the negative impacts on the environment can be minimised, ecosystems can be preserved, and wildlife habitats can be protected.

Climate change poses also significant challenges to agriculture, impacting crop yields and altering growing seasons. Sustainable farming practices can help reduce greenhouse gas emissions, sequester carbon in soils, and enhance the resilience of farming systems to adapt to changing climate conditions (Lynch et al., 2021). Furthermore, agriculture is a major consumer of natural resources like water and land. Sustainable farming methods, such as precision agriculture and water-efficient irrigation techniques, optimise resource use, minimising waste and conserving valuable resources (Monteiro et al., 2021). When farmers adopt sustainable practices, they can often reduce input costs, improve productivity, and gain access to premium markets that value sustainably produced goods and foster social equity by promoting fair labour practices, supporting rural livelihoods, and ensuring access to nutritious food for all segments of society (Carlisle et al., 2019; Dessart et al., 2019; Gebska et al., 2020).

To achieve agricultural sustainability in the Mediterranean, it is vital to facilitate robust research and development efforts to identify sustainable agricultural practices that are suitable for the Mediterranean region's unique climate, soil, and natural resources. Innovation in technology and diversifying production can enhance agricultural productivity while reducing the reliance on traditional agricultural practices and increase the adaptability of the sector to changing conditions. Enhancing the managerial competencies of farmers is crucial too. Providing farmers with access to training and education on sustainable farming practices, modern techniques, and efficient resource management empowers them to make informed decisions for their farm businesses.

Identifying the needs and requirements of stakeholders in the agricultural sector is also essential. This includes involving farmers, local communities, policymakers, researchers, and extension service providers in the decision-making process. Stakeholder engagement fosters a collaborative approach towards sustainable farming and ensures that policies and strategies align with the realities on the field. Governmental agencies and relevant authorities should implement policies that support and incentivise sustainable agricultural practices. This may include providing subsidies for adopting eco-friendly technologies, establishing market incentives for sustainably produced goods, and creating regulations that discourage harmful practices.

Finally effective advisory and extension services play a vital role in disseminating knowledge about sustainable farming practices to farmers. These services can help bridge the gap between research institutions and farmers, making scientific insights accessible and actionable in practice. In conclusion, the need to identify strategies and develop recommendations to support farmers and extension service providers in enhancing agricultural sustainability in the Mediterranean is imperative for the well-being of society, the preservation of the environment, and the economic prosperity of farming communities. By adopting sustainable practices and prioritising innovation and collaboration, the long-term viability of agricultural systems can be ensured, promoting a more resilient and prosperous future for all.

Greece is a major beneficiary of the CAP of the European Union (EU). As a result of the country's entry to the European Community in 1981, much of its agricultural infrastructure has been upgraded and agricultural output has been increased (Eurostat, 2009). Nevertheless, the author notes from his experience as a senior agronomist and extension manager that the sector appears to be at a “crossroads” as more and more farmers are concerned about the ongoing changes in the production environment and the market requirements, making their role increasingly challenging. On the one hand, farm sustainability (economic, social and environmental) has always been a critical point for Greece’s agricultural systems, for a number of reasons; for instance, the small size of agricultural properties (DG Agriculture and Rural Development, 2018), the subsidies from CAP (Massot, 2017), and the tradition of the dowry-giving (Nikolajeva, 2014). On the other hand, implementation of planning and control methods is low or non-existent due to the features of the rural population, the farmers’ low level of education and the lack of state interventionism in the use of farm advisory services (European Commission, 2019).

According to EU Agricultural and Farm Economics Briefs (2017), the number of farmers under 35 years old for every farmer over 65 years old, is 0,15. Moreover, according to EU, CAP Context Indicators 2014-2020, 97,4% of farmers and farm managers over 55 years old learned their profession through practical experience only, while for those under 35 years old the percentage is still 91,1%. This clearly depicts that those who intend to go into farming have little formal education in the subject. Existing public services only limit the offering of educational programs to new entrants to the sector to comply with EU regulation (European union, 2013).

These features mirror the institutional problems that require resolution within the framework of a long-term agricultural sector strategy. Agriculture in Greece and often more broadly within the Mediterranean basin, could be substantially strengthened and benefited from a process of institutional restructuring, leading to increased farmer accountability and improved government services (Iakovidis et al., 2022). In order to enable this, it is necessary to engage farmers into educational programmes and reorientate the teaching methods such as problem solving instead of educational programs without specificity (V Brinia & Tsiliopoulou, 2015).

A holistic assessment of agricultural production at farm level, has been considered a reliable approach in addressing the challenges and problems in the agriculture industry (Berbeć et al., 2018). It is an important approach because it can provide inception data facilitating the monitoring of progress in sustainability and efficiency of environmental and sustainability management in agriculture (Bachev, 2018). It is therefore necessary to recognise and state the gaps in farm sustainability awareness and bridge them with the deployment of the respective educational programs, promote planning and control methods adoption and use and finally identify the needs and requirements of farmers on DST use. By doing so it is envisaged that a better and tailored to the needs of the farmer's decision-making process will be developed, towards the improvement of the sustainability performance of farm businesses. This would encourage the participation of farmers along with other stakeholders to the design of tools and policies, so that challenges can be tackled collectively and efficiently.

Furthermore, the region of the Mediterranean basin faces another significant gap in terms of regional policies and extension services in the realm of agriculture. This gap, while multifaceted, poses a challenge to sustainable agricultural development and food security across the area. One of the fundamental challenges is the absence of coordinated and harmonised regional policies addressing agricultural development. The Mediterranean Basin is composed of countries with distinct political systems, economic priorities, and cultural nuances (Tovias, 2014). This diversity often hampers the establishment of unified policies that could effectively address shared challenges such as water scarcity, soil degradation, and climate change adaptation. The lack of a cohesive policy framework can result in inefficient resource allocation and missed opportunities for collaboration.

The importance of research and innovation in agriculture cannot be overstated, especially in a region grappling with climate change-induced shifts in growing conditions (Octavi et al., 2021). The gap in funding and support for agricultural research inhibits the development and dissemination of sustainable farming practices, drought-resistant crops, and efficient water management techniques. Investing in innovative solutions tailored to the region's unique challenges is essential to ensure long-term food security. Extension services play a pivotal role in disseminating knowledge and best practices among farmers. They play a crucial role by improving skills and access to information that result in greater farm level innovations, especially on family farms which are the predominant form of agriculture in the world. However, the Mediterranean Basin faces a gap in terms of extension services accessibility and effectiveness (Jara-Rojas et al., 2020). Many small-scale farmers, particularly in remote or marginalised communities, lack access to up-to-date agricultural information, modern farming techniques, and market insights. Bridging this gap could empower farmers to adopt more efficient and sustainable practices, leading to improved yields and livelihoods (Gatzweiler & Von Braun, 2016).

Collaboration among different stakeholders, including governments, non-governmental organisations, research institutions, and local communities, is crucial for effective agricultural development. The existing gap in collaboration inhibits the exchange of knowledge, experiences, and resources across borders. Promoting platforms for knowledge sharing, joint research projects, and cross-border partnerships can foster innovation and enhance the resilience of agriculture in the region (FAO, 2016). The Mediterranean Basin encompasses countries with diverse levels of socioeconomic development. The gap between more developed and less developed areas can lead to disparities in the allocation of resources, access to information, and capacity-building opportunities (Jara-Rojas et al., 2020). To address this gap, policies should be designed to prioritise equitable distribution of resources, focusing on empowering marginalised communities and promoting inclusive agricultural growth.

1.2 Aim of thesis

The primary and overarching aim of this thesis is to engage in an in-depth and comprehensive investigation of the various, multifaceted ways and means through which the management and sustainability performance of farming systems can be bolstered and fortified within the context of a typical Mediterranean area, more specifically, the region of Argolida, which is situated in the south-eastern area of Greece, in the Peloponnese region.

To address it , this research aims to compare the results of an indicator-based sustainability assessment tool, at a farm level, with the results of a thematic analysis on the perceptions of farmers/managers on decision-making, farm sustainability of their businesses and Decision Support Tools (DST) to assess the current situation in the area. Consequently, the degree by which planning, and control methods are used, is going to be investigated through a content analysis of interviews with farmers and advisers, to evaluate and quantify the implementation and adoption of farm management means in the decision-making process towards improving the sustainability performance of farm businesses. Finally, a user-need analysis for the investigation of the needs and requirements of farmers and advisers (end-users) about the use and adoption of DSTs will serve as an early-stage step in a potential co-production of services approach for the design of effective DSTs for stakeholders.

The thesis is divided into seven chapters:

1. Chapter 1 discusses the background and the problem statement for the research and sets the aim of the thesis that needs to be addressed.

2. Chapter 2, offers a review of the general literature providing a contextualisation of the research and sets the research questions.

3. Chapter 3, provides an overview of the theoretical framework of the research, the study area and an overarching subchapter of methodology to support the approaches used in the three empirical chapters that follow.

4. Chapter 4, reports on the use of an indicator-based tool and Farm Accountancy Data Network (FADN) data to evaluate the sustainability performance of 20 farm businesses in the area and investigates farmers' perceptions of the importance of effective decision-making in the context of sustainability performance.

5. Chapter 5 explores factors that inhibit/promote the adoption and implementation of planning and control methods as decision-making tools.

6. Chapter 6, investigates the adoption and use of DST and identifies the needs and requirements of farmers and advisers, for the promotion of evidence-based, decision-making towards improving farm sustainability performance.

7. Chapter 7, focusses on the discussion and conclusion of the research study, taking into consideration the research questions and presenting the concluding remarks and recommendations derived.

1.3 Research questions

The work presented in the thesis in fulfilment of the above-mentioned aim and the literature review, addresses the following research questions:

1. What is the sustainability performance of farm businesses in Argolida, Peloponnese, Greece?
2. Do farmers perceive that their decision-making affects the sustainability performance of small-scale farming systems in Argolida, Peloponnese?
3. What are the factors that motivate or hinder farmers' adoption and implementation of planning and control methods that may enhance farm sustainability?
4. Does farm sustainability advice present different challenges to farm advisers beyond the established consideration of productivity and profitability?
5. What is the current situation and the future prospect for the use of DSTs to enhance farm sustainability?
6. What are the needs and requirements of farmers and advisers regarding the use and adoption of DSTs?

1.4 Summary

Farm sustainability is the cornerstone of a thriving rural system, nurturing the land, preserving natural resources and ensuring a resilient future for generations to come (Brodt et al., 2011). The aim of this thesis is to fill an important gap in farm sustainability awareness through exploring how evidence-based and data-informed decision-making through the adoption and use of planning and control methods and DSTs can enhance the management approach of farmers/advisers towards improving the sustainability performance of their farming systems.

CHAPTER 2. Literature Review

2.1 Introduction

The agricultural sector faces a multitude of challenges and conditions on both local and global level (FAO, 2017). Agriculture is associated with climate change, soil erosion and biodiversity loss, while trying to satisfy consumers' changing tastes and expectations and meet market rising demand for more food of higher quality (Ortiz et al., 2021). This puts farmer in a rather difficult position as it is expected from him/her to make informed, evidence-based decisions towards producing in a sustainable manner.

Sustainable food production faces several obstacles that need to be addressed to achieve sustainability. Strategies that are able to upgrade the decision-making process towards achieving sustainability at the same time such as promoting farming in harmony with nature, increasing transparency along the supply chain, addressing environmental consequences, improving education, and reducing food waste can help overcome these obstacles and achieve sustainable food production.

Overall, the literature supports the notion that access to information and relevant knowledge by farmers is crucial towards promoting sustainable farming practices and improving sustainability performance. Access to information helps farmers make informed decisions, reduces uncertainties in decision-making, promotes innovation, and enhances the adoption of sustainable farming practices. In a study by Klerkx and Aarts (2013), the importance of information exchange networks towards enhancing innovations in the agricultural sector was noted. Similarly In a study by Bachev et al. (2021), access to information and knowledge was noted as a key element that could help agricultural producers to apply appropriate farming methods, reduce negative externalities of farming practices, and improve their productivity by utilizing effective management practices.

This chapter provides an overview of the literature underpinning this research. It stretches to four sub chapters investigating the literature on farm sustainability, decision-making, planning and control methods and DSTs and a fifth one presenting an overview of the theoretical framework of the research.

2.2 Farm Sustainability.

2.2.1 Origins of the sustainability concept.

Interest in the concept of sustainability can be tracked back to ancient Greece, Rome and China (Pretty, 2008). Existing in harmony with nature and neighbours was the initial concern about sustainability, but actual interest in agricultural sustainability can be traced back to 1713, when Hans Carlowitz (1645-1714) developed a theory on the optimal use of forests, which were the energy sources for the iron and silver industry. He argued that the volume of production in this industry could not exceed the speed of reproduction of forests (Marquardt, 2006). The concept of sustainability emerged again between 1950 and 1960 to address the then environmental concerns. The introduction of the term *"sustainable development"* became better known with the publication of the World Conservation Strategy of the International Union for the Conservation of Nature (Cisneros-Saguilán et al., 2015).

In 1983, United Nations (UN) established the World Commission on Environment and Development while in 1987 published the well-known report *"Our Common Future,"* which was "*a global agenda for change"* that proposed long-term environmental strategies for achieving sustainable development by the year 2000 and beyond. Sustainable development was defined as *"development that meets the needs of the present without compromising the ability of future generations to satisfy their own needs"* (Keeble, 1988). Consequently, the UN began the planning for the *"Earth Summit"*, the Conference on Environment and Development that took place in Río de Janeiro in 1992. During the conference the concept of sustainability was adopted, and the global program Agenda 21 emerged. Agenda 21 was a reference manual created to determine policies and called for development at local level. This agenda essentially included a guideline for all personal decisions based on sustainability principles and explained the behaviour that mankind should follow to allow for future generations to make a decent living (Koroneos & Rokos, 2012).

2.2.2 Sustainability in agriculture

Thinking about the future, improving quality of life whilst not over-exploiting natural resources is at the heart of the Sustainable Development Goals (SDG), a set of goals that establish an ambitious future development agenda (UN, 2014). The goals proposed by all United Nations Member States in 2015 with targets through to 2030, providing mutual ground of peace and prosperity for people and the planet, for the present and the future (FAO, 2018). The promotion of sustainability in agriculture is described in SDGs (Goal 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture), as well as in other policy recommendations (Charatsari & Lioutas, 2016). According to the Food and Agriculture Organization (FAO) (2009), by the year 2050, due to the increase of the world's population, food production has to be increased by 70% to cover the emerging needs.

Agriculture lies at the heart of sustainable development. It is precisely because of its centrality to many of the defined SDGs that the potential for synergies and trade-offs arises (Kanter et al., 2018). The process of sustainability involves not only the use of appropriate production practices, but also a change in attitude and behaviour of producers and society in general in order to achieve SDG targets (Cisneros-Saguilán et al., 2015). The rate of change to more sustainable agriculture will impact future food scarcity, environmental damage, depopulation and migration of people towards rural areas (Björklund, 2018). As in other productive sectors, achieving sustainability in agriculture is a growing concern in modern-day societies (Piedra-Muñoz et al., 2016). Sustainable agriculture preserves biodiversity, enhances soil resources, protects water reserves, provides healthier food, decreases dependence on external resources, and ensures a solid income for farmers (Soldi et al., 2019). It can be defined as a set of practices that satisfy the current and future societal needs for food production and consumption, for environmental security, and for healthy lives. It is achieved by maximising the net benefit to society when all costs and benefits of the practices are considered (Ren et al., 2019)

To make progress in the complexity of the socio-economic and environmental systems it is crucial that public policies and governance are designed and implemented based on the principles of sustainable development (Jones et al., 2019). Recent studies demonstrate that agriculture is currently changing its approach from solely focusing on profit maximisation towards a more diverse governing approach with increased focus on promoting alternative values of farming such as biodiversity, and animal welfare (Saunders, 2016). With agriculture facing a multitude of challenges such as climate change, scarcity of natural resources, market globalisation and environmental pollution, Policymakers, governing stakeholders and academics have directed, via policy interventions, farmers towards sustainable forms of producing (Martin et al., 2018). Through these strategies and policies different forms of agricultural production models have emerged such as organic farming, and regenerative farming that promote sustainable development of agriculture. In addition, emphasis has been given in promoting agroecology, farm practices that are enhancing biodiversity and the delivery of eco-system services by agricultural systems. These are practices integrated in agricultural production to create prosperous farming circumstances that enrich the environment and engage local communities.

2.2.3 The three pillars of sustainability.

The assessment of agricultural sustainability is a challenging task. Achieving sustainability involves trade-offs and skilful balancing between a range of perspectives. (Hayati et al., 2011) These perspectives are often defined as the economic, environmental, and social pillars which are viewed as three components which provide a holistic approach towards farm sustainability. The three pillars are interlinked but influence the sustainability performance of the farm business differently. The analysis of the trade-offs helps to better understand and manage the countless interactions between agronomic, environmental and socioeconomic outcomes associated with the agricultural sector (Kanter et al., 2018).

These sustainability pillars can be utilised to frame and assess economic viability, environmental subsistence and social benefits, in addition to political, cultural and institutional dimensions (Toro et al., 2010). The design of sustainable agricultural ecosystems based on the three classic pillars (economic, environmental, and social) can only ensure sustainability if socio-cultural aspects such as local and traditional knowledge of producers about the management and use of natural resources are incorporated in production processes (Cisneros-Saguilán et al., 2015). Such an approach illustrates the importance of the user-centred management system for the increase in the sustainability performance of the farm business. The level of engagement with the three pillars or dimensions relates to the mind-set of the owner-manager and how these incorporate sustainability concepts into their management strategy (Barth et al., 2017).

The significance of restructuring agricultural production systems to embrace sustainability (particularly in terms of social equity and environmental conservation) is underlined by Holden et al, (2017). Yet farming systems are responsible for producing environmental externalities mainly because of the over-use of natural resources and the high rates of energy expenditure required for production purposes (van Vuuren et al., 2017). These externalities lead to increased amounts of carbon dioxide (CO_2) emissions (Luo et al., 2017). In the European Union, agricultural activities produced around 435.3 Tg CO2 eq, for the year 2018 , an amount which is equivalent to about 10% of the total emissions of greenhouse gases (Mielcarek-Bocheńska & Rzeźnik, 2021), whereas worldwide this percentage is estimated to about 13% (Charatsari & Lioutas, 2019).

According to Brodt et al (2011), sustainable agriculture integrates three main goals: environmental health, economic profitability, and social equity. However, there is an attempt to disassociate from economic aspects, particularly profitability, as it was considered conflicting with the other two pillars. The principle of sustainable agriculture is to meet the needs of the present without compromising the ability of future generations to meet their own need (Keeble, 1988). Long-term stewardship of both natural and human resources is of equal importance to short-term economic gain. According to Pretty (2008) agricultural sustainability is not a single, well-defined end goal, and scientific understanding about what constitutes sustainability in environmental, social, and economic terms, is continuously evolving and is influenced by contemporary issues, perspectives, and values. Furthermore, according to (Calus & Huylenbroeck, 2010; Martens et al., 2013; Sulewski et al., 2018) in the context of small-scale family farming systems, there is an association between environmental, social and economic pillars and more specifically there is a definite association between economic profitability and sustainability orientation of the farm. Innovation uptake for environmental protection and conservation for example, is considered by Piedra-Muñoz, et al (2016), as a means of increasing agricultural production and thus profit while at the same time rural development and environmental safety are favoured. Accordingly, animal welfare as part of the awareness of food-related ethics and ethical consumption can be used as an example of increasing profitability and also enhance the sustainability objectives of agriculture (Broom, 2010; Lagerkvist & Hess, 2011).

A key part of enhancing sustainability and moving forward in the context of the three pillars is to be clear what the farm sustainability goals are, what the current position is and what needs to change to make progress. This can be achieved via sustainability assessments.

2.2.4 Farm sustainability assessment.

To achieve an in depth understanding of the sustainability performance of farms, and ultimately support farmers in their decision-making process towards sustainable development, an extensive range of sustainability assessment tools have been developed (de Olde et al., 2018; Whitehead, 2017).

The selection of a sustainability assessment tool can be challenging as it depends on the theoretical background adopted, the correct evaluation of the economic/social/environmental context and surely the understanding of the needs and values of the stakeholders under assessment (Gasparatos & Scolobig, 2012). This is the reason why such tools can bias the assessment process, carrying ethical and practical implications. Ethically the choice of a specific tool carries with it a specific background and theoretical framework upon which was built, the perception of sustainability and the measured features (Gasparatos, 2010). The practical challenge is that the tool's values might not coincide with the stakeholder's needs and values, leading towards inferences unacceptable or even irrelevant to stakeholders/decision makers and thus not particularly useful for the decision-making process (Vatn, 2005).

Sustainability assessment tools have been developing for almost 40 years (de Olde et al., 2017). Reviews of the literature suggest that sustainability assessment tools can be divided into three broad categories: a) monetary, b) biophysical and c) indicator-based (Bebbington et al., 2007; Gasparatos et al., 2008; Singh et al., 2009). All tool categories can be used to evaluate the sustainability impact of different project/policies, even though certain tools such as biophysical, are rarely used in ex-ante assessments. Furthermore, monetary, and indicator-based tools are flexible enough to quantify a wide range of economic, social and environmental issues (Gasparatos & Scolobig, 2012). Conversely biophysical tools cannot capture adequately social and economic sustainability issues as a result of the valuation perspective they employ. Biophysical and monetary sustainability assessment tools are considered to be rather simplistic (Gasparatos et al., 2008). They follow a rather confined valuation perspective, from the multitude of perspectives that become related when assessing the sustainability of projects/policies, the human factor and decision-making and/or the management practices and production approaches.

A combination of biophysical and monetary tools or a well-balanced indicator tool, might be a more appropriate than using a single tool. Indicator-based tools, Composite Indicators (CI) or Multi Criteria Assessment (MCA), can adopt a more comprehensive view of sustainability and capture a wider range of perspectives (Gasparatos & Scolobig, 2012). The choice of a sustainability assessment tool inherently carries with it features and attributes that frame the assessment and its inferences. In this respect, sustainability assessment methods are not inherently flawed but contain significant biases towards specific framings (Bond & Morrison-Saunders, 2011).

When undertaking on-farm adoption of sustainability assessment it is essential to establish communication about the progress towards sustainability, both with the different agricultural sub-sectors (benchmarking) and society (stakeholder involvement) (Coteur et al., 2016). While sustainability is a potential arena for competition and differentiation between farmers, systematic use of tools on actual farms to assess progress is limited. This may be due to the high time and financial costs of performing sustainability assessments, the limited availability of farm data and a lack of perceived relevance of these assessments among farmers (De Olde et al., 2016).

Nevertheless, at-farm level assessment tools, show a large diversity in, for example, data, time and budget requirements, measurement and aggregation methods, output accuracy and complexity (De Olde et al., 2016). On completion of the sustainability assessment additional efforts are needed to discuss the assessment outcomes with farmers and other stakeholders and translate them into meaningful decisions for change. These outcomes are a starting point to discuss sustainability at the farm level and to contribute to awareness and learning about sustainability (De Olde et al., 2016). Providing farmers with a generic sustainability assessment is neither feasible nor desirable. Assessment tools must be specific enough to be able to highlight differences in similar but varied systems (de Olde et al., 2018). Sustainability assessment used for marketing and quality insurance purposes (e.g., certification schemes, metric initiatives and label rewarding evaluations) is one approach, while aiming at supporting farmers in improving their practices and decision-making towards greater sustainability is a different approach. The first should be generic and rigid to allow for credible standards while the second should be specific and flexible to take into account the specificity of each farm and each farmer (de Olde et al., 2018).

At the farm level, producers both generate and use diverse information that can include elements related to demographics, production, sales, and environmental sustainability outcomes. Some of the information they generate is forwarded to other stakeholders, including supply chain actors, metric initiatives, local government agencies and certification organizations. Assurance schemes play a broader role in promoting farm-level sustainability by ensuring trust, verification, and adherence to certain standards and protocols. Overall, they have a significant impact on farm-level sustainability by promoting environmental stewardship, animal welfare, social equity, and the adoption of long-term sustainable practices. They provide a framework for monitoring and improving sustainability performance on farms.

Slätmo et al, (2017) argue that the way sustainability assessment frameworks are applied, is crucial for their success in changing agriculture at farm level. In this regard, they note that using the assessment results as a basis for dialogue on changes on a specific farm, rather than a set of pre-defined actions for changing agriculture, can be helpful. The implementation of indicator-based frameworks to assess farm sustainability is not an expression of power by the developers of the framework and the expert performing the assessment over the farmer but rather should be seen as a means to encourage change on farms , and allow other contributing actors to be considered and not overlooked as far as the outcome of the assessment is concerned (Slätmo et al., 2017). In this spirit, local measurements of sustainability have recently proven to be an important part of sustainability assessment for researchers and practitioners (N. Jones et al., 2019). They present an interest as they can facilitate decision-making and policy tailoring, through incorporated perceptions of locals. In this way there is a better understanding of the importance of indicators of the chosen assessment tool at a local level (O Ryan & Pereira, 2015) and on the degree of awareness and the perception of sustainability from different social groups (Wynveen, 2015).

Overall, improvement of sustainability performance of farm businesses is imperative in many cases and the assessment gives useful inferences for the management approach of the business. By meticulously assessing the potential outcomes, implementing sustainable practices, and embracing innovative solutions, farmers can make informed decisions that blend productivity with environmental stewardship, creating a resilient and flourishing agricultural environment for generations to come. As farmers contend with the complexities of addressing the alimentary needs of an augmenting population whilst ensuring the conservation of the ecosystem, the choices they make have a direct impact on the well-being of the land, the prosperity of their societies, and the sustainability of their practices. In the following section, planning and control methods will be explored as means of enhancing farm management approach towards improving decision-making of farm business through informed and data-evidenced decision-making.

2.3 Planning and Control Methods

2.3.1 Farm management. The farmer as an entrepreneur.

Production processes should be planned and monitored. In modern economies farming is no longer simply a way of life but is just as much a business requiring careful planning, organisation, and control (Barnard & Nix, 1979). Business planning has a positive effect on financial performance of farming systems (Vanhuyse et al., 2021). The organisation of all aspects of the production process is crucial for the success of the farm enterprise. Historically, management of a farm was based mostly on empirical knowledge passed on from generation to generation. However, the modern farmer is confronted with a range of challenges: , for example, rising costs, lower product prices, escalating interest rates on the purchase of farming land, and labour shortages. These factors are forcing farmers to optimally develop their business acumen and managerial skills in order to manage their farming enterprises as economically as possible (Iakovidis, 2023; Van Reenen & Davel, 1989).

Farm management can be defined as the process by which resources and situations are manipulated by the farm manager in trying, with less than full information, to achieve his/her goals (Dillon, 1980). Management has to take decisions in many spheres of activity and go on to say that management it is concerned with the organisation of resources, with planning their use, both within and between enterprises, and with the control of plans both during their implementation and afterwards (Barnard & Nix, 1979). The full management framework involves several key steps that are interlinked and support a particular approach to a specific objective. These steps include setting objectives, planning, decision making, and control. The nature of management frameworks is that they are a combination of interlinked items that support a particular approach to a specific objective (Budler & Trkman, 2019). A management framework can be used to evaluate a system, assess the consequences of different options, and make decisions based on the results (Thyberg & Tonjes, 2015).

According to the dominant economic terminology, management is determined to be a rational operating and supervising activity over entrepreneurship (Vasylieva, 2019). Vasylieva argues that along with capital, labour, and land, management belongs to the key factors of production. Studies in the farm management field widely agree that the farmer is one of the most important elements affecting farm performance (Barnard & Nix, 1979; Nuthall, 2009). Furthermore, the farmer's importance in the management context is emphasised also when the farmer's managerial capacity is seen as the fourth production factor (Rougoor et al., 1998; Vukelić & Rodić, 2014), or when the managerial input is considered as a major resource along with nature, labour and capital (Nuthall, 2006). An entrepreneurial orientation to the business involves the recombination of resources with the intention of improving outcomes (Stanford-Billington & Cannon, 2010).

Agricultural entrepreneurs are significantly different from entrepreneurs in other sectors. Some farmers with weaker entrepreneurial capabilities, sometimes older farmers, tended to be less proactive in making changes and adopting new strategies in a Swedish study (Björklund, 2018). McElwee and Baker, (2008), showed that conventional farmers in England were less confident of their abilities as entrepreneurs than those who were engaged in value-added or non-farming enterprises. According to De Lauwere, Verhaar, & Drost (2002) management and strategic planning are crucial factors in entrepreneurship success while McElwee, (2007) suggested that strategic management, marketing and entrepreneurial skills consist of a number of skills which are needed mostly for the improvement of English farmers. In the Mediterranean basin it has been highlighted that there is a need to enhance the managerial competencies of farmers which will facilitate an improvement in their farm businesses (Iakovidis, 2023). An entrepreneurial approach may involve the development of new products or niche markets. However it also applies to the implementation of new processes and procedures so that the already existing products or markets are supplied more efficiently (Zellweger et al., 2010).

2.3.2 Planning principles and concepts.

A large and growing body of literature has investigated the concept of planning. The importance of the concept has been approached internationally in many different ways. People from the politics, culture, science, and business sectors have all added to the argument of the usefulness of planning. Dwight D. Eisenhower (1890-1969) suggested that "*In preparing for battle I have always found that plans are useless, but planning is indispensable"*, while Antoine de Saint-Exupery (1900-1944), argued that *"A goal without a plan is just a wish"*. Thomas Edison (1847-1931) quoted that *"Good fortune is what happens when opportunity meets with planning"* whilst Sir John Harvey-Jones (1924-2008), former chairman of chemicals firm ICI was usually referred to planning as *"Planning is an unnatural process; it is much more fun to do something. And the nicest thing about not planning is that failure comes as a complete surprise rather than being preceded by a period of worry and depression"*.

Planning can be strategic (deciding what the farm should do) or tactical (deciding how to do it) (Edwards & Duffy, 2014). Strategic planning has to do with the vision of the business, a systematic process to determine a desired future and the way to turn this vision into broadly defined goals and/or objectives. Tactical planning tackles the process, outlines the sequence of steps to achieve these goals. Tactical planning can be called operational planning as it utilises all the necessary elements to make progress towards organisational goals and objectives on a day-by-day basis. This is the role of the operational planning. The operational plan focuses specifically on how the business will achieve short-term objectives (Miller et al., 1998). Shorter term arm planning is an evolving process, during which decisions are made continuously and sequentially over time to react to new available information. The farmer needs to be able to build a flexible plan to anticipate likely changes in their operating environment (Robert et al., 2016). At the same time, the ability to respond in a timely manner to avoid negative consequences and improve overall results, depends on the frequency of use of planning methods such as budgeting, that is, the decision affects the result (Nuzhna et al., 2019).

Farming is a complex sector involving many decision-making processes that depend on a multitude of factors. Some factors like climatic conditions and land characteristics are inherent to the farm and cannot be altered or controlled. Other farm properties, like the current structure of the machinery stock and personnel and the irrigation infrastructure in place are important planning factors as in theory they can be more easily changed. The above factors are what constitute the farmer's options. According to Recio, Rubio and Criado (2003), these options cover a wide variety of alternatives on which decisions have to be made on specific operations. This is also known as field operation planning. Therefore, the field operation planning problem is inseparable from any analysis involving activity scheduling and cost control (Recio et al., 2003).

Strategic planning will set the overall direction of the farm business. Inderhees and Theuvsen (2009) argue that strategic management is essential to the long-term viability of firms in general, and that farm businesses are no different in this respect. On the other hand, Mintzberg considered strategic planning as an *"oxymoron"*. He argued that despite the fact that planning is necessary in order to implement strategies, one cannot formulate strategies by planning. Tools can be used to inform strategic planning (Roney, 2010). In fact firms in the UK manufacturing and service sectors that were implementing strategic planning, were making considerable use of a number of strategy tools, and they had increased their usage over time (Tassabehji & Isherwood, 2014). Thus strategic planning is a competitive advantage that may *"give managers the confidence and sense of purpose to act"* instead of stagnating (Stanford-Billington & Cannon, 2010).

Integrating strategic planning and tactical/operational planning is very important for the viability of the farm business. Balancing the components of planning will assist farmers/managers to exercise efficient control over them. Effective control procedures will ensure that tactical/operational planning will be more successful and thus lead to improved implementation of strategic plans of the farm business (Miller et al., 1998).

2.3.3 Control principles and concepts.

"It is one thing to make a plan; it is quite another to put it into operation and make sure that it works" (Barnard & Nix, 1979). According to them, changing plans is not something that is made frequently on most farming systems. Nevertheless, controlling the course of plans is a continuous process. Checking the progress that is being made, making necessary adjustments because of changing circumstances or to bring a *"drifting"* plan back onto course are perpetual actions needed to assess the way things are evolving. Effective control concerns the constant checking for a correspondence between the set and obtained results of activity (Vasylieva, 2019). It is the process via which the farmer ensures that the actual activities correspond with the planned activities it is used to determine if progress is being made towards the goals that have been set for the farm business. Based on this information, needed changes in strategies can be identified and new budgets can be created for the next planning cycle (Edwards & Duffy, 2014).

Even though many would argue that management is the most important part, its importance depends on how broadly the term *"control"* is interpreted. One could perceive that a single procedure such as the annual checking of actual results against a budget forecast, is covering its extent. On the other hand, it might justifiably be held to cover every aspect of administering the farm business. This way the concept would encompass not only recording data and analysis but a lot more, that would affect day-to-day decision-making. Planning is considered effective when plans are implemented and checked periodically to assess their progress towards the achievement of the goals/objectives set (Bailey, 2019). Management should correct any unplanned deviations in order to keep the farm business on course. Control outcomes may lead to the alteration of initial planning according to the circumstances. It is therefore clear that control forms the end point of the management process, but also immediately gives rise to new planning, new organisation, new implementation and thus the need for new control procedures (Van Reenen & Davel, 1989).

2.3.4 Effective on-farm planning and control

The management team (the farmer, and/or the family and/or the adviser) of a farm business is responsible for taking decisions. Decisions are taken in all stages of planning and control process. Planning and control methods such as budgeting, and/or an accurate set of financial statements will indicate the profitability, liquidity and solvency of the farm business and thus the overall financial health of the business (Edwards & Duffy, 2014; Sumelius, 2004). According to Mäkinen (2013), production planning supported by the monitoring of farm outcomes, use of bookkeeping, budgeting practices and economically oriented objectives also facilitate the technical efficiency of farms. It is evident that the adoption and implementation of planning and control methods depends on the management capacity of the farmer

(Mäkinen, 2013) and the application of analytical management tools with these higher level business skills leading to increased productivity and improved business outcomes (Stanford-Billington & Cannon, 2010). The literature suggests there are a multitude of methods, techniques and tools that can be used in order to achieve efficient planning and control of the farm business. Some of these are highlighted in the table 2.1.

Table 2.1: Planning and control methods

<table>
<tr><th>Author / Task</th><th>Planning</th><th>Control</th></tr>
<tr><td>Barnard & Nix, 1979</td><td>Budgeting
Partial Budget
Product substitution
Change of enterprises without substitution
Factor substitution
Complete Budget
Trading Budget
Final trading budget
Development trading budget
Capital Budget
Simple capital budget
Cash flow budget
Discounted cash flow budget
Gross margin planning
Programme Planning
Linear Programming</td><td>Financial Control
Annual Budgetary Appraisal
Monthly Budgetary Appraisal
Whole Farm Budgetary Control
Monthly Cash Flow
Physical Control
Levels of Production
Amount of foods or inputs (agrochemicals)
Management by Objectives</td></tr>
<tr><td>Van Reenen & Davel, 1989</td><td>Enterprise budget
Partial Budget
Break-Even Budget
Capital Budget
Payback Period
Rate of Return
Net Present Value
Farming Budget
Total Budget
Financing Budget</td><td>Management Information System Statements
Opening Balance Sheet
Income & Capital Reconciliation
Closing Balance Sheet
Flow-of-Funds</td></tr>
<tr><td>Edwards & Duffy, 2014</td><td>Enterprise Budget
Whole Farm Budget
Partial Budget
Cash Flow Budget</td><td>Financial Statements
Net Worth Statement (Balance Sheet)
Net Income Statement (Profit & Loss)
The Statement of Cash Flows</td></tr>
</table>

Overall, table 2.1 provides a useful overview of different financial planning and control methods and tools that can be used in agricultural management. It can help farmers and advisers understand the importance of planning and control in farm management and provide them with a starting point for exploring different contemporary methods and tools (Gantt charts, critical path analysis, and earned value management) in more detail (Stanford-Billington & Cannon, 2010). This in its turn will allow the exploration of other planning and control methods such as risk management, change management, and quality assurance (Cortés et al., 2019; Wang et al., 2022). These tools are used to identify and manage potential risks, changes, and quality issues that may arise during the cultivation year.

Informed organisation and planning mean that record-keeping, staff training and engagement, market development and communication are considered and implemented to ensure the effective and efficient running of the farm business. In addition, good organisation and planning will reduce business risk whilst making it more resilient to unexpected events (Midmer et al., 2014). Accurate record keeping aids decision making, results in better attention to detail and should be an integral part of farm planning process and in the context of this research will aid in the process of change to more sustainable systems.

By having access to reliable data, farmers can analyse past performance, track trends, and identify areas for improvement. This allows them to make more informed choices that align with their goals and objectives. By meticulously documenting farm activities, inputs, and outcomes, farmers are more likely to notice patterns, detect inefficiencies, and spot potential issues. This attention to detail enables proactive problem-solving and proactive management, resulting in increased efficiency and productivity. In terms of sustainability though this data becomes crucial when implementing changes towards more sustainable methods. It provides a baseline for measuring progress, identifying areas for improvement, and monitoring the effectiveness of sustainability initiatives. As far as decision-making is concerned though the use and adoption of planning and control methods, it is crucial in informing the decision process with evidence and data that will enable and facilitate this challenging task.

2.4 Decision-Making

2.4.1 The decision-making process.

Decision-making is an integral task of human activity in all areas of everyday life (Francik et al., 2016). It is often described as a challenging process due to the limited access to information and knowledge someone in relation to a given situation. Effective decision-making processes have been the focus of many disciplines, engaging multiple methodologies and approaches. Nevertheless, the study of the decision-making processes remains topical due to the correlation between the design and implementation of decisions and effectiveness of business tasks (Omarli, 2017).

In order to understand the decision-making process, the definition of decisions and the mechanism supporting decision-making needs to be examined. According to Drucker (1974) a decision is a judgement, it is a choice between alternatives. The choice of an alternative is not a choice between a correct and an incorrect decision but more likely between two courses of action, both neither totally right nor wrong. The absence of alternatives reveals the lack of purpose for taking a decision (Omarli, 2017).

"To do nothing is in every man's power". Samuel Johnson, English writer, could not have posed it better to emphasise the importance of decision-making. On the other hand, one could argue that if a decision is just a course of action reached after consideration and processing the features of a situation, then choosing to do nothing may be a possible decision according to the circumstances (Creelman et al., 2016). Several studies have outlined that in the agricultural sector 20% of the most profitable farm businesses are distinguished from the rest of the businesses by the ability of their decision makers to take the correct decision at the right time (Creelman et al., 2016). In addition, Creelman et al.(2016), distinguish between the "good" and the "right" decision based on the difference in the process and the inference. A good decision needs to be informed in order to be characterised as one, but for a decision to be identified as the "right" one, it needs to be proven and judged by its inference and through time.

Decision-making is a process consisting of various stages which will need to be modelled in a framework for farmers to adapt and implement (Fountas et al., 2006). Gladwin (1989) was an advocate of the idea that it would be beneficial to realise and understand the pattern of behaviour and action of a specific group of people. In this way it is possible to intervene in the process and assist in making good decisions. It will not mean necessarily that the right decisions will be made but it could act as a guideline for a farm manager to behave in a rational and standardised manner when facing choice alternatives (Fountas et al., 2006). Understanding the way in which farmers make decisions is fundamental in order to develop such models (Huber et al., 2018).

In relation to agriculture, most of the decisions are associated with production and are affected by short term and long-term components. Additionally, inferences are often time-lagging from the decision point

(Mehdi et al., 2018). Finally, the fact that agricultural production is affected by components that are almost impossible to control such as the environment and the biological properties of the primary products, makes the decision-making process an intriguing and demanding task in order to overcome these inherent challenges (Mazzetto & Sacco, 2019).

A different perspective on the decision-making process characterises it according to temporal and spatial scales (Robert et al., 2017). The division of the decision-making process into stages such as strategic (long-term), tactical (medium-term) and operational (short term) (Le Gal et al., 2010) is employed in order to explore the ability and possibility for farming systems to adapt and include all desired features of the process. This allows the impact of changes on the farm's production system to be evaluated and possible options for farming system adaptation to be included and explored.

2.4.2 Factors shaping the decision-making process.

Taking into consideration the decision process as an event, it is clear that a multitude of factors are critical in order to make good decisions (Öhlmér, Olson, & Brehmer, 1998). The decision-making process is a complex mechanism of human thinking, as various factors and courses of action intervene in it, with different results (Omarli, 2017).

Intuition is a factor based on which farmers often base their decisions (Fountas et al., 2006). These kinds of decisions are commonly made when decision makers are responding to urgent incidents or rapidly changed business environments. The decisions may be intuitive but follow a pattern e.g., a farmer notices that a particular crop is not growing well in a certain area of the field. The farmer recalls a similar situation from a previous year and remembers that the soil in that area was compacted. The farmer decides to till the soil in that area to loosen it up, based on their intuition that this will improve crop growth. The crop in that area of the field improves, confirming the farmer's intuition. This pattern can be predicted if the decision maker's ranking of alternatives is known. The highest ranked alternative appears to be the most rational choice for a decision (Samuelson & Zeckhauser, 1988). Creelman et al (2016) described the intuitive decision-making process as *"the gut"*. This illustrative metaphor is used to enhance the intuitive origin of the process, mainly shaped by the knowledge and past experiences of the decision maker. The terms *"head"* and *"heart"* are also used in the same context, the former indicating the rational way and latter being seen as the emotional way of deciding.

Nuthall introduced the "*managerial ability concept"* (1999, 2001, 2006, 2009). He aimed to focus on ways for the farmer to develop this ability. The results suggested that the most crucial factors influencing decision-making process are personality, a person's true intelligence, and exposure to experiences. Omarli (2017) also emphasised the manager's personality, among others, as an important factor affecting the decision-making process. The important influence of social and psychological factors on farming behaviour and hence decision-making is also flagged by Willock et al (1999). According to Ilbery (1979), economic factors such as for example market demand, policies, use of land, socio-personal factors such as personal preference, training/education, experience also influence and determine decision-making. Available data and information are important aspects of the decision task (Benda et al., 2011). The objective understanding and correct reading of them, shapes the intention towards specific action which is expressed through decision-making.

The influences of social stimulus in decision-making have received important academic attention. According to Edwards-Jones (2006), these can be characterised into six groups, these being:. Socio-demographics of the farmer, psychological makeup of the farmer, the characteristics of the farm household, structure of the farm business, the wider social environment, and the characteristics of the innovation to be adopted. By adopting a profit maximisation approach, it is possible to assume some very broad predictions about land use for example (e.g., crop selection, water management, fertilisation), but these predictions have to do purely with financial transactions.

According to Boserup (1965) the intensification of agriculture has long been the subject of analysis, the need for a holistic approach to intensification (not only from the scope of profit maximisation). Her theory suggested that population growth is the cause rather than the result of agricultural change, and the principal means of increasing agricultural output is a holistic approach to intensification as this population pressure is a major cause of change in land use, agricultural technology, land tenure systems, and settlement form. This led to the term "*sustainable intensification"* as a form of production where yields are increased to meet global needs for food but without negative environmental impacts and the expansion of cultivated land (The Royal Society, 2009). According to Garnett and Godfrey (2012), sustainable intensification can provide a framework for exploring what mix of approaches might work best based on the existing biophysical, social, cultural and economic context in which a farm operates. Farmers' reactions to all these are present in their decision-making process and for the explanation of this behavioural approach disciplines such as sociology and psychology are involved (Edwards-Jones, 2006).

The contribution of the agricultural sector in economic development worldwide and its significance as the main food producing sector for the world highlight the importance of mitigating risks and uncertainties in farming by understanding their origin and then constraining them as much as possible. Mitigating risks and uncertainties in farming is crucial for the agricultural sector. By understanding the origin of these risks and constraining them as much as possible, we can ensure the stability and productivity of the sector. Effective decision-making plays a vital role in mitigating risks and uncertainties. It enables faster and informed decisions, empowers employees, fosters innovation, reduces the likelihood of poor decisions, and allows for timely identification and assessment of risks

Risk perception, as far as vulnerability of the business or environmental risk such as weather conditions is concerned, co-shapes the decision-making process. Risk and uncertainty usually refer to the degree of knowledge in the decision-making process (Sonkkila, 2002). In the case of agriculture many activities related to it are subject to uncertainty (Ullah et al., 2016). As previously mentioned, this is related to the variability of the economic environment and the diversity of the biophysical environment in which agriculture is operating. Uncertainty and risk are typical characteristics of agricultural production (Moschini et al., 1999).

2.4.3 Decision-makers' styles

The pattern in which, decisions are taken, depends on the characteristics of the decision-maker and other personal parameters such as age, gender, team size and working ones such as management level (Remenova & Jankelova, 2019). For example in a study by Gonzalez-Ramirez et al (2018) the decision-makers had a short-term vision for economic results and a longer term vision concerning the prospective impacts on environmental and social aspects. Different management styles reflect different personality features of the decision-maker.

According to Sager and Gastil, (2006) the *sensitive* style is based on decision-maker's personality giving great attention to detail, reality and facts whereas the *conceptual* style of decision-making tends to be correlated to an "*intuitive"* personality (Ambrien et al., 2012). The "*thinker"* personality type positively correlates with the "*directional"* style of decision-making, but negatively with the "*behavioural"* style. The "*analytical"* style of decision-making depends on the "*decisive*" personality type, while the "*perceptive"* type negatively correlates with this decision-making style (Remenova & Jankelova, 2019).

Another reason, apart from the personality of the decision-maker, which explains the appearance of such a large number of decision-making styles is the existence of so many different decision-making situations due to the multidimensionality of agriculture. Adapting decision-making styles to the particular situation and enhancing it with personality attributes enables farmers/managers to function in a turbulent environment (risks and uncertainty are so typical in agriculture) and increase the efficiency and quality of their decisions (Remenova & Jankelova, 2019). In this context there is a strong link between decision-making and the evolution towards more sustainable systems.

2.4.4 Decision-making and sustainability

Agriculture has always faced numerous challenges. Currently, climate change, natural resources scarcity, human and animal welfare issues and societal demands and needs are tasks that are prompting agriculture to adopt more sustainable farming practices (Coteur et al., 2016). In general, sustainability issues have been raised in the context and with a certain perspective of how agricultural practices are applied. The development of farm sustainability has topical currency in the management approach of farmers/managers. As policy and market protection measures change within the agricultural sector, farmers/managers must be ready to undertake short and long-term changes in decision-making (Öhlmér, Olson, & Brehmer, 1998). In the current era it is likely that the development of enhanced farm sustainability will be necessary for businesses to survive.

Farm sustainability performance could be a unit of measurement for effective decision-making and vice-versa. As sustainability assessments make sustainable development tangible and achievable (Hajer, 1995), sustainability assessment can be seen as *"a range of processes that all have the broad aim to integrate sustainability concepts into decision making"* (Pope, 2006). The correlation between the two has been and will continue to be important for the sustainable development of agriculture. Furthermore, sustainability assessment can be described as a process that aims to use sustainable development as a decision-guiding strategy, as a guide for decision-making through anticipating the future outcomes of current and planned actions (Hugé et al., 2013). There is still a need for improved guidance and compliance of strategic decision-making and (Russillo & Pinter, 2009) the selection of the available tools and actions to measure and assess sustainability progress are often uncoordinated. Literature on sustainability assessment has grown rapidly over the last two decades. For example, Marchand et *al*., (Marchand et al., 2014), Gasparatos and Scolobig, (2012) and Binder et *al,* (2010) consider sustainability assessment and the sustainability assessment tools to support farm decision-making.

In this spirit, in order to remain competitive, farmers need to adapt their decision-making and hence management approach to the challenges of the constantly changing global environment (Darnhofer et al., 2010). Robert et al (2016) suggested that two basic fields dominate decision-making in the farm management approach. Agricultural economics and agronomy. For economists, long term (strategic) decision-making, presents the greater interest while agronomists focus largely on short-term (tactical) decisions affecting everyday farm management. Agronomists try to organise farm practices through a bio-physical context in the short-run, in order to ensure farm production (Martin et al., 2013), while economists strive to efficiently use resources in the long-run. Both of these decision-frames can be influenced by external pressure and policy with the Common Agricultural Policy (CAP) providing a key policy framework within the European Union (EU).

2.4.5 Decision-making and CAP

One of the most important and geographically wide-ranging parameters impacting the decision-making process, is the CAP. The support farmers receive through the CAP mechanisms shapes their decision-making practices and approach (Greer & Hind, 2012; Heyl et al., 2021). It is recognised that subsidies can influence the decision-making of farmers in terms of resource use, labour allocation, production choices, and investment (Hennessy, 1998; Sckokai & Moro, 2009). It is essentially shaping the farming system's direction towards producing food, enhancing rural community development and coherence, and promoting environmentally sustainable farming (Pe'er & Lakner, 2020). Since 1962, when the CAP was first launched and introduced it has undergone considerable change and reform. During this time it has played and continues to play an important role in providing the directional backcloth for rural development (Pe'er et al., 2020). In many situations decision-making by farmers/managers has been based on CAP legislation, funding mechanisms and monitoring and evaluation frameworks. It is clearly evident in the European context that CAP substantially shaped the landscape of farming systems through influencing farmer's decision-making (Huber et al., 2018; Siad et al., 2017).

It is clear that farmers have changed their decision-making process due to the CAP as they tend to give greater attention to determinants other than profit maximisation (Sonkkila, 2002). Understanding this behaviour and the factors that influence it, would enable a more accurate prediction of behaviour (Serebrennikov et al., 2020). This understanding can improve the predictability of farmers' decisions, thereby promoting effective agricultural policies, sustainable farming practices, and enhancing farmers' decision-making processes. For instance, Gómez-Limón et al, (2020), show that an understanding of a farmer's risk attitude could help predict their decision-making while Tze Ling et al, (2011), indicate that different farmer behavioural profiles can lead to different predictions of farmer decisions. Initially the CAP aimed to increase agricultural productivity by promoting technical progress and ensuring the optimum use of the factors of production and ensuring a fair standard of living for farmers of the member countries (Massot, 2017). Technical efficiency can contribute to both and it is therefore informative to policymakers to know whether specific types of subsidies do improve farm technical efficiency (Latruffe et al., 2017) and therefore decision-making.

The recent re-orientation of the CAP 2023-27 towards more environmentally sustainable farming with a focus on tackling climate change, protecting natural resources and enhancing biodiversity. With the application of measures like cross-compliance, green direct payments and rural development it is clear that green farming and the enforcement of environmental rules are in place to enhance sustainability. Thus, encouraging low-input agriculture along with the continuous assessment of environmental measures, research, innovation and updated farm advisory systems are meant to drive sustainable agriculture in the EU through the enhancement of decision-making processes. However, change to more sustainable systems will only happen when individuals and businesses change their practices and thus it's increase is seen as imperative to engage stakeholders widely in the process of change (Goodman & Sanders Thompson, 2017; Kujala et al., 2022).

2.4.6 A user-centred management approach.

Researchers and scholars in the farm management field widely and throughout time agree that the farmer is probably the most important element affecting farm performance (Barnard & Nix, 1979; Biesheuvel et al., 2021; Corsi et al., 2021; Dessart et al., 2019; Hayden et al., 2021; Nuthall, 2009). Overall, these articles suggest that farmers are a critical element affecting farm performance, and their decision-making is influenced by a wide range of factors, including financial and non-financial factors, disease prevention and control, economic, demographic and succession factors, crop yield, and behavioural factors. How important, successful management is, is also emphasised when the farmer's managerial attributes and qualities are perceived as the fourth production factor (Rougoor et al., 1998). Additionally, the managerial aspect is seen as a major resource of the business along with nature, labour and capital (Nuthall, 2006).

Farm business management is closely related to farmer's personal views and beliefs (Hansson & Sok, 2021). It is an extent of his/her personality and usually mirrors the vision and perception they have regarding the business environment. In *"Managerial Thinking"*, Mäkinen (2013) relates directly to the farmer personal perspective, and influences decision-making and thus sustainability performance of the farm. This aspect of farmer's behaviour reflects on the attributes and the values of the farm business while at the same time impacts the way decisions are made about it (Mäkinen, 2013). Farmer's objectives about the business's orientation and vision are included to the stimuli triggering farmer's managerial thinking (Liu et al., 2018). The perception of the farmer about the farm business as a means of satisfying economic goals but also environmental and social ones contributes to shaping a mind-set from which decision-making and agricultural practices are influenced (Hayden et al., 2021).

The section pertaining to decision-making provides invaluable insights into the vital role of sustainable choices in shaping the future of agriculture. Within this subchapter, the complex process of assessing choices and their ramifications, while seeking the most knowledgeable and responsible path forward, was extensively explored. One crucial aspect of decision-making is the consideration of the long-term implications of actions, a concept that is intricately linked with the subchapter on farm sustainability.

As discussed above the successful enhancement of sustainability on-farm will only happen when effective control and monitoring is in place which will provide an indication of successful change. Thus, good recording and evidence-based decision-making are critical elements in the context of enhancing sustainability and as technology use on farms has both evolved and increased so has the availability and use of decision support tools to aid a range of aspects of managerial planning and control.

2.5 Decision Support Tools (DSTs)

2.5.1. Evidence-based decision-making in agriculture.

In environmental management decision support tools (or "decision support systems") are increasingly used to assist decision-making (Laniak et al., 2013). In other sectors such as medicine, evidence-based clinical practice based on DSSs is routine (Graham et al., 2011). In agriculture, the use of such tools is more limited, although increasing (Rose et al., 2016). This has been attributed either to farmer's or adviser's difficulty to access scientific data and information for decision-making (Bayliss et al., 2012), and/or to a difficulty to integrate the increasing amount of available data into the decision-making process (Segan et al., 2011).

The multitude of economic, environmental, and social challenges facing agriculture have been outlined earlier in the introduction. In order to address these challenges farmers need tools to evaluate farming system sustainability and to offer alternatives and to assist the change to more sustainable systems (Cadero et al., 2018). "*Scientists develop DSSs to make agricultural science more accessible for farmers and extension officers*" (Jakku & Thorburn, 2010). They have insightfully argued that DSTs can be understood, not just as instrumental devices, but as 'boundary objects 'through which different meanings and knowledge are negotiated and shared (Ayre et al., 2019). Furthermore, decision support tools developed from models can help farmers to simulate and understand the influence of changes in their management practices on the economic and environmental performance of their production system (Gouttenoire et al., 2011). Kerr (2004), suggested that models should be simplified in order to help people make decisions suggesting that DSTs are often over engineered for the problem they are meant to provide solutions for. He proposed a more top-down approach to system evaluation rather than an analytical approach based on data. (Kerr, 2004)

So, what is a decision support tool? According to Dicks, Walsh and Sutherland (2014) it is "*a tool, usually software-based, designed to assist decision-makers with a particular decision, often by illustrating different possible outcomes visually or numerically, or leading users through logical decision steps*". Rose et al (2016), refer to them as usually considered to be software-based and attribute to them a very important role in the quest for evidence-based decision-making in agriculture in order to improve productivity but also increase environmental outputs. Their use is bounded to improve the decision-making process through incorporating information into the evidence base for decisions. After all, the world today is an increasingly *"spatial and temporal data-rich environment"* and the sector of agriculture, cannot escape from this. Available data need to undergo appropriate processing in order elicit the required information and then make informed management decisions. (Leroux et al., 2018).

2.5.2 Decision Support Tools in agriculture.

The growing popularity of DSTs use results partly from their capacity to incorporate scientific evidence into the decision context. In agriculture DSTs for use on-farm can act as a vehicle for delivering scientific knowledge directly to the farming community in order to raise productivity and reduce environmental impact (Rose et al., 2016). Agricultural DSTs perform activities described below (Agrios, 2004):

(i) collect, organise, and integrate several types of information required for producing a crop or animal product;
(ii) analyse and interpret the information; and
(iii) use the analysis to recommend the most appropriate action or action choices.

A DST enables decision-makers to take into consideration complex and interacting factors. In this context an increased number of alternatives can be examined, better understanding of the business/processes can be achieved, identification of unexpected situations can be provisioned, improved communication can be attained, and cost saving can be achieved. Also, better decisions, time saving, and better use of data and resources can be accomplished for the benefit of the business.

The potential of DSTs, to improve farming decisions is well-recognised (Kragt & Llewellyn, 2014), nevertheless expectations of farmer adoption and use have not been realised (McCown, 2002). Instead, a common response has been to abandon the project rather than try to adjust and fix it. Market failure has been accepted as tolerable in the context of other research successes (McCown, 2002). There is no doubt, that every researcher starts with good intentions to provide a tool that would benefit farm management (Rossi et al., 2014). The adoption of a DST though, requires the implementation of new work practices at the farm level, therefore, future end-users must be convinced of the relevance and benefits of the DSTs and to consider their actual use in order to be able to implement the new procedures (McCown et al., 2009).

In this context, technology must be incorporated into farmers' practice. Farmers then, should implement it based on their knowledge, mostly gained through experience, in order to lead towards increasing sustainability in their farming system. To date agricultural researchers have used DSTs to transfer scientific knowledge to operational on-farm action, aiming to increase farmers' uptake of scientific knowledge (McCown et al., 2009). However, as described above, results have been controversial as many DSTs have not been used appropriately, or at all, in practice (McCown, 2002; Rossi et al., 2014). Therefore, it is important to gain a better understanding of how individuals in complex situations actually make decisions and use agriculture-based DSTs for social learning (Lundström & Lindblom, 2018). Social learning is a framework strategy that plays a prominent and growing role in interventions to achieve sustainability by changing behaviours and intentions. It involves acquiring knowledge through social networks by means of communication, observation, collective labour groups, public meetings, socio-cultural norms, and other forms of social interaction (Noguera-Méndez et al., 2016).

2.5.3 Determinants affecting DST uptake.

The growing popularity of such tools, results partly from their capacity to incorporate scientific evidence into the decision-making process (Stewart et al., 2013). However, adoption of decision support tools by farmers, is generally low relative to the number of tools available (Huber et al., 2018; David C. Rose et al., 2016). The possibility that a decision support tool will be used, increases when it proves its effectiveness in terms of positive results, it proves to be accessible and easy to use, and it is aligned with what the user needs and is capable of (Rose et al., 2016). The notion of the tool supporting and assisting the end-user rather than replacing him/her, tends to influence adoption rate positively (Rossi et al., 2014)

From a farmer's perspective, the reliability of the information provided by a decision support tool is just as crucial as its easiness of use (Diez & McIntosh, 2011). Thus, determinants that influence DST adoption and implementation are usually two-fold. For example, farmer's information technology (IT) literacy influences DST uptake as farmers are generally not as computer literate as many researchers. Technology development is often based on what researchers and developers of DSTs consider usable and credible and therefore not always adapted to farmers' actually needs and practices (Lundström & Lindblom, 2018). It is likely that farmers' dependency on computers will continue to grow tracking the trend of the wider society, but there is little reason to believe it will eventually be evident that the agricultural DST uptake crisis, has resulted because the DSTs for farmers was *''an idea ahead of its time"*. (McCown, 2002). Apart from that features such as culture, educational level and age also affect a farmer's ability to adopt new technology (Gallardo et al., 2020a; Kerr, 2004). Often lack of computers, insufficient computing skills, lower IT education levels and lack of progressive attitudes, were some of the reasons that farmers initially ignored such products (McCown et al., 2009; Monteiro Moretti et al., 2023).

Despite initial low acceptance rates DSTs are becoming increasingly useful for agriculture and technologically superior. Nevertheless the uptake of computer-based support systems by farmers has remained disappointingly low as evidenced by studies spanning at least two decades (Rose et al., 2018). Rose et al (2018), suggested that without changing the way systems are developed, especially how users participate, use of this technology will remain low. They suggested that in order to encourage a more effective *"user-centred design"*, before building and launching a product a *"decision support context assessment"* must be undertaken. This of course requires a better knowledge of user-centred design practices, Knowledge on how advice systems function, and finally, close collaboration with human-computer interaction researchers. Monteiro Moretti et al., (2023), found that negative perceptions of the economic and social aspects of DSTs for precision agriculture are a source of discrepancies among the actors. Conversely, positive perceptions of the prospective value propositions of DSTs seem to be a point of coherence. Another dimension is illustrated in Lowenberg-DeBoer et al, (2022), where requiring 100% on-site human supervision almost wipes out the economic benefits of autonomous crop equipment for small and medium farms and increases the economies-of-scale advantage of larger farms. Finally, Gallardo et al., (Gallardo et al., 2020b), suggested that there has been perceived to be a trade-off between the accuracy of a DSTs and their practicality. This is because growers and advisors have very limited time and are unwilling to spend much time when using a DST. Consequently, these potential users require simple, easy-to-use interfaces, and a reduced number of manual data inputs.

Summarising the findings of all the above fifteen factors (Table 2.2) were identified as possible influences on the use and uptake of decision support tools. These factors were previously identified and were also evident in research published by McCown (2012), Venkatesh et al. (2012), Hochman and Carberry (2011), Alvarez and Nuthall (2006), Kerr (2004) and McCown (2002).

Table 2.2: Factors influencing DST uptake and use in agriculture.

	Factors		**Factors**
1	Performance	**9**	Age of user
2	Ease of use	**10**	Scale of business
3	Peer recommendation	**11**	Farming type
4	Trust	**12**	IT education
5	Cost	**13**	Facilitating conditions
6	Habit	**14**	Compliance
7	Relevance to user	**15**	Level of marketing
8	Farmer-adviser compatibility		

Table adapted from Rose et al (2016)

Findings in the same research also the use of a DST as required by legislation and/or as a market requirement yet noting that such measures are forcing the use and uptake rather than allowing farmers to choose the use of the tool consciously for the expected outcome. A solution to this could be the implementation of such a tool to be subsidised through covering the cost of purchase by the state or through EU programs promoting innovation and technology. However, results presented in the research, highlighted that a large proportion of those farmers who had purchased DST with 80% or 100% grants were not actually using them regularly (Rose et al., 2016). Another determinant influencing uptake and use is the calibration and parameterisation of the DST for the agricultural frame in which it is designed to function. Comprehensive testing can be useful in order to present an easy-to-use tool with reliable and accurate function as far as operation and results are concerned (Rinaldi & He, 2014). Thus a key factor that influences the adoption of a DST is the establishment of its practical impact along with its market credentials (Rossi et al., 2014).

The perception of farmers and advisers on the usefulness of DSTs is related to their attitude towards the tool as a discontinuous technology (Trauffler et al., 2005). Such a perspective considers that a DST necessitates significant change in everyday practice and this way it is considered as not relevant. A different look may be of use when it comes to think differently about the tool and the possible effects that it may have to the established practice. Practice relevance along with a vision of significant benefit to goal attainment (McCown et al., 2009), should be investigated for enhancing DST uptake and use.

2.6 Theoretical framework

2.6.1 Introduction

This research focuses on the sustainability assessment of farm businesses and the adoption and implementation of planning and control methods and the DSTs in the context of farm sustainability. As adoption of decision-making/management tools is under consideration, the theoretical framework should emphasise on understanding the individual's ability to perceive, understand and interact with the environment in a specific intelligent manner. In this way the individual and his/her environment are important elements of the process (Botha & Atkins, 2005). Rogers (2004) defines innovation as *"any idea, object or practice that is perceived as new emergence"*. A method/object may have been invented and used for a long time ago, but if people perceive it as new, then it may still be an innovation for them (Ibrahim & Monsurat, 2015).

Another important factor affecting the adoption of innovations is at farmers *"access to sound knowledge, information and advice. This is a critical factor in their being able to manage their resources well"* (Garforth, 2010). So, any effort to improve innovation adoption and implementation, should be addressed in the context of farmers' social learning abilities and stakeholders' extension policies. As Kuehne et al. (2011) suggested, predicting innovation adoption is influenced by two factors. First, the *"learnability"* characteristics, or those factors that determine how the end-user finds out about an innovation. Secondly, the *"relative advantage"* of the innovation must be recognised, in other words the end user must be convinced that uptake and use of an innovation is better than doing so (Kuehne et al., 2017).

In assessing theories and frameworks required in the study of the sustainability assessment, the adoption and implementation of planning and control methods, and the use and adoption of DSTs as innovative behaviour, their combined use offer useful constructs for studying the adoption process.

2.6.2 Theoretical framework and qualitative research

Qualitative research is concerned primarily with the process, rather than the outcomes or products (Atieno, 2009). In this sense it coincides with the expected outcomes of this project seeking to understand the degree of adoption and implementation of planning and control methods, the reasons behind farmers' willingness to adopt and their perception of influence on farm sustainability improvement. Qualitative research has both a descriptive and inductive nature (Atieno, 2009). It can also serve as a tool for the generation, development, qualification and correction of theory (Bitsch, 2001). A better understanding of the process, concept visualisation and hypothesis building is expected to emerge and explain farmers' attitudes towards adoption of *"innovations"* leading to an altered decision-making/management approach towards farm sustainability improvement.

The theories of Reasoned action, Extension, and Perceived Attributes are underpinning the research on decision-making, farm sustainability, adoption and implementation of planning and control methods, and use and adoption of decision support tools in several ways. The theory of Reasoned Action is a behavioural model that has been used to explain environmental management decision-making in the context of farm sustainability (Rose et al., 2018; Sok et al., 2021). This theory suggests that an individual's behaviour is determined by their intention to perform the behaviour and their attitude towards the behaviour. A limitation of the theory of Reasoned Action is the fact that the theory assumes that people are always rational and make rational decisions. One of the major lessons from the extension theory is that it is important to make new things visible, to make visible the state of the environment and the extent to which present farming practices are untenable. The modern approach to agricultural research and extension, however, has been to emphasise comprehensive packages of technologies. Few farmers are able to adopt these technologies, and the extension theory by Rolling (1988) suggests that it is important to make new things visible and to energise extension staff to make these technologies accessible to farmers. This theory's limitation might be the oversimplification of intentions, meaning real-life behaviour is often influenced by multiple factors beyond just intentions.

Perceived attributes refer to the characteristics of a decision that influence an individual's decision-making process (Campbell & King, 2022). In the context of farm sustainability, perceived attributes may include the perceived benefits and risks of adopting practices and innovative technologies. Perceived attributes can influence the attitudes and beliefs of farmers towards sustainable practices and technological advancements, which in turn can affect their decision-making process (Campbell & King, 2022; Senger et al., 2017). The theory of perceived attributes may be limited in addressing emotional and social influences.

Overall, the theories of reasoned action, extension, and perceived attributes provide a framework for understanding the decision-making process of farmers in the context of farm sustainability. These theories will help to identify the factors that influence farmers' decisions to adopt sustainable practices and innovative technologies, and to develop strategies to promote the adoption of these practices and technologies.

2.6.3 The Theory of Reasoned Action (TRA)

The Theory of Reasoned Action aims to explain the relationship between attitudes and behaviours within human action. Fishbein (1967) was the first to discuss TRA. TRA suggests that attitude and subjective norms are important for persuasive communication (Nguyen et al., 2018). Within the TRA framework, the intention towards adopting a specific behaviour, is an additive function of two variables: attitudes and subjective norms. The attitudes essentially represent the assessment of performing a certain behaviour while the subjective norms represent the perception of the effect that external/social influences may have (Fishbein, 2008). Thus, attitude is an person's salient belief as to whether the outcome of their behaviour will be positive or negative (Fishbein & Cappella, 2006). Subjective norms are assumed to be a function of beliefs that individuals approve or disapprove of the behaviour. Individuals will intend a behaviour when they perceive that important others think they should do so. Important others might be someone from the family (e.g., wife), close friends or the extension officer, stakeholder among others. This is assessed by asking respondents to judge how likely it is that most people who are important to them would approve or disapprove of their behaviour (Fishbein & Yzer, 2003).

2.6.4 The Extension Theory

Extension science, which originated from rural sociology, has undergone changes over time and has become more aligned with social psychology and communication. According to Rölling (1988), the adoption of innovation is based on the level at which innovation is adopted. The adoption of innovation is a process that occurs over time and involves the following stages: awareness of the need for an innovation, decision to adopt or reject the innovation, initial use of the innovation to test it, and continued use of the innovation. The adoption of a new idea, behaviour, or product does not happen simultaneously in a social system; rather, it is a process whereby some people are more likely to adopt the innovation than others. A further assumption was that increased adoption rates would occur as information about the innovation was communicated through farmers' social networks. This organised and formal process of actively communicating such information was called extension, basically the process of changing voluntary behaviour via communication. The goal of extension is to determine how to convey information regarding an innovation to a certain population (such as farmers) so that they will adopt it. The challenge then of extension is to design an appropriate communication channel (Rölling, 1988).

Over time within the field of agricultural extension the term extension has also been used to collectively include any advisory, consulting, technology transfer, research, training, marketing, industry development, learning, change, communication, education, attitude change, collection and dissemination of information, human resource development, facilitation, or self-development activities that are undertaken with the aim of bringing about positive change on farms and in agriculture (Fulton et al., 2003).

2.6.5 The Theory of Perceived Attributes

The theory of perceived attributes is based on the notion that individuals will adopt an innovation if they perceive that the innovation has the following attributes (Nutley et al., 2002). First, the innovation must have some relative advantage over an existing innovation or the status quo. Second, it is important the innovation be compatible with existing values and practices. Third, the innovation cannot be too complex. Fourth, the innovation must have trialability. This means the innovation must have been trialled for a limited time without wider adoption. Fifth, the innovation must offer observable results (Rogers, 1995).

2.7 Summary

In this chapter, the literature and underlying principles supporting the present thesis are expounded upon. It has been demonstrated that the implementation of business planning and control methods and DSTs, through decision-making, plays a vital role in increasing farm sustainability. By incorporating evidence-based and data-informed decision-making processes into their daily practices, farmers and advisers can enhance the sustainability performance of their farm businesses. This chapter has also provided an overview of the theoretical framework in relation to the shaping of the research design and the methodology thus providing a solid theoretical grounding that enhances the validity, reliability and significance of the research. It serves as a guiding framework that helps the structure of the study, develops research questions or hypotheses, interprets findings, and contributes to the existing knowledge in the field. In the following chapter, the study area is introduced, along with the overarching methodological approach that is being employed in the following three paper/chapters.

CHAPTER 3. Study context

3.1 Introduction

Although farm sustainability is a global issue, the Mediterranean basin has a range of common features and attributes that present challenges in relation to the evolution of more sustainable farming systems. These challenges can only be overcome if a different management approach is taken by the owners/managers of farm businesses in the region. This chapter provides an overview of the methodological approach of the following paper/chapters. The suitability of the Argolida region as the study area is also presented.

3.2 Area of study

3.2.1 The Mediterranean basin context

The economy and culture of the Mediterranean basin have relied on agriculture for a significant period of time (Zeder, 2008). Countries such as Spain, France, Italy, Greece, Turkey, and Morocco, which constitute part of the Mediterranean region, have a rich history of agricultural production. The Mediterranean climate, characterised by moist and mild winters as well as hot and dry summers, provides favourable conditions for a diverse range of crops. However, due to the region's topography, which includes mountainous terrain and arid areas, farmers have developed various farming techniques and systems. For instance, terracing, involving the construction of walls or steps on hills or mountainsides to create flat areas for planting crops, and irrigation, which compensates for the limited rainfall in the region, are examples of the sophisticated methods employed by farmers for collecting and distributing water (Zeder, 2008). Irrigation is an important practice in the Mediterranean basin, with approximately 70% of agricultural land being irrigated. Nevertheless, there are concerns about the sustainability of irrigation practices in the region, particularly in areas where water resources are scarce.

Notably, crops like olives, grapes, citrus fruits, and wheat have played a substantial role in the economic prosperity of this region (Fader et al., 2015). One of the most iconic crops both economically and agriculturally of the Mediterranean region is the olive tree (Hijawi, 2021). He suggests that, both table olives and olive oil are major components of the daily human diet, and olive trees are a dominant landscape component of rural areas across the Mediterranean. Extra-virgin olive oil (EVOO) is an important element in the Mediterranean diet and a major agricultural crop for Southern European countries in terms of both farm income and cultivated area (Giudice et al., 2015). Citrus crops are also an important crop in the region (Aznar-Sánchez et al., 2020). The Mediterranean basin, which is a major global producer and trader of citrus fruits, is the second-highest citrus-growing region in the world. Traditional permanent crops such as olive, almond, citrus, and other fruit trees occupy around 20% of the cultivable area throughout the Mediterranean Basin (Aznar-Sánchez et al., 2020).

Overall, agriculture continues to be an important economic activity within the Mediterranean basin providing food and financial stability to many communities. The Mediterranean basin is home to over 250 million people and agriculture provides a livelihood for a significant portion of the population. According to FAO, the Mediterranean basin is the world's largest producer of olives, accounting for over 97% of global production. In 2020, the region produced approximately 3.4 million tons of olive oil, with Spain, Italy, and Greece being the largest producers. Wine production is also a significant industry in the Mediterranean, with countries such as France, Italy, and Spain being major producers. The Mediterranean basin also produces large amounts of edible grapes, wheat, almonds, and tomatoes. According to the European Commission, the agricultural sector in the Mediterranean region contributes approximately 10% to the region's GDP. According to the FAO (2018), the average agricultural land use in the Mediterranean basin is approximately 36%, with some countries, especially in the south Mediterranean such as Tunisia and Morocco, having much higher levels of agricultural land use. The Mediterranean basin is also home to a rich variety of livestock including cattle, sheep, goats, and poultry.

Nevertheless, the agricultural sector in the Mediterranean basin faces challenges such as climate change, water scarcity, and rural depopulation leading to land abandonment. Sustainable agriculture practices are gaining momentum in the region, with initiatives such as the Mediterranean Action Plan (MAP) and the Mediterranean Organic Agriculture Network (MOAN) promoting sustainable agriculture and biodiversity conservation. Overall, Mediterranean agriculture is a complex and highly developed system that has evolved over thousands of years. Its unique combination of crops, techniques, and traditions has helped to sustain the region's population and economy for generations.

3.2.2 Agriculture in the region of Argolida

The case study region of Argolida in the Peloponnese (Fig. 3.1) is representative of many areas of Mediterranean agriculture. Farming has played an important role, not only as an occupation but also as a key feature in shaping the culture of the inhabitants in the region for more than 7000 years. For instance the city of Argos has been continuously inhabited for the past 7,000 years (Bolender, 2010). The hinterland has been cultivated with the indigenous species over that time while the current agriculture is considered as one of the primary economic activities in the area accounting for 26% of total output in the region (Hellenic Statistical Authority, 2021). Even though at the end of the 19th century the fields were mostly cultivated with arable crops (wheat, barley etc), the arid plain of Argolida was completely bare. The cultivation of oranges began during the interwar period when it became possible to irrigate the plain with water from wells.

Figure 3.1: Map of region of Argolida. Adapted from https://en.m.wikipedia.org/wiki/File:Greece_location_map.svg

Today, about 58% of orange trees in Greece are grown in the Argolida plain. In Argolida orange cultivation spread widely in the 1950s and today accounts for 70% of total cultivation. As a result of the intense farming activity, a number of factories for fruits' processing mainly for exporting, and olive oil mills have been developed in the area. Agricultural activity shaped the social and cultural heritage of the area and its inhabitants, had considerable influence on the occupational choices of each generation while at the same time has been the major source of income for the people in the region (Hellenic Statistical Authority, 2014). It has influenced the lives of people in such a degree that even today that agriculture faces so many structural and inherent challenges (increased production cost, low prices, CAP, dependency on subsidies, etc), still remains a key element to the region in terms of importance and contribution as an occupation and annual income source for the majority of the inhabitants, professional farmers or not.

Argolida has been chosen as the study region because it presents all these features that typifies it as a representative Mediterranean area, the edaphoclimatic conditions, the typical small-scale farming systems, the predominant crops, the holding size, the age of rural population and the education/training of farmers. It has typical dry Mediterranean climate conditions, and permanent crops, mainly olive and citrus trees. The holdings in their majority (>90%) are below 10 hectares, while 90% farmers are more than 55 years of age and do not have any comprehensive agricultural education. This is generally the case not only for the region but for Greece as a whole.

3.3 Methodological approach

3.3.1 Introduction

The methodologies used during the course of this research are mentioned and analysed in each of the respective sub-section of the empirical chapters that describe the fieldwork undertaken. Nevertheless, this chapter provides an overview of the methods and techniques employed (fig. 3.2), to aid a coherent understanding of the research supporting the credibility and rigour of the study. It provides a detailed description of the research methodology that was used to carry out the study. It outlines the research design, methods, and procedures that were employed to collect and analyze data and explains how the findings were interpreted and reported.

The methodological approach as depicted in Figure 3.2, essentially contextualises the theories employed in the theoretical framework. In this spirit, the thematic analysis approach and the RISE 3.0 sustainability assessment in a sample of 20 farmers drawn from FADN, investigates the assessment of performing a certain behaviour in line with the theory of reasoned action. In the same spirit and with the use of content analysis in a sample of 28 farmers from FADN and 20 advisors (10 agronomists & 10 accountants) explores and quantifies the perceptions of the two groups of participants on the possibility of adopting an innovation (planning & control methods) if they perceive that the innovation has certain attributes according to the theory of perceived attributes. Finally, with the engagement of several groups of stakeholders (farmers from the area (FADN), farmers from the area (no FADN), advisers, extension officers, industry representatives, policy makers) it is attempted to identify the needs and requirements of them for the effective design of a decision support tool, stepping on the extension theory that suggests that it is important to make new things visible and accessible to end users.

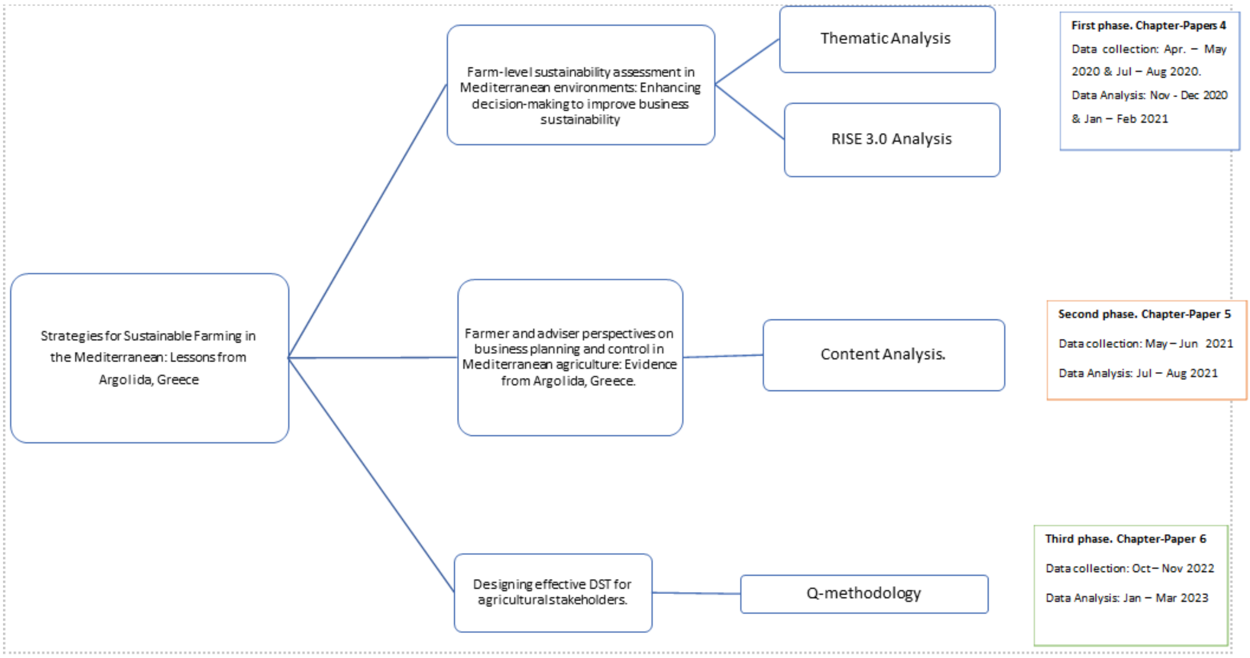

Figure 3.2: Methodological approach of empirical chapters

The interviews for the thematic analysis in the first phase were conducted with a sample of 20 farmers from the FADN dataset of the area under study. The same sample was used for the RISE 3.0 sustainability assessment. For the interviews of the content analysis in the second phase, 20 advisers and 28 farmers from the FADN dataset for the area were employed. For the farmers, 18 of them have been employed for the first phase (thematic analysis). Finally, for the third phase (the Q-methodology interviews), a subset of farmers (5 farmers) and advisers (5 advisers) used also in the thematic and content analyses, were employed. For this phase a new group of farmers was introduced and employed to identify possible differences in perceptions from the FADN group of farmers.

3.3.2 Thematic Analysis

Thematic analysis is a qualitative research method that involves identifying and analysing patterns or themes within qualitative data to gain insights and understanding of a particular phenomenon or research question (Braun & Clarke, 2006).

The use of thematic analysis allows researchers to explore and gain a deep understanding of qualitative data. It helps identify patterns and trends and highlight recurring ideas within the data. At the same time, it is a flexible approach that can be applied to different types of qualitative data, including interviews, focus groups, and surveys. Most importantly though, thematic analysis focuses on understanding the meaning and interpretation of the data. It helps uncover participants' perspectives, experiences, and beliefs, providing rich descriptions and narratives that capture the complexity and nuances of the research topic.

The gains from using this method are that it enhances the validity and reliability of qualitative research so that researchers can ensure rigour and transparency in the analysis process, making it easier to evaluate the reliability of the findings. The findings can then inform policy development and practical applications as the identified themes can provide valuable insights for decision-makers, practitioners, and professionals working in relevant fields. In this research it allowed for the identification and analysis of patterns or themes within qualitative data from interviews as far as decision-making, farm sustainability and decision support tools are concerned.

Thematic analysis has been used in various agricultural studies, including those exploring farmers' perceptions of antibiotic use and resistance (Wemette et al., 2020), perceptions of present and future climate change impacts on water availability for agricultural systems in the Western Mediterranean region (Nguyen et al., 2016), and risk perceptions, preferences, and management strategies of German livestock farmers (Meraner & Finger, 2019). Overall, thematic analysis is a versatile and powerful method that enables researchers to explore, understand, and interpret qualitative data in a systematic and rigorous manner, making it a popular choice for qualitative researchers. In this research, the use of thematic analysis was decided in order to contrast the findings with those of RISE 3.0, in an effort to understand clearer the current situation in farm businesses of the area under study.

3.3.3 RISE 3.0

The RISE 3.0 (Response-Inducing Sustainability Evaluation) is a sustainability assessment tool that is designed to assess the economic, social, and environmental sustainability performance of agricultural production at the farm level. It seeks to create a tangible yet science-based evaluation, enabling the initiation of measures to improve sustainability (Grenz et al., 2009). It has been developed at the Bern University of Applied Sciences, School of Agricultural, Forest, and Food Sciences (HAFL) in Switzerland and applied in many countries. Experiences with previous versions of RISE 1.0 and 2.0 have been presented in the literature (Häni et al., 2003). There was an iterative development process of the RISE method considering user feedback, expert consultations (extension workers, scientists, tool developers, and farmers), and cross-comparisons against other sources.

Adaptations to the thematic scope of the indicators were made compared to previous RISE versions. Version 3.0 of RISE has a partially generic character, reflected by a flexible indicator set, to better cover the diversity of production conditions in the agricultural sector and the different requirements of its users. In this study, the indicator set was calibrated at regional level for all farm analyses, for better comparability (see Appendix 1 – Sustainability Assessment). This tool is also designed to be used with all types of production and evaluates three aspects of sustainability with a set of 10 themes.

RISE is a response-inducing sustainability evaluation method, which with the use of in-depth interviews can assess sustainability at farm level, taking into account farm management practices for economic, social and environmental development (Cruz et al., 2018; Schindler et al., 2015). It obtains its indicators in a top-down process. In practical terms, this implies that agricultural sustainability goals are pre-defined, derived from the definition of sustainability (Binder et al., 2010). Although according to Schindler et al (2015), with the use of pre-defined sustainability criteria, the method is simplifying the meaning of sustainability and *"neglects the local perspective and development priority"*, at the same time it constitutes an assessment tool in which the results are discussed and evaluated with the end user of (farmer, stakeholder) that form the actual group for finding solutions in a participative way (Schindler et al., 2015). As seen above RISE provides a standard set of themes and indicators that refer to crucial economic, social, and environmental processes, that makes it a multi-dimensional method. RISE generates a questionnaire indicating the data that must be quantified. This has the advantage that different farms are comparable with each other and that benchmarks can be developed. Similar farming conditions should be taken under consideration to ensure credibility of research using the same questionnaire (Binder & Wiek, 2007).

RISE analysis starts with the collection of information on the ecological, economic, and social aspects on a visited farm through a questionnaire-based interview with farmer. A computer program uses these data to calculate 47 sustainability indicators, condensed into 10 themes.

Table 3.1: Themes and indicators of RISE 3.0

Soil use	• Soil management • Crop productivity • Soil organic matter • Soil reaction • Soil erosion • Soil compaction
Animal Husbandry	• Herd management • Livestock productivity • Opportunity for species-appropriate behaviour • Living conditions • Animal health

Material use and environmental protection	• Material flows • Fertilization • Plant protection • Air pollution • Soil and water pollution
Water use	• Water management • Water supply • Water use intensity • Irrigation
Energy & Climate	• Energy management • Energy intensity • Greenhouse gas balance
Biodiversity	• Biodiversity management • Ecological infrastructures • Intensity of agricultural production • Distribution of ecological infrastructures • Diversity of agricultural production
Working conditions	• Personnel management • Working hours • Safety at work • Wage and income level
Quality of life	• Occupation and training • Financial situation • Social relations • Personal freedom and values • Health
Economic viability	• Liquidity • Stability • Profitability • Indebtedness • Livelihood security
Farm Management	• Business goals, strategy and implementation • Availability of information • Risk management • Sustainable relationships

Adapted from Bern University of Applied Sciences, (Bern University of Applied Sciences, 2017)

To calculate the sustainability performance of a farm, four types of data are used: quantitative farm data (e.g., crop areas, yields, amount of fertilizers, number of working hours, and debts), qualitative farm data (implementation of water-saving measures, level of satisfaction, and impact of farm strategy on social aspects), regional reference data (e.g., moisture index, humidity zone) and global reference data (e.g., toxicity of plant protection products, energy density of energy carriers, and water consumption of different livestock categories). The farm raw data are entered to a computer program (www.farmrise.ch) during the interview. Calculation functions compare these data with threshold values and normalise them onto a scale that ranges from 0 to 100 points.

A performance between 0 and 33 points is considered to be problematic, between 34 and 66 points to be medium, and between 67 and 100 points to be positive. For example, realised yields are compared to threshold values that represent high (100 points), medium (67 points), low (33 points), and very low yield level for this specific crop and region (0 points) (Grenz et al., 2009). The three areas of sustainability performance are represented also in a colour scale as shown in the following figure.

Degree of Sustainability	Problematic 0 - 33	Critical 34 - 66	Positive 67 - 100

Figure 3.3: Degree of sustainability

With the development of over 100 sustainability assessment tools in the recent years (Smith, 2017), selecting one should follow specific criteria that are based on the nature of the research project and the aims and objectives of the analysis. For this research project, the criteria taken into consideration for choosing the appropriate tool were the following:

• The tool needed to evaluate sustainability at farm level with the use of an indicator-based questionnaire.
• All aspects of sustainability (economic, environmental, and social) were required to allow an integrated assessment of the farm.
• The tool needed to be applicable and useable in the context of the range of Mediterranean farming systems
• Ideally the tool used would have been published in a peer-reviewed scientific journal and/or peer-reviewed scientific report to ensure scientific rigour.

After reviewing the literature in the context of the above (see Appendix 1 – Sustainability Assessment, Tools List), four tools emerged as most appropriate: RISE (Response-Inducing Sustainability Evaluation), SAFA (Sustainability Assessment of Food and Agriculture systems, FAO 2013), PG (Public Goods) and IDEA (Indicateur de Durabilité des Exploitations Agricoles) (de Olde et al., 2017; Hayati, 2017; Schindler et al., 2015; Smith, 2017). From the tools that cover this convention, RISE was perceived to include all important elements by offering farm level sustainability assessment but also taking into consideration the specific features of each farming system along with the opportunity of making on site decision-making/management interventions to potentially improve farm sustainability performance (Marchand et al., 2014). RISE combines a high user-friendliness, high complexity (de Olde et al., 2018) and is at the same time consistent with the principle of transparency associated with uncertainties and trade-offs (Arulnathan et al., 2020).

RISE has also the broadest coverage of SAFA (Padel et al., 2015), subthemes and a high level of coverage of subthemes included in PG and IDEA (de Olde et al., 2017; Hayati, 2017). Recently the assessment has been adapted to align with the SAFA framework. The PG tool focuses on public goods instead of sustainability, but some consider it a suitable tool for assessing sustainability because of its compliance with the selection criteria and because data are more accessible. The RISE, PG and IDEA tools are adapted specifically for measuring the sustainability at farm level, whereas SAFA has a broader scope in that it extends to supply chains in agriculture, forestry and fisheries (de Olde et al., 2016). Also, SAFA and PG are organic farming focused (Smith, 2017). In the study of Röös et al (2019), RISE showed the ability to capture the social features of farmers while at the same time SAFA and IDEA both failed to identify aspects of the social situation of Swedish farmers. SAFA also includes questions that seem to be less-relevant to Mediterranean and Greek small/medium-scale family farmers such as child and forced labour (Röös et al., 2019).

To date RISE has been applied around the world in 57 countries and more than 3,300 agricultural operations on different farming systems in terms of size and orientation. This suggests it is a tool that can be adapted to regional conditions and circumstances at farm level. The approach adopted in RISE encourages farmers to act in the direction of improving sustainability of their farms. It allows farmers to *"situate themselves within a benchmark"* and provides the basis for identifying successful farm management practices (Binder et al., 2010). The report generated is useful as the results are easy to understand. Though lengthy it uses fewer categories, so it is easier to interpret, compared to other multi-criteria sustainability assessment tools (Smith, 2017). A strong point of the application of RISE, is that it allows for farm-level research and development to occur at the same time (Urutyan & Thalmann, 2011).

RISE presents certain advantages that make it an appropriate sustainability assessment tool to choose in this research. It assesses sustainability in a holistic way, considering the three main pillars of sustainability. It is a tool to evaluate sustainability at farm level and focuses on stimulating discussion as part of the feedback process with farmers. These results can be used by farmers for establishing an action plan but also by stakeholders for initiating policy-making procedures that will facilitate the improvement of farm sustainability in the agricultural systems of the region (European Commission, 2019).

As De Olde et al. (2016), suggested, *"farmers believed that RISE was the most relevant tool in order to gain insight on the sustainability performance of their farms"*. The fact that it uses regional data and references and because of its context-specific approach, seems to attract farmers' interest and esteem. The case with the context-specific approach allows inclusion of specific characteristics, such as *"regional sustainability challenges and norms"* (Gasso et al., 2015). Economic challenges, environmental concerns and social implications of farm labour and their inter-relations within the subject of the production process, challenge everyday farmers' practices. RISE supports a holistic approach towards the issue of sustainability and covers its three pillars giving equal weight to each one of them. Economic stability and efficiency of farming, food security, price fluctuation and economic crisis as well as social security and working conditions in the agricultural sector along with regional challenges which include dynamism of rural regions and the diversification of EU agriculture, are covered by the sustainability assessment tool. Environmental aspects of the farming business such as climate conditions, greenhouse gas emissions (GHG), soil degradation, water/air quality, biotopes and biodiversity are also considered crucial and are addressed in the same context.

A strong point of the application of RISE is that by establishing the basis for research (through sustainability assessments at farm level) improvements of farming practices are directly initiated in the feedback discussions between the extension offices and farmers (Urutyan & Thalmann, 2011). These results can be used by farmers for establishing an action plan but also by stakeholders for initiating policy-making procedures that will facilitate the improvement of farm sustainability in farming systems of the region.

3.3.4 Content Analysis

Content analysis is a useful method as it involves the systematic analysis of qualitative data, such as interviews or documents, to identify patterns or themes related to the research question. Content analysis has been used in various agricultural studies, including those exploring competencies and traits of successful agricultural science teachers (Meraner & Finger, 2019), and the optimum planting dates for horticultural crops in Jordan (Massimi & Al-Bdour, 2018). It has also been used in studies improving planning and standardization of costs in the management information system (Ermakov et al., 2020) and analysing fixed assets in the management of real investments of agricultural enterprises (Wemette et al., 2020). Overall, content analysis is a valuable tool in studying the adoption and implementation of planning and control methods in agriculture, as it allows for a deeper understanding of the content and context of the data and gives a quantified perception of qualitative data.

3.3.5 Q-methodology

Q-methodology is a useful method for studying agricultural technology adoption as it allows for the systematic elicitation of individual perspectives and the extraction of common elements. This method has been used in various agricultural studies, including those exploring sustainability perspectives in rural innovation projects (Hermans et al., 2011), constraints to the adoption of innovations in agricultural research and environmental management (Guerin & Guerin, 1994), and the adoption of Internet of Things (IoT) in the agriculture industry (Pillai & Sivathanu, 2020). Q-methodology has also been used in studies investigating the disparity in adoption of wheat production technology packages in Eastern Ethiopia (Kebede et al., 2017), and interpreting farmers' agricultural production decisions in Southern Lao PDR (Alexander et al., 2018). Additionally, Q-methodology has been used in studies exploring discourses on the performance gap of agriculture in a green economy (Amaruzaman et al., 2017) and re-conceptualizing the pathway of agricultural technology for better impact assessment (Moumouni et al., 2019). It is important to note that Q-methodology research is performed on small samples and focuses on subjectivity (Valenta & Wigger, 1997; Watts & Stenner, 2012a). Overall, Q-methodology is a valuable tool in studying agricultural technology adoption as it allows for a deeper understanding of individual perspectives and common elements related to the adoption of new technologies such as DSTs in agriculture. An interesting fact is that it allows the shift from the actual tool to the views and beliefs about it. In this way, the findings of the methodology can be used as an action base on which a prospect co-production of services approach can be applied for the adoption and use of DSTs.

3.4 Summary

A short overview of the geographic study area was given, and there was also an outline of the methodological tools used, these are discussed in more detail, as appropriate, in the subsequent empirical chapters.

In the following chapter the sustainability assessment of farming systems in the study area is reported along with the application of a separate questionnaire which was analysed with the help of thematic analysis to investigate the perceptions of farmers on decision-making, farm sustainability and DSTs.

CHAPTER 4. Farm-level sustainability assessment in Mediterranean environments: Enhancing decision-making to improve business sustainability.

4.1 Introduction

Climate change, the scarcity of natural resources, human and animal welfare issues and societal challenges (e.g., food security, demographic change, population rise etc.) suggest the need to adopt more sustainable farming practices to reflect upon the challenges (Coteur et al., 2016). In wider context sustainability issues relate to applied agricultural practices and thus the development of farm sustainability is strongly associated to the management approaches used by farm owners and managers. Within this context agribusinesses are adapting their production practices so they may remain profitable and are undertaking short- and long-term decision-making to both enhance environmental sustainability and business viability (Öhlmér et al., 1998). It is argued that the development of farm sustainability practices will be necessary to ensure businesses' survival and that farm sustainability performance can serve as a unit of measurement for effective decision-making and vice-versa. Hence, sustainability assessment (SA) tools have been designed to promote the monitoring and evaluation of agricultural practices using key performance indicators and therefore enable more sustainable development (Hajer, 1995). SA can be conceptualised as a range of processes that all have the broad aim to integrate sustainability concepts into decision making' (Pope, 2006).

SA can therefore be described as a process aiming to use sustainable development as an underpinning decision-guiding strategy useful for decision-making by anticipating the future outcomes of current and planned actions (Hugé et al., 2013). There remains a need for improved guidance and compliance in strategic decision-making, but the selection of available tools and actions to measure and assess sustainability progress are often uncoordinated (Russillo & Pinter, 2009). The growth of literature on SA over the last two decades re-enforces the interest and potential utility of this approach to decision-making. For example, Marchand et al. (2014), Gasparatos and Scolobig (2012) and Binder et al. (2010) each consider SA (the process) and SA tools (the methods and applications available to run SA projects) to support decision-making.

To evolve towards more sustainable futures, and to remain competitive, farmers need to adapt their decision-making and management approaches to meet the challenges of the constantly changing global environment (Darnhofer et al., 2010). Robert et al. (2016) suggested that two basic fields dominate decision-making in the farm management spectrum, firstly agricultural economics and secondly agronomy. For economists longer-term (strategic) decision-making is generally of greater interest, while agronomists focus largely on shorter-term (tactical) decisions affecting everyday crop and animal health and productivity. Agronomists aim to organise farm practices in terms of the bio-physical context in the short run usually to ensure optimal farm production in a single or small number of production cycles (Martin et al., 2013). Economists though strive to use resources efficiently in the long run and offer solutions for utilising available farm resources in accordance with farmers' objectives and constraints, usually within an optimising framework.

For the members of the EU it is acknowledged that CAP support can influence the decision-making processes of farmers in terms of resource use, labour allocation, production choices and investment (Hennessy, 1998; Sckokai & Moro, 2009). This shapes decision-making and influences the nature of the wider farming system and can provide differential impact on, for instance, food production, enhancement of rural community and/or the promotion of environmentally sustainable farming.

Considering the Mediterranean region, the importance of agricultural systems in the area in terms of biodiversity and species conservation is evident (Myers et al., 2010). According to them endemic species such as citrus and olive trees that dominate the plantation orchards in the area are threatened from diseases and present exceptional loss of habitat. Since 1962, the EU member states have benefited from the CAP subsidies. Due to the financial, technical, and administrative support their agricultural infrastructure has been upgraded and modernised and their agricultural output has increased (Eurostat, 2009). Initially, the CAP subsidies focussed on improving agricultural productivity by promoting technical progress and ensuring the optimum use of the factors of production, in particular labour, while also ensuring a fair standard of living for farmers in the member countries (Massot, 2017).

The gradual removal of agricultural market protection measures has led to a more market-orientated sector characterised by increased competition and imports, reduced statutory subsidies, export supplements and intervention measures (Galanopoulos et al., 2006). The CAP for the period 2021-27 (European Commission, 2021a), focuses on:

- ensuring stability and income support for farmers,
- setting higher green ambitions for environmental and climate action,
- placing farmers at the heart of Europe's society.

These broad goals align with the three pillars of farm sustainability and point towards the transition to a new farmer centred structure of the farming system. As such, the development of farm sustainability will be a necessity for business survival. Therefore, it is imperative to underline the need for SA as part of an enhanced decision-making processes.

Farm sustainability (economic, social, and environmental) has always, for a multitude of reasons, been a challenge within agricultural systems. Especially in the Mediterranean basin, a range of factors potentially undermine farm sustainability:

- small size of agricultural holdings, (DG Agriculture and Rural Development, 2018)
- spatial characteristics of the area, (Hellenic Statistical Authority, 2021)
- dependency on CAP subsidies for small and medium holding farms, (Massot, 2017)
- an ageing rural population (Doignon, 2019)
- farmers' low level of education, (Grasso & Feola, 2012; Harmanny & Malek, 2019)
- an enduring tradition of providing women with a dowry, (Nikolajeva, 2014)

A SA of agricultural production at the farm-level can provide a robust approach for mitigating the inherent challenges and problems occurring in the sector at present. Such an approach would provide decision-making information that in turn would advance and apply innovation and technological uptake, where appropriate, at the farm level (Rivera, 2011). This would influence a multitude of decision-making processes, bring about changes in the structure of farming systems or collective decision-making on rational resource use (van den Ban, 1998). The potential for a substantive improvement in performance should provide a driver and encourage farmers' participation, along with other stakeholders, in the design of tools and policies so that challenges can be tackled collectively and efficiently.

The research reported herein investigates farmers' perceptions of the importance of effective decision-making in relation to the sustainability performance of their farming businesses. Farmers' behaviours and attitudes towards decision-making and the subsequent correlation with sustainability performance are presented in a case study for the Argolida region in the Peloponnese, Greece. This paper evaluates the sustainability performance of farm businesses in the region and how farmers perceive that decision-making affects the sustainability performance of their farms. Even though farm sustainability is an important concept in Greece and the Mediterranean basin there is a paucity of research which links sustainability assessment with thematic analyses exploring farmers' views and perceptions on decision-making, farm sustainability and DST awareness and use. To provide a new perspective on addressing the sustainability challenges in these environments a multi-method approach has been implemented and the findings outlined in this paper.

4.2 Scope of the Research

Several studies have examined SA of agricultural production systems in the Mediterranean basin (Casas et al., 2015; Dantsis et al., 2009; Giourga et al., 2008; Manos et al., 2011; Stylianou et al., 2020b). Using a variety of frameworks for the assessment of farm businesses' sustainability the performance of agricultural production systems has been evaluated and optimal practices have been proposed for enhancing the sustainability of these systems.

Building on and extending this, the research reported here assesses farm sustainability performance based on a sample of farm businesses in a southern region of Greece, an area with features typical and representative of the Mediterranean basin, using an indicator-based assessment method. The research then extends this to correlate the results of the SA to the attitudes and behavioural patterns of farmers that emerged from a thematic analysis, based on the outcomes of the semi-structured interviews with the same sample.

The research combines the use of the RISE 3.0 tool in Greece as an SA tool at the farm- level with effective evidence-based decision-making to enhance sustainability performance. This paper is focused on a case study of a Mediterranean area specialised in citrus and olive production. This farming system has a prominent role in terms of what is defined Mediterranean and hence Greek agriculture, composed of small size farms that are gaining importance in numerical terms and concentrating increasing shares of the total agricultural output, labour and land of the country, the region and worldwide (Lowder et al., 2016).

4.3 Materials and Methods

4.3.1 Identifying an appropriate sustainability assessment tool

With the development of over 100 sustainability assessment tools in the recent years (Smith, 2017), selecting one should follow specific criteria that are based on the nature of the research project and the aims and objectives of the analysis. For this research project, the criteria taken into consideration for choosing the appropriate tool were the following:

• The tool needed to evaluate sustainability at farm level with the use of an indicator-based questionnaire.
• All aspects of sustainability (economic, environmental, and social) were required to allow an integrated assessment of the farm.
• The tool needed to be applicable and useable in the context of the range of Mediterranean farming systems
• Ideally the tool used would have been published in a peer-reviewed scientific journal and/or peer-reviewed scientific report to ensure scientific rigour.

After reviewing the literature in the context of the above, four tools emerged as most appropriate: RISE (Response-Inducing Sustainability Evaluation), SAFA (Sustainability Assessment of Food and Agriculture systems, FAO 2013), PG (Public Goods) and IDEA (Indicateur de Durabilité des Exploitations Agricoles) (de Olde et al., 2017; Hayati, 2017; Schindler et al., 2015; Smith, 2017). From the tools that cover this convention, RISE was perceived to include all important elements by offering farm level sustainability assessment but also taking into consideration the specific features of each farming system along with the opportunity of making on site decision-making/management interventions to potentially improve farm sustainability performance (Marchand et al., 2014). RISE combines a high user-friendliness, high complexity (de Olde et al., 2018) and is at the same time consistent with the principle of transparency associated with uncertainties and trade-offs (Arulnathan et al., 2020).

RISE has also the broadest coverage of SAFA (Padel et al., 2015), subthemes and a high level of coverage of subthemes included in PG and IDEA (de Olde et al., 2017; Hayati, 2017). Recently the assessment has been adapted to align with the SAFA framework. The PG tool focuses on public goods instead of sustainability, but some consider it a suitable tool for assessing sustainability because of its compliance with the selection criteria and because data are more accessible. The RISE, PG and IDEA tools are adapted specifically for measuring the sustainability at farm level, whereas SAFA has a broader scope in that it extends to supply chains in agriculture, forestry and fisheries (de Olde et al., 2016). Also, SAFA and PG are organic farming focused (Smith, 2017). In the study of Röös et al (Röös et al., 2019), RISE showed the ability to capture the social features of farmers while at the same time SAFA and IDEA both failed to identify aspects of the social situation of Swedish farmers. SAFA also includes questions that seem to be less-relevant to Mediterranean and Greek small/medium-scale family farmers such as child and forced labour (Röös et al., 2019).

To date RISE has been applied around the world in 57 countries and more than 3,300 agricultural operations on different farming systems in terms of size and orientation. This suggests it is a tool that can be adapted to regional conditions and circumstances at farm level. The approach adopted in RISE encourages farmers to act in the direction of improving sustainability of their farms. It allows farmers to *"situate themselves within a benchmark"* and provides the basis for identifying successful farm management practices (Binder et al., 2010). The report generated is useful as the results are easy to understand. Though lengthy it uses less categories, so it is easier to interpret, compared to other multi-criteria sustainability assessment tools (Smith, 2017). A strong point of the application of RISE, is that it allows for farm-level research and development to occur at the same time (Urutyan & Thalmann, 2011).

To conclude, RISE presents certain advantages that make it an appropriate sustainability assessment tool to choose in this research. It assesses sustainability in a holistic way, considering the three main pillars of sustainability. It is a tool to evaluate sustainability at farm level and focuses on stimulating discussion as part of the feedback process with farmers. These results can be used by farmers for establishing an action plan but also by stakeholders for initiating policy-making procedures that will facilitate the improvement of farm sustainability in the agricultural systems of the region (European Commission, 2019).

4.3.2 Research region

The regional unit of Argolida, Peloponnese, Greece was selected as the area for field research (Figure 4.1).

Figure 4.1: Map of Argolida, adapted from https://greece-map.net/greece-argolida-maps/

This area has features typical of a humid mid-Mediterranean climate (Kavvadias et al., 2013). It is also of interest given its predominant cultivation of olive and citrus trees which are typical crops for southern and eastern Greece and the wider Mediterranean area. Argolida, is one of the major suppliers of oranges for the Greek and export market (Kavvadias et al., 2013; Kelepertzis et al., 2015). Olive cultivation, primarily for oil, is considered particularly important for Greek farmers according to FAO (2018). Greek olive oil production in 2014 was estimated to account for roughly 7% of global production, placing Greece third in the world by volume. Collectively, the countries of the Mediterranean basin account for approximately 96.5% of global olive oil production (Niavis et al., 2018) while the EU's Mediterranean area is responsible for approximately 20% of the worlds citrus production and 70% of global citrus exports (European Commission, 2019).

4.3.3 Research participants

i) Sampling and recruitment

The Greek Ministry of Rural Development and Food provided access to a list of farm holdings based in the regional unit of Argolida. Data derived from the FADN database for Greece for the year 2017 was provided for research purposes. FADN is an EU-wide survey that monitors the income and general farm business activities. Based on national surveys that cover holdings that can be characterised as commercial it is essentially a data source for the annual realisation of farm incomes, analysing the economic operation and investigating econometrically the effects of direct and indirect subsidies and design and implementation of the new CAP 2021-27. It is essentially a data source for the annual evaluation of farm incomes (European Commission, 2021). A homogenous group based on production characteristics and farm business structure were selected for the purpose of this research.

ii) Sample size

Sustainability performance assessment presents specific challenges related to time and resource management (de Olde et al., 2016). Therefore, to reach the explanatory power, the decision over sample size was important. It had to be small enough to handle yet large enough to provide robust evidence so that most or all perceptions of the wider population were uncovered (Mason, 2010). The information saturation point, that is, the time when new evidence can no longer be gleaned from the information source (Guest et al., 2006), was identified by other studies as occurring after six or between 12 and 15 individual interviews (Isman et al., 2013; Latham, 2013). A sample of 20 participants was thus selected to be representative of crop type, holding size and farming system. Research methods and ethics were approved in line with institutional protocols.

4.3.4 Interview structure

For the purpose of the thematic analysis and the RISE 3.0 assessment two sets of questions were employed. For the thematic analysis the interviews were conducted via telephone due to the Covid-19 pandemic restrictions. Eighteen open-ended questions were asked in a semi-structured interview format with each of the participants. Interviews began with questions about the demographic characteristics of the farm managers/owners such as their age, gender, marital status and agricultural training. Questions then addressed the aspects of decision-making, sustainability awareness and assessment and DST awareness and use. Finally, the interviews concluded with questions about the ongoing challenges they believed agriculture will be facing in the coming years. The interviews were recorded with the permission of the participants, transcribed verbatim, and translated into English. These interviews took place between the 21 April and the 15 May 2020 with each interview taking between 15 and 30 minutes.

The RISE 3.0 questionnaire was applied to the same sample. This time the farm data were collected through face-to-face and in-depth interviews on farm based on RISE's 10 themes (ranging from biodiversity and energy use to economic viability, farm management, quality of life and working conditions) and the 47 indicators under assessment. Answers were entered into a computer program (www.farmrise.ch) during the interview with the researcher working in both online and offline modes. The procedure included the collection of information on the ecological, economic, and social aspects of the visited farm through a questionnaire-based interview with each farmer. FADN data were entered into the program prior to the interview for time management reasons so as to reduce the length of each on-farm visit. The interviews were conducted between the 1 July and the 3 August 2020 and on average each interview took 2 hours and 30 minutes.

4.3.5 Data analysis

i) Thematic Analysis

The data from the first questionnaire was analysed with the use of thematic analysis (TA), as this qualitative analysis method makes it possible to identify and analyse patterns and attitudes within a given data set (Braun & Clarke, 2006). According to Braun and Clarke (2006), TA is a flexible tool that can provide a rich and complex account of a data set. The TA structure was based on Braun and Clarke (2006), familiarising with the data, generating initial codes of interesting features, searching for themes in all relevant data, reviewing themes, defining, and naming themes and producing a report relating back to the research question. Data analysis was a recursive process. NVivo 12 software was used for the data analysis and identifying themes.

The themes were identified within the data using an inductive process and a bottom-up approach to the analysis. Since semi-structured interviews were employed for collecting the data, no conceptual framework was present; so, the analysis was conducted without any preconception or advance knowledge. This made inductive coding the best choice. In this case, given that the inductive approach was data-driven, there was no specific frame for coding. As far as the decision concerning the *"level"* at which themes were identified, a semantic/explicit approach was adopted. Because of the rich, verbatim transcriptions provided by the participants, themes were identified solely based on what the participants reported. No attempt was made to theorise or interpret interview replies.

ii) Applying the RISE 3.0 method

To calculate the sustainability performance of a farm, four types of data were used: quantitative farm data (e.g., crop areas, yields, amount of fertilisers, number of working hours, and debts), qualitative farm data (implementation of water-saving measures, level of satisfaction, and impact of farm strategy on social aspects), regional reference data (e.g., moisture index, humidity zone) and global reference data (e.g., toxicity of plant protection products, energy density of energy carriers and water consumption of different livestock categories). The farms' raw data were entered into the RISE 3.0 software program, before and during the interview in offline mode. The RISE tool then compared these data with threshold values and normalised them onto a scale that ranges from 0 to 100 points. The scores follow a colour scale which is depicted in Figure 4.2.

Degree of Sustainability	Problematic 0 - 33	Critical 34 - 66	Positive 67 - 100

Figure 4.2: RISE 3.0 degree of sustainability

iii) Data triangulation

Figure 4.3 illustrates how the three sources of research data were integrated within this research. The FADN data were used to inform the RISE 3.0 analysis with the economic data as well as with the use of inputs (fertilisers, plant protection products etc.) and outputs (sales, yields etc.) of the farming systems under study. Findings of both analyses, RISE 3.0 and thematic, and the data from the FADN dataset were then triangulated to provide an analysis of decision-making, sustainability and DST awareness and use.

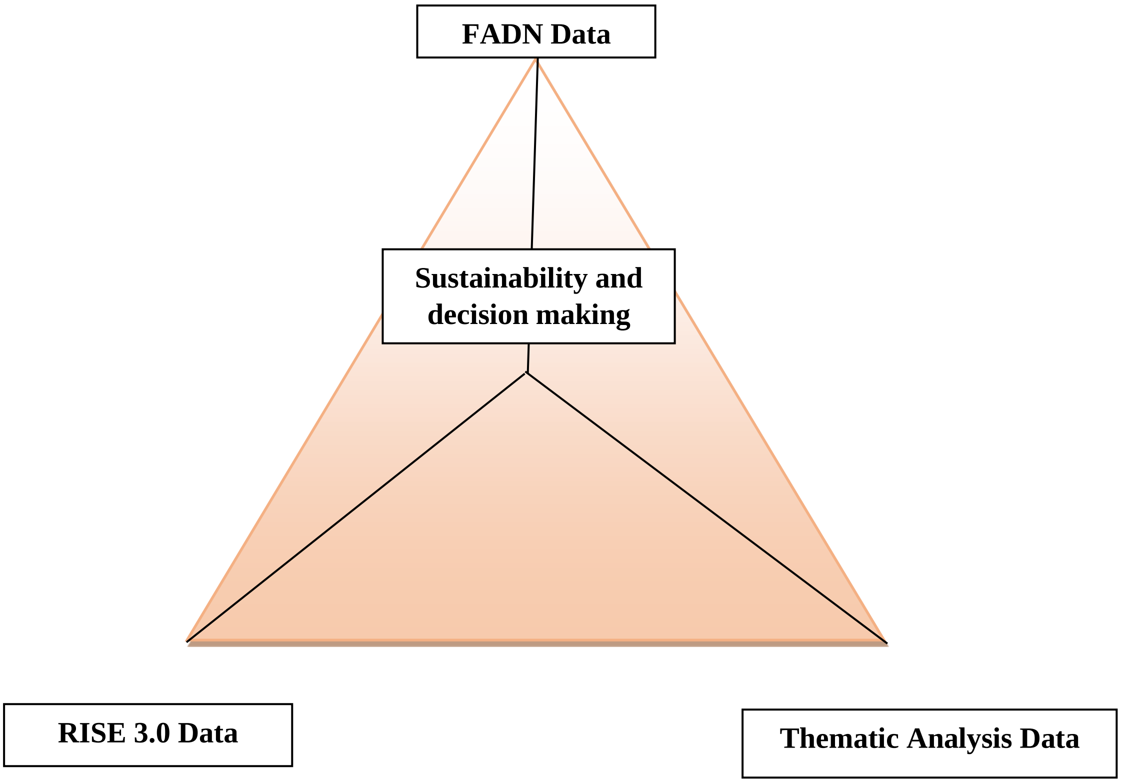

Figure 4.3: Data Triangulation

4.4 Results and Discussion

4.4.1 General characteristics of the sample

The vast majority (90%) of the farmers cultivate olive trees, for oil production or table olives, while 85% cultivate a species of citrus trees (oranges, mandarins, and lemons) or/and a mix of them. This cropping pattern is similar to that reported by others (FAO, 2018; Kavvadias et al., 2013; Kelepertzis, 2014). Moreover, crops such as apricots, vegetables, vine, and pomegranates were grown but in smaller areas, acting as supplementary income to that from olive and citrus trees. 85% of holdings in the sample were below 10 hectares in area which aligns with the region's statistical data which shows that farms with less than 10 hectares of agricultural land (86,550 farms) represent 93.6% of the total number of farms in the region of Peloponnese in 2013 (European Commission, 2019). Table 4.1 provides a broad characterisation of the 20 farms under study.

Table 4.1: Selected sample from FADN Greece. Adapted from FADN dataset Greece.

Sample	Holding Size (ha)	Crop Type	Type of Farming
Farm 1	5.12	Citrus, Olive, Apricot, Vine	Conventional
Farm 2	4.6	Citrus, Olive	Conventional
Farm 3	3	Citrus, Olive	Conventional
Farm 4	10.39	Citrus, Olive	Conventional
Farm 5	4.2	Citrus, Olive	Conventional
Farm 6	8.93	Citrus, Olive, Vegetables	Conventional
Farm 7	14.03	Citrus, Olive	Conventional
Farm 8	16.8	Citrus, Olive, Apricot	Conventional
Farm 9	4.4	Citrus, Olive	Conventional
Farm 10	3.55	Citrus, Olive, Apricot	Conventional
Farm 11	3.58	Citrus, Olive, Apricot	Conventional
Farm 12	6.05	Olive, Apricot, Vegetables	Organic
Farm 13	7.25	Olive, Apricot, Vine	Conventional
Farm 14	6.9	Citrus	Conventional
Farm 15	3.1	Citrus, Olive, Pomegranate	Conventional
Farm 16	1.4	Citrus, Olive	Conventional
Farm 17	1.75	Olive, Apricot, Vegetables	Conventional
Farm 18	32	Olive	Organic
Farm 19	6.07	Citrus, Olive, Apricot	Conventional
Farm 20	2.3	Citrus	Conventional

Table 4.2 illustrates features derived from the questionnaires and the FADN data of the sample farms in comparison to the Northern Mediterranean region countries.

Table 4.2: Features of the sample farms. Adapted from questionnaires and FADN.

	Organic farming as part of UAA (2019)	**Farmers over 40 years (2019)**	**Comprehensive agricultural training (2019)**
Research Sample	**10%**	**95%**	**15%**
Greece	10.20%	91.70%	0.60%
Spain	9.70%	91.40%	1.90%
Portugal	8.20%	95.60%	2.50%
Italy	15.20%	92%	6.10%
Cyprus	5%	96.80%	0.60%
Malta	0.50%	93%	1.70%

The sample proves to be representative, following the percentages in Greece and the Mediterranean regarding the type of farming and the age of the farmers. In the case of comprehensive agricultural training the sample may have a high percentage in relation to the national or Mediterranean average but in terms of vocational lifelong training about the profession, the participants' answers suggested that the percentage is very low matching the averages for the country and the Mediterranean region in general.

4.4.2 Research findings

i) Effective decision-making

The link between effective decision making and agricultural production practices has been recognised as one of the most important factors for farmers based on the thematic analysis. High quality/quantity of production was seen as a crucial determinant for achieving higher market prices and gaining negotiating power to ensure favourable sales.

Nevertheless, the RISE 3.0 assessment indicated that 95% of farmers had not conducted a soil analysis in the past 10 years. Therefore, although their fertilisation management process scores were high, suggesting good cultivation practices and professional fertilisation application, the process was not informed and planned using data enhanced by an evidence-based application, but rather based solely on previous experience and knowledge. In contrast all farmers were using irrigation methods such as sprinklers and drip irrigation and they determined their irrigation needs based on evidence related to weather conditions and plant developmental stage.

20% of the farmers interviewed identified that spatial characteristics shaped their decision-making. Weather variability, land morphology and water scarcity directly influenced farmers' decision-making process. Hence, either when designing the long-term strategy for the sector, or during the annual harvest and sales time, these parameters affected their actions. Cooperation with exporters and traders also emerged from the thematic analysis as a sign of effective decision-making in terms of establishing good relationships to aid product marketing. The RISE 3.0 analysis illustrated that 45% of farmers characterised their relationships with customers as *"positive"* and nearly one third (approx. 33%) described them as *"satisfactory"*. The remaining 25% indicated that their relationship could be defined as *"negative"* as their dependency on current markets and customers does not favour their farm's future business plans.

During the interviews, 20% of farmers noted the need for effective financing of their production processes. Emphasis was placed on business planning and control parameters, such as liquidity and solvency. Turnover was identified as playing a crucial role in farms' business viability. Data on farms' liquid assets at the end of the year were taken from the FADN dataset. The vast majority (95%) of the participating farms returned a profit, with just one farm demonstrating a net loss. CAP subsidies, the holding size and the type of farming all played an important role in determining farm profitability. Even with the existence of CAP subsidies the durability of small farms is often only possible due to unpaid family work. Many of them would not be considered profitable if the labour provided by family members was valued at the same rate paid to casual workers (Mylonas, 2015). Larger holdings and those based on organic farming systems presented higher profit levels. This was also documented in similar Northern Mediterranean research, for instance in Spain (Pardo et al., 2014; Torres et al., 2016).

A dependency on CAP subsidies was evident in the farms' profitability as in many cases the amount of money from these policies made a significant contribution to overall profitability. Some farms received higher levels of subsidy per hectare because of their geographic location (i.e., higher altitude) and these were particularly reliant of the CAP payments to maintain profitability. Organic farms received additional payments for implementing agricultural practices beneficial for the climate and the environment in addition to those from the basic payment scheme. Even though CAP subsidies are largely decoupled from production there were still some active payments connected to production for the period 2014-2020 although these were due to expire at the end of 2021. Such examples are the subsidies connected with oranges intended for juicing or the subsidies for abandoning tobacco cultivation. The cessation of these will also have a negative impact on profitability as projected in other studies (Pardo et al., 2014) too.

Farmers linked effective decision-making to a set of determinants such as agricultural practices, product sales, area characteristics, economic reasons, their own attitudes, goals, and sustainability. In addition, most of farmers indicated that their decision making was correct, but external factors were affecting implementation and their ultimate characterisation of 'effective'. It was evident in the RISE 3.0 indicators *"business goals, strategy, implementation"* and *"personal freedom and values"* results that farmers' ideas about their own management efficiency were of a high standard. Yet, external factors such as weather conditions, diseases, prices, state guidance and policymaking were attributed to determining the success of the farm business. For example, in relation to the national agricultural insurance agency for crop production, the provisions by the agency related to their plant capital and produce were considered inadequate and in need of restructuring.

In the context of agricultural practices, the commonest recurring theme was that farmers linked the quality and quantity of their products to measures of the effectiveness of their decision-making. Detailed analysis of the data showed they relied mainly on experience and existing practices to make decisions, so they were rarely well- informed about new advances related to agronomy or the use of a range of newer technologies. For example, a lack of soil and crop nutrient demand analyses for fertilisation and a reliance on *"how it has always been done"* is illustrative of this.

Farmers' attitudes and vision, goals set, sustainability-minded processes and even statements such as *"there is no effective decision-making when I am not in the position to determine the price of the product"* all emerged from the interviews related to effective decision-making. During the thematic analysis interviews 90% of farmers reported that they take the advice of agronomists/advisors to make informed decisions about their production practices or processes while 60% also make decisions based on their own experience or after discussions with family members. Less often (only 15%) they accept peers' recommendations or address their questions to extension officers. The importance of state guidance was noted, but the lack of guidance from the region's Directorate of Agriculture was also commented upon. Based on this, using a scale from 1 to 10, with 1 being the least informed and 10 totally informed, half of farmers answered that their decision-making was *"totally informed"* by good agricultural practices. The remaining 50% answered between 6 and 9 on that scale. The RISE 3.0 analysis also showed that farmers believe they have sufficient access to expert information and all the necessary information about their farms' financial situation, water and energy consumption and the future demand for labour. At the same time the use of advice on biodiversity species, conservation management and habitat conservation was limited in all businesses. All scored 0 in this respect. This is interesting as research shows that the inherent diversity and heterogeneity of the area, supports high levels of biodiversity and promotes ecological resilience (Babai et al., 2015; Konvicka et al., 2016).

In relation to farmers' views of what constituted a successful farm business more than half (60%) of them consider good agricultural practices to be an especially important attribute. Emphasis was placed on the quality of the produce and thus in the decisions associated with the organoleptic properties of fresh produce and the use of crop-protection practices. The participants justified their decision-making approaches with their final higher yields, market prices and farm incomes. Finding the appropriate marketing channels for trading their products seemed equally important to all interviewees. This helped them to mitigate their dependency on a small number of traders, or even how their products were traded; this was also evident in the RISE 3.0 results.

A fifth of farmers recognised that the crop species they grew was a key determinant of business success. Early or late ripening as well as the introduction of new varieties have been considered as offering added value to their product mix, allowing flexibility amid supply and demand concerns. Farmers also identified their holdings' size as an attribute of success. All of them noted the significance of farm size, especially during times of low prices and increased production costs. The fragmentation of agricultural land was viewed as a factor that adversely impacted farm' success due to increased production costs arising mainly from the duplication of activities which essentially doubles the time spent and the equipment and machinery moving around to perform tasks such as harvesting, spraying, ploughing etc. At the same time this fragmentation and generally the small size of holdings can present an opportunity to develop innovative business models (Koutsou et al., 2011) and this may still be the only realistic structure for farms situated in areas of high altitude and can offer a diversification in terms of varieties and crops (Karantininis, 2017).

Farmer concerns, expressed in both the interviews for the thematic and RISE 3.0 analyses, were linked to their management approach and decision-making processes. Due to the predominant crop types for the area most of the farm businesses encounter the bulk risk that arises from a significant proportion of their income coming from one or two crops. In this case they were vulnerable to adverse impacts of, for instance, bad weather and disease which are common underlying challenges within the agriculture sector. Ensuring that their decision-making is well-informed and evidence-based may help reduce risk associated with these challenges in the future. Further, decision-influencers such as agronomists and advisers need to be equipped with the latest skills and knowledge set to promote sustainable agriculture (Charatsari & Lioutas, 2016), suggesting that regular continued professional development is essential in these roles.

Other features, such as farmers' attitudes, innovation adoption and state guidance were noted but less frequently. Nevertheless, attributes such as personality, hard work, passion for the profession, as well as luck, were also mentioned. Avoidance and management of Citrus Tristeza Virus (CTV) was considered relevant to the success of the farm business as the disease affects the robustness and the yields of citrus trees. The adoption of new technology and several other innovative steps available to farm businesses were seen as helpful for achieving multiple benefits. For example, deploying contemporary irrigation methods and harvesting machinery were indicated as sources of enhancing the business' success. In this context, farmers ranked their own businesses in terms of success on a scale from 1 to 10 with 1 being the least successful and 10 being the most successful. Marginally more than the two thirds situated their businesses between 7 and 8 on the scale. The remaining third ranked their farms between 5 and 6.

ii) Sustainability

The majority (90%) were unaware of the term *"farm sustainability"*. Ten out of the 18 farmers in this category had never heard the term, while the other eight had heard it but were unaware of its meaning.

Only two stated they knew the term and could explain the concept. Furthermore, 19 of the 20 farmers had never assessed their farm's sustainability; one stated that they had once had a carbon footprint measurement taken by a trader who marketed his produce. Nevertheless, the farming systems' sustainability performance assessments that followed, completed using the RISE 3.0 tool, generated interesting results, as shown in Figure 4.4. This illustrates the assessment of the average scores of the 20 farms in the study for each theme.

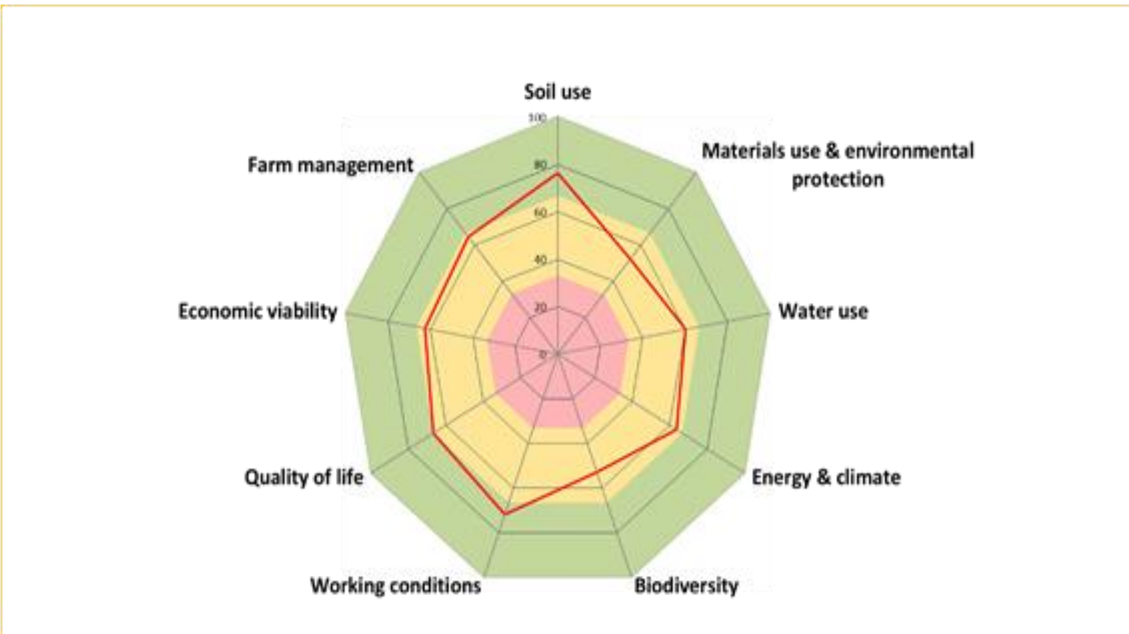

Figure 4.4: Farm sustainability polygon, adapted from RISE 3.0.

According to calculations from the RISE 3.0 model, three out of nine themes — soil use, working conditions and quality of life — were assessed in the green (positive) area of sustainability performance with scores over 67, while the remaining six were evaluated in the yellow (critical) area. From these six themes, three — energy & climate, economic viability, and farm management — scored marginally lower than the positive area. It must be noted that some individual farms scored in the red (problematic) area.

According to the FADN data and the results of the thematic analysis, farmers who were aware of the meaning of 'sustainability' had a higher educational background than others. As indicated by Kountios et al. (2018), in Greece, the delay in the adoption and implementation of precision agriculture (PA) and more sustainable agricultural practices is due to a multitude of reasons, among them, education. Although farmers have a range of training opportunities, the existence of a feeling of 'impunity' to use past harmful practices, economic interests weigh greater in their decision-making than any other factor (Aznar-Sánchez, Velasco-Muñoz, et al., 2020).

There has been a misconception between farmers' attitudes and beliefs towards their approach on sustainability and the results of the RISE method. In terms of agricultural practices, the main pattern observed was a routine based on experience and existing practices rather than on evidence and planning. Decision-making was indicated as associated with financial sustainability, but the general lack of awareness of environmental sustainability hindered farmers' understanding of the change in processes required to strengthen the bond between the two. Figure 4.5 illustrates the range of farm scores in each theme and shows that a number of farms in the themes of energy & climate and economic viability fell in the problematic category (for more information on the indicators' scores, see Appendix 1 – Sustainability Assessment).

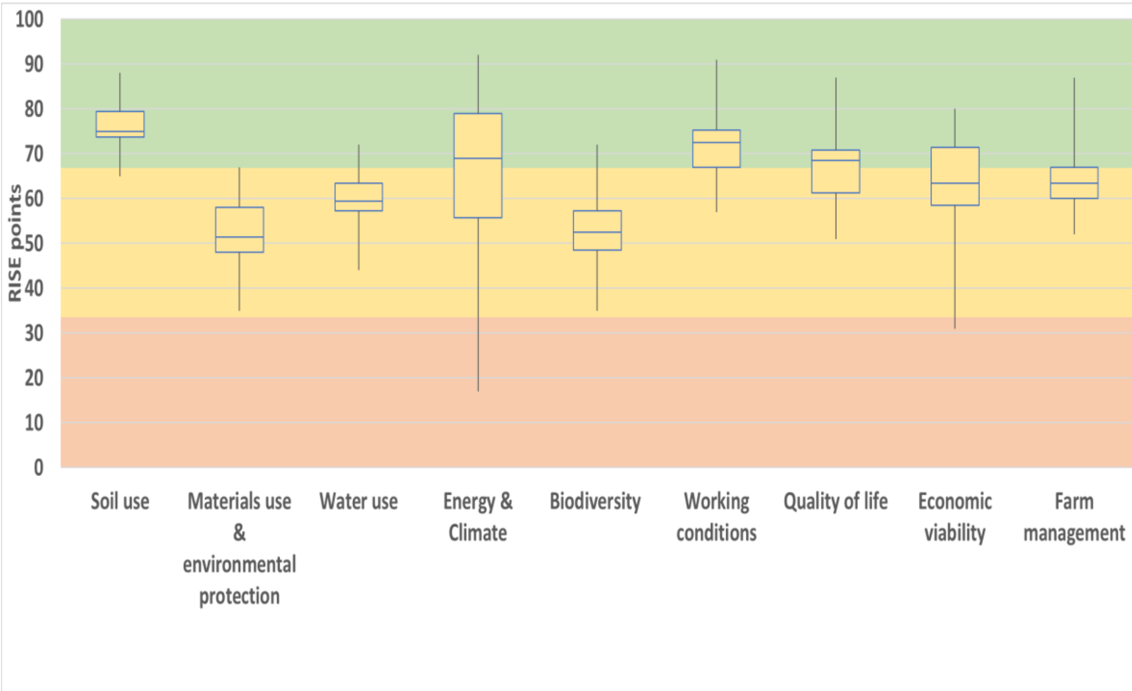

Figure 4.5: Farm sustainability assessment, adapted from RISE 3.0.

For the purposes of the thematic analysis an explanation of the term *"farm sustainability"* was provided. Even though the participants scored low on sustainability awareness and assessment when called upon to answer to what degree elements of overall sustainability performance are a part of their farm's decision-making process, they indicated that it does affect them via different means and mechanisms. A relationship was noted between farm sustainability and decision-making in the context of agricultural practices. For instance, in the context of environmental sustainability concerns about the use of agrochemicals, mitigation of the use of highly toxic plant protection products (PPP), overcoming water scarcity via appropriate irrigation systems and the possibilities of organic farming or the techniques used were raised by 40% of respondents.

The impact of education was also evident in the biodiversity theme of the RISE assessment. The non-use of biodiversity advice to promote species and habitats resulted in negative scores in this area. The analyses indicated that no measures were implemented for the conservation of species and native habitats. A lack of education and knowledge on the benefits of biodiversity prevented farmers from understanding the value of species and habitat conservation towards environmental sustainability. Even though concerns were raised by farmers in the thematic analysis related to environmental issues resulting from the use of fertilisers and PPP, the RISE assessment showed that farmers' use of high levels of fertilisers and PPP led to low sustainability scores, due to the frequency, environmental toxicity and the persistence of herbicides and insecticides used. This suggests that farmers' perceptions and concerns were not well-aligned with their practice, mirroring well- known inconsistencies between farmer attitudes to key practices and subsequent behaviour (Munoz et al., 2019). Highlighting and aiding the bridging of the gap between farmers' perceptions and real-life practices is thus key in evolving towards more sustainable systems.

The materials use and environmental protection scores ranked in the *"critical"* area of sustainability performance for 19 of 20 farms, with only 1 farm scoring only marginally in the *"positive"* area. Material flows indicators had low scores (10–49 points), due to low nitrogen and phosphorus self-sufficiency in fertilisers, with 19 of 20 farms lacking their own resources (manure), and hence relying on inputs from locally sourced materials, or sometimes from further afield. Furthermore, fertilisation intensity scores also raised concerns with 40% scoring in the *"low"* area of sustainability performance and a further 25% scoring medium in the "*critical"* area. In short, 65% of the farms use nitrogen at levels which can potentially damage groundwater, soil, and plant communities.

The preference for using mechanical weed control was expressed by only 4 of 20 farms, while another six used pesticides and mechanical pest management. Half of the farms reported spraying for pest control. The use of PPP resulted in 80% of farms scoring *"low"* and being in the *"problematic"* zone; the remaining 20% scored medium thus being in the *"critical"* zone. These RISE 3.0 results reflect the high environmental toxicity and persistence of herbicides and insecticides used and the high number of applications.

The thematic analysis demonstrated that 35% of farmers follow decision-making processes that are driven by mainly financial and social sustainability performance concerns as shown in their desire to pass the property on to their children to farm in the future. The organic farmers in the sample noted that their choice to adopt organic farming was based on holistic sustainability criteria not only to stand out among their competitors, but also to be environmentally and socially sensitive.

A few (15%) interviewees said that they take into consideration sustainability performance in their decision-making, but not always. One interviewee said that the sustainability performance of their farm does not affect their decision-making process.

iii) DST's use and future trajectories

The answers to the DST awareness question were triggered by an explanation of the term. Initially, 85% of interviewees did not understand the concept so the term *"DST"* had to be explained. The explanation given was derived from Rose et al (2016). *"DSTs are designed to help users make more effective decisions by leading them through clear decision stages and presenting the likelihood of various outcomes resulting from different options"*. Only 15% were initially aware of DSTs. After explaining the term in more detail, half of the interviewees said they had never heard of DSTs. Some asked why they should use DSTs, while others suggested that in the regional unit of Argolida, such tools could only be used by farms with greenhouses and not by the other sectors. The remaining 50% realised they have heard of DSTs but did not use them.

The reasons hindering DSTs awareness and use were found to be familiarity/technology adoption, financial concerns and practical issues. Interviewees indicated that they would not use a DST because they were unfamiliar with technology. Financial reasons hindered their use by others. The purchase and use costs also appeared to be a deterrent against DSTs. Even if DSTs were subsidised interviewees still argued that the current situation of Argolida's agriculture does not favour their use. It was suggested that high production costs, low prices and market uncertainty following the economic crisis and during the pandemic make DST investments uneconomical. These reasons resonate with the research of Rose et al. (2018).

The interviewees raised several practical issues that would prevent them from using a DST, such as their small holding size, land fragmentation and their own experience — *"no need of a machine to tell me when the trees need irrigation"* — and an unwillingness to change. The latter was evident in the RISE 3.0 findings where only one farmer reported being dissatisfied with their own farm management performance and wanted to change something about it.

Interestingly, as far as changes were concerned, more than half (60%) of farmers recognised CTV (Dimou et al., 2002) as one of the main challenges that will impact Argolida's agricultural sector. They noted it would impact their incomes because citrus trees, and especially oranges, are the predominant crop in the region; they are also considered emblematic of the area. The RISE 3.0 results also show that CTV is regarded as one of the major threats in the risk management indicator.

More than half (60%) of farmers mentioned land abandonment as another concern, as young people are not entering the profession preferring instead to join different sectors. This fact, in correlation with the presence of CTV, has increased production costs. Lack of state guidance was also cited as an additional reason that has led many farmers to abandon the sector, so their properties were subsumed by a small number of farmers or remained uncultivated. For a significant number of farmers this is a second profession, so they see it as a supplementary source of income. Furthermore, even among existing farmers the issue of attitude and vision was highlighted, with 30% stating that they want to evolve their approach, but the rest were uninterested in changing their existing production practices.

Water scarcity was predicted by 20% of farmers as a problem in the region in 10 years' time. Over-pumping from existing wells and drilling or pumping from greater depths along with delays in the progress of the irrigation duct network from the Anavalos River, are the main reasons for this. Finally, 20% of farmers predict that only limited changes will occur; only one farmer projected that things will be better in the years to come, due to the new programmes such as the one concerning the settlement of young farmers (sub-measure 6.1) and policies launched by the state.

An unwillingness to change was noted. Farmers predicted CTV and land abandonment would be the main changes in the region along with water scarcity. The fact that the vast majority foresaw these "external" changes occurring in a 10-year period but only 30% were interested in adjusting their approach to tackle them, is indicative of limited vision and a general resistance to change. It is evident that the routines the farmers have always followed were well established and the majority were reluctant to change practices.

There was some misalignment between the results of the two analyses. For instance, the findings of the thematic analysis suggested that effective decision-making and farm sustainability were connected. Even though it was implied that there was a connection between them, the findings from the RISE 3.0 assessment indicated that there is a lack of evidence-based decision-making. Furthermore, a lack of awareness and assessment of sustainability enhanced the notion that decision-making and farm sustainability were concepts unfamiliar to a majority of the sample.

Further, decision-making related to achieving the desired quality and quantity of production, along with marketing and the trading of produce (i.e., what was seen to relate to financial sustainability) was claimed to be informed and in accordance with the advice of the agronomist/adviser. In fact, the RISE 3.0 analysis suggests that in each step of the production process there is a lack of decision-making based on factual information and evidence from available data, such as soil analyses, nutrient demands estimations, GHG emissions, biodiversity advice and financial indicators.

4.5 Conclusions

This research illustrates the inherent challenges that the agricultural sector faces in Greece and the wider Mediterranean region. Differences identified between the perceptions of farmers in relation to financial and environmental sustainability and their actual practice provide a basis for suggesting mechanisms that can enhance the sustainability of farming systems in the Mediterranean basin. Consequently, the methodology utilised in this research can be appropriately adapted to other similar crops and areas in the Mediterranean basin. Therefore, provide a useful tool for decision-makers and stakeholders to prioritise interventions in farm management practices. Moreover, it aids the identification of efficient mechanisms to evolve towards more sustainable agricultural production at a regional level.

In relation to the research questions, the RISE 3.0 sustainability assessment provided benchmarked sustainability assessments for the Argolida region. Benchmarking against the wider RISE dataset illustrated the strengths and weaknesses of farm businesses in the area. In relation to farmers' perceptions of the importance of effective decision-making in relation to the sustainability performance of farming systems, the results from the thematic analysis, the sustainability assessments and the FADN data highlighted important sustainability characteristics of farm businesses in the region. Finally, the DST awareness and their (limited) use suggested the need for further research to identify the needs and requirements of stakeholders in relation to DSTs, but also consideration of how the use of such tools could be encouraged as a mechanism to enhance sustainability.

Overall, this research indicates a gap in the understanding of wider sustainability issues within the context of farm decision-making. While just a few farmers had a clear grasp of the dimensions of sustainability and just one farmer had ever undertaken a sustainability audit, it was clear that in order to enhance the sustainability of the production process, the educational, technological and consultancy framework needs to be reformed to address the challenges indicated previously. Farming systems were considered sustainable as long as they were profitable. Distinctions between economic and other aspects of sustainability were not made and this is an element that could be tackled through training and workshops that address the concept of agricultural sustainability. The findings highlighted that even though farmers believed their existing cultivation practices were in line with the preservation of the environment, the promotion of biodiversity and the protection of soil and water properties, the results of the sustainability assessment indicated that these were the factors that farmers should focus more attention on, to improve their overall farms' sustainability performance. The absence of adequate advisory services or the paucity of provision of independent advice, are also potential areas for improvement.

Orientation towards holistically addressing the practicalities of incorporating sustainability into the farmer decision-making process is of increasing importance as options for change narrow (i.e., climatic change, environmental degradation, water scarcity). The findings of this research via the sustainability assessment and the thematic analysis illustrates the need to encourage farmers and advisers to change their actions in order to enhance wider agricultural sustainability. One element of this is the formulation of educational and professional development frameworks and networks to facilitate and enable the change to more sustainable systems. Key elements that would raise the general profile of sustainability are related to, for instance climate resilience, soil quality improvements, water use efficiency and a reduction in environmental pollution.

Farmers will need to change or be encouraged to change for instance by diversifying their production using new varieties and crops to efficiently address the challenges that will occur in the future such as CTV, land abandonment, and water scarcity. Changes in policy such as the decoupling of payment schemes as part of the CAP subsidies and continued 'greening' of the CAP may aid this transition but the additional support via farmer advisory services, opportunities for continuing professional development (CPD) and the introduction of DST will potentially all have a role to play in these change processes.

Thus, to aid the change process this research recommends:

- A review and update of the educational framework for both farmers and advisers to tackle the challenges of sustainability awareness and performance, and technology uptake.
- The creation of vocational training programs oriented towards enhancing the continuing education of farmers on contemporary methods and skills.

• An enhancement of the role of the extension services to provide responsible guidance and advice possibly from a restructured network of extension officers that can support the change to more sustainable systems.

4.6 Additional material and summary

[1]The analysis illustrated that the majority of the farms were in the problematic zone (see figure 3.2) of sustainability performance for more than half of the RISE themes. Problematic themes included "materials use & environmental protection", "water use", "energy & climate", "economic viability" and "farm management".

For the theme of *"soil use"* (see Appendix 1, figure 9.1) the indicators that need greater attention are crop productivity and soil reaction. As far as productivity is concerned most farms presented lower yields than the benchmark for the area. In terms of soil reaction, the low performance is derived from the overuse of fertilisers that can cause increase or decrease of the pH from the optimum range of 5.5 – 7.0. For the ""materials use & environmental protection" theme (see Appendix 1, figure 9.2) all farm businesses scored in the problematic area with indicators such as *"material flows"* and *"fertilisation"* scoring very low in the problematic and critical area. This was related to the inefficient utilisation of fertilisers which in the case of the sample farms was not informed from a soil analysis, and the regionality of fertilisers' supply meaning that all materials are sourced locally, from sustainable sources, which in many cases was not the case.

The *"water use"* theme (see Appendix 1, figure 9.3) presented an interesting feature of crop production of the area. Irrigation and water supply systems may be sophisticated and technologically advanced, but water use intensity scored low as farms are dependent on externally supplied water to cover their needs as regional coefficients and climatic conditions can not cover them. All farms in the sample scored in the problematic area of sustainability performance, raising the possibility of water scarcity for the future. In the *"energy & climate"* theme (see Appendix 1, figure 9.4) half of the farms scored in the positive area with the rest scoring in both the critical and problematic areas. Even though the energy intensity of agricultural production and the energy management indicators score mainly in the positive area, the greenhouse gas balance indicator was low. This was calculated using data on land and energy use, production methods, animal husbandry and land use changes, and was then rated against global and/or

[1] The material presented here is additional content (analysis/results) not included in the published paper.

EU benchmarks (Grenz et al., 2009). When combined with the lack of use of renewable energy sources result in the medium and/or low performance for 60% of the farms.

The *"biodiversity"* theme (see Appendix 1, figure 9.5) score was also in the critical area for 90% of the farm businesses. The main issue in this theme emerged from the biodiversity management. The farms did not receive comprehensive advice or had a good operational knowledge of biodiversity management. Consequently, their biodiversity management system did not incorporate a strategic and systematic approach to planning, decision-making, implementation and monitoring of activities geared towards species protection and ecosystem conservation. The fact that many fields provided a habitat for beehives scored positively on the sustainability performance grid. On one hand the production intensity was not low enough to provide habitat for a diverse flora and fauna and on the other hand the distribution of ecological infrastructures in the landscape was low. However, most importantly the diversity of agricultural production was low too with a small number of species dominating the cultivation pattern for the area. The *"working conditions"* theme (see Appendix 1, figure 9.6) score was in the positive area as farmers considered that aspects such as occupational health and safety/physical working conditions, work organization, respect of basic rights, remuneration, and justice were adequately addressed. The aspect of wage and income level was the only challenge for the sample, as 85% of it was rated in the critical and/or problematic area. The main reason for this was the fact that the farmer and/or the family members were not paid a wage and did not receive appropriate hourly compensation.

For the *"quality of life"* theme (see Appendix 1, figure 9.7), the indicators of social relations, personal freedom and values, and health were evaluated positively while occupation and training were assessed in the critical and/or problematic area for 90% of the farms mainly because of the lack of supply of vocational training for farmers and workers. The financial position of farms not surprisingly was considered as very important. The theme of *"economic viability"* (see Appendix 1, figure 9.8) gave crucial insights about the financial situation of farming systems in the area. The economic dimension of sustainability is typically determined through the aspects of profitability, liquidity and stability. In terms of profitability 90% of the farms were found to be financially profitable on both a short- and long-term basis. In other words, their earnings allowed them to meet their financial obligations, make investments and earn a profit that adequately recompenses the equity invested in the business. As far as stability was concerned, 55% of farms scored in the positive area, 45% in the critical area and 5% being problematic. Stability for a farm business means that it is regularly able to break even over a period of several years with a normal level of household consumption, and that the long-term future of production on the farm is secure (Grenz et al., 2018). Guaranteed land access means that it is possible to plan and ensure the continuation of production on a long-term basis, whilst a high equity ratio allows the farmer to make their own decisions about how the business evolves (Grenz et al., 2018). The liquidity indicator was a challenge for all 20 farms of the sample, but this seems to result from the unwillingness of the interviewees to give additional details and had to rely on FADN financial data for it.

In the *"farm management"* theme (see Appendix 1, figure 9.9) the business goals, strategy and implementation challenges are analysed, and the business objectives are checked for compatibility with sustainability goals. On this basis, the chosen strategy should have a positive impact on economic, social and environmental sustainability. For this indicator, 65% of the farms scored in the critical area of sustainability performance.

This was the result of farms lacking an explicit long-term strategy. Even when they had one, it is often exclusively geared towards economic and/or agronomic performance indicators. Agroecological approaches such as integrated soil fertility management, adapted crop rotation and diversified farming systems such as agroforestry (Altieri et al., 2015) were not adopted. In terms of risk management, farmers identified climate conditions and weather as the greater threat expressing at the same time their lack of power to manoeuvre the farm management, particularly in terms of risk prevention but also in terms of minimising the negative impacts of any adverse events. Nevertheless, internal and external relationships are managed in such a way as to provide a sound basis for the farms' long-term success and the people responsible for managing the farm answered that they have access to adequate information and reliable planning tools so that they can manage the farm systematically and professionally.

In summary, the practical implications of this chapter are that the methodology used in the research can be adapted to other similar crops and areas in the Mediterranean basin, providing a useful tool for decision-makers and stakeholders to prioritise interventions in farm management practices and evolve towards more sustainable agricultural production at a regional level. The research identifies differences between the perceptions of farmers in relation to financial and environmental sustainability and their actual practice, providing a basis for suggesting mechanisms that can enhance the sustainability of farming systems in the Mediterranean basin. It also highlights the need for farmers to be better informed about sustainability and to use decision support tools to improve their decision-making processes. The findings of this research can be used to develop policies and programs that promote sustainable agriculture in the Mediterranean region. The next chapter investigates the management practices, methods and tools, through which decision-making can be informed from a differentiated management approach that can lead towards more sustainable farming systems.

CHAPTER 5. Farmer and adviser perspectives on business planning and control in Mediterranean agriculture: Evidence from Argolida, Greece

5.1 Introduction

Climate change and the more frequent appearance of extreme weather phenomena (Abbas et al., 2021; Elahi et al., 2022), land degradation and the increasing scarcity of natural resources have impacted on farming and food production in the Mediterranean basin (Lange, 2020). The traditional structure and organisation of agricultural and food production systems in the Mediterranean basin have also been challenged by the changing political, economic, and technological environment (Malek & Verburg, 2017).

Hence, it is imperative to explore appropriate strategies in which the agricultural sector can overcome these challenges. According to Kahan (2013) enhancing the managerial attributes of farmers and farm managers is crucial to enable them to balance risks and uncertainties. Several studies have discussed the subject of farm planning and control in the area of the Mediterranean basin (Bournaris and Papathanasiou, 2012; Martinho, 2021; Stylianou et al., 2020) and have highlighted the importance of improving decision-making processes to enhance the sustainability of farm businesses.

This paper investigates whether farmers intentionally adopt and implement planning and control methods as a decision-making tool to enhance farm sustainability and explores the factors motivating or hindering them doing so. It also investigates the contribution of agricultural advisers in farm sustainability design and supporting farmers with decision making beyond their normal focus on productivity and profitability. Finally, it explores the current use and the future prospect of Decision Support Tools (DST) as a mechanism to inform decision-making and enhance sustainability.

Successfully addressing successfully the four functions of management (planning, organising, leading, controlling) is a fundamental of business viability (Boddy, 2017). Historically the management of a farm was based mostly on empirical knowledge passed on from generation to generation. Traditionally it was not necessary for farmers to become involved in many arithmetical calculations, but farm businesses are changing (Van Reenen & Davel, 1989). Today’s farmers are being confronted with a range of challenges for instance rising input costs, lower product prices, escalating interest rates on the purchase of farming land, labour shortages and the threat of climatic change (FAO, 2015). These factors are forcing farmers to further develop their business acumen and managerial skills to manage their farming enterprises as efficiently and effectively as possible.

Farmers often have their own perception of what it is to be *"a good farmer"* and this is not necessarily shaped by the highest economic returns, but has to do with the meeting of existential, stylistic and moral goals (Cusworth & Dodsworth, 2021). For example, many US farmers perceive that high input/high output production systems that manage to produce large amounts of food, fibre or fuel define their identity (McGuire et al., 2013). However in Greece and generally in the Mediterranean region there is a shift towards developing sustainable production systems that can address the societal concerns regarding the environment, the nutrition of people and still maintain a viable farm businesses (Walters et al., 2016). This is in part because farmers are experiencing pressure from a variety of environmental factors, such as the increasing need for water use efficiency and decreasing output due to soil erosion (Harmanny & Malek, 2019), (Walters et al., 2016). The plain of Argos has already been designated as a nitrate vulnerable zone (NVZ) by the Greek authorities and according to the nitrates directive (91/676/EEC). Generally, farmers are in a unique position: they serve as providers of food and biofuel but are also obliged to serve as stewards of natural biodiversity and in some cases societal coherence. McGuire et al (2013) note that social and economic research that guides public policy and farmer practice is needed if society is to establish a balanced equilibrium between sustainable food security, entrepreneurship, and environmental soundness.

In Sweden research has illustrated that some farmers with lesser entrepreneurial capabilities, often older farmers, tended to be less proactive in making changes and adopting new strategies (Björklund, 2018). McElwee and Baker, (2008) showed that conventional farmers in England were less confident of their abilities as entrepreneurs than those who were engaged in value-added or non-farming enterprises on their farms. According to De Lauwere et al. (2002) management and strategic planning are crucial factors in entrepreneurial success while McElwee, (2007) suggests that strategic management, marketing and entrepreneurial skills are most necessary for the improvement of English farmers' practice. An entrepreneurial approach may be applied to the development of new products or niche markets. However, Zellweger et al (2010) suggest that it must not only be restricted to this context but also extended internally to new mechanisms of implementing processes and procedures so that the already existing products or markets are covered more efficiently.

In the Mediterranean basin, after the end of the second world war, the farmer was often viewed as a rational entrepreneur, according to agricultural modernisation theories about making farm processes rational, efficient and replicable (Nori & Farinella, 2020). The emergence of studies discussing the behavioural factors affecting the adoption of sustainable farming, for instance Dessart et al, (2019), highlighted the need for a more holistic approach to policy-making when designing strategies to support sustainable farming. This enables the consideration of the technical and natural characteristics of the system but also the behavioural factors influencing farmers adoption of sustainable farm management practices.

Financial planning and control methods, such as budgeting, programming and an accurate set of financial statements assist the promotion of profitability, liquidity and solvency of the farm business providing an indication of its financial health (Boddy, 2017; Edwards & Duffy, 2014; Sumelius, 2004). The findings of Mäkinen (2013) suggest that production planning, supported by monitoring farm outcomes, the use of bookkeeping and budgeting practices, and economically oriented objectives also facilitates the technical efficiency of farms.

Overall, the adoption and implementation of planning and control methods depends on the management capacity and inclination of the farmer (Mäkinen, 2013) and the application of analytical management tools as a higher level of business skill leads to increased productivity and improved business outcomes. Other factors affecting the degree of planning and control include education, vocational training, age, farm size and crop selection (Stanford-Billington & Cannon, 2010).

In order to enhance the use of business planning and control methods in the farming systems of the Mediterranean, this paper focuses on the following questions:

1. What are the factors that motivate or hinder farmers' adoption and implementation of planning and control methods in the context of farm sustainability?
2. Does farm sustainability present different challenges to farm advisers beyond the consideration of productivity and profitability?
3. What is the current use of and the prospects for the future use of DSTs to enhance farm sustainability?

Even though farm sustainability is considered an important concept in Greece and the Mediterranean basin, there is limited research which links farm sustainability with farm management practices. The research reported here uses farmers and their advisers to investigate the reasons motivating or hindering farmers' adoption and implementation of planning and control methods, to identify if advisers address farm sustainability holistically or one-dimensionally. The research also explores the current use of, and prospect for the future use of, DSTs as a means to enhance farm sustainability.

The following sections outline the methodology used to address the research questions, provide greater detail of the study area and the sample methods employed, before presenting results and concluding comments with key messages.

5.2 Materials and Methods

5.2.1 Outline of the research

Data was derived from a sample of farm business advisers, i.e., agronomists and accountants, and farmers from the area of Argolida in the south of Greece, with features typically representative of the Mediterranean basin.

By using these three groups of respondents (i.e., agronomists, accountants, and farmers) a range of perspectives on planning and control were investigated including the relations and interdependencies between the groups. This enabled a better understanding justification, and validation of attitudes and behaviours.

5.2.2 Research region

Argolida, a regional unit of the Peloponnese peninsula in Greece (fig. 5.1), was selected as the area for field research.

Figure 5.1: Map of region of Argolida. Adapted from https://en.m.wikipedia.org/wiki/File:Greece_location_map.svg

This area has features typical of the humid mid-Mediterranean climate (Kavvadias et al., 2013). It is an area where the cultivation of olive and citrus trees is predominant, which are typical crops for southern and eastern Greece and the wider Mediterranean area. Argolida is one of the major suppliers of oranges for the Greek and export market (Kavvadias et al., 2013; Kelepertzis, 2014). Olive cultivation, primarily for oil, is considered particularly important for Greek farmers; according to FAO (2018), Greek olive oil production in 2020 was estimated to account for roughly 9% of global production, placing Greece third in the world by volume according to IOC (International Olive Council) statistics. Collectively, the countries of the Mediterranean basin account for approximately 96.5% of global olive oil production (Niavis et al., 2018) while the EU's Mediterranean area is responsible for approximately 20% of the world's citrus production and 70% of global citrus exports (European Commission, 2019).

5.2.3 Research participants

i) Farmers

Farm businesses from the Farm Accountancy Data Network (FADN) for the region of Argolida were used as a basis for this research. The total regional number of participants in the FADN sample was 57 owners/managers for the year 2018. After communicating with farmers for the purpose of recruitment, from the initial 57 farmers in the sample, 29 had to be excluded for various reasons[2] allowing a sample of 28 farm businesses to be utilised within the research.

ii) Advisers

The advisers interviewed were both agronomists and accountants. They have influence over and advise on aspects of the planning and control process and by the nature of their role are in close contact with farmers. Based on previous published work and similar projects (Guest et al., 2006), a sample of 20 advisers was considered to provide an adequate representation for the region. The random sampling technique was used to select the participants and to provide an unbiased sample.

Agronomists were considered not only as sources of advice to farmers on production aspects such as agricultural practices, but also as techno-economical consultants. That considered government or EU funded programmes in which farmers took part, such as organic farming, use of plant protection products

[2] One of them has passed away in the meantime, another one withdrew from the FADN program, while 27 of them did not want to participate to the research mainly for time availability reasons.

and the new entrants programme in the agricultural sector as well as other services. The 10 agronomists participating in the study were selected from a pool of 40 agronomist members of the *"Association of Self-Employed Agronomists of the region of Argolida"* (i.e., 25% of the total)

Accountants were also considered as advisers, for instance on the farm businesses' financial issues in general, and taxation matters. This included the annually submitted tax declaration, the insurance coverage for farmers and farm labour and regular VAT returns in relation to income and expenses. In the area there were two accountants' associations, in the towns of Nafplio and Argos with 50 members in total. From this pool 10 accountants were selected (i.e., approximately 20% of the total).

5.2.4 Interview structure

For the purposes of the content analysis two sets of questions were employed. One set was prepared for the advisers (agronomists and accountants), and the other set was used as a basis for the interviews with the farmers. The interviews in both cases were conducted via telephone, due to the Covid-19 pandemic restrictions.

Each of the participating advisers was asked seventeen open-ended questions in a semi-structured format. These questions addressed their personal characteristics, their experiences and exchanges with farmers as well as their attitudes and understanding of the concepts of planning and control methods and the actual use of such methods by farmers. The questions examined the frequency and type of methods used, the relationship of these methods to sustainability and finally the attitudes and perceptions of advisers for the steps that were necessary to adopt and implement more rigorous planning and control methods. The interviews were recorded with the permission of the participants, transcribed verbatim, and translated into English. These interviews took place between the 6 of January and the 8 of February 2022, with each interview taking an average of 20 minutes

Each of the participating farmers was asked twenty-one open-ended questions in a semi-structured format. These questions addressed their personal characteristics and farm business related information, and then asked about the implementation of planning and control methods. During the interviews, their confidence and experience of implementing planning and control methods, the types of methods already used, their relation to sustainability, the risks incurred because of non-adoption and implementation, the types of advisers they made use of and finally the extent to which they used the services provided by advisers. The interviews were recorded with the participants permission, transcribed verbatim, and translated into English. These interviews took place between the 22 of January and the 15 of February 2022 with each interview taking 15 minutes on average.

5.2.5 Data analysis

i) Content analysis

The participant responses were analysed using content analysis. The aim of the analyses was to produce replicable and valid inferences from the interview texts (Krippendorff, 2004). This method was selected because content analysis allows the researcher to quantify and analyse the presence, meanings, and relationships of such certain words, themes, or concepts. It enables the researcher to understand the aspects of a phenomenon and identify and analyse patterns and attitudes within a given data set (Braun & Clarke, 2006b). Thus, content analysis is a research method that provides a systematic and objective means to make valid inferences from verbal, visual, or written data to describe and quantify specific phenomena (Bengtsson, 2016). According to Krippendorff (2004), the processes needed to organise the content analysis, in a linear fashion, are unitising the words, sentences and paragraphs, sampling to obtain a manageable subset, recording/coding to create durable records, reducing the diversity of text to what matters, inferring contextual phenomena from texts, and narrating the answers so that the results are comprehensible to others.

In this study inductive content analysis was used as it is a more exploratory approach. Through the study of the recorded interviews key themes were identified that emerged from repeated examination and comparison of the raw data. NVivo 12 software aided the data analysis and the distinguishing of segments of texts. Because of the rich verbatim transcriptions provided by the participants segments of texts were distinguished solely based on what the participants reported. No attempt was made to theorise or interpret interview replies. Coding (creation of the nodes) and word frequency measurements were used to analyse the interview texts. Coding was used to understand how these key themes emerged and word frequency was used to quantify the appearance of these words next to the concepts under study. The interviews were conducted in Greek and were transcribed and entered in NVivo 12 software. The creation of the themes (nodes) during the process of coding and the word frequency measurements were performed in English, for the purposes of the analysis.

ii) FADN data

As well as aiding in the identification of the study sample the FADN data were used to inform and generate results for the social and economic elements of the 28 farm businesses in the study. The Greek Ministry of Rural Development and Food provided data on specific features of the farm businesses taking part in the sample: these were holding size, crop type, expenses, profits, and subsidies. These, when combined with the findings from the content analysis, gave a clearer image of the specificities and characteristics of the farms and how the opinions and perceptions of their owners were formed.

5.3 Results and discussion

5.3.1 General characteristics

The general characteristics of the farmers in the sample compared to regional data are shown in Table 5.1:

Table 5.1: Regional data adapted from FADN data and (European Commission, 2021)

	Sample		Regional data	
Gender	85% male		75% male	
Type of farming	82% conventional		90% conventional	
Age	85% > 40 years		75% >40 years	
Holding size (ha)	Mean 7.2 ha	82% < 10 ha	Mean 6.6 ha	93% < 10 ha
Education	80% primary and secondary		95% primary and secondary	

Most farmers in the sample cultivate citrus crops, mainly orange trees (Citrus sinensis), mandarin trees (Citrus reticulata), and lemon trees (Citrus limon), as well as olive trees (Olea europaea) for oil production along with varieties of table olives. Other crops grown on smaller areas were apricots, vine, vegetables, and pomegranates. One of the participants was farming sheep for dairy and meat production, although they also produced olive oil. Table 5.2 provides a broad characterization of the 28 farms under study.

Table 5.2: Selected sample from FADN Greece. Adapted from FADN dataset Greece.

Interviewee ID	Type of Farming	Holding Size (ha)	Crops
Farm1	Conventional	3.55	Citrus, Olive, Apricot trees
Farm2	Conventional	4.4	Citrus, Olive trees
Farm3	Conventional	8	Citrus, Apricot trees
Farm4	Conventional	8.46	Citrus, Olive, Apricot trees & Vine (Wine)
Farm5	Conventional	12.75	Citrus, Olive, Apricot trees
Farm6	Conventional	8.93	Citrus, Olive trees & Vegetables
Farm7	Organic	6.05	Citrus, Olive trees & Vegetables
Farm8	Organic	22	Olive trees
Farm9	Conventional	7.8	Citrus, Olive, Apricot trees
Farm10	Conventional	6.7	Citrus, Olive, Apricot, Peach trees

Farm11	Conventional	4.2	Citrus, Olive trees
Farm12	Conventional	10.39	Citrus, Olive trees
Farm13	Mix	9.81	Citrus, Apricot trees
Farm14	Conventional	7.25	Olive, Apricot trees & Vine (Wine)
Farm15	Conventional	6.07	Citrus, Olive, Apricot trees
Farm16	Conventional	16.8	Citrus, Olive, Apricot trees
Farm17	Organic	2.95	Citrus, Olive trees
Farm18	Conventional	6.9	Citrus trees
Farm19	Conventional	4.6	Citrus, Olive trees
Farm20	Organic	7.03	Citrus trees & Vine (Wine)
Farm21	Conventional	1.4	Citrus, Olive trees
Farm22	Conventional	3.1	Citrus, Olive, Pomegranate trees
Farm23	Conventional	1.75	Citrus, Olive trees & Vegetables
Farm24	Conventional	3	Citrus, Olive trees
Farm25	Conventional	9.03	Citrus, Olive trees
Farm26	Conventional	3.58	Citrus, Olive, Apricot trees
Farm27	Conventional	14	Olive trees, Pastureland & Sheep
Farm28	Conventional	2.4	Citrus, Apricots trees

The agronomists were all male which is also the case in the wider region. In the case of accountants, there were a number of female respondents (30%) which is also reflected in the wider region. The age of the majority of the participants was between 40 and 59 years with at least 10 years of experience.

5.3.2 Research findings

Table 5.3 provides a quantitative overview of the main research findings.

Table 5.3: Key themes of the content analysis and information drawn from respondents.

A/A	KEY THEME	FARMERS	ADVISERS	
			Agronomists	Accountants
1	Planning in agriculture	100% of 28 farmers agreed on the importance of planning in agriculture.	100% of agronomists agreed on the importance of planning in agriculture. Main focus was agricultural practices, timely application of them to reduce costs, mitigation of climate change, and improvement of quality and yields of produce.	100% of accountants agreed on the importance of planning in agriculture. Main focus was economic benefits, tax avoidance, insurance, investments, business growth, and development.
2	Use of planning methods	93% of farmers use planning methods, while 7% do not. Challenges were related to weather conditions, prices, inputs costs, and agricultural practices.	70% of agronomists think the use of planning methods offers benefits. 90% of agronomists consider their use also presents challenges. 10% of agronomists think there are no challenges to the use of planning methods. Challenges were related to age, culture, reluctance to change, education, size of holding, and benefits with labour organisation, agricultural practices, and crop restructuring.	50% of accountants think the use of planning methods offers benefits. 80% of accountants consider their use also presents challenges. 20% of accountants think there are no challenges with the use of planning methods. Challenges have to do with lack of education, part-time employment, age, holding size, and mentality, and benefits with timely anticipation of situations, production reducing costs, etc.

3	Planning and sustainability	93% of farmers consider planning in relation to farm sustainability as important, while 7% consider that it does not affect sustainability at all.	100% of agronomists consider planning in relation to farm sustainability as important. 80% focused on financial issues, while 20% showed a more holistic understanding of sustainability.	100% of accountants consider planning in relation to farm sustainability as important. 90% focused on financial issues, while 10% showed a more holistic understanding of sustainability.
4	Control in agriculture	100% of farmers agreed on the importance of control in agriculture.	100% of agronomists agreed on the importance of control in agriculture. The word that prevailed was "important", followed by words such as improvement, evaluation, previous years, prevention, analysis, results, and action.	100% of accountants agreed on the importance of control in agriculture. "Important" was the most featured word here too, followed by avoid tax, taxes, agricultural practices, education, and part-time employed.
5	Use of control methods	96.5% of farmers use control methods, while 3.5% do not. Challenges mainly consist of economic issues, input costs, and prices.	30% of agronomists think the use of control methods offers benefits. 70% of agronomists consider their use also presents challenges. Challenges were related to age, approach to profession, reluctance to change, and economic reasons.	30% of accountants think the use of control methods offers benefits. 80% of accountants consider their use also presents challenges. Challenges were related to age, education, and reluctance to change.
6	Control and sustainability	89.5% of farmers consider control in relation to farm sustainability as important. 7% consider that it does not affect sustainability at all. 3.5% are not sure about it.	100% of agronomists consider control in relation to farm sustainability as important. 100% focused on financial issues such as better prices, reduction of costs, and trading prices.	100% of accountants consider control in relation to farm sustainability as important. 100% focused on financial issues such as revenue-income and profit.
7	Advice common subjects	46% Agrochemicals (fertilizers, spraying) 39% Agricultural practices 18% Plant protection 18% Tax issues	90% Plant protection and nutrition 30% New varieties 30% Irrigation 30% Yield increase 10% CAP subsidies	90% Taxation issues 30% National insurance 10% Investments 10% Financial situation of the business
8	DST use to inform decision-making		70% Yes 30% No	100% Yes
9	DST farmers' stance		80% Positive 20% Neutral/Varied depending on age, size of holding, cost/benefit balance	50% Positive 30% Negative due to age and ease of use 20% Neutral due to culture
10	DST steps forward		60% State intervention 50% Cost of use 40% Team organization of farmers 30% Applied research	60% Training/education 50% State intervention 30% Change of mentality/extroversion 30% Cost of use

Further analysis of the summary findings from Table 5.3 is presented below with the discussion incorporating relevant literature.

5.3.3 Factors influencing planning and control methods use

The participants have highlighted how useful the engagement with the function of planning has been for their agri-businesses. Particularly, it was noted how it had contributed to developing contingency plans for challenges that would otherwise have emerged during the production and harvest period, such as diseases, drought, limited access to and cost variability in the production inputs. When considering irrigation and water use efficiency and the risk of drought in the region of Argolida, and extending this to the Mediterranean basin, contingency plans are of paramount importance (Mellor, 2008).

For farmers, the function of planning was mainly associated with, and considered important, for guiding the decision making about the agricultural and agronomic practices in place for next year's production period. Financial aspects associated with the function of business planning have received less attention by farmers. For instance, one of the farmers stated *"Financial planning cannot be done by the farmer, I think. It depends on… let me tell you, it's all about weather and you never know what's going to happen…"* In addition, although the function of planning is used to develop a coherent strategic longer-term plan for the agri-business (Neves et al., 2019) this was not reflected in the responses from farmers.

In comparison to farmers, advisers had a different perception of the importance and use of the management function of planning. Agronomists recognised the importance of planning beyond immediate agricultural practices, which could yield long-term benefits in production, costs and eventually profit. Accountants prioritised the planning of economic factors of production to minimise tax and insurance payments.

A key difference amongst the farmers and agronomists was that the latter was considering the function of planning as a systematic process which was informed by science, and data driven while according to farmers, the whole process was designed and implemented "in their head"[3]. For farmers, the implementation of the production plan depended on multiple parameters such as tradition, experience, weather, and economic ability rather than on documented evidence-based recommendations from the adviser or based on data from past years or indeed data relating to future scenarios. Their planning process stems solely from the fact that they schedule agricultural practices without any, or limited reference to financial planning. However, it must be argued that business planning and benchmarking of the performance of the farm business and the individual enterprises can improve financial performance and thus enhance long-term economic sustainability (Vanhuyse et al., 2021). In the case of the accountants the plan and the advice provided usually had a binding character and effect, being based on legislation, with clear and distinct time boundaries and being linked to actual financial data.

Of equal importance to the function of planning, all groups suggested that monitoring and controlling the agribusiness to attain its objectives was also of high importance. Whereas the planning process was seen

[3] This is an expression meaning that the plan was devised in an offhand way and without it being written down somewhere.

as being focussed on short term agricultural practice (with constant reference to cultivation practices, land protection, irrigation and fertilisation), the monitor and control process was almost exclusively related to financial parameters. Responses suggest they did not evaluate the effect of their practice on production but assessed only its economic dimension.

The majority of the farm businesses in the sample (70%) had been managed directly by the farm owner whereas for the other 30% of businesses family members, employees or agronomists had some involvement in the planning design and implementation. The reported rate of adoption and implementation of planning methods was over 90% of the farm businesses surveyed, whilst just two farms suggested they had not used any kind of planning method. In two cases the function of planning was undertaken by the agronomist or a family member without the active participation and engagement of the farmer themself. Based on the responses received from all groups, planning was associated with *"designing agricultural practices"* like *"spraying, pruning, irrigation, applying fertilisers"* and *"establishing new varieties"* (Fig. 5.2).

Figure 5.2: Planning process - word cloud. Adapted from N-VIVO analysis

The challenges encountered during the planning process, as mentioned by the farmers, were:

- the weather conditions, which are unstable and unpredictable,
- the variability of input prices, which makes it harder to perform agricultural practices in the intended way and increases production costs while simultaneously reducing gross margin,
- lack of access to credit limits the farmers' ability to perform necessary actions,

- Water scarcity, part-time employment, and the general difficulty of covering the labour requirements were also cited.

While for advisers, the challenges were:

- The changing climatic conditions, especially recent unpredictability of weather conditions,
- The culture and lack of attention of farmers towards their business development,
- Related to the above the unrealised potential to increase profit margins via better cost management and increase of yields.

5.3.4 Features of planning and control

Features that emerged during the content analysis could be attributed to the adoption and implementation of planning and control methods by farmers and their advisers and are presented in Table 5.4.

Table 5.4: Features of planning and control identified from the content analysis[4]

	FEATURES
AP	Agricultural Practices
FI	Financial
CR	Crop Restructuring
TR	Trading
IN	Investments

These features emerged from the discussion with farmers and at least one of the features was mentioned by each respondent whilst some mentioned more than once and up to five (all of them). If a farmer is able to plan or control for all five features then that would cover the operational, tactical and strategic goals of the business as described in Boddy (2017) and result in well-informed and evidence-based decision-making thus enhancing the sustainability performance of the farm business.

[4] Agricultural Practices: All cultivation processes such as fertilisation, irrigation etc
Financial: All financial statements and budgets such as cash flow budget, enterprise gross margins etc.
Crop Restructuring: Changes in varieties and crops.
Trading: Sales and prices of produce.
Investment: Investments in machinery, land purchase etc.

From the perspective of advisers, planning was considered a crucial parameter for the success of the farm business. For instance, one adviser noted, *"I think, especially in the current period, if you do not do proper planning there is a chance that your farm business will go bankrupt"*. Agronomists emphasised that the increasing unpredictability of the weather conditions affects the outcome of the planning process. This increasing weather variation suggests that planning is more important in order to mitigate risks and in preparation of timely response to changing circumstances.

Control methods were also found to be important to both agronomists and accountants. All agreed that it was crucial to monitor and keep records of previous years as a basis on which to plan for following years. For accountants their advice and guidance was focused and limited to avoiding over taxation, although they generally avoided advising on the financial management of the crops and the farming system. Agronomists were more holistic in their approach noting that the function of monitoring and controlling was necessary for the improvement of the business, as it would help farmers to avoid difficulties and to mitigate risk. The control function allowed farmers to develop a well-informed strategic pathway that was based on information and feedback to form the control process. This enabled the businesses to attain their production output and sales goals. Farmers generally discussed their production data with the agronomists so that potential changes could be made. Nevertheless, the main feature of the control process was related to economic data meaning that the control process primarily encompassed its use at the end of the year rather than monitoring data from the crops throughout the year.

Accountants were not asked by farmers to advise on business control i.e., farmers did not consider their accountants as an adviser in the context of providing management advise. Some agronomists suggested that farmers had an *"amateur approach towards the profession and their businesses"*. This may be as a result of lack of vocational of training and education as only 4.5% of farmers had attended at least one training course on agricultural-related subjects and less have graduated from agriculture or closely related education (Brinia & Papavasileiou, 2015) or lack of direction from the state. Another reason may have been the lack of an organised approach from the advisers, and it is possible that increased knowledge of available DST could stimulate farmers to make use of them. According to one agronomist *"An organised approach would benefit not only the farmers but also my colleagues themselves as a lot of them have no idea what a tool like that can offer them"*. The latter indicated a crucial gap of knowledge and lack pf access to information or at least the means through which information could be found and used.

Agronomists tended to strike a balance between both production and financial aspects taking into consideration the economic outcome of the previous year if available along with data on the results of the application of agrochemicals, fertilisers, irrigation etc. Accountants continually accumulated data on the farmer's economic activity in order to bring it under firmer control: they may suggest an investment or any other kind of action to mitigate the regularly recurring tax and insurance burdens.

From the farmer's perspective the benefits of planning and control methods are the prediction, development, motivation, and anticipation of unprecedented situations. However, structural issues in the agricultural sector in Argolida and the wider Mediterranean basin provide specific challenges to the adoption and implementation of planning and control methods by farmers. These challenges, as noted in this research are:

- the ageing rural population
- farmers' lack of vocational training,
- limited access to information and advisers,
- rural culture and traditions that have influenced agricultural practices
- the small size of the holdings and their distributed nature
- and finally, a poorly- informed management approach that farmers have.

As one of the advisers noted...., *"they cultivate as they did 20 years ago and as long as they can sell their produce it's ok"*. This summarises the overall approach that many Argolida farmers have towards their businesses. For instance, although the area is designated as a nitrate vulnerable zone (NVZ) with the intensive agricultural activities (high fertilizer usage) and the over-abstraction of groundwater having a direct impact in water availability and quality, none of the respondents noted these as factors that restrict their daily practices. That can be attributed either to lack of knowledge or to the negative view that farmers have towards the NVZ, often viewing the restrictions as too inflexible (Brinia & Papavasileiou, 2015).

Such challenges have been documented in the Mediterranean region previously. Doignon (2019) has talked about the agricultural population and the ageing problem in the area while many more have referred to the lack of vocational training for farmers (Grasso & Feola, 2012; Harmanny & Malek, 2019) and advisers (Österle et al., 2016). This research shows that the application of planning and control tends to be either completely lacking or very restricted in its scope and can be linked to reduced economic performance (Stanford-Billington & Cannon, 2010). Nevertheless, it is also a feature that aligns with the notion that the process of planning and controlling has an iterative character and depends clearly on the needs and requirements of the observer (van Mourik et al., 2021).

Overall, according to advisers planning and control in the Argolida area was deficient mainly because of the farmers' attitude toward management techniques. Planning and control methods were employed informally and tentatively. This affects the development of farm businesses in the area under study and similar areas in the Mediterranean region.

Planning and control methods should be employed by the farmer/adviser in order to control factors of the external environment having access and making use of knowledge and information (Bournaris & Papathanasiou, 2012). In terms of strategic planning, although the results of the content analysis reveals low number of farmers implementing methods to support it, as population increases and society is evolving with increased environmental and social pressures, farm businesses must adapt in order to survive (Miles et al., 1997). In such a volatile area in terms of natural, economic and political issues (Capitanio et al., 2020), the need to consider planning and control is compelling. Nevertheless, the lack of clear mission and vision from farmers compromises the form of any coherent strategic planning at the farm level (Stanford-Billington & Cannon, 2010).

For the agricultural systems of the Argolida to evolve in a more sustainable manner this research suggests there is a need for policy making to encourage the informed use of planning and control methods on farms. Sustainability orientation for farming systems of the region requires improved planning (either operational and tactical or strategic) and control in order to ensure their future viability.

5.3.5 Advisers' and farmers' perspectives of sustainability

i) Advisers' perspectives

Advisers acting as private extension officers play a key role as a critical link within farming populations in shaping the behaviour and attitudes of farmers (Herrera et al., 2019). Essentially, the role of advisers is to ensure interaction with farmers in the context of problem solving and involves tasks and activities that have to do with the use of communication skills to stimulate and enable change (Leeuwis & Ban, 2004). In this research agronomists and accountants were a critical source of information and advice for the owners/managers of the farm businesses from practical subjects such as agricultural practices, tax and insurance to more complex concepts like sustainability. For instance, one adviser *noted "If proper planning is not implemented, sooner or later the farm will collapse. In other words, the products will be sold at prices lower than the cost, so the sustainability of the farm, cannot be guaranteed if this is not done. Environmentally, climate change is now very intense and this factor should also be considered in planning."*

Advisers stressed the importance of planning and control methods to the sustainability of farm businesses but generally focussed on economic performance which was linked to profitability and productivity. Their answers to the questionnaire indicate that there is a gap in the understanding of wider sustainability issues. Reduced production costs and increased prices and profits were the main benefits perceived from improving the economic performance of the business and thus, the pillar of economic sustainability. The environmental and social pillars were just mentioned by a few (12%), but without any further comments on how these could be affected using a systematic approach to planning and control methods.

The responses of the agronomists about the role of planning and control methods were mainly focused on securing better prices for products and the reduction of production costs. A small proportion of advisers (around 10%) mentioned climate change and depletion of natural resources (water) as factors that businesses needed to consider in their planning strategy. They also recognised that there were economic (increased production costs, low prices, smaller profit margins) and social (land abandonment, ageing rural population, lack of young people entering the sector) changes in agriculture which would impact on farm businesses. The consensus was that the adoption of planning methods is an organised process leading to economically sound cultivation with better prices and trading.

Accountants' perception of the role that planning and control methods had on the performance of the farm business was different. They suggested that the main outcome would be business benefits in terms of economic viability and future business development opportunities. Just one accountant referred to the benefits as economic, environmental, and social thus suggesting a more holistic approach to sustainability. According to agronomists, in order to obtain the benefits associated with economic security, environmental soundness and social coherence then farmers need to change their orientation, i.e., the challenge that must be overcome is that policymakers and consumers were increasingly concerned about the sustainability of food production, the environment and rural society whilst the farmers themselves are still focussed primarily on financial sustainability. They stated that changing attitudes, training, and education of both farmers and many of the advisers would be necessary in order to instigate developmental change. For instance, most accountants considered that farm business development could be measured in monetary benefit alone. There was also the suggestion that larger holdings were key to development as they had greater bargaining power due to production volume and could thus command higher prices.

The subjects of advice are totally justified by the scientific expertise of each category of adviser. The question here is whether the advice goes beyond necessary instructions about agrochemicals and fertilisers (Österle et al., 2016) and extends to guiding the decision-making process towards choosing a more sustainable way of farming. The fact that agronomists tend to act more like traders than advisers endangers the integrity and quality of private extension services, and this is not only their fault. One of the agronomists interviewed noted *"we do not always have all the weapons to fight it and we do not have the methods to lead the farmer. We are not always precise in our advisory role because agriculture changes year by year and we cannot easily follow these changes, there is no research program in Greece that supports and helps us in this"*.

The new CAP aims to encourage the agriculture sector to be more dynamic, competitive and effective (European Commission, 2021). However, the advisers suggested that although seminars and workshops of private companies promoting new agrochemicals or fertilisers do take place, there are no meetings organised by the ministry or the respective directorate of rural development to inform them about the national and European vision of stimulating sustainable agriculture (European Commission, 2021) This lack of interaction between farmers and advisers in the form of private extension services, suggests there may be the opportunity to develop a co-production model of services (Lioutas et al., 2019). Such an approach recognises that farmers are collaborating actors and not clients and would enable a co-design platform where extension services, public or private, and farmers work collaboratively towards a sustainable future.

ii) Farmers' viewpoints

Although the majority of the farmers in the sample (over 90%) highlighted the importance of planning and control methods in relation to farm sustainability, only few considered the term in a holistic manner. Many of the respondents simply linked sustainability to the economic prosperity of the farm business while others linked it to the accurate scheduling of the agricultural practices to guarantee the quality and quantity of their produce. This demonstrates the constrained view of the Argolida farmers in relation to sustainability and highlights that their decision making is primarily based on the economic sustainability of the business. Thus, they only perceive one dimension of sustainability in their decision making and they ignore the environmental and social pillars.

Return on investment was the main motivation behind farmers' decision-making and statements such as *"budgeting is unrealistic, because of rising prices of inputs"* and *"I trade my produce in open markets so I* *try to produce as high-quality products as I can"* re-enforced the perception that sustainability awareness was low. The scant appearance of statements about high-quality products possibly stems from the fact that trade arrangements for the produce are mainly characterized by bulk sales to processing and packaging units in the area, thus having an impact on the targeted quality of the products, since producers will aim for high volume and low quality. For example, in the case of oranges due to market specific features, produce for export and produce for juicing (lower quality) enjoy in a lot of cases comparable low selling prices. There was a small number of organic farmers (12%) that considered sustainability more holistically. They linked the future prospect of their businesses to management consistency, good organizational structure, machinery and technology usage, and environmental and societal challenges awareness.

This convention of focusing primarily on the economic performance, probably explains the interaction between farmers and advisers in terms of the advice given, the advice used and opinions about the services provided. The interviewees gave thought-provoking responses to the questions about the advice and the adviser. Farmers frequently named agronomists as their advisers, while a minority (10%) of the respondents considered accountants in that capacity (Fisher, 2013). There are two main reasons for that happening. First, the knowledge and skills of the agronomists is more familiar to the farmers as they have a relationship with it, founded on theory and practice (Salembier et al., 2018). An influencer with a common background (farming) will likely be more effective at influencing as trust is partly based on experience and occupation (Rust et al., 2022; Salembier et al., 2018). Secondly, they considered the advice of the accountant mainly in the context of tax advice for the farm business, relating to legal and legislative requirements. They do not consider the advice of accountants as a form of management advice that can determine the farm's current state, identify the economic outcomes and establish the participation of each enterprise in the total income; elements that can lead to informed, customised decisions towards the management for sustainable development are also mentioned by Kouriati et al., (2021) in their work. The lack of understanding of the financial management processes, as well as effective learning and practice change facilitation by farmers are factors that hinder the adoption of advisory services from accountants. It has also been highlighted from previous work that accountants were more likely to be trusted and considered for business advice if producers consider the accountant capable of providing statutory services (Carey & Tanewski, 2016). This passive attitude towards financial management not being central to farmers' culture compared to other technical farming practices has been also mentioned in other studies (Fountas et al., 2006).

The gap in the understanding of wider sustainability issues within the context of farm decision-making, management efficiency and effectiveness emerging from the responses amongst farmers, is also confirmed by Iakovidis et al., (2022). As Dessart et al., (2019) suggest, the exclusive pursuit of economic goals makes farmers resistant to change, while more outward-looking behaviours are linked to higher adoption rates of sustainable farming practices.

5.3.6 Decision Support Tools (DSTs) current situation and future prospect

This research has highlighted that via the more effective use of planning and control methods the decision-making process of farmers could be improved leading to better business outcomes and a more sustainable way of farming (Lundström et al., 2016). DSTs could provide a means through which more sustainable methods can be adopted and implemented more efficiently and effectively in farm businesses (Rose et al., 2016). On this basis advisers were asked their views on the current usage of DSTs by themselves and the farmers. Advisers were also asked to reflect on farmers' attitudes towards the use of DSTs and what strategies to follow to encourage their use and adoption amongst farmers.

In relation to the use of DSTs there was a differentiation between agronomists and accountants. Of the former, 70% answered that they used some type of DST to inform their decision-making and advice to farmers. DST applications included soil analyses, planning fertilisation patterns, and weather stations to programme applications for plant protection; they also used more complex devices and applications such as drones with smart spraying machinery, sensors for humidity, and applications for map plotting for plant protection and soil humidity recording. The remaining 30% stated that they did not use DSTs. The software programs used by the accountants were focused on calculation of taxes and other accounting services. These can be classified as DST although there only purpose is to inform the farmers' decision-making process on accounting matters.

Advisers suggested that the key challenges to be addressed in order to promote DST use to farmers were the cost of owning and using a DST as well as the education level, age and openness to the use of new technology. Farmers attitude to the use of DSTs has changed over recent years as they have become more closely acquainted with technology and receptive to systems of objectively relevant and sound information. (McCown et al., 2009). Accountants suggested that the farmers' attitude to the use of DST had gradually improved although there are still considerable further opportunities for their use, Reluctance to use DST is greatest among those aged over 60 years old. Some farmers are still lacking interest in DST and do not have the technological know-how to use these systems or interpret the outputs from them. The provision of tools that have greater transparency and ease to use could motivate hitherto unwilling farmers to support this innovation (Rose et al., 2016).

Agronomists saw farmers adopting a positive attitude to some DSTs but there were still some issues that needed to be addressed to achieve greater acceptance. Their experience from the use of DSTs suggests that they are acceptable to farmers if they are evidence-based. Establishment costs of DSTs, the lack of subsidies for such kinds of technology, the absence of state guidance and infrastructure, the lack of training and education and the absence of outward-looking cultural attitudes to innovation are challenges that need to be addressed if the use of DSTs is to be fully embraced by farmers.

Consequently, agronomists and accountants agreed that state intervention for the promotion of DSTs and subsidisation of the establishment cost, along with training for their use would provide the best mechanisms to encourage uptake They also emphasised the importance of encouraging a change in the farmers' attitude towards a more contemporary and sustainability-oriented way of farming.

Agronomists also stressed the absence of research programmes on sustainable or precision agriculture that were accessible to advisers and/or farmers in the region. They also noted the need for farmers to form groups to capitalise on the advantages of their common use of inputs, machinery, technology and also on their combined bargaining power over their sales of produce. In addition, accountants focused on the enhancement of the information flow and the creation of local workshops and seminars that could increase the acceptance of DST particularly among ageing, less educated and traditional farmers. Accountants' DST consist of software programmes that non-professionals find hard to use. This suggests the need for a corresponding transparent and perhaps farmer friendly DSTs to provide the farmer with an informative image of the farm's current or future economic situation.

Agronomists seem to promote DST uptake, but the promotion always comes through a private company that the farmer does not know, does not trust or fears as a potential source of hidden costs. The result is that the promotion effort is finding considerable resistance among farmers.

The usefulness of DST uptake that could incorporate planning and control methods, along with other necessary management attributes for the farm business, would be proven, if, along with the identification of the needs and requirements of users, there was a way to fit DST into farmers' practices and in that way be coordinated with their experienced-based local knowledge (Lundström & Lindblom, 2018). Inevitably, there are challenges that need to be overcome in order to achieve better results. The challenges mentioned earlier have also been described by Rose et al. (2016). They note one feature which is described in their paper as habit which has been referred to herein as culture, tradition and established practice and is a characteristic that needs to be addressed with caution. Farmers' unwillingness to change and reluctance to adopt technical innovations and upgrades is totally justified by the surrounding environment. This research suggests that the absence of continuing vocational educational programmes for farmers and advisers the lack of training workshops and seminars for farmers (Brinia & Tsiliopoulou, 2015; Brinia & Papavasileiou, 2015; Kountios et al., 2018) when combined with limited guidance from the state on the agricultural policy followed at national or regional level, shape an environment that stifles innovation uptake, technological upgrade, and/or sustainable development of farming. Similar findings have been reported by others, (Brinia & Tsiliopoulou, 2015; Brinia & Papavasileiou, 2015; Kountios et al., 2018).

5.4 Conclusions

Mediterranean agriculture is facing a range of challenges due to the interplay of many factors. These include a reliance on traditional agricultural practices, climate change, the spatial distribution and size of holdings, an ageing rural population and environmental and social pressure to address key concerns of sustainability. This research, taking into consideration the findings of the content analysis previously mentioned in Table 5.4, provides an improved understanding of the factors that enable or hinder farmers and advisers with respect to the adoption and implementation of planning and control methods to inform the agricultural decision-making process. The incentives and the difficulties associated with changes required to evolve towards more sustainable farming systems are identified. This evolution to more sustainable systems also presents advisers with challenges that go beyond the more traditional focus on productivity and profitability. Finally, in considering future sustainability improvements the research outlines the attitude of farmers and advisers towards DST on the current situation and considers future prospects in the context of DST uptake.

This investigation of adoption and implementation of planning and control methods outlines the inherent challenges faced by farmers and advisers as part of their management approach and suggests the strategies through which the agricultural sector can overcome these challenges. These include the efficiency and effectiveness of current management practices, the similarities and differences in behaviour between farmers and/or advisers and potential mechanisms that may aid the evolution toward more sustainable systems.

In summary there are two key take-home messages for farmers and advisers in the region of the Mediterranean basin:

First, there is a need to enhance the managerial competencies of farmers which will facilitate an improvement in their farm businesses. Farmers would benefit from the systematic use of planning and control methods as a tool that will lead them to a more sustainable way of farming. The adoption of such methods can provide a pathway for farm advisers and farm owners/managers to reduce business risk and improve management efficiency and effectiveness.

Secondly, advisers must incorporate in their perspective the ultimate goal of sustainable agriculture for the region. Continuous vocational training on sustainable development of agriculture, technological innovation, and change of behaviour from a sales-oriented approach to a more advisory role can offer the farmer, who is the final recipient all the guidance and necessary parameters required to change his/her way of farming accordingly.

5.5 Summary

This chapter concludes that the adoption and implementation of business planning and control methods are essential for sustainable agricultural systems in the Mediterranean Basin. The research identifies the factors that enable or hinder farmers and advisers in adopting these methods and highlights the incentives and difficulties associated with evolving towards more sustainable farming systems. The study also emphasises the need for advisers to diversify their role from a purely market-driven approach to a role that includes guidance and scientific advice for supporting the sector's needs for sustainable development. The findings of this study can be used by policymakers, agricultural advisers, and farmers to develop strategies and policies that promote sustainable agricultural practices in the Mediterranean region.

In the following chapter, the findings for the adoption and implementation of business planning and control methods are developed further as we identify, through the engagement of farmers, advisers, extension officers, industry representatives and Policymakers in an early-stage co-production of services approach, the needs and requirements of farmers and advisers in DST, so that use and adoption of such tools can be improved to enhance the decision-making process of end users and ultimately improve the sustainability of farming systems in the area.

CHAPTER 6. Improving the design of decision support tools for agricultural stakeholders.

6.1 Introduction

Farming systems in the Mediterranean basin are facing considerable challenges that are linked to intrinsic (small holding size, ageing rural population, low level of education) and extrinsic factors (climate change, land degradation, natural resources scarcity) that affect the sustainable future of agriculture in the area (Iakovidis et al., 2023).

Addressing sustainability challenges through DST adoption and use can be more effective when the tools are co-produced with key stakeholders as this approach may help to address the complex nature of contemporary sustainability challenges better than traditional scientific approaches (Norström et al., 2020). The traditional linear model of knowledge production, where researchers generate information and then pass it on to policymakers is being challenged by a co-production approach. This approach emphasises the meaningful interaction between researchers and knowledge-users, such as policymakers, to collaboratively create knowledge that is relevant and actionable in decision-making processes (Mach et al., 2020).

However, before engaging in the co-production approach it is crucial to identify the needs and requirements of the end-users. This involves actively involving the stakeholders in the research process and understanding their perspectives, priorities, and knowledge gaps (Smith et al., 2022). Such a participatory approach allows researchers and developers to gain insights into the practical problems and concerns faced by decision-makers, enabling them to ensure that research is aligned with the needs of the intended users and address real-world challenges more effectively.

Thus, by implicating other stakeholders too, their understanding of DSTs is explored, and their needs are better identified. This aids the recognition of DST requirements so that emerging challenges can be framed in a manner that will facilitate solutions that can act as a base for future co-production of services for DSTs. This research thus explores the needs and requirements of farmers and advisers with the aim of enhancing and promoting DST adoption and use.

The use of effective DSTs within the agricultural sector provides the opportunity to improve the sustainability performance of farms (Lundström et al., 2016) and therefore address wider region challenges effectively. Innovative and technologically advanced DST products can provide farmers and advisers with a mechanism to rationalise their production processes which in turn can lead to better financial, environmental and societal results (Lundström et al., 2016). Even though the available tools vary in terms of approach their overall aim is to improve the effectiveness of farm management (Rossi et al., 2014) by incorporating science into practice in a user-friendly manner to assist food production and ultimately livelihood (Hochman & Carberry, 2011).

A DST supports management practices by enabling informed and evidence-based decision-making that takes into consideration all relevant and available data and information (Dicks et al., 2014). These decisions could be strategic, tactical or operational and can have an immediate impact on the sustainability performance of the farm business (Lundström, 2016).

Yet despite the advantages presented, a number of studies (for instance see Alvarez and Nuthall (2006) and Rose et al., (2016)), spanning almost three decades, have come to the conclusion that the adoption rate of DSTs remains disappointingly low for various reasons. These reasons include: the cost-benefit ratio; tool complexity; failure to address the actual problem; lack of integration with existing systems and poor computer literacy of users. As Stewart et al., (2013), and Michels et al., (2020) concluded, the barriers to uptake are diverse and successful DST adoption and use is dependent on satisfying a range of criteria rather than just addressing one.

The following sections outline the methodology employed before presenting results and concluding comments with key messages.

6.2 Materials and methods

6.2.1 Outline of research

This research engages stakeholders within a framework of participatory methods to identify the end-user needs and requirements for effective DST use and adoption to improve farm sustainability. Stakeholders' subjective viewpoints and beliefs about DSTs are presented and evaluated in a case study based on the Argolida region in the Peloponnese, Greece. To illustrate the engagement of stakeholders working cooperatively towards a sustainable future for agriculture, groups of farmers, advisers, extension officers, industry representatives and Policymakers were recruited to take part in focus groups discussions. A Q-methodology approach was then used as a basis to identify the needs and requirements of farmers and advisers in the use and adoption of DSTs. This method involved a combination of qualitative and quantitative methods to investigate the subjective viewpoints and beliefs of the stakeholders.

6.2.2 Q-methodology

Q-methodology is a research approach that integrates quantitative and qualitative methods in order to explore subjective viewpoints and beliefs about a topic (Valenta & Wigger, 1997). An interesting feature of the Q-methodology is that the research is better applied to small samples (Brown, 2003). The Q methodology objective –the eliciting of a diversity of opinions- can be achieved with small samples as long as the sharing of diverse opinions is encouraged by the researcher (Gabor & Cristache, 2021). Sampling when using the Q-methodology differs from many social science norms in that selecting the participants (P-set) for the study does not follow the criterion of random choice but allows for the selection of participants based on the chance to bring more subjectivity and new viewpoints and beliefs to the research.

In this research, the steps followed are described in Figure 6.1.

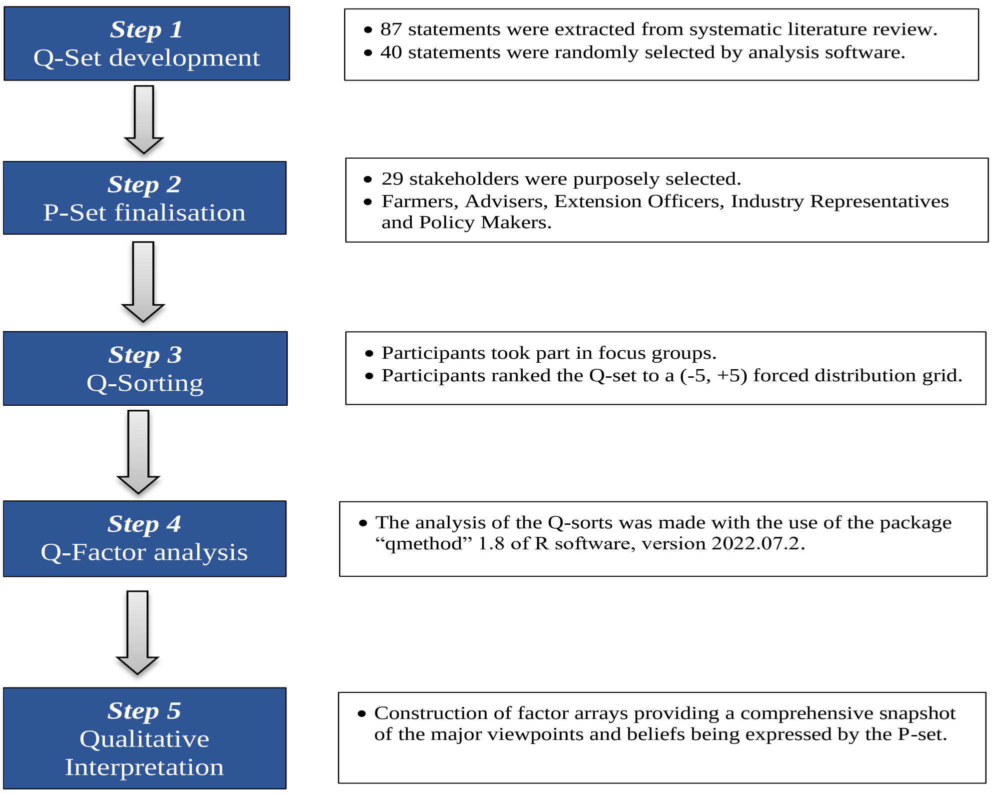

Figure 6.1: Q-Methodology process used in the research.

i) Step 1: Q-set development

Q-set development involves the creation of statements about the topic under study. In similar studies this is referred to as concourse sampling and it involves the selection of key statements from relevant academic literature and/or an infinite set of possible expressions that refer to a topic of concern (Zabala & Pascual, 2016). These key statements should cover the ideas and the concepts that can be sensibly expressed about the topic in the literature or alternatively in any other publicly available resources. As Farrimond et al., (2010) quoted *"The concourse can never be fully known, of course, but the sample of items (usually written statements) should give a workable estimate of it"*. So, the relative completeness of a sound concourse is a limitation for every Q-methodology study and moreover the representativeness of a sample drawn therefrom (Kampen & Tamás, 2014) .

For the purposes of this research a systematic literature review of published peer-reviewed articles was conducted with the use of key words associated with the research topic and the use of Boolean operators (AND, OR and NOT). The search was conducted in two major multidisciplinary databases of bibliographic information, Scopus and Web of Science with no timeframe limitation but with the only criterion being the number of citations for each article.

The search string used was formed as follows:

- ''decision support tools'' OR ''decision support systems'' AND ''decision-making'' OR ''farm sustainability'' OR ''farm management'' OR ''effective design'' AND ''agriculture''

To reach the highest possible explanatory power, the statements included in this step should represent a variety of different opinions (Brown, 1993). In order to report the results of the systematic review a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement was used. The process followed is shown in Figure 6.2:

PRISMA FLOW DIAGRAM

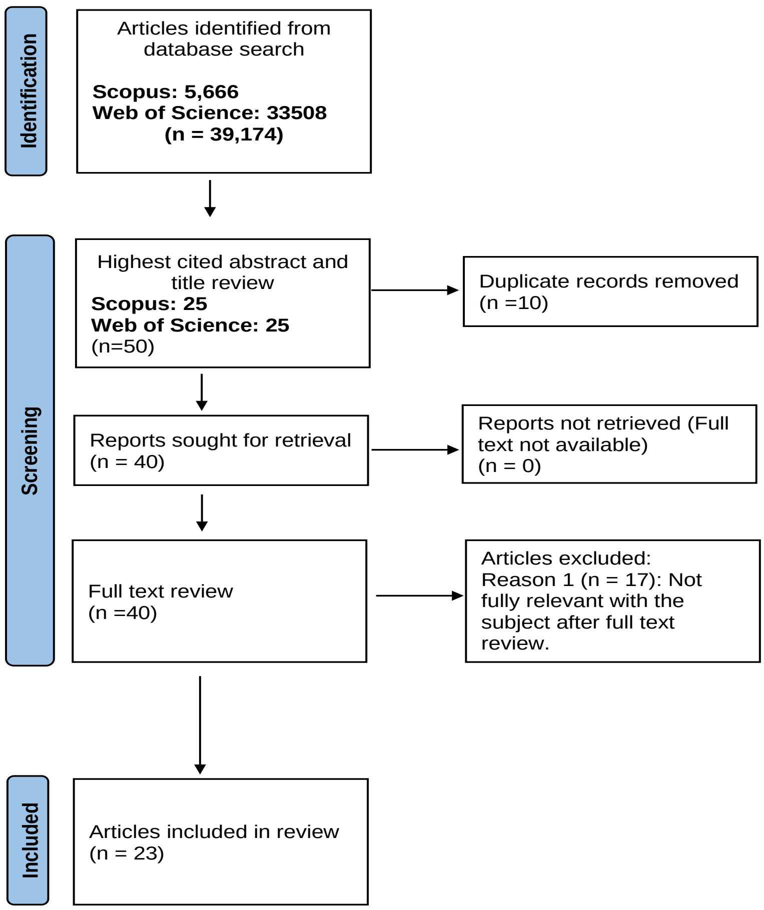

Figure 6.2: Flow chart of ''Decision Support Tools'' systematic review. Adapted from (Page et al., 2021)

From the review step 23 articles were selected. After a thorough review of these 23 articles, 87 statements were extracted from the original texts by the researchers. These statements were imported into the "R" software for analysis using the function "import.q.concourse" of the package "qmethod" 1.8 (Zabala & Held, 2020) and with the function "build.q.set" 40 being used to randomly[5] select the Q-set.

The selected set of statements typically between 40 and 80 (Watts & Stenner, 2012) are normally written on one card each, and in later steps these cards are given to participants to rank them over a grid that represents a prearranged frequency distribution. The number of statements being used in a Q-methodology varies with subject. Ultimately, a sufficient number of statements that cover the viewpoints on the topic is needed whilst noting that an excessive number of unnecessary statements may reduce the motivation of the participants to maintain engagement throughout the entire ranking process.

[5] The function "build.q.set" implements a number of tests on the validity and consistency of inputs (e.g., statements need to be represented as a matrix) and subsets a concourse of items into a sample of selected items. Returns a dataframe with handles as row names, and languages (if applicable) as columns (Zabala & Held, 2020).

ii) Step 2: P-set finalisation

This stage involves the selection of the Q participants. These participants are referred to as the "P-set". A Q-methodology essentially uses purposive sampling. Thus, participants are selected because of their ability to articulate a viewpoint on the topic under study and because of their knowledge, experience, and professional expertise i.e., their perspective matters. Additionally, it is important to have a P-set that can represent the subjective views pertaining to the topic under investigation. Finally, participants should be selected so as to enable the researcher to explore all the viewpoints associated with the topic under study.

The P-set represents the variables rather than the sample (statements), so it does not require a large number of participants, usually not more than 40 (Brown, 2003). More recently Webber et al., (2009) commented that the typical number of participants sufficient for a given P-set is between 12 and 36. For the purposes of this research a group of 29 stakeholders were engaged as the P-set and their professions and coding are presented in Table 6.1.

Table 6.1: P-sample with codification

	Stakeholders	No	Code name
1	Farmers	10	Far1 – Far10
2	Advisers	5	AD1 – AD5
3	Extension Officers	5	EO1 – EO5
4	Industry Representatives	5	IR1 – IR5
5	Policymakers	4	PM1 – PM4

These stakeholders were selected from within the area under study (regional unit of Argolida, Greece) with the exception of the policymakers who were recruited from the National Ministry of Rural Development and Food.

iii) Step 3: Data collection – Q-sorting

The data were collected in October 2022. The 40 statement cards described in step 1 were used in the Q-sorts with the forced distribution (-5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5) described in Figure 6.3 using (+5) for the statement "Most like what I think" and (-5) for the "Least like what I think" (with "I", being a given participant). The Q-sort was conducted in focus groups of five. Farmers (2 groups), advisers (1 group), extension officers (1 group) participated in the focus groups. For Industry representatives and policymakers, it was not possible to convene in-person focus groups due to their other commitments and geographic location and thus they were provided with instructions and guidance, and they were given the Q-sorts (Figure 6.3) and the Q-set in order to complete them in individually. The focus groups took place between 24th October and 28th October 2022 with each focus group lasting an average of 1 hour 45 minutes. The Q-sorts from the industry representatives and the policymakers were completed by 14th November 2022.

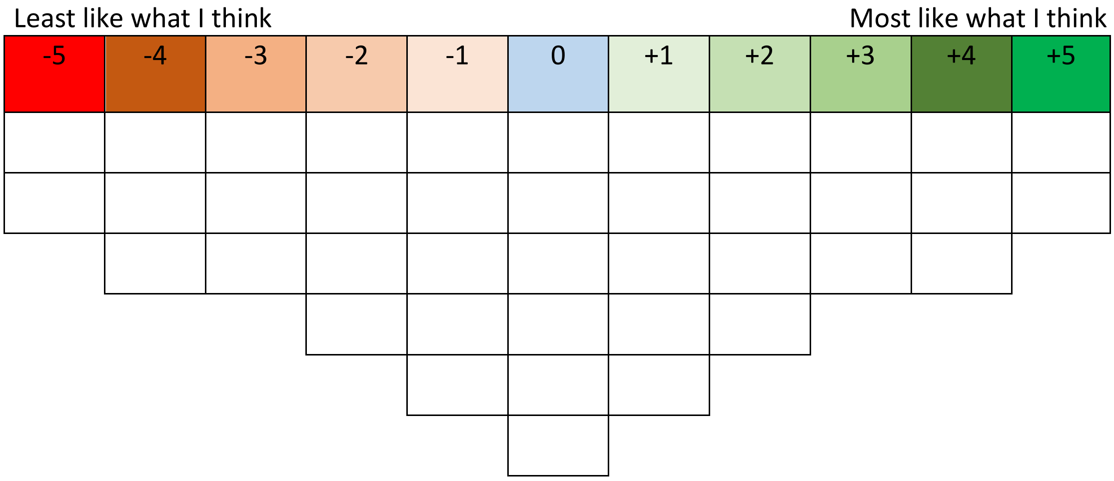

Figure 6.3: Exemplar blank Q-sort presented in the focus groups.

iv) Step 4: Quantitative Analyses – Q-factor Analysis

Step 4 in the Q-methodology is the Q-factor analysis which utilises a principal component analysis (PCA), a separate factor analysis, for the extraction of factors, then a varimax rotation[6] to clarify the relationship among factors and maximize the variance of the first extracted ones, automatic flagging to calculate the statement scores and the application of the Pearson correlation coefficient.

The number of factors that were extracted from the Q-factor analysis were calculated using the Kaiser-Guttman criterion and the Scree test (constructing the screeplot) was employed to decide on the number of principal components to retain. These two methods gave a clear indication of the factors' strength and potential explanatory power.

The analysis of the Q-sorts was conducted using the package "qmethod" 1.8 (Zabala & Held, 2020) of R software, version 2022.07.2 that implemented a number of tests on the validity and consistency of inputs.

v) Step 5: Qualitative Interpretation of factors

[6] A varimax rotation is a statistical technique used in factor analysis and principal component analysis (PCA) to simplify the expression of a particular sub-space in terms of just a few major items each (https://en.wikipedia.org/wiki/Varimax_rotation).

Qualitative interpretation of factors is achieved by constructing factor arrays, meaning representative Q-sorts for each of the extracted factors, calculated from the weighted averaging Q-sorts of the participants that loaded on each factor. The way the statements are configurated on a factor Q-sort is important and ensures that a comprehensive snapshot is provided of the major viewpoints and beliefs being expressed by the P-set. The accuracy and efficacy of the qualitative interpretation can be verified from other data of participants whose opinions essentially *"loaded"* on that factor and/or by simply asking the participants to reflect upon them. The *"loaded"* opinions were the opinions of those participants that heavily influenced that factor and can be used to verify the accuracy and efficacy of the interpretation of the data collected.

6.3 Results

6.3.1 Q-factor analysis

Five factors were extracted for this research. These factors presented in Table 6.2 satisfy the Kaiser-Guttman criterion with eigenvalues (EV) over 1 and the five factors account for 55.2% of the total study variance. According to Watts and Stenner (2012), a percentage above 35-40% would be considered a sound outcome.

Table 6.2: Factor characteristics

	F1	F2	F3	F4	F5
Average reliability coefficient	0.8	0.8	0.8	0.8	0.8
Number of loading Q-sorts	9	6	4	4	2
Eigenvalues	4.4	3.7	2.9	2.8	2.2
Explained variance (%)	15	12.9	10	9.5	7.8
Cumulative explained variance (%)	15	27.9	37.9	47.4	55.2
Composite reliability	0.97	0.96	0.94	0.94	0.89
Standard error of factor scores	0.16	0.2	0.24	0.24	0.33

The composite reliability of each factor is above average (0.8). In Q-methodology, the emphasis is on participants' subjectivity rather than on validity and reliability. However, perfect agreement means similar results, whereas perfect reliability illustrates high correlation (Thomas, 2017).

6.3.2 Sociodemographic structure of the sample

The structure and sociodemographic characteristics of the P-set are presented in Table 6.3.

Table 6.3: The sociodemographic structure of the P-set

Characteristics		P-sample					%
		Farmers (#10)	Advisers (#5)	Extension Officers (#5)	Industry Representatives (#5)	Policy Makers (#4)	
Gender	Male	8(80%)	5 (100%)	3 (67%)	5 (100%)	2(50%)	79%
	Female	2 (20%)	0	2 (33%)	0	2(50%)	21%
Age group	18 - 39 years	0 (0%)	0	0	0	0	0%
	40 - 59 years	7 (70%)	5 (100%)	5 (100%)	5 (100%)	4 (100%)	94%
	60 – 74 years	3 (30%)	0	0	0	0	6%
Education	Primary	1 (10%)	0	0	0	0	3%
	Secondary	4 (40%)	0	0	3 (67%)	0	25%
	Post-secondary	1 (10%)	0	0	0	0	3%
	University	4 (40%)	5 (100%)	5 (100%)	2 (33%)	4 (100%)	69%

Table 6.4 illustrates how the characteristics, and the participants were associated and attributed to each factor:

Table 6.4: Characteristics and participants for each factor

		Factor 1 (#9)	Factor 2 (#6)	Factor 3 (#4)	Factor 4 (#4)	Factor 5 (#2)
Gender	**Male**	4 (45%)	5 (83%)	4 (100%)	4 (100%)	2 (100%)
	Female	5 (55%)	1 (17%)	-	-	-
Age group	**18 - 39 years**	-	-	-	-	-
	40 - 59 years	7 (78%)	6 (100%)	4 (100%)	4 (100%)	2 (100%)
	60 – 74 years	2 (22%)	-	-	-	-
Education	**Primary**	1 (11%)	-	-	-	-
	Secondary	2 (22%)	-	1 (25%)	2 (50%)	2 (100%)
	Post-secondary	-	-	-	-	-
	University	6 (67%)	6 (100%)	3 (75%)	2 (50%)	-
Farmers		4 (45%)	1 (17%)	1 (25%)	1 (25%)	2 (100%)
Advisers		1 (11%)	-	2 (50%)	-	-
Extension Officers		2 (22%)	2 (33%)	-	1 (25%)	-
Industry Representatives		1 (11%)	-	1 (25%)	2 (50%)	-
Policymakers		1 (11%)	3 (50%)	-	-	-

6.3.3 Factor interpretation

In order to facilitate factor interpretation, two distinct sets of data were utilised. Firstly, the socio-demographic data of the P-set and consequently the characteristics and the participants for each factor, as presented in tables 6.3 and 6.4, were employed. Subsequently, the findings of the Q-factor analysis, as outlined in table 6.5, were also utilised. Furthermore, the interpretation process was aided by the implementation of the holistic technique of *"crib sheets"* as suggested by Watts and Stenner (2012). The crib sheets provide a list of statements for each factor classified into four categories. Two of these categories include the statements that were given the highest ranking in the factor array (the two items ranked at +5) and those that were given the lowest ranking (the two items at -5). The other two categories refer to statements that were either ranked higher or lower respectively to a given factor than any of the other extracted factors.

The value of this categorisation is that it allows the identification of the statements that had the most influence and critical contribution within each factor array. A factor array is a single Q-sort configured to represent the viewpoint of a particular factor. The five factors' arrays were created by examining the statements that were most or least associated with each one of the factors, based on the Q-sorts.

Q-factor analysis produced z-scores for statements and all factors. The z-score is a weighted average of the values that the Q-sorts give to a statement most closely related to the factor. In practical terms it indicates a statement's relative position within the factor. In table 6.5, the factor z-scores for the statements are presented. In colour for each factor, there is the statement that "loads heaviest on it" meaning it is highly correlated to that factor.

Table 6.5: Factor z-scores for statements and normalised and rounded scores for Q-sorts

		Factor Z-scores					Factor scores				
	STATEMENTS	**zsc_f1**	**zsc_f2**	**zsc_f3**	**zsc_f4**	**zsc_f5**	**f1**	**f2**	**f3**	**f4**	**f5**
1	Research of DST must focus on the right application areas	1.01	0.57	0.54	-0.43	1.46	3	1	1	-1	4
2	The number of case studies must increase to improve relevance	0.45	0.34	-0.06	-1.1	0.73	2	0	0	-3	2
3	Initial cost and cost of use of DST must be efficient	1.98	0.62	0.77	0.63	0	5	1	2	2	0
4	A broader theoretical psychological foundation may cause DST research to embrace practice than ignore it.	0.4	-0.64	-1.24	-1.51	-1.46	1	-2	-4	-5	-4
5	Farmers should actively involve in the processes of agricultural technology development	2.15	-0.28	1.56	1.53	1.83	5	-1	4	4	5

6	DST do not take into account uncertainty and dynamic factors.	-1.7	-1.04	1.19	-1.09	-1.1	-5	-3	4	-3	-3
7	DST must match the skills and habits of different age groups	0.93	0.45	-0.27	-1.91	-1.83	3	1	0	-5	-5
8	DST use results in effort savings but not improved decision performance	-1.6	-1.4	-1.39	-0.62	-1.1	-5	-4	-4	-2	-3
9	Commercial agronomists should train, be supported and accredited for DST use	1.5	-1.16	0.87	0.89	0	4	-4	2	3	0
10	DST must comply and satisfy legislative and market requirements.	0.81	-0.36	0.14	0.1	1.1	2	-1	1	0	3
11	DST low adoption rate is due to low adaptation to the farm situation	-1.44	0.47	-0.76	0.29	-0.73	-4	1	-2	1	-2
12	The low practical relevance of DST is a symptom of research inertia	-0.76	-0.19	1.06	-1.47	-1.1	-2	0	3	-4	-3
13	Managers' fluid approach to decision-making requires ongoing monitoring of the consequences of past decisions	0.11	-0.06	-0.84	-0.62	-1.46	0	0	-3	-1	-4
14	The low practical relevance of DST is due to farmers' inertia	-1.04	-0.14	-2.13	-0.99	0.37	-3	0	-5	-2	1
15	DST must perform a useful function and work well	0.81	1.54	0.77	0.14	0	2	4	2	0	0
16	DST must be applicable to all scales and types of farming	0.94	0.75	-0.3	0.42	1.1	3	2	-1	1	3
17	DST users have access to information about such tools	0.33	-0.56	-0.49	0.24	0.73	1	-1	-1	1	2
18	DST low adoption rate is due to lack of confidence	-1.07	0.14	-0.4	-0.62	1.1	-3	0	-1	-1	3
19	DST should be sustainable in design as well as through design	0.16	0.68	0.77	0.2	-0.37	0	2	2	0	-1
20	DST low adoption rate is due to lack of incentive to learn and adopt new practices	-0.58	0.76	0.89	0.3	0.73	-1	2	3	1	2
21	DST assist my decision-making regarding my management approach	1.57	1.82	-0.82	0.92	-0.37	4	5	-3	3	-1
22	DST are usually used for the exception and rarely for the routine situations	-1.26	-2.23	0.09	-1.25	-1.46	-4	-5	0	-4	-4
23	DST are not used to their full potential	-0.72	0.53	1.49	-0.1	0	-2	1	4	0	0
24	DST role lies in their potential to support social	0.1	-0.92	0.06	-1.05	1.46	0	-3	0	-3	4

	learning between stakeholders										
25	A DST must be inexpensive to acquire.	1.28	0.95	0.93	-0.16	0.73	4	3	3	-1	2
26	DST provide an honest and responsible test of underlying science	0.17	-0.73	-0.5	-0.79	1.46	0	-2	-2	-2	4
27	DST must have multiple benefits for the stakeholders involved	0.26	1.59	-0.31	0.64	1.83	1	5	-1	2	5
28	Subsidies must act as an incentive for the farmer towards sustainable farming	-0.72	0.68	1.59	0.4	-1.83	-2	2	5	1	-5
29	Farmers need to be trained deeply to learn and apply new technologies	0.25	1.33	0.56	1.75	-0.37	1	4	1	4	-1
30	Production inputs should be used under provisions and restrictions	0.88	-0.86	-1.07	-0.03	0.37	2	-3	-3	0	1
31	All available information regarding my profession can be accessed easily.	-0.6	-1.83	-2.14	0.06	0.37	-1	-5	-5	0	1
32	DST assist my decision-making regarding soil properties	-0.31	-0.4	-0.71	1.77	-0.37	-1	-1	-2	5	-1
33	DST are not adapted to the trade-offs and high complexity that characterises farmers' decision-making	-1.16	-0.67	0.5	-1.35	-0.37	-3	-2	1	-4	-1
34	DST use requires good IT skills	-0.62	-0.78	-0.76	0.82	0.37	-1	-2	-2	2	1
35	Agricultural practitioners are concerned about using certain smart technologies	-0.81	-0.53	-0.13	-0.39	0.37	-2	-1	0	-1	1
36	The success of DST implementation is based on design rather than on iterative learning.	-0.53	-0.26	-0.29	0.61	-0.73	-1	0	-1	2	-2
37	DST assist my decision-making regarding crop practices	0.42	1.57	-1.48	1.15	0	1	4	-4	3	0
38	DST low adoption rate is due to tedious data input requirements	-1.39	-1.68	-0.22	-0.86	0	-4	-4	0	-2	0
39	DST is improving managerial decision-making	0.04	1.07	0.57	1.95	-0.73	0	3	1	5	-2
40	DST must be relevant to the individual farm circumstances	-0.22	0.83	1.97	1.53	-0.73	0	3	5	4	-2

Table 6.5 outlines the five factor arrays for the research and aids the interpretation and definition of the factors in terms of attitudes and/or opinions that people in that factor expressed. For example, in Factor 1, statement 5 loads heavier than any other statement and it was ranked highest by two farmers and one industry representative. The higher the z-score, the more correlated the statement was to the factor. The statements that load heavier on each factor are coloured in green and red (green for positive loading and red for negative loading).

Table 6.5 also presents the normalised and rounded scores from the Q-sorts for each factor and a heat map for the final scores. In order to improve the visualisation of the results, the heat map with the final scores was created with shades of green colour for statements *"Most like what I think"* and shades of red colour for statements *"Least like what I think"*. Taking into consideration all the above the interpretation and definition of the five factors is presented below:

Factor 1: "Cost Efficiency – Education/Training"
For Factor 1 major attention was given by the participants to the cost of attainment and use of DSTs, the active involvement of farmers in the process of agricultural technology development and the need of farmers to be offered training to learn about and apply new technologies. The issue of low adoption due to poor adaptation of the DSTs to the farm situation (for instance due to burdensome data input requirements or lack of confidence in the technology), has been downgraded and not seen as so important.

Factor 2: "Functionality – Performance"
In the context of Factor 2 respondents pinpointed the help DSTs offered to the management approach of end users and the multiple benefits for the stakeholders involved. In contrast, they didn't agree with the perception that DSTs are only used in exceptional circumstances noting their usefulness in more routine management.

Factor 3: "Relevance – Usefulness"
For this factor participants acknowledged the necessity for DSTs to be applicable and advantageous to specific farm situations. Furthermore, they believed subsidies (or grants) must serve as an inducement for farmers to adopt more sustainable farming techniques. They refuted the notion that all relevant information pertaining to their profession was easily accessible and that farmers' reluctance to utilise DSTs stems from their inertia towards change

Factor 4: "Applicability – Innovation Uptake"

The participants involved in this factor expressed a high level of agreement about the potential of DSTs to enhance managerial decision-making. Specifically, they noted that DSTs can be particularly useful in facilitating decision-making related to soil properties and should be applicable to farming operations of all scales. Conversely, participants held divergent views regarding the necessity of DSTs to be tailored to the skills and habits of different age groups. Furthermore, they argued that a more comprehensive theoretical foundation in psychology may serve to enhance the practical application of DST research rather than impede it.

Factor 5: "Active Involvement – IT Skills"

The participants affiliated with the fifth factor expressed their favourable outlook towards the active participation of farmers in the development of agricultural technology. Moreover, they believed that the adoption of DSTs should have manifold advantages for all stakeholders involved. However, they emphasised that farmers need to undertake extensive training to gain proficiency in the application of new technologies. Conversely, this group of participants did not support the notion that DSTs should accommodate the skills and practices of different generations. Additionally, they did not view subsidies as an effective incentive for farmers to pursue sustainable farming practices.

In summary, the analysis of the factors revealed the perspectives on needs and requirements of the five stakeholder groups related to improved DST adoption and use. These needs and requirements are summarised in Table 6.6.

Table 6.6: Needs and requirement of end users

1.	**Cost:** The tool must be inexpensive to acquire and use.
2.	**Education/Training:** End-users need the appropriate training to apply new technologies.
3.	**Functionality:** The tool must be related to farmer's actual practices regarding management, soil properties and crop practices.
4.	**Performance/Benefits:** The tool must perform well and have multiple benefits for the stakeholders utilising the tool
5.	**Relevance:** The tool must be relevant to the individual farm circumstances.
6.	**Usefulness:** The tool must consider the dynamic nature of the farm business.
7.	**Applicability:** The tool should be usable at a range of scales of farming.
8.	**Innovation Uptake:** End-users must be open-minded about the use of new technologies.
9.	**Active Involvement:** There is considerable benefit from involving farmers in agricultural technology development.
10.	**IT Skills:** End-users must continue to develop their IT Skills.

6.4 Discussion

In this research, Q-methodology was used to analyse a set of statements from the literature related to DST adoption and use. Instead of directly involving the end-users (farmers and advisers) in defining and ranking their needs and requirements, a different approach was employed. Five different categories of stakeholders, which included farmers, advisers, extension officers, policymakers, and industry representatives, were engaged. These stakeholders were chosen based on their knowledge and expertise in the field of DSTs.

Forty statements were selected from peer-reviewed articles with the highest number of citations on the topic of DSTs from the literature. These statements represented various aspects of DST adoption and use, covering a range of perspectives and issues relevant to end-users. By utilising Q-methodology and involving multiple stakeholders, the objective was to attain a deeper understanding of the needs and requirements of end-users regarding DST adoption and use. The analysis of the statements allowed the identification of common themes, patterns, and differing viewpoints among the stakeholders, providing a broader and more holistic understanding of the topic.

Overall, the research has explored the perspectives of various stakeholders and gained an understanding of the needs and requirements of end-users related to DSTs. This was achieved without directly involving these stakeholders in the ranking and definition process but rather by integrating their scientific knowledge and subjective perspective into the analysis. This approach can inform the development and implementation of DSTs that align with the practical needs and preferences of the end users while being grounded in scientific knowledge and evidence.

6.4.1 Methodology applications

The results show that Q methodology is a robust tool and a congruent method for eliciting end users' subjective thoughts about DST use and adoption. This is similar to the findings of (Carr & Liu, 2016) and (Cuppen et al., 2016)

As noted by Pereira et al., (2016). the use of Q-methodology enabled a shift in focus from the technology itself to the potential users needs and their attitudes and beliefs towards it. This approach enabled stakeholders to express their viewpoints on the usefulness of DST in their working practices. The documented behaviours, viewpoints together with the beliefs of farmers, advisers, extension officers, industry representatives, and policymakers can be used at an early stage in a co-production of services approach for the design of an effective DST in agriculture.

Q-methodology can facilitate the investigation of diverse viewpoints across a range of agricultural topics, adding to existing research methods. It can also be used as a potential learning tool to help stakeholders further understand the sector from a broader professional, cultural, and social context. Finally, Q-methodology can be used to create policies for the dissemination of innovative tools such as DSTs providing an improved understanding of the transfer of innovation to the agricultural sector thus enhancing the effectiveness of innovation policy This is similar to the findings of Ara et al., (2021) and Vecchio et al., (2022).

6.4.2 Needs and requirements

The major points emerging from Factor 1 were associated with the cost of purchase and use of such tools and the education and training of end users on technology advancements so that they can become part of their daily practices in relation to more sustainable farming. Rose et al. (2016), also refer to the issue of cost , giving two alternatives for the likelihood of use, one when there is a funding scheme to support purchase and use or the likelihood of the tool being inexpensive. Venkatesh et al. (2012) also add price value as a predictor of behavioural intention to use technology while Clark et al., (2013) give a different dimension regarding cost and its influence of user involvement in the development of the DSTs.

As far as education and training were concerned, while this research focuses on a specific area in the Mediterranean basin, it is argued that the results can be extrapolated to other areas. As Lundstrom (2016) suggests intuitive experience-based knowledge is equally important to technology that enables more sustainable farming. That makes the need for education and training related to contemporary technology advancements necessary in order for farmers to remain up to date. The development of a skillset that will allow the proper use of such technologically advanced tools (Bournaris & Papathanasiou, 2012) is considered necessary for the improvement of the adoption rate of DSTs, (Bournaris & Papathanasiou, 2012). Zhai et al., (2020) also suggested that these skills should not be ignored by DST developers.

Factor 2 participants expressed a more technocratic view in relation to the adoption and use of DSTs focusing on functionality and performance. As noted in table 6.3, all of the Factor 2 participants held a university degree related to agriculture and all but one of them worked in the respective ministry for the central government or the regional administration. Knowledge in the field and professional interactions influence choices such as personal beliefs, political affiliations, and/or external pressures are equally important and crucial and can influence choices. The themes that emerged were the importance of DST use and adoption for the management approach of farm businesses and the need for multiple benefits for all categories of stakeholders involved. Participants also recognised the difficulty of accessing information about practices farmers undertake on a daily basis. They also noted a requirement and an opportunity for DSTs to be used in more routine situations rather than just in occasional exceptional circumstances.

The benefits emerging from the use and adoption of DSTs are multidimensional. The achievement of better decisions and/or of a better decision-making process was not always the goal. In many cases the benefits for stakeholders could be identified as greater reliability, better communication, better coordination or even the achievement of competitive advantage. As Pick, (2008) describes, *"In some cases, neither the outcome nor the process is affected, but the system serves to document the quality of the process in a way that may convince stakeholders of the correctness of a decision"*. Sophisticated decision support systems can be very useful in agriculture, but their utility must be considered from a number of perspectives. First, the limits of current access to information for the profession must be considered. Second, the diversity of aspects of sustainability, including economic, social, and environmental perspectives, must be incorporated into the planning and design process. Finally, it is important to consider who the end-user will be (Ellis & Schoeneberger, 2004; Yousaf et al., 2023; Zhai et al., 2020).

In relation to the management process of each user, the only hypothesis that can be made regarding the farmers' decision-making processes and management approach, is that each farming system differs to some degree in terms of management approach. In many instances the effective adoption of DSTs may require a considerable change to a given farming system but would probably benefit farmers to switch towards more sustainable farming businesses (Gouttenoire et al., 2011).

In relation to Factor 3 the main points that emerged were the relevance to the user and the usefulness of the DSTs. Advisers were the most prevalent amongst the participants associated with this factor. Arnott and Pervan (2005) identified that low practical relevance of DST research is not only due to farmers' passivity and attitude but is also a symptom of research inertia. This was also the main concern of advisers who suggested there was no research connected to the production process and the effective dispersal of information to end-users either by research institutes or through demonstration in experimental farms. It was noted that research institutes used to operate throughout the countryside and were integrated with farmers' communities but now appear largely inactive or no longer there and demonstration farms are rare to find.

Access to agronomic advice and information to the farmer is important in decision-making for a sustainable farm business. Farmers need different types of information from various sources to refine existing practices and adopt new more sustainable technologies. This includes data on weather patterns, pest control, crop selection, soil health, water management, market trends, and more. The respondents in this factor stressed the absence of information from the state and its agencies noting that many of the research and extension facilities were non-operational and obsolete. Nikam et al., (2022) noted that depending on the time and situation, farmers require various types of information throughout the production process. Having access to accurate and up-to-date agronomic advice and information about the farming profession is crucial for making well-informed decisions that contribute to a sustainable farm business. (Parmar et al., 2019). To promote sustainable farming, authorities must re-establish research facilities and disseminate agronomic advice to farmers. Providing information to farmers can increase productivity and promote sustainable practices that benefit the environment and livelihoods.

Factor 4 was constituted mainly of industry representatives, see table 6.3. They were focused on farmer compliance during the production process to regulations and legislation. The participants in the fourth factor noted that DSTs can improve managerial decision-making and assist their decision-making regarding soil properties. Diverging opinions were expressed regarding DSTs matching the skills and habits of different age groups, and that a more comprehensive and inclusive theoretical psychological foundation may cause DSTs research being more aligned to practical applications. By broadening the theoretical foundation of psychology, the developers of DSTs may be able to better understand the practical implications of their work and develop more effective and useful applications of DSTs. The uptake of innovation also emerged, as members of this group agreed that it can offer solutions to productivity, input efficiency and the adoption of smarter farming approaches to increase the sustainability of farming systems. This agrees with the findings of Eastwood & Renwick, (2020), Eneji et al., (2012), and Masi et al., (2022).

The management options that DSTs provide to their users allow them considerable flexibility for implementing and improving management strategies e.g. for crop rotations and pesticide management (Jones et al., 2003; Pahmeyer et al., 2021; Young et al., 2021). The same can be argued for assessing soil properties and allowing the appropriate cultivations and fertilisation to be programmed and implemented.

The support and improvement of managerial decision-making is documented by Arnott and Pervan (2005, 2014) in terms of contemporary professional practice. Others have noted that DST facilitates the implementation of improved farm management practices Carberry et al., (2002), Kragt & Llewellyn, (2014), and McCown et al., (2009). In terms of relevance, participants think that there is no issue between research and practice and that the reference theories used did not constrain DST projects and what have been thought to be feasible and important similarly suggested by Arnott & Pervan, (2005).

In relation to age and the ingrained skills and decision-making habits, (Rose et al., 2016) the participants did not feel this was a major issue related to future adoption and use of DSTs. This is contrary to the findings of Rose et al. (2016) who noted that age was probably a significant determinant of DST adoption. Lindblom et al., (2017), recognises that ingrained skills and habits, which may be more so in older famers, were related to a lower adoption rate of DSTs. Similarly age was also found to have a negative effect on smart-phone DST adoption (Michels et al., 2020).

Participants related to the fifth factor (farmers, see table 6.3) had positive opinions concerning farmers actively being involved in the processes of agricultural technology development and that DST's had the potential to have multiple benefits for the stakeholders involved. However, some also noted that a DST must match the skills and habits of different age groups and that subsidies could act as an incentive to encourage more sustainable farming.

Kernecker et al., (2020) note that DSTs adoption and use was based on the active involvement of farmers in the processes of agricultural technology development. This helped convince farmers that the appropriate technologies are available and accessible, helps overcome peer-to-peer communication as the main source of information and can change their perception about innovation processes such as the use of DSTs.

In order to achieve this, there is need for training on new technologies (Saiz-Rubio & Rovira-Mas, 2020) and realisation that the science incorporated in these tools and other benefits can be more easily accessible from farmers and their advisers through their use (Jakku & Thorburn, 2010). Multiple benefits such as precision farming and resource management, crop health monitoring and management, market insights and demand forecasting, and financial planning and budgeting, were considered necessary for the stakeholders in a study by Demetriou et al., (2012). Most of the crops farmer in the study region are market goods in the sense that they do not depend on subsidies. This could be one of the reasons why the two farmers do not concur with Sorensen et al. (2010), who advocate that subsidies can act as motivators for sustainable farming practices. Additionally, the lack of awareness concerning farm sustainability in the area, as reported in our preceding research (Iakovidis et al., 2022), may serve as another explanation.

The needs and requirements identified in this research provide guidelines for the design of effective DSTs, see table 6.6. The findings presented align with other research studies and that confirms the importance of stakeholders' viewpoints and beliefs on the subject. Cost appears to be a crucial determinant and funding for initial purchase and use was considered imperative from the participants. Relevance to the user was found to be important as well as the need of the DST to be adaptable to the individual farm circumstances.

Incorporating the DSTs into the daily decision-making process of the users was viewed positively. It was characterised as pivotal and perceived to enhance their decision performance on technical and managerial aspects while not disturbing their particular daily routine.

The need for enhanced farm performance and additional benefits for the stakeholders were also stressed. The tool must work well, perform as promised and offer multiple benefits to all implicated stakeholders. To tackle technology development and innovation uptake, there is a need for positive and regular engagement in education and training. Active involvement in the DST development processes is seen as beneficial, for instance via co-production where all stakeholders are involved, collaborate in order to determine problems and identify and produce solutions. Regular and appropriate access to agronomic advice and information was also stressed, with a belief that currently there is not easy access to sources of knowledge and information.

Finally, the issue of financial support and its role in the transition to sustainable farming was a key issue. Farmers did not consider subsidies as an incentive towards sustainable farming while extension officers, industry representatives and policymakers assessed it positively as a motive for enhancing farm sustainability.

6.5 Conclusions

The paper suggests that the early-stage engagement of stakeholders utilising a participatory approach is a desirable requirement for an effective design of a DST. The Q-methodology approach was utilised to provide an in-depth understanding of the perspectives and needs of the differing stakeholder groups. The research confirms that the Q-methodology can serve as the first step of an end-user need analysis in a co-production of services approach for the design of an effective DST in agriculture. The paper emphasises the importance of understanding the factors affecting the uptake and use of decision support tools by farmers and the need for site-specific agronomic management strategies for agricultural growth.

The key messages from the research are:

- **Farmer-Centric Approach:** Ensure that DST design and implementation prioritise the needs and aspirations of farmers and advisers. Engage with stakeholders from diverse backgrounds to understand their unique challenges and requirements.
- **User-Friendly Tools**: Develop DSTs that are intuitive, user-friendly, and accessible to farmers and advisers with varying levels of technological expertise. The tools should provide practical solutions that align with farmers' daily operations.
- **Sharing and Demonstrating Practices:** Establish demonstration farms where farmers can observe and experience the benefits of incorporating DSTs. This practical, hands-on approach can enhance farmers' understanding and motivation to adopt sustainable practices.
- **Knowledge Exchange:** Facilitate knowledge exchange and learning among farmers, advisers and researchers. This exchange can help disseminate best practices and foster a collaborative learning environment.
- **Local Context Considerations:** Tailor the DSTs to suit the local context, considering factors such as agro-climatic conditions, available resources, and socio-economic realities. Generic solutions may not be as effective as context-specific ones.
- **Financial Support:** Acknowledge the financial constraints faced by farmers and explore ways to provide financial support for DSTs. Incentives, subsidies, or low-cost financing options can encourage wider adoption.
- **Capacity Building:** Offer training and capacity-building programs to familiarise farmers with the DSTs and build their skills in using them effectively.
- **Policy Advocacy:** Advocate for supportive policies and regulations that promote the integration of DSTs and sustainable farming practices. Engage with policymakers to highlight the benefits and encourage their adoption.

Overall, the paper provides practical implications for the design and development of DSTs in agriculture that can enhance the decision-making of farmers and advisers, safeguard the natural resource base, enhance resilience and food security, and promote sustainable production systems. By incorporating these strategies, the effective design of DSTs can bridge the gap between them and farmers' needs, leading to greater adoption and the realisation of the potential benefits of sustainable farming practices.

6.6 Summary

This chapter delves into the challenges encountered by agriculture in the Mediterranean region and suggests that DSTs can facilitate evidence-based decision-making for farmers and advisers, thereby overcoming these challenges and promoting sustainable production systems. It underscores the significance of involving stakeholders in the preliminary stages of DST design to ascertain the user needs and requirements of farmers and advisers. Employing a Q-methodology approach, the research comprehended the outlooks and necessities of diverse stakeholder groups. The findings highlighted the necessity for user-friendly interfaces, data precision and dependability, flexibility and adaptability, and training and support. The research provides practical implications for the development and design of DSTs in agriculture and can be utilised as a reference for a future co-production of services approach and research in this area.

In the next chapter the conclusions of the research are discussed in relation to the research questions and the noteworthy recommendations for different groups of stakeholders are highlighted.

CHAPTER 7. Final discussion and conclusion

7.1 Introduction

This chapter examines the thesis' findings in light of its research questions. This thesis advances and expands on a subject of significance importance for the future development and sustainability of temperate climate agricultural production systems: The work expands on the discussion regarding the available methods employed for sustainability assessment at a farm-level in a typical Mediterranean setting. Assessing the sustainability status for typical and representative farming systems in the region of Argolida, Greece provides the opportunity to explore the farm management implications to enhance decision-making. Moreover, it highlights the importance of identification of the needs and requirements of end users regarding the adoption and use of DSTs towards achieving farm sustainability. The main aim was to fill an important knowledge and managerial gap as this has been identified by existing literature (Stylianou et al., 2020a) in farm sustainability awareness in small holding farming systems in the Mediterranean basin through exploring how evidence-based and data-informed decision-making, utilising DSTs, can enhance the management approach of farmers/advisers towards improving the sustainability performance of their farming systems. The research focuses on:

- farm sustainability assessment with the use of an indicator-based tool,
- identifying the perceptions of farmers on decision-making, farm sustainability and DSTs,
- the implementation of business planning and control methods as management tools
- the identification of the needs and requirements of farmers and advisers regarding the use of DSTs.

The motivation behind the research is that farm sustainability is the target for all agricultural and food producing farming systems and the management approach taken is crucial in order to achieve this outcome (European Commission, 2021c; Velten et al., 2015).

The chapter is organised as follows: Section 7.2 summarises the main findings of the thesis while in section 7.3 the research questions as mentioned in section 1.3 are answered. Section 7.4 highlights the main noteworthy recommendations for stakeholders and section 7.5 concludes the thesis.

7.2 Summary of research activities

The structure of the thesis includes four main research components. The first one which includes chapters one, two and three refers to the problem statement and the research questions, reviews the general literature and provides a study context. In Chapter 1, the inherent challenges of agriculture in the Mediterranean basin and more specifically in the region of Argolida, Greece are outlined and the challenges that derive from them are highlighted. In the second chapter the underlying theory and the relevant published literature that support this research are described. In chapter two, the theoretical framework is introduced, while in chapter 3 the study context is explained.

In the second part of the thesis, Chapter 4, the need for more sustainable farming practices in response to challenges such as climate change, resource scarcity and societal issues are highlighted. The development of farm sustainability is strongly associated with the management style of farm owners and managers. Hence, developing tools for the sustainability assessment of agriculture is eminent. Moreover, enabling positive change and effectively allocating resources is identified as a strategy to enhance environmental sustainability and business viability in agribusinesses.

Another crucial factor supporting the future sustainability of farming systems is the consideration at a farm level of the importance of short- and long-term decision-making. The lack of evidenced based decision making and understanding of the requirements for sustainable food production systems by farmers in the region of Argolida were identified using the RISE 3.0 sustainability assessment in Chapter 4. The results have been enhanced with a series of semi-structured interviews followed by thematic analysis. The outcomes in respect to farm business management were used to inform the structure of the questions for the survey in chapter five.

The third part of the thesis, chapter 5, highlights the importance of developing effective management strategies for Mediterranean agricultural systems to mitigate the impacts of climate change, land degradation, and the changing political, economic, and technological factors. The study focuses on a group of farmers and agronomists and advisers. This part of the research concludes that the adoption and implementation of business planning and control methods are essential to ensuring the adoption of sustainable agricultural systems in the Mediterranean Basin. The study identifies the factors that enable or hinder farmers and advisers in adopting these methods and highlights the incentives and difficulties associated with evolving towards more sustainable farming systems. The research emphasises the need for advisers to diversify their role from a purely market-driven approach to a role that includes guidance and scientific advice for supporting the sector's needs for sustainable development (Iakovidis et al., 2023). This will support farmers' decision-making based on the latest scientific knowledge and use of available data to enhance the sustainability of these important agricultural systems.

In the fourth and final part of the research, chapter 6, highlights the challenges faced by farming systems in the Mediterranean basin due to intrinsic and extrinsic factors that affect the sustainable future of agriculture in the area. It discusses the use of DSTs within the agricultural sector to improve the sustainability performance of farms. DSTs can provide farmers and advisers the means through which they can rationalize their production processes and better adapt to the needs and requirements of their crops which in turn can lead to better financial, environmental and societal results (Rose et al., 2016). DSTs influence management practices by leading users to clearer decision stages. These decisions, either strategic, tactical or operational have an impact on the sustainability performance of the farm business. Q-methodology is used to explore the perspectives and needs of different agricultural stakeholders. Thus, making the design and use of DSTs more effective while also supporting the use and adoption for improving farm sustainability. The findings can be interpreted in two ways. First related to the usefulness of the method and secondly in terms of the needs and requirements of farmers and advisers that emerge from its application. The results illustrated that the use of Q-methodology can offer valuable insights and can be used to study distinct perspectives existing within a group on a topic of interest. The importance of early-stage engagement of stakeholders and end-users in a co-production approach to define needs and requirements for an effective DSTs design are highlighted. This part of the research concluded that the use of DST can enhance the decision-making of farmers and advisers, enabling evidence-based decisions which will improve the sustainability of farming systems in the Mediterranean basin.

7.3 Consideration of research questions

1. ***What is the sustainability performance of farm businesses in Argolida, Peloponnese, Greece? (Chapter 4)***

The majority of the farms analysed in the study were found to be in the problematic zone of sustainability performance, particularly in areas such as materials use, environmental protection, water use, energy climate, economic viability, and farm management. The lack of an explicit long-term strategy and the exclusive focus on economic and agronomic performance indicators were identified as key factors contributing to the farms' low sustainability performance.

In terms of risk management, farmers identified climate conditions and weather as the greater threat, expressing their lack of power to manoeuvre farm management and minimize negative impacts. Farmers considered aspects such as occupational health and safety, physical working conditions, work organisation, respect of basic rights, remuneration, and justice to be adequately addressed, but wage and income levels were a challenge, with most rated in the critical and problematic area.

The main reason for this, was that farmers and/or family members were not paid a wage and did not receive appropriate hourly compensation. The indicators of social relations and personal quality of life were also considered in the analysis, with the farmers responding positively on both. The liquidity indicator was a challenge for all 20 farms in the sample, but there is always a limitation in the extent of information farmers were prepared to give. The importance of business goals, strategy, and implementation challenges in farm management for long-term production continuation and decision-making were highlighted.

2. *Do farmers perceive that decision-making affects the sustainability performance of small-scale farming systems in Argolida, Peloponnese? (Chapter 4)*

The thematic analysis demonstrated that the decision-making process was poorly informed and not always evidence-based and that the concept of sustainability was not well understood by most of the farmers. The majority of the farmers have either not heard the term and/or they could not give a persuasive definition about it. However, 35% of farmers follow decision-making processes that are driven by mainly financial and social sustainability performance concerns as shown in their desire to pass the farm business on to their children to farm in the future. Moreover, after the explanation of the term "sustainability" 45% of them noted the correlation between decision-making and farm sustainability as far as agricultural practices are concerned. Environmental issues, negative implications from the use of agrochemicals, mitigation in the use of Plant Protection Products (PPP) with high toxicity, fighting water scarcity with the use of appropriate irrigation systems, the choice of organic type of farming in full or adopting some of the practices used in organic agriculture, were some of the challenges the farmers raised. The reduction of production costs was also mentioned by 40% of them as a result of rationalising their approach. The correlation of the RISE assessment with the perceptions of farmers on decision-making and sustainability performance identified the challenges of moving towards more sustainable systems in typical Mediterranean environments.

These challenges include:

- Poorly informed and not always evidence-based decision-making processes among farmers.
- Lack of understanding of the concept of sustainability among most farmers.
- The impact of CTV on the sustainability of incomes of farmers in the region, as citrus trees are the predominant crop in the area.
- The need for farmers to be better informed about sustainability and to use decision support tools to improve their decision-making processes.
- The need for policies and programs that promote sustainable agriculture in the Mediterranean region.

Overall, just a few farmers had a clear grasp of the dimensions of sustainability and only one farmer had ever undertaken a sustainability audit. It was evident that in order to enhance the sustainability of the production process, the educational, technological and consultancy framework needs to be reformed to address the challenges indicated previously and also in chapter 4, subchapter 4.4.2. Farming systems were considered sustainable as long as they were profitable. Distinctions between economic and other aspects of sustainability were not made by the famers, this being an element that could be tackled through training and workshops that address the concept of agricultural sustainability and decision-making. Further research is needed to explore the methods and tools through which decision-making can be informed and aiding the evolution to more sustainable farming systems in the Mediterranean region. Revitalising, and reorganising training for both farmers and advisers needs to be taken into consideration and be incorporated into future regional, national and CAP policies.

3. *<u>What are the factors that motivate or hinder farmers' adoption and implementation of planning and control methods that may enhance farm sustainability? (Chapter 5)</u>*

The research identifies several factors that motivate or hinder farmers' adoption and implementation of planning and control methods towards farm sustainability. These factors include motivating factors such as the need for enhancing managerial competencies for effective decision making and strategic design, and/or the use of planning and control methods as a tool to enhance efforts towards a more sustainable approach to farming. They also include hindering factors such as the lack of knowledge and skills in using planning and control methods, insufficient access to information and data, limited availability of financial resources, difficulty in predicting market trends and prices, uncertainty in weather conditions and climate change impacts, inadequate support from agricultural advisers, limited availability of suitable technologies and equipment and the difficulty in balancing economic, social, and environmental objectives.

From the farmer’s perspective the benefits of planning and control methods were noted to be the prediction, development, motivation, and anticipation of unprecedented situations. However, there are structural issues in the agricultural sector in Argolida and the wider Mediterranean basin that provide specific challenges to the adoption and implementation of planning and control methods by farmers. These challenges, as noted in this research are the ageing rural population, farmers’ lack of vocational training the rural culture and traditions that continue to influence agricultural practices, the small size of the holdings and their distributed nature and the poorly- informed management approach of farmers.

Overall, these factors and challenges highlight the need for farmers to enhance their managerial competencies and for advisers to diversify their role to provide guidance and scientific advice for supporting the sector's need for more sustainable development. The research suggests that addressing these factors can help promote the adoption and implementation of planning and control methods to inform the decision-making process towards farm sustainability in the Mediterranean region.

4. *<u>Does farm sustainability advice present different challenges to farm advisers beyond the established consideration of productivity and profitability? (Chapter 5)</u>*

Based on the research, farm sustainability does present different challenges to farm advisers beyond “the usual” consideration of productivity and profitability. Their responses indicate that there is a gap in the understanding of wider sustainability issues. Reduced production costs and increased prices and profits were the main benefits perceived from improving the economic performance of the business. The environmental and social pillars were just mentioned by a few advisers (12%), but without any further comments on how these could be affected using a systematic approach to planning and control methods.

The challenges that farm advisers face in promoting farm sustainability, as identified in the research, include:

- The need to provide guidance and scientific advice for supporting the sector's needs for sustainable development.
- The need to help farmers enhance their managerial competencies, particularly the systematic use of planning and control methods, for effective decision making and strategic design.

- The need to address the lack of access to scientific knowledge and data, as well as the lack of financial resources to invest in planning and control methods.
- The need to address the lack of incentives and support from policymakers and agricultural advisers.

The research suggested that advisers need to diversify their role from a purely market-driven approach to a role that includes guidance and scientific advice for supporting the sector's needs for sustainable development. This means that advisers need to consider not only productivity and profitability but also the environmental and social impacts of farming practices. By doing so, advisers can help farmers make decisions that promote sustainable farming practices and enhance the sustainability of agricultural systems.

5. *<u>What is the current situation and the future prospect for the use of Decision Support Tools (DSTs) to enhance farm sustainability? (Chapter 5)</u>*

According to the interviews with the advisers, farmers are adopting a positive attitude to a number of DSTs mainly technologies that have to do with agricultural practices such as drones and weather stations, but there were still some issues that needed to be addressed to achieve greater acceptance. The main challenges that need to be addressed are the cost of owning and using a DST, the education level of farmers, their age, and their openness to using new technology. DSTs are computer-based tools that help farmers make decisions related to crop management, resource allocation and other aspects of farming (Rose et al., 2016). According to them, these tools use data from various sources, such as weather forecasts, soil sensors, and satellite imagery, to provide farmers with information that can help them make more informed decisions.

According to the interviewees, the cost of purchasing and/or using a DST is a major challenge for them as these tools can be expensive to purchase and maintain. In addition, farmers may not have the necessary technical skills to use these tools effectively, which can further increase the cost of ownership or reduce its usefulness. The education level of farmers is another important factor that affects their ability to use DSTs. Farmers who have a higher level of education may be more likely to use these tools, as they may have a better understanding of how they work and how to interpret the data they provide.

Age is also a factor that affects farmers' willingness to use DSTs. Older farmers may be less familiar with new technology and may be more resistant to change. This can make it difficult to promote the use of

DSTs among this particular group, noting that many farmers in the region fall into this category. Finally, farmers' openness to using new technology is an important factor that affects their willingness to use DSTs. Some farmers may be more open to using new technology, while others may be more resistant to change. This can make it more difficult to promote the use of DSTs among certain groups of farmers.

Considering the future, advisers agreed that state intervention for the promotion of DSTs and subsidisation of the establishment cost, along with user training would provide the best mechanisms to encourage uptake. They also emphasised the importance of encouraging a change in the farmers' attitude towards a more contemporary and sustainability-oriented way of farming. Overall, the challenges highlighted suggest that promoting the use of DSTs among farmers will require addressing a range of factors, including cost, education, age and attitudes towards new technology. By addressing these challenges, it may be possible to increase the adoption of DSTs and improve the sustainability of agricultural systems.

6. *<u>What are the needs and requirements of farmers and advisers regarding the use and adoption of DSTs? (Chapter 6)</u>*

The needs and requirements of farmers and advisers regarding the use and adoption of DST have been identified in this research. The research highlights the importance of engaging stakeholders and end-users in a co-production of services approach to define needs and requirements. These needs and requirements can be summarised as:

- The initial cost of acquiring and implementing a DST should be reasonable and affordable.
- The DST should be practical and meet the needs of end-users (i.e., farmers and advisers).
- The DST should be user-friendly and easy to understand for farmers and advisers.
- It should provide accurate and reliable information to farmers and advisers.
- It should be compatible with existing systems and technologies.
- The DST should be customisable to meet the specific needs of individual farmers and advisers.
- Stakeholders (i.e., policy makers, industry representatives and extension officers) and developers should be receptive to the opinions and beliefs of farmers and advisers regarding the use and adoption of DST.

Overall, the research emphasises the importance of understanding the needs and requirements of end-users during DST development (i.e., farmers and advisers) in order to promote the effective use and adoption of DSTs.

7.4 Recommendations

The purpose of this section is to provide actionable suggestions and guidelines based on the research outcomes. These recommendations are aimed at addressing the research objectives and contributing to the existing knowledge in the field and are the result of a comprehensive analysis of the research data, extensive literature review, and consideration of the research objectives. They offer practical insights and potential solutions to the identified challenges, gaps, and/or opportunities uncovered during the course of the research. The recommendations are tailored to the specific context and scope of the research, ensuring their relevance and applicability to the target audience.

Moreover, it is important to note that the recommendations provided here are intended to serve as a starting point for further exploration and refinement. The dynamic nature of the research field requires continuous evaluation and adaptation of strategies to meet evolving needs and changing circumstances. Therefore, the suggested recommendations should be viewed as a basis for further discussion, experimentation and customisation depending on the unique requirements and constraints of each situation.

Thus, the following recommendations are made:

For farmers

i) **Adopt sustainable practices aligned with the new CAP 2023-27:** The new Common Agricultural Policy (CAP) emphasises the importance of sustainable agriculture practices that are economically viable, environmentally sound, and protect public health. Farmers can take advantage of this opportunity to adopt more sustainable practices that align with the new CAP. For example, they can reduce water consumption by utilising contemporary irrigation systems such as sprinklers, drip irrigation and micro irrigation for increased efficiency.

ii) **Improve decision-making processes:** Farmers can enhance their decision-making processes by increasing their managerial competencies, particularly the systematic use of planning and control methods, for effective decision making and strategic design. They can also increase their awareness and openness to the use of Decision Support Tools (DST) by engaging with tangible examples from demonstration farms and research institutes' presentations.

iii) **Seek guidance and scientific advice:** Farmers can benefit from increased guidance and scientific advice from agricultural advisers to support their decision-making based on the latest scientific knowledge and use of available data, to enhance the sustainability of agricultural systems. They can also use remote sensing technology in sustainable agriculture to provide data for the most accurate and reliable analytics.

For advisers

i) **Diversify services:** Advisers should diversify their services from a purely market-driven approach to a role that includes guidance and scientific advice for supporting farmers' needs for sustainable development. This can be achieved through vocational training and aligning their approach to the CAP 2023-27 reform.

ii) **Consider farm sustainability holistically:** Advisers should consider farm sustainability holistically (economic, environmental, and social pillar) as this approach not only benefits the farm itself but also contributes to the overall well-being of the broader community and the environment. Achieving holistic farm sustainability involves embracing technology, engaging with the community, providing education and training opportunities, optimising resource use and ensuring fair labour practices on the farm.

iii) **Encourage the use of DSTs:** Advisers should encourage the use of DSTs that can enhance the decision-making of farmers and advisers, enabling evidence-based decisions which will improve the sustainability of farming systems in the Mediterranean basin, and facilitate the advisory role of agronomists and accountants in the area. This can be achieved by developing training programs for farm managers, establishing experimental and demonstration farms and working with the policymakers to advocate for policies that support the adoption of DSTs in agriculture.

For policymakers

i) **Create and support policies and programs that promote sustainable agriculture in the Mediterranean region:** This can be achieved through the engagement with stakeholders and the facilitation of the discussion with them and their counterparts in order to create an enabling framework meaning establishing favourable regulatory conditions and legislation that support sustainable agriculture in the Mediterranean region.

ii) **Ensure the engagement of stakeholders in a co-production of services approach so as to promote diversity of opinions and inclusivity:** This can be achieved through diverse representation, the use of inclusive language accessible to all stakeholders, utilise technology to facilitate virtual engagement and make sure that policies are more inclusive, and reflective of the varied needs of different stakeholders' groups.

7.5 Concluding remarks

In conclusion, the topics of decision-making, farm sustainability, business planning and control methods, and the use of decision support tools all intersect to enhance the efficiency and profitability of farm businesses, while minimising their environmental impact and societal pressures.

Decision-making involves weighing alternatives, considering risks and benefits, and ultimately making choices that align with the goals and values of farmers. Thus, employing a systematic and informed approach to decision-making can enhance the ability of farm managers to achieve the desired outcomes and to navigate through complex challenges.

These complex challenges have emerged as a crucial focus area as far as farm sustainability is concerned and in response to the need for responsible resource management, conservation, and long-term viability. By implementing sustainable practices farmers can address the need for financial viability, risk management, value addition, fair trade and rural economic development while safeguarding natural resources, preserving biodiversity, reducing greenhouse gas emissions, and adopting renewable energy sources. Moreover, they can emphasise the importance of social equity, community engagement, education and cultural preservation. By considering and addressing the social dimensions of farming practices farmers can create a more inclusive, equitable and resilient agricultural systems that benefit both individuals and communities.

In tandem with sustainability efforts, effective business planning and control methods are essential for the success of agricultural enterprises. Farmers need to develop comprehensive business plans that incorporate market analysis, financial forecasting, risk management strategies and operational objectives. Regular monitoring, evaluation, and control mechanisms are crucial to track performance, make informed decisions, and adjust strategies accordingly. This allows farmers to navigate market fluctuations, optimise resource allocation and ensure profitability in a competitive landscape.

The use of decision support tools plays a pivotal role in modern agriculture by providing valuable insights and facilitating informed and evidence-based decision-making. These tools, powered by data analytics, machine learning, and artificial intelligence, enable farmers to analyse complex information, optimise production processes, and mitigate risks. From weather forecasting and pest management to yield prediction and resource allocation, decision support tools empower farmers to make data-driven decisions that will improve productivity, reduce costs, minimise environmental impact and benefit the well-being of individuals and communities associated with agricultural activities.

In conclusion, the integration of farm sustainability practices, robust business planning and control and the use of decision support tools represent a powerful combination for the modern farmer. By embracing sustainable practices, conducting thorough business planning and control and leveraging cutting-edge technologies, farmers can achieve economic viability, environmental stewardship, and social resilience in the face of evolving challenges. The collective adoption of these approaches will contribute to the transformation of Mediterranean agriculture into a more sustainable and productive sector, ensuring the availability of food and resources for future generations.

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Appendix 1 – Sustainability Assessment

Calibration of RISE 3.0

Project Title: Strategies for Sustainable Farming in the Mediterranean: Lessons from Argolida, Greece.

REFERENCE DATA

1. Region

1.1. General Information

- **1.1.a.** Name of Region: Argolida
- **1.1.b.** Country: Greece
- **1.1.c.** National Currency: EUR, according to the list of ISO 4217 currency codes: www.xe.com/iso4217.php
- **1.1.d.** Regional distance (Transportation of imported feed and organic fertiliser: 100 km)

1.2. Climate, Soils, Ecology

- **1.2.a.** Vegetation Zone: Subtropical Dry, FAO Global Ecological Zones Map, www.geo.arizona.edu/~rees/faoglobalecozones.jpg
- **1.2.b.** Mean Annual Temperature: 16.96 ^{o}C, Hellenic National Meteorological Service, www.emy.gr/emy/en/climatology/climatology_city?perifereia=Peloponnese&poli=Pyrgela
- **1.2.c.** Humidity Zone: Dry, www.fao.org/nr/climpag/climate/index_en
- **1.2.d.** Moisture Index: -50, www.fao.org/nr/climpag/pub/en3_051002_en.asp
- **1.2.e.** Regional Water Stress Index: Medium Stress, https://esd.ifu.ethz.ch/downloads/ monthly-water-scarcity-assessment---water-footprinting.html
- **1.2.f.** Climate Erosivity (Water Erosion): Very high, www.nrcs.usda.gov/wps/portal /nrcs/detail/soils/use/maps/?cid=nrcs142p2_054006
- **1.2.g.** Climate Erosivity (Wind Erosion): Very High, www.nrcs.usda.gov/wps/portal /nrcs/detail/soils/use/maps/?cid=nrcs142p2_054007
- **1.2.h.** N loss from Housing and Storage: 20%
- **1.2.i.** N loss during Application and from Field: 30%
- **1.2.j.** N input from atmosphere per year: 10%, Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions, Galloway et al 2008.
- **1.2.k.** Average energy intensity of agriculture in the region: Deactivated in RISE 3.0
- **1.2.l.** Effective Precipitation (Pe) and Potential Evaporotranspiration (Et0) in mm/month: Effective Precipitation (Pe) from the Hellenic National Meteorological Service, www.emy.gr/emy/en/climatology/climatology_city?perifereia=Peloponnese&poli=Pyrgela and Potential Evaporotranspiration (Et0) in mm/month from In situ estimation of actual évapotranspiration. A case study in Argos plain, In situ estimation of actual évapotranspiration. A case study in Argos plain, Giannoulopoulos P.,Poulovassilis A (2008)

1.3. Ecological Benchmarks

- **1.3.a.** Number of Crop Types: 2, is considered to be corresponding to the area's crops and also is evident from the crop selection of the sample (Tree crops, arable farming).

1.3.b. % of Ecologically Protected Areas: 17%, according to the Aichi Target 11 of the Convention on Biological Diversity, https://www.cbd.int/nbsap/targets/. ***Target 11*** *By 2020, at least* ***17 per cent*** *of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes*.

1.3.c. Proportion of ecologically connected areas: 100%, The default value of 100% translates into all "ecological infrastructures" (EI), e.g. hedgerows, creeks, trees, being at most 50 meters apart from each other.

1.3.d. Evaluation of 100% ecologically connected areas: 100, the default value of 100 points is attributed to farms with 100% ecologically connected areas.

1.3.e. Regional target: stocking density: **1 Large Animal Units (LAU)**, according to a global overview of such units, see https://en.wikipedia.org/wiki/Livestock_grazing_comparison. 1 LAU corresponds to the annual nitrogen and phosphorus emissions of one dairy cow.

1.3.f. Maximum stocking density: **3 Large Animal Units (LAU)**.

1.3.g. Regional target: Number of Plant Production Product (PPP) applications per area per year: **0**, The default value of 0 PPP applications reflects the view that a pesticide-free agriculture is optimal for wild biodiversity.

1.3.h. Regional limit: Maximum number of PPP applications per area per year: **3**, The default value of 3 PPP applications is based on expert opinion in a Greek (Argolida Region) context.

1.3.i. Regional target for number of crop plants (arable and permanent crops) per farm: **5**, The rating is automatically adjusted for small farms, so more than one crop species per hectare will never be required.

1.3.j. Tolerable soil loss in tons per hectare and year in the case of a slope length of 15 meters: **5tn/ha**, This parameter corresponds to the "T" value of the Revised Universal Soil Loss Equation (RUSLE), http://www.iwr.msu.edu/rusle/tvalue.htm. The default value of 5 tons per hectare and year can be tolerated in soils with 30-60 cm depth. Higher values can be accepted for deeper and lower values for shallower soils. This information is used in the rating of soil water erosion.

1.3.k. N balance for reference 1: Under-supply: **0%**, mirrors the complete lack of N nutrients inputs and is considered the worst possible scenario.

1.3.l. N balance for reference 2: Ideal situation lower limit: **90%**, Default value from RISE for Western Europe and East Asia.

1.3.m. N balance for reference 3: Ideal situation upper limit: **110**%, Default value from RISE for Western Europe and East Asia.

1.3.n. N balance for reference 4: Over-supply: **133%**, Default value from RISE for Western Europe and East Asia.

1.3.o. P balance for reference 1: Under-supply: **0%**, mirrors the complete lack of N nutrients inputs and is considered the worst possible scenario.

1.3.p. P balance for reference 2: Ideal situation lower limit: **90%**, Default value from RISE for Western Europe and East Asia.

1.3.q. P balance for reference 3: Ideal situation upper limit: **110%**, Default value from RISE for Western Europe and East Asia.

1.3.r. P balance for reference 4: Over-supply: **167%**, Default value from RISE for Western Europe and East Asia.

1.3.s. Target value for own supply of rainwater: **150%**, The ratio between effective annual precipitation on the farm area and farm water demand corresponds to 100 RISE points. The default value of 150% reflects the assumptions that distribution of precipitation during the year is not considered and water in the farm is enough only for farming activities and not to cover other social needs.

1.3.t. Limit for proportion of irrigation of crops: **100%**, is a default value of 100% based on the assumption that in the case of covering crop water needs through irrigation sustainability is affected negatively.

1.4. Units and Conversion Factors

1.5. Crops

1.5.a. Yields are calculated and entered into the regional data system according to data provided from the Hellenic Statistical Authority for the years 2012 – 2017. The data were provided through email, after the relevant question of the researcher, from the responsible regional office of the Hellenic Statistical Authority in Nafplio, Argolida. In this context, the regional standard yield can be calculated using the mean yield for the 6 quoted years. The higher and the lower yield for each of the crops under investigation is made possible to be recognised.

1.5.b. The proposed quality criterion for each crop is selected to be market requirements as it is exclusively used in the area.

1.5.c. Cultivation period per year is expressed in days. It is considered 365 days for all annual crops (citrus trees, olive trees, vines, apricots, pomegranates) and is accordingly adjusted for vegetable production produced in a crop rotation cycle in the same field.

1.5.d.

1.6. Animals

1.6.a. Yields are calculated and entered into the regional data system according to data provided from the Hellenic Statistical Authority for the years 2012 – 2017. The data were provided through email, after the relevant question of the researcher, from the responsible regional office of the Hellenic Statistical Authority in Nafplio, Argolida. In this context, the regional standard yield can be calculated using the mean yield for the 6 quoted years. The higher and the lower yield for each of the crops under investigation is made possible to be recognised.

1.6.b. The proposed quality criterion for each product is selected to be market requirements as it is exclusively used in the area.

1.6.c. **LAU factor for this species** = Number of Large Animal Units (LAU) or Large Livestock Units (LLU) to which one individual of this animal category corresponds. Note that one LAU corresponds to the **an-nual nitrogen and phosphorus emissions of one dairy cow**. For a global overview of such units, see https://en.wikipedia.org/wiki/Livestock_grazing_comparison. The default values in RISE are based on the Swiss system (GRUDAF, 2009), where **1 LAU = 115 kg N total/year = 41 kg P2O5/year. Please relate every LAU value that you enter to this reference**, as otherwise the calculated N and P balances will be wrong! If in your country, 1 LAU corresponds to larger or smaller quantities of N resp. P, be sure to transform your LAU values accordingly. LAU factors are used to calculate animal N and P excretions, which affect various RISE indicators, such as material flows, fertilization, greenhouse gas balance and intensity of agricultural production.

1.7. Values for Working Conditions

1.7.a. Optimum number of working hours per week: **40 hours**, default value based on ILO recommendation no 116.

1.7.b. Number of working hours per week: **48 hours**, default value based on ILO conventions and recommendations.

1.7.c. Maximum number of working hours per week: **48 hours**, default value based on ILO recommendation no 30.

1.7.d. Optimum number of working days per week: **5 days**, considering usual working conditions in western European countries for workers in other sectors. Also based on ILO conventions and recommendations.

1.7.e. Maximum number of working days per week: **6 days**, according to a default value, based on ILO conventions no. 14 and no. 30. Although everyday practice proves that longer hours and more days of work is common in the agricultural sector, there is no medical ground for considering workers in agriculture differently.

1.7.f. Optimum number of vacation weeks per week: **6 weeks**, according to default value, based on ILO conventions and recommendations. Although everyday practice proves that longer hours and more days of work is common in the agricultural sector, there is no medical ground for considering workers in agriculture differently.

1.7.g. Minimum number of vacation weeks per year: **1.5 weeks**, according to a default value, based on ILO conventions no. 101 and no. 132. Although everyday practice proves that longer hours and more days of work is common in the agricultural sector, there is no medical ground for considering workers in agriculture differently.

1.8. Year-Dependent Regional Data

1.8.a. *Analysis year*: **2017.**

1.8.b. *Inflation (%) in survey year:* **1.12%**, according to https://ec.europa.eu/eurostat/databrowser/view/tec00118/default/table?lang=en .

1.8.c. *Basic Needs.*

1.8.c.1. *Demographics & Value*

1.8.c.1.1. *Number of adult family members and minors (14 years and older) in an average-sized family in the region:* **2.20**, according to data provided from the Hellenic Statistical Authority for the years 2012 – 2017. The data were provided through email, after the relevant question of the researcher, from the central office of the Hellenic Statistical Authority in Athens.

1.8.c.1.2. *Number of children (0-13 years) in an average-sized family in the region:* **1.67**, according to data provided from the Hellenic Statistical Authority for the years 2012 – 2017. The data were provided through email, after the relevant question of the researcher, from the central office of the Hellenic Statistical Authority in Athens.

1.8.c.1.3. *Increase of basic needs per additional adult and minors (aged 14 years and older):* **50%**, default value following the OECD family equivalence scales used for the determination of the equivalent available income (Hagenaars et al., 1994).

1.8.c.1.4. *Increase of basic needs per additional child (0-13 years):* **30%**, default value following the OECD family equivalence scales used for the determination of the equivalent available income (Hagenaars et al., 1994).

1.8.c.1.5. *Should a value for basic needs of an average-sized family spending be used (alternatively the basic needs of a single person spending are used)?* **YES,** annual basic needs will be calculated based on basic needs, family and not on single person’s basic needs.

1.8.c.2. *Basic Needs, Family*

1.8.c.2.1. *Housing costs for a family for one year:* **3000 EUR**, equivalent for rent or mortgage (rates and compulsory repayments) for an inexpensive residential property typical of the area.

1.8.c.2.2. *Ancillary housing costs for a family for one year:* **3000 EUR**, Insurance premiums typical for the area, charges, running costs, repairs and maintenance, upkeep of garden and grounds. Calculate 120*12=1440 EUR for utilities and 1560 EUR for heating and maintenance.

1.8.c.2.3. *Further living costs for a family for one year, can be compensated through payments in kind:* **330 EUR**, according to FADN data household own consumption.

1.8.c.2.4. *Further living costs for a family for one year, cannot be compensated through payments in kind (= minimal requirements):* **4800 EUR**, for insurances, taxes, health costs, clothing, education, personal items etc.

1.8.c.3. *Level of wages and poverty line*

1.8.c.3.1. *Attractiveness of hourly wage for employees: By what factor should an attractive hourly wage exceed the minimum wage (poverty line) measured with a total of 100 points:* **2**, default value

1.8.c.3.2. *Attractiveness of hourly wage for household members: By what factor should household spending exceed minimum private spending measured with a total of 100 points?* **2**, default value

1.8.d. *Economic Benchmarks*

1.8.d.1. *Minimum farm cash-flow reserve:* **15 weeks**, default value, corresponds to the weeks for which the cash reserves of the farm business can cover the operational costs in the case that no revenue is achieved.

1.8.d.2. *Good farm cash reserves:* **25 weeks**, default value, corresponds to the weeks for which the cash reserves of the farm business can cover the operational costs in the case that no revenue is achieved.

1.8.d.3. *Ideal farm cash reserves:* ***40 weeks****, default value, corresponds to the weeks for which the cash reserves of the farm business can cover the operational costs in the case that no revenue is achieved.*

1.8.d.4. *Cash-flow/sales ratio minimum:* **5%**, mirrors the ratio between the annual operational cash flow and the annual sum of revenues. It is used in the assessment of profitability of the farm business.

1.8.d.5. *Cash-flow/sales ratio:* **10%***,* mirrors the ratio between the annual operational cash flow and the annual sum of revenues. It is used in the assessment of profitability of the farm business.

1.8.d.6. *Cash-flow/sales ratio optimum:* **20%***,* mirrors the ratio between the annual operational cash flow and the annual sum of revenues. It is used in the assessment of profitability of the farm business.

1.8.d.7. *Low debt servicing coverage ratio:* **50%**, default value used in the assessment of debts. It is a ratio between the annual sum of interest and repayments and the farm's capacity to make such payments.

1.8.d.8. *Medium debt servicing coverage ratio:* **75%**, default value used in the assessment of debts. It is a ratio between the annual sum of interest and repayments and the farm's capacity to make such payments.

1.8.d.9. *High debt servicing coverage ratio:* **100%**, default value used in the assessment of debts. It is a ratio between the annual sum of interest and repayments and the farm's capacity to make such payments.

1.8.d.10. *Low level of indebtedness: years to repay debt from cash flow:* **5 years**, default value. It is based on the assumption that long-term debts associated with agriculture, have to do mainly with the finance of machinery, buildings and land (infrastructure). Their life expectancy is assumed at least 20 years.

1.8.d.11. *Medium level of indebtedness: years to repay debt from cash flow:* **15 years**, default value. It is based on the assumption that long-term debts associated with agriculture, have to do mainly with the finance of machinery, buildings and land (infrastructure). Their life expectancy is assumed at least 20 years.

1.8.d.12. *High level of indebtedness: years to repay debt from cash flow:* **20 years**, default value. It is based on the assumption that long-term debts associated with agriculture, have to do mainly with the finance of machinery, buildings and land (infrastructure). Their life expectancy is assumed at least 20 years.

1.8.d.13. *Target ROE:* **5%**, default value. The return on equity is calculated as operational cash flow minus depreciation), divided by the owner's equity at the start of the year.

Total Farm Income

Components
Total Income from Income Sources + Subsidies

Total Income from Income Sources

Components
Total Sales, **Value** - Direct Costs - Structural Costs

Direct Costs

Column1
Labour and machinery costs **and inputs, Wages and social security costs for** paid **labour**
Specific livestock costs, **Purchased concentrated feedstuffs for grazing stock (equines, ruminant**
Specific livestock costs, **Purchased coarse fodder for grazing stock (equines, ruminants)**
Specific livestock costs, **Purchased feedstuffs for pigs**
Specific livestock costs, **Purchased feedstuffs for poultry and other small animals**
Specific livestock costs, **Farm-produced feedstuffs for grazing stock (equines, ruminants)**
Specific livestock costs, **Farm-produced feedstuffs for pigs**
Specific livestock costs, **Farm-produced feedstuffs for poultry and other small animals**
Specific livestock costs, **Veterinary expenses**
Specific livestock costs, Other specific **livestock costs**
Specific crop costs and inputs, **Seeds and seedlings purchased**
Specific crop costs and inputs, **Seeds and seedlings produced** and **used on the farm**
Specific crop costs and inputs, **Fertilisers and soil improvers**
Specific crop costs and inputs, **Purchased manure**
Specific crop costs and inputs, **Crop protection products**
Specific crop costs and inputs**, Other specific crop costs**
Specific costs for OGA, **Specific costs for forestry and wood processing**
Specific costs for OGA, **Specific costs for crop processing**
Specific costs for OGA, **Specific costs for cow's milk processing**
Specific costs for OGA, **Specific costs for buffalo's milk processing**
Specific costs for OGA, **Specific costs for sheep's milk processing**
Specific costs for OGA, **Specific costs for goat's milk processing**

Specific costs for OGA, **Specific costs for meat processing and other animal products processing**
Specific costs for OGA, **Other specific costs for other gainful activities**
Farming overheads, **Electricity**
Farming overheads, **Heating fuels**
Farming overheads, **Water**
Farming overheads, **Agricultural insurance**
Farming overheads, **Other farm insurance**
Farming overheads, **Taxes and other dues**
Farming overheads, **Taxes on land and buildings**
Farming overheads, Other farming overheads
VAT systems in the farm, VAT system, **balance non- investments transactions**

Structural **Costs**	Components
	Labour and machinery costs and inputs, **Contract work and machinery hire**
	Labour and machinery costs and inputs, **Current upkeep of machinery** and **equipment**
	Labour and machinery costs and inputs, **Motor fuels** and **lubricants**
	Labour and machinery **costs and inputs**, **Car expenses**
	Farming overheads, **Rent paid, total**
	Farming overheads, **Rent paid for land**
	Farming overheads, **Interest and financial charges paid**

<u>Theme boxplots with indicator scores</u>

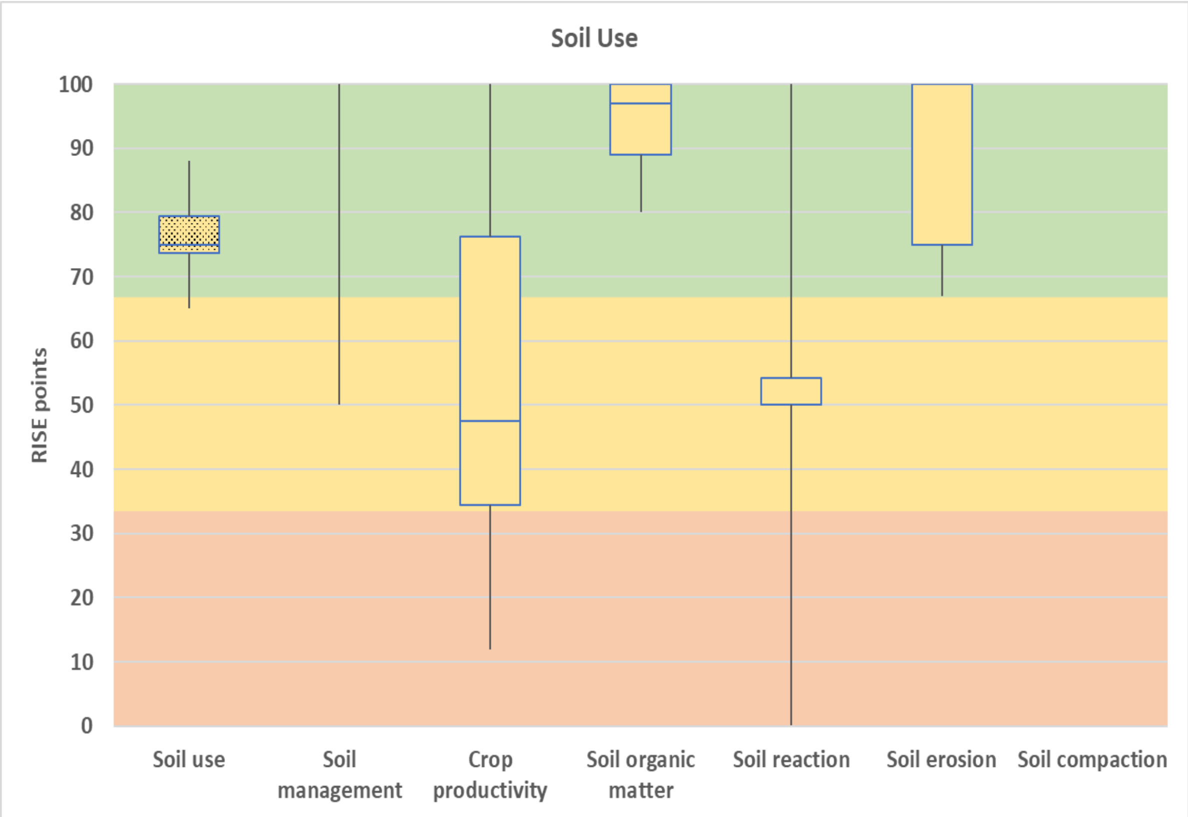

Figure 9.1: Soil Use theme with indicator scores

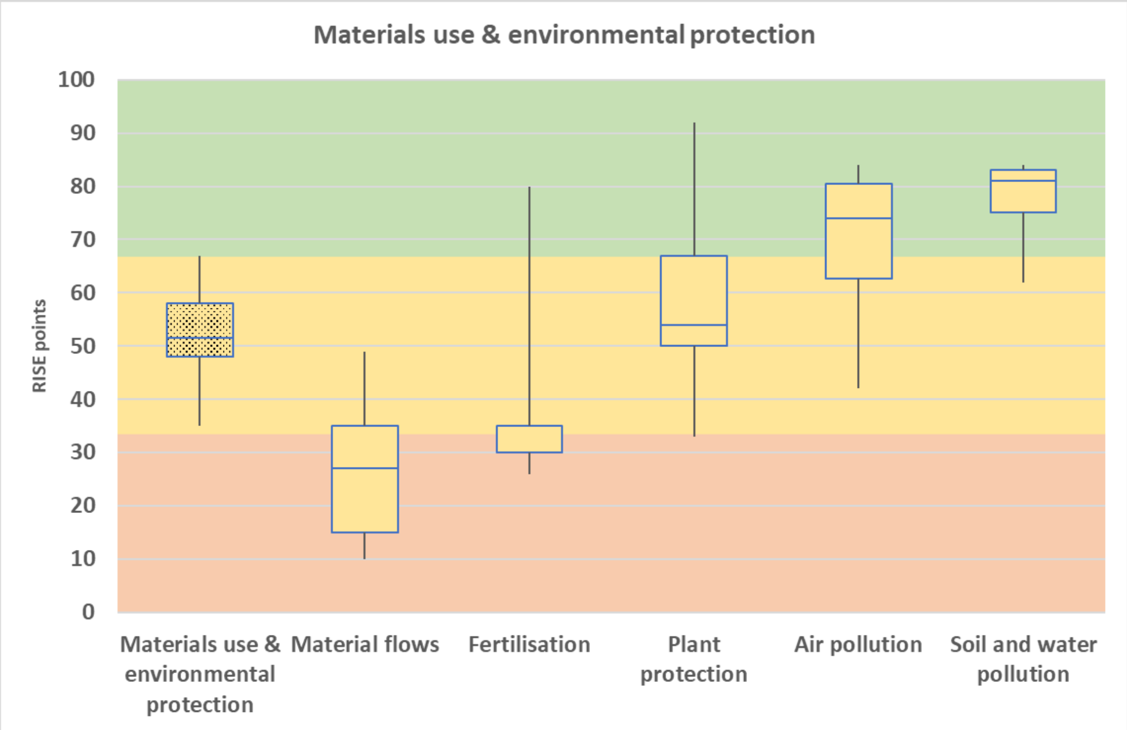

Figure 9.2: Materials use & environmental protection theme with indicator scores

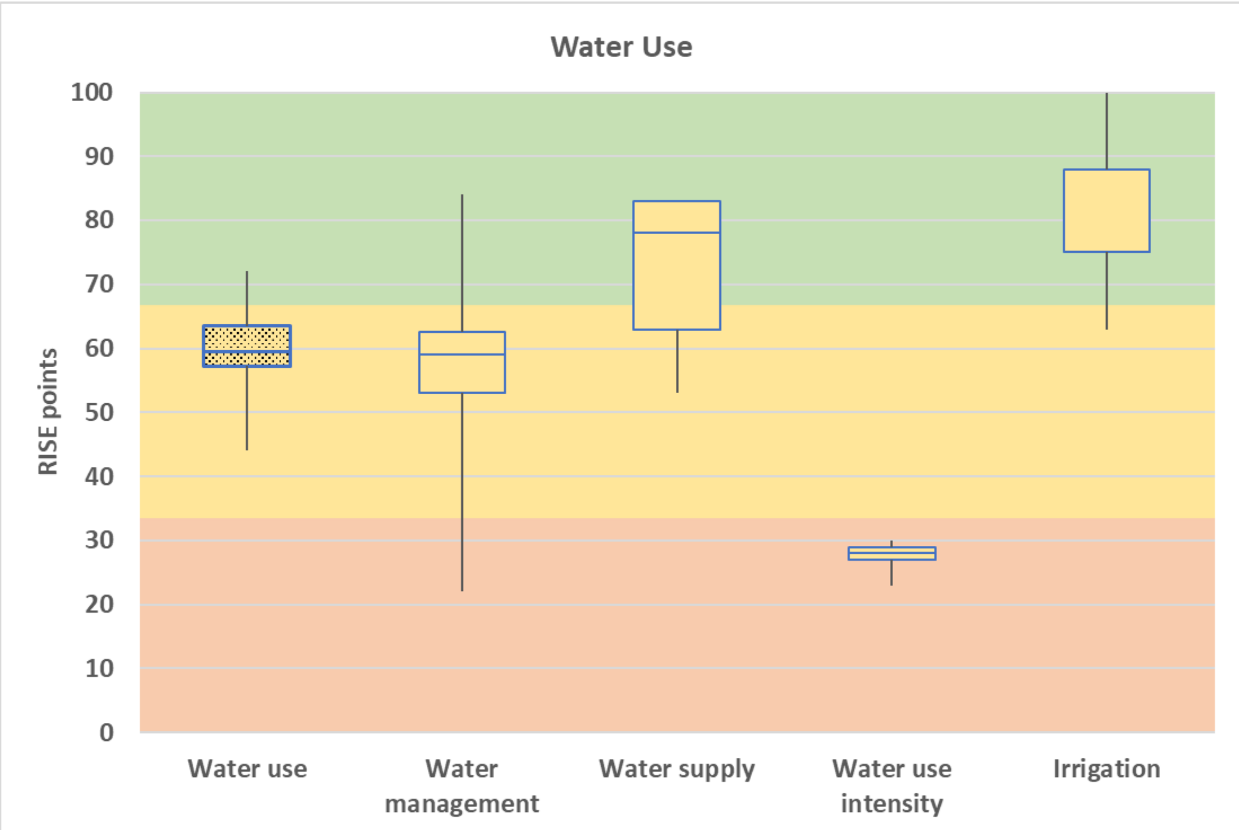

Figure 9.3: Water Use theme with indicator scores

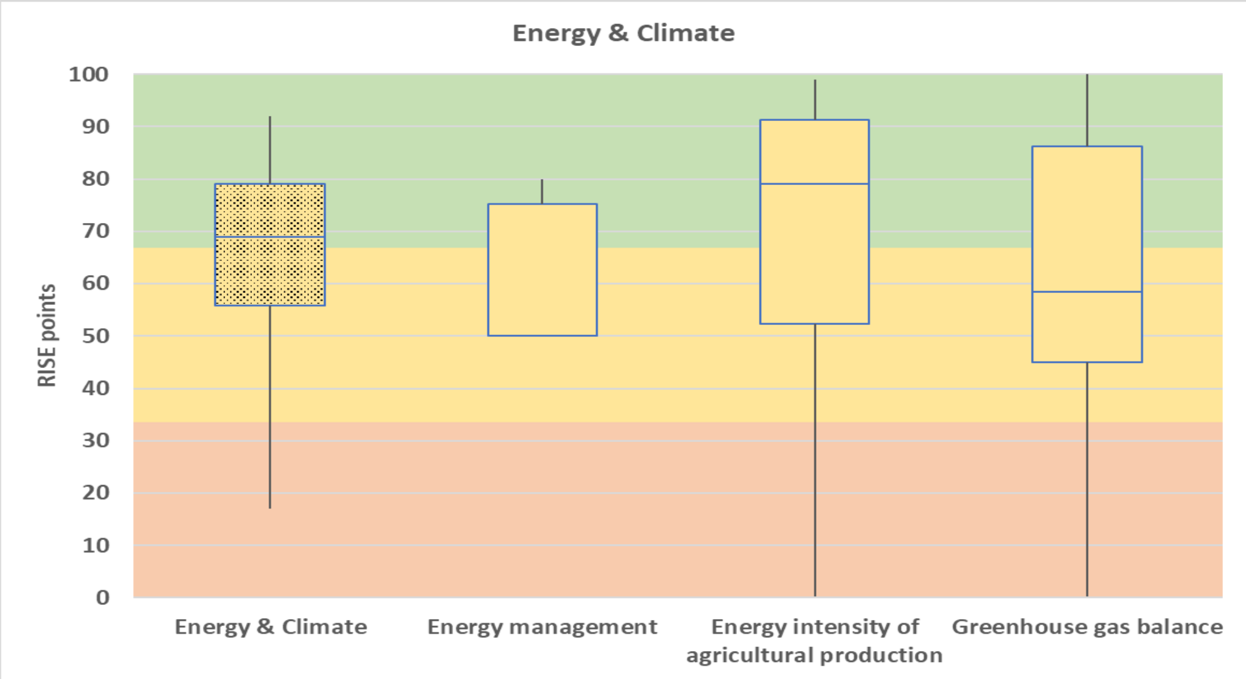

Figure 9.4: Energy & Climate theme with indicator scores

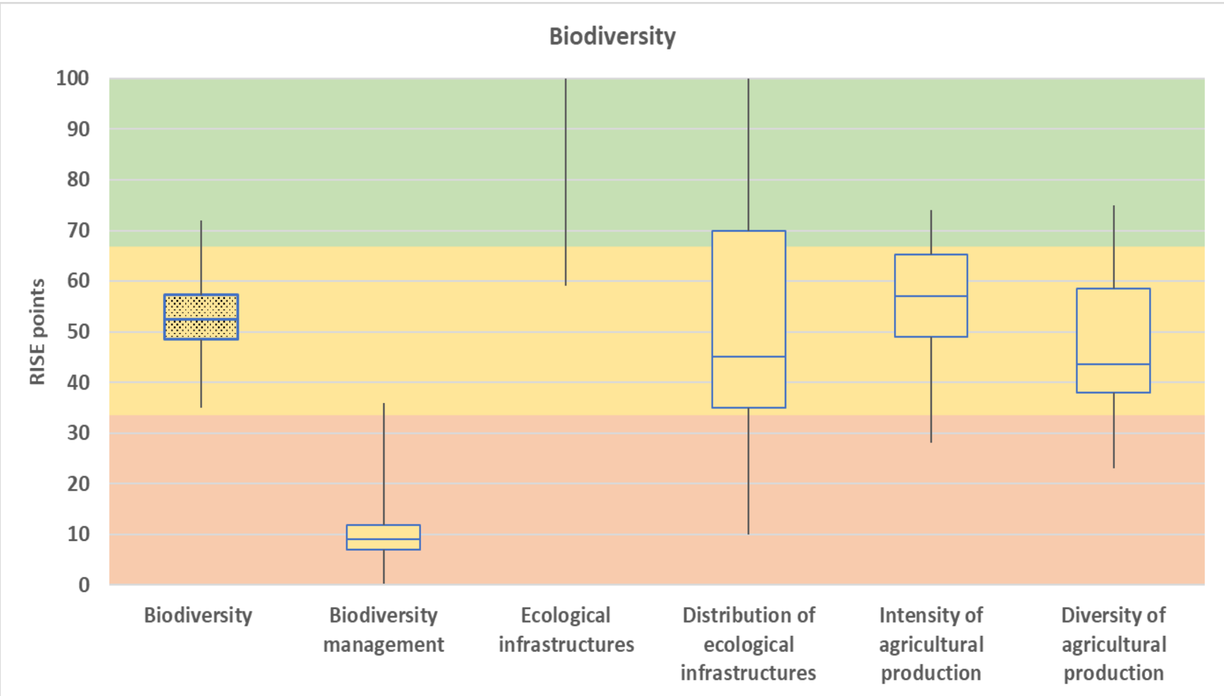

Figure 9.5: Biodiversity theme with indicator scores

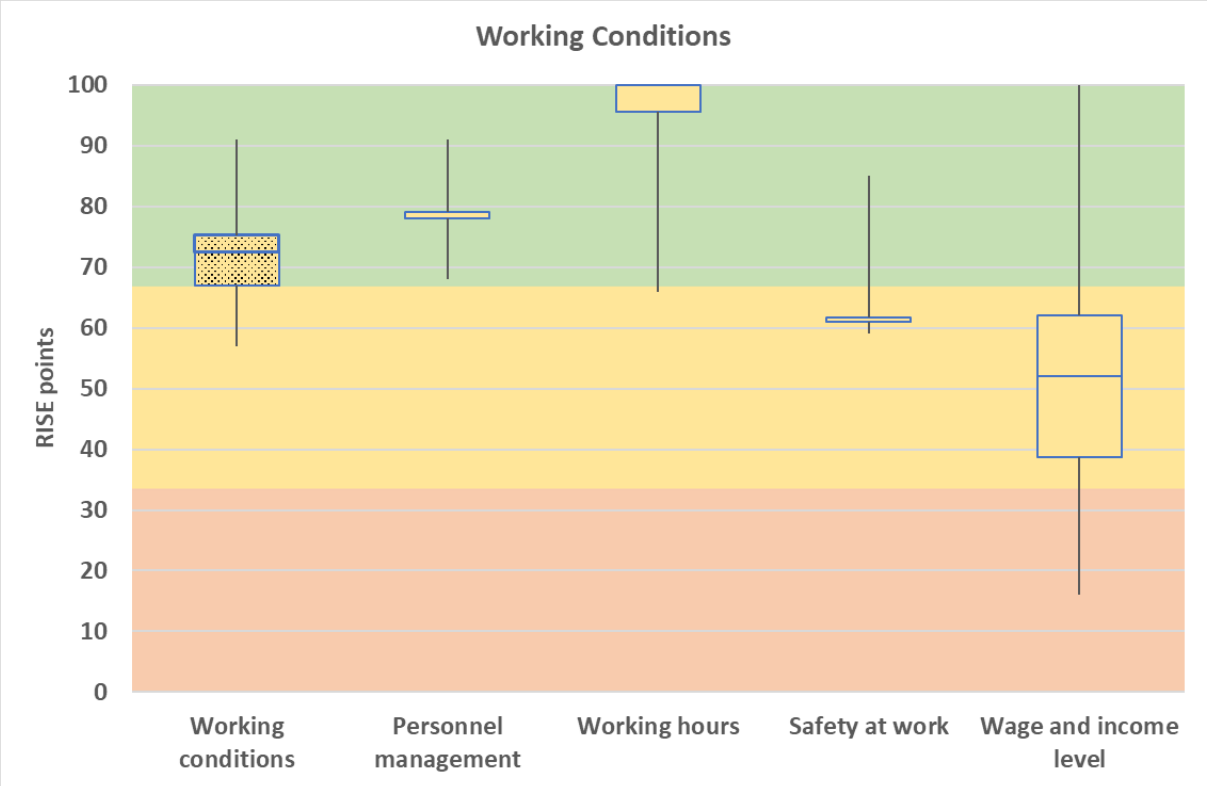

Figure 9.6: Working Conditions theme with indicator scores

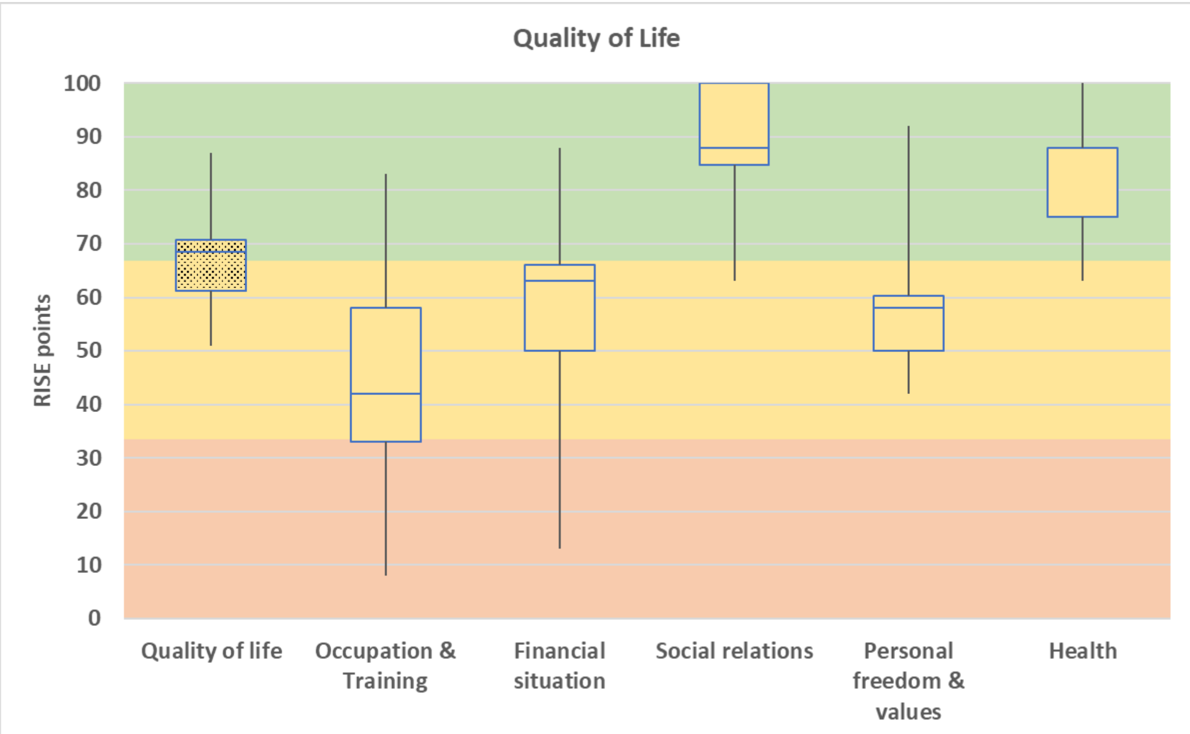

Figure 9.7: Quality of Life theme with indicator scores

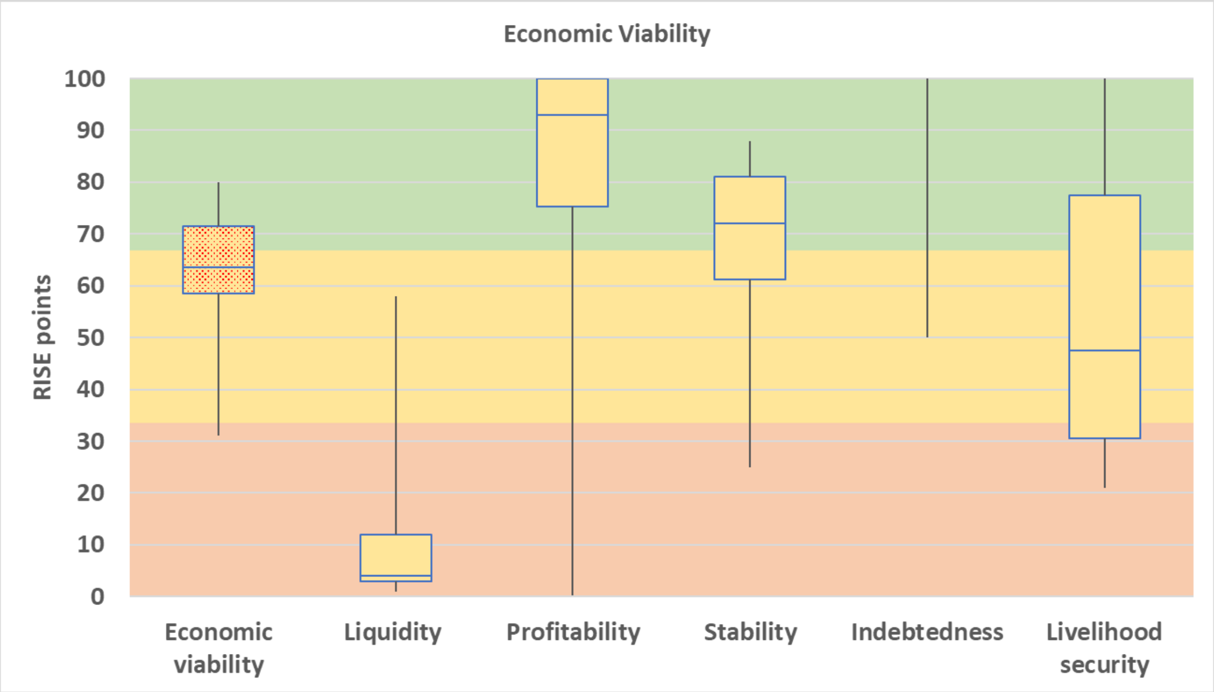

Figure 9.8: Economic Viability theme with indicator scores

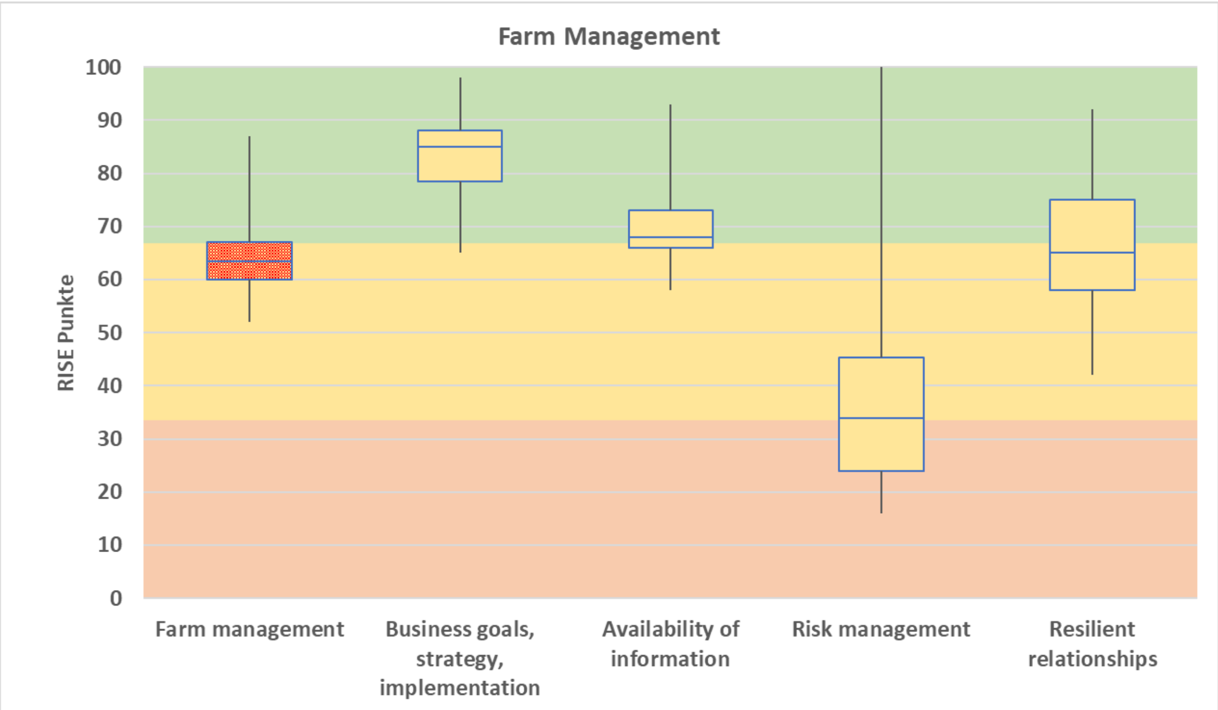

Figure 9.9: Farm Management theme with indicator scores

Table 9.1: Theme and indicator scores per farm

		Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8	Farm 9	Farm 10	Farm 11	Farm 12	Farm 13	Farm 14	Farm 15	Farm 16	Farm 17	Farm 18	Farm 19	Farm 20
1	**Soil use**	75	74	75	74	75	74	73	72	82	81	79	86	65	69	77	82	72	88	76	74
1.1	Soil management	67	67	67	67	67	67	67	67	67	67	67	100	67	67	67	67	50	67	67	67
1.2	Crop productivity	27	13	42	33	35	39	19	66	74	96	83	85	59	48	47	100	35	99	74	12
1.3	Soil organic matter	89	94	89	92	100	89	100	100	100	100	100	80	94	83	100	100	81	84	100	100
1.4	Soil reaction	67	67	50	50	50	50	50	0	50	50	50	50	0	50	50	22	67	100	50	67
1.5	Soil erosion	100	100	100	100	100	100	100	100	100	75	75	100	67	67	100	100	100	75	67	100
1.6	Soil compaction	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
3	**Materials use & environmental protection**	60	54	58	53	58	58	52	51	48	47	48	67	48	51	40	51	52	35	51	64
3.1	Material flows	24	15	38	15	35	31	49	35	10	15	15	35	30	15	19	19	40	35	15	31
3.2	Fertilisation	45	30	30	33	30	40	35	33	30	30	30	40	30	30	30	33	26	35	30	80
3.3	Plant protection	67	67	58	67	67	75	50	50	50	42	58	92	42	50	33	50	58	50	58	50
3.4	Air pollution	80	75	83	79	82	62	42	52	67	63	55	84	65	78	44	75	73	83	69	84
3.5	Soil and water pollution	84	81	80	72	75	84	82	84	84	83	82	83	73	81	74	78	62	82	81	75
4	**Water use**	58	55	68	59	59	67	63	59	52	63	60	71	61	72	52	59	63	44	65	54
4.1	Water management	68	39	75	59	56	84	59	56	31	59	59	84	59	78	28	61	44	22	59	56
4.2	Water supply	53	63	83	73	63	63	83	63	73	83	73	73	83	83	83	83	83	83	83	63
4.3	Water use intensity	27	28	27	27	29	27	23	28	29	28	28	26	27	26	29	29	30	26	28	29
4.4	Irrigation	83	88	88	75	88	94	88	88	75	81	81	100	75	100	69	63	94	0	88	69
5	**Energy & Climate**	56	77	75	83	55	92	78	73	40	27	24	86	82	56	76	17	65	91	60	57
5.1	Energy management	50	50	50	80	72	80	76	80	50	50	50	80	50	70	50	50	72	75	50	50
5.2	Energy intensity of agricultural production	60	91	89	88	50	95	91	83	35	11	10	92	96	53	94	0	66	99	75	61
5.3	Greenhouse gas balance	57	91	87	82	42	100	66	55	35	19	12	86	100	46	83	0	57	100	56	60
6	**Biodiversity**	59	49	51	60	54	55	50	57	45	49	45	72	58	55	54	47	51	68	46	35
6.1	Biodiversity management	11	8	9	18	9	7	14	9	7	0	2	36	3	14	11	11	7	17	4	9
6.2	Ecological infrastructures	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	59
6.3	Distribution of ecological infrastructures	35	45	45	50	55	65	70	75	30	35	35	100	75	40	70	35	40	100	35	10
6.4	Intensity of agricultural production	74	57	61	69	49	64	28	44	51	49	48	58	71	62	45	50	57	74	51	74
6.5	Diversity of agricultural production	75	36	42	65	55	40	40	58	35	63	38	65	40	60	45	38	50	48	38	23
7	**Working conditions**	64	73	76	75	72	66	57	58	71	72	71	84	67	76	75	91	73	77	67	75
7.1	Personnel management	79	79	79	79	79	91	68	79	75	79	79	86	91	79	75	79	79	75	79	75
7.2	Working hours	96	100	100	100	84	69	70	66	99	100	100	100	100	100	100	100	100	100	94	100
7.3	Safety at work	61	61	61	61	61	61	61	59	64	61	61	67	61	61	61	85	61	67	61	65
7.4	Wage and income level	19	52	63	61	62	41	30	29	46	46	43	81	16	62	62	100	52	64	32	60
8	**Quality of life**	51	64	83	56	70	73	69	64	55	68	73	87	51	70	69	63	52	69	63	80
8.1	Occupation & Training	8	17	50	33	42	58	58	58	25	33	42	83	17	42	58	58	42	42	33	83
8.2	Financial situation	13	50	75	50	63	63	63	63	38	63	75	88	25	75	75	50	38	63	63	63
8.3	Social relations	88	88	100	75	100	100	100	63	88	88	100	100	88	88	100	75	75	100	75	100
8.4	Personal freedom & values	58	75	92	58	58	58	50	50	50	67	58	75	50	58	50	58	42	50	58	67
8.5	Health	88	88	100	63	88	88	75	88	75	88	88	88	75	88	63	75	63	88	88	88
9	**Economic viability**	50	67	64	54	62	74	57	80	62	63	59	75	31	73	66	75	61	71	65	50
9.1	Liquidity	2	12	13	1	3	4	3	12	3	4	6	58	3	2	12	36	18	3	4	1
9.2	Profitability	71	79	100	73	90	98	67	100	91	100	66	76	0	86	100	100	95	96	97	100
9.3	Stability	56	44	63	56	69	81	88	88	63	81	81	88	75	88	56	63	63	75	81	25
9.4	Indebtedness	100	100	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	100
9.5	Livelihood security	21	100	43	42	50	85	26	98	53	29	40	52	29	87	61	76	31	82	45	25
10	**Farm management**	54	71	63	63	67	73	65	65	56	57	67	87	67	61	57	75	52	64	62	63
10.1	Business goals, strategy, implementation	73	85	88	88	85	85	79	98	75	88	85	90	92	77	79	65	77	90	83	83
10.2	Availability of information	68	68	68	73	71	81	76	71	66	61	68	93	76	73	66	61	58	73	66	68
10.3	Risk management	16	44	36	24	36	32	53	24	24	19	41	78	36	28	24	100	16	49	49	16
10.4	Resilient relationships	58	88	58	67	75	92	50	67	58	58	75	88	63	67	58	75	58	42	50	83

Sustainability Assessment (Indicator-Based) Tools

A/A	Name	Application	Peer Rev.	Sustainability Assessment	Agricultural Sector	Suitability
1	AEMBAC, European Analytical Framework for the Development of Local Agri- Environmental ProgrammesAgro-Environmental	Landscape	Yes	Environmental	Universal	All countries
2	AESIS, Agro-Environmental Sustainability Information System	Farm	Yes	Environmental	Universal	NW Europe
3	Agro-Eco-Index	Farm	Yes	Environmental	Universal	Pampas of Argentina
4	ANCA, Annual Nutrient Cycle Assessment System	Farm	Yes	Environmental	Dairy	NW Europe
5	APOIA NOVORURAL, System for Weighted Environmental Impact Assessment of Rural Activities	Farm	Yes	Economic Environmental Social	Universal	All countries except NW Europe
6	ARBRE, Arbre de l'Exploitation Agricole Durable	Farm	No	Economic Environmental Social	Universal	NW Europe
7	AUI, Agrarumweltindikatoren	Farm	No	Environmental	Universal	NW Europe
8	Avibio, AVIculture BIOlogique	Farm, Chain	Yes	Economic Environmental Social	Universal	NW Europe
9	BROA, Biodiversity Risk and Opportunity Assessment	Landscape	No	Environmental	Universal	All countries
10	COSA, Committee on Sustainability Assessment	Farm	Yes	Economic Environmental Social	Coffee and Cacao	All countries except NW Europe
11	Coteur et al. (2014) 12	Farm	Yes	Economic Environmental Social	Fruit, arable and greenhouse	NW Europe
12	DairySat, Dairy Self-Assessment Tool	Farm	No	Environmental	Dairy	NW Europe
13	Dantsis et al. (2010)	Farm, Regional	Yes	Economic Environmental Social	Plant production	NW Europe

A/A	Name	Application	Peer Rev.	Sustainability Assessment	Agricultural Sector	Suitability
14	DIAGE, DIAgnostic Global d'Exploitation DIAgnostic	Farm	No	Environmental	Universal	NW Europe
15	DIALECTE, DIAgnostic Liant Environnement et Contrat Territorial d'Exploitation	Farm	No	Environmental	Universal	NW Europe
16	DIALOGUE, Diagnosticagri environnemental global d'exploitation	Farm	No	Environmental	Universal	NW Europe
17	DLG, DLG Zertifikat Nachhaltige Landwirtschaf	Farm	No	Environmental	Universal	NW Europe
18	DSDI, Dairyman Sustainability Index	Farm	Yes	Economic Environmental Social	Dairy	All countries
19	DSR, Driving Force State response	Regional	No	Economic Environmental Social	Universal	All countries
20	EF, Ecological Footprint	Farm, Product, Local, Regional	Yes	Environment	Universal	All countries
21	EMA, Environmental management for Agriculture	Farm	Yes	Environmental	Universal	NW Europe
22	EP, Eco points	Farm	No	Environmental	Universal	NW Europe
23	FARMSMART	Farm	Yes	Economic Environmental Social	Universal	NW Europe
24	Field Print Calculator	Farm	No	Economic Environmental Social	Arable farming	NW Europe
25	GA, Green Accounts for Farms	Farm	No	Environmental	Universal	All countries
26	IDEA, Indicateur de Durabilité des Exploitations Agricoles	Farm	Yes	Economic Environmental Social	Universal	All countries
27	IFSC, Illinois Farm	Farm	No	Economic, Environmental	Universal	State of Illinois
28	INDIGO, Sustainability Calculator	Farm	Yes	Environmental	Crop production, viticulture	NW Europe

A/A	Name	Application	Peer Rev.	Sustainability Assessment	Agricultural Sector	Suitability
29	ISAP, Indicator of Sustainable Agricultural Practice	Farm	Yes	Economic Environmental Social	Horticulture	NW Europe
30	KSNL, Kriteriensystem Nachhaltige Landwirtschaf	Farm	No	Economic Environmental Social	Universal	NW Europe
31	LCA, Life Cycle Assessment	Product	Yes	Environmental	Universal	All countries
32	MESMIS, Framework for Assessing the Sustainability of Natural Resource Management	Farm, Local	Yes	Economic Environmental Social	Smallholder	Mexico and Latin America
33	MMF, Multiscale Methodological Framework	Farm, Local, Regional	Yes	Economic Environmental Social	Smallholder	Purhepecha Region of Michoacán, Mexico
34	MOTIFS, Monitoring Tool for Integrated Farm Sustainability	Farm	Yes	Economic Environmental Social	Dairy	NW Europe
35	PG, Public Goods Tool	Farm	Yes	Economic Environmental Social	Universal	All countries
36	RAD, Réseau del'Agriculture Durable	Farm	Yes	Economic Environmental Social	Dairy	NW Europe
37	REPRO, Reproduction of Soil Fertility	Farm	No	Environmental	Environmental	NW Europe
38	RISE, Response-Inducing Sustainability Evaluation 3.0	Farm	Yes	Economic Environmental Social	Universal	All countries
39	SAFA, Sustainability Assessment of Food and Agriculture Systems	Farm, Chain	Yes	Economic Environmental Social	Universal	All countries
40	SAFE, Sustainability Assessment of Farming and the Environment	Farm, Landscape, Regional	Yes	Economic Environmental Social	Universal	NW Europe
41	SAI-SPA, Farmer Self-Assessment 2.0	Farm	No	Economic Environmental Social	Universal	All countries

A/A	Name	Application	Peer Rev.	Sustainability Assessment	Agricultural Sector	Suitability
42	SALCA, Swiss Agricultural Life Cycle Assessment	Farm, Product, System	Yes	Environmental	Universal	NW Europe
43	SeeBalance, Socio-Eco-Efficiency Analysis developed by BASF	Product	Yes	Economic Environmental Social	Universal	All countries
44	S-LCA, Social Life Cycle Assessment	Product	Yes	Social	Universal	All countries
45	SMART, Sustainability Monitoring and Assessment Routine	Farm	No	Economic Environmental Social	Dairy	All Countries
46	Soil & More Flower, Sustainability Flower Quick Assessment	Farm	No	Economic Environmental Social	Flowers	All countries
47	Sustainability Dashboard, Australian Government, The Sage Farmers	Farm	No	Economic Environmental Social	Universal	Australia
48	Van Calker et al. (2006), multi-attribute sustainability function for Dutch dairy farming systems	Farm	Yes	Economic Environmental Social	Dairy	NW Europe

Appendix 2 – Thematic Analysis

Questionnaire

1. What is your age?

18-39 years old   40-64 years old   65 and over

2. What is your gender?

Male   Female

3. What is your marital status?

Single   Married or domestic partnership   Widowed   Divorced

Separated   Prefer not to say

4. How did you get into farming?

5. How long do you intend to continue to manage the farm business?

a. Less than 5 years
b. Between 5 and 10 years
c. More than 10 years

6. What kind of agricultural training do you have?

a. Practical experience only,
b. Basic agricultural training like seminars on specific topics held at a basic agricultural training school or similar institution,
c. Full agricultural training at a middle or higher level,
d. University level agricultural school for at least 2 years after the completion of compulsory training.

7. What do you think are the most important attributes of a “successful” farm business?

8. Based on the most important attributes identified above, what do you think of your farm business compared to the farm businesses in the Argolida region?

Unsuccessful   Successful

1   2   3   4   5   6   7   8   9   10

9. Do you feel decision-making for your farm is informed by good agricultural practices?

Never								Always	
1	2	3	4	5	6	7	8	9	10

10. What is your perception of effective decision-making?

11. Who influences the decisions you make in your farm business?

a. On his/her own
b. Family/Household
c. Peer recommendation
d. Agronomist/Adviser
e. Extension Officer
f. Other (please define)

12. What is your degree of awareness of farm sustainability performance?

13. To what degree is sustainability performance a part of the decision-making process for your farm business?

14. Have you ever assessed your farm's sustainability performance until now? If yes how did you assess it?

a. Social Environment goals (i.e., Food security)
b. Economic goals (i.e., Profit maximisation)
c. Environmental goals (i.e., soil degradation, natural resources management)

15. Are you familiar with decision support tools (DST) for assisting decision-making?

If yes:

a. Can you indicate any decision support tools you have used so far for the decision-making process?
b. What are the challenges/problems in implementing decision support tools for effective decision-making towards improving farm sustainability performance?
c. Do you believe that the use of decision support tools enhances effective decision-making?

If no:

a. What are the reasons hindering you from using decision support tools?

16. What is your perception of changes that will occur in 10 years' time, in the region of Argolida?

17. Have you changed your approach in relation to management and agricultural practices on your farm business, during the last three years?

If yes:

Can you indicate the changes you have made?

18. Can I come back and speak to you again?

Appendix 3 – Content Analysis

Questionnaire Farmers

1. What is your age group?

18-39 years old   40-59 years old   60-74 years old   75 and over

2. What type of farming are you following?

Conventional   Organic   Mix

3. How long have you managed the farm business?

a. Less than 10 years
b. Between 10 and 20 years
c. More than 20 years

4. What is your educational level?

a. Primary school,
b. Secondary school,
c. Post-secondary vocational education and training
d. University level,

5. Have you undergone any other form of additional professional training during your time as a farm owner/manager?

6. Do you think planning is important in agriculture?

7. Does your farm have a person with explicit responsibility for the planning process?

8. What is included in your planning process?

9. Do you adopt and/or implement any planning methods to inform your decision-making?

   a. If Yes:

      i. Which methods do you use?
      ii. What are the benefits of using such methods?

iii. What problems have you faced in the process?

b. If No:

i. What are the reasons hindering the adoption and/or implementation of planning methods?

10. Do you think the adoption and/or implementation of planning methods is affecting farm sustainability?

a. If Yes:

i. Why do you think this is happening?

b. If No:

i. Can you elaborate on the reasons you believe they have no effect on farm sustainability?

11. Do you think control is important in agriculture?

12. Who is responsible for the control process in your farm?

13. What is included in your control process?

14. Can you indicate any control methods?

15. Do you adopt and/or implement control methods to enhance your decision-making?

a. If Yes:

i. which methods do you use?

ii. What are the benefits of using such methods?

iii. What problems have you faced in the process?

b. If No:

i. What are the reasons hindering the adoption and/or implementation of control methods?

16. Do you think the adoption and/or implementation of control methods is affecting farm sustainability?

a. If Yes:

i. Why do you think this is happening?

b. If No:

i. Can you elaborate on the reasons you believe they have no effect on farm sustainability?

17. Do you consider the lack of adoption and/or implementation of planning and control methods is putting your farm business at risk?

18. Do you use an adviser for your farm business?

19. What kind of advice do you usually seek from them?

20. Do you think you actually use in full, the services potentially provided?

a. If Yes:

i. How did you end-up using fully the services provided?

b. If No:

i. Can you elaborate on the reasons that hinder you from fully exploiting the provided services?

21. Can I come back and speak to you again?

<u>Questionnaire Advisers</u>

1. What is your age group?

18-39 years old   40-59 years old   60-74 years old   75 and over

2. What is your profession?

Accountant   Agronomist   Other

3. How long have you practising your profession?

a. Extensive Knowledge, experience, or training (10 or more years)
b. Moderate knowledge, experience, or training (5-9 years)
c. Limited knowledge, experience, or training (1-4 years)
d. No knowledge, experience, or training (less than 1 year)

4. How often do farmers seek advice from you?

5. What are the most common subjects, farmers ask for advice?

6. Do you think they use the advice to inform their decision-making?

a. Yes, and if yes why do you think this is happening?
b. No, and if not why do you think this is happening?

7. Why do you think planning is important in agriculture?

8. Do you use or suggest any planning methods as a decision-making tool for the farmer?

a. If Yes:
    i. Which methods do you use?
    ii. What are the benefits of using such methods?
    iii. What challenges have you faced in the process?
b. If No:
    i. What are the reasons that hinder the use of planning methods by farmers?

9. Do you think the adoption and/or implementation of planning methods is affecting farm sustainability?

a. If Yes:
    i. Why do you think this is happening?
b. If No:
    i. Can you elaborate on the reasons you believe they have no effect on farm sustainability?

10. Why do you think control is important in agriculture?

11. Do you make use or suggest of any control methods to inform decision-making for the farmer?

a. If Yes:
    i. Which methods do you use?
    ii. What are the benefits of using such methods?
    iii. What challenges have you faced in the process?
b. If No:
    i. What are the reasons that hinder the use of control methods by farmer?

12. Do you think the adoption and/or implementation of control methods is affecting farm sustainability?

a. If Yes:

i. Why do you think this is happening?

b. If No:

i. Can you elaborate on the reasons you believe they have no effect on farm sustainability?

13. Do you think you farmers actually use in full, the services potentially provided?

a. If Yes:

i. Can you identify any distinct features of farmers that use in full the provided services?

b. If No:

i. Can you elaborate on the reasons that hinder them from fully exploiting the provided services?

14. Have you ever used and/or proposed to use any decision support tools (DST) to enhance the decision-making process?

15. Based on your professional opinion what is the stance of farmers concerning the use of DST?

16. What do you consider could be the steps forward in order to enhance use and adoption of DST by farmers?

17. Can I come back and speak to you again?

Appendix 4 – Q-Methodology

The package used for to perform Q-methodology analysis was “qmethod”. The code used is the one that follows, and it is divided in two parts. The first part included the preparation and the selection of the Q-set and the second one the actual analysis and the crib sheets generation. There is also a third part explaining the criteria of the selection of the Q-set.

PART 1

```
######Q-Set Preparation#######
#library to load xlsx files
library(readxl)
#q methodology
#library(qmethod)

#setting directory laptop
#setwd("C:/Users/dimia/OneDrive - University of Reading/FIELDWORK PHASE 3/Q-METHODOLOGY/ANALYSIS - R")
#setting directory PC
setwd("C:/Users/cj828291/OneDrive - University of Reading/FIELDWORK PHASE 3/Q-METHODOLOGY/ANALYSIS - R")

#loading statements
finalCon <- read_excel("Final_concourse.xlsx")

#converting statements to tex. files (https://stackoverflow.com/questions/34970128/exporting-data-frame-columns-into-separate-txt-files)
for (i in 1:nrow(finalCon)) {
  write(finalCon$Statements[i], paste0("data/",
                                       finalCon$id[i], ".tex"))
}

#importing created concourse
concourse <- import.q.concourse("data/", languages = NULL)

#building q set
idsVector = as.character(finalCon[[1]]) #using column id (lower case)
idsVector40 <- sample(idsVector, 40) #own sample generation
qSet <- build.q.set(concourse, idsVector40, c(40))


#exporting qset
qSetDF <- as.data.frame(qSet)
qSetDF$id <- rownames(qSetDF) #rownames as Id
colnames(qSetDF)[which(names(qSetDF) == "V1")] <- "statem"
library(writexl)
write_xlsx(qSetDF, "finalQset16092022.xlsx") #Adding date to final Q-set to avoid overlapping between q-sets
```

PART 2

```
 #####Q-method Analysis#####
library(qmethod)

#importing Q-sorts
data = read.csv("Q-SortsCSV.csv", row.names = 1, header=TRUE)
head(data)

#results

results = qmethod(data,
            forced = FALSE,
            distribution = c(rep(-5,2), rep(-4,3), rep(-3,3), rep(-2,4), rep(-1,5), rep(0,6),
                  rep(1,5),rep(2,4), rep(3,3), rep(4,3), rep(5,2)),
            nfactors=5)
results

#to see all results
print(results, length = NULL, digits = 2)

#exporting results to .txt file
export.qm(results, "qmOutput.txt")

#plotting
resultsPlot = plot(results, xlab = 'z-scores', ylab = 'statements')

screeplot(prcomp(data), main = "Screeplot of unrotated factors",
     type = "l")

#Crib sheets
state<-read.csv("C:/Users/cj828291/OneDrive - University of Reading/FIELDWORK PHASE 3/Q-METHODOLOGY/ANALYSIS - R/Statements.csv" ,header = FALSE)
temp1<-results$zsc_n

tempcrib<-list()
crib<-list()
for(i in 1:ncol(temp1)){
 max<-which(temp1[,i]==max(temp1))
 tempcrib[[1]]<-state[max,1]
 min<-which(temp1[,i]==min(temp1))
 tempcrib[[2]]<-state[min,1]
 bigger<-rep(FALSE,nrow(temp1))
 for(j in 1:nrow(temp1)){
  bigger[j]<-ifelse(temp1[j,i]==max(temp1[j,]& temp1[j,i] !=max(temp1)) ,TRUE,FALSE)
 }
 tempcrib[[3]]<-state[which(bigger==TRUE),1]
 smaller<-rep(FALSE,nrow(temp1))
 for(j in 1:nrow(temp1)){
  smaller[j]<- ifelse(temp1[j,i]==min(temp1[j,])& temp1[j,i] != min(temp1) , TRUE, FALSE)
 }
 tempcrib[[4]]<-state[which(smaller==TRUE),1]
 crib[[i]]<-tempcrib
}
crib
```

Part 3 – Explanation of the selection of the Q-set

```
build.q.set <- function(q.concourse, q.sample, q.distribution) {
  q.sample <- as.character(q.sample) #  just to be safe

  # Validate input ============================================================
  if (!is.matrix(q.concourse)) {
        stop("The input specified for q.concourse is not a matrix.")
  }
  if (!is.vector(q.distribution)) {
    stop("The input specified for q.distribution is not a matrix.")
  }
  if (!is.vector(q.sample)) {
   stop("The input specified for q.sample is not a vector.")
  }
  if (length(q.sample) != sum(q.distribution)) { #  test if sums are equal
    stop(
      paste(
        "There are",
        length(q.sample),
        "items in your q-sample, but",
        sum(q.distribution),
        "entries expected in the q-distribution",
        sep=" "
      )
    )
  }
  missing.in.concourse <- !q.sample %in% rownames(q.concourse)
  if (any(missing.in.concourse)) {  # if any missing, stop
    stop(
      paste(
         "There are item handles in your sample not defined in the concourse:",
        q.sample[missing.in.concourse],
        sep=" "
      )
    )
  }

  # Subset the concourse ==================================================
  q.set <- q.concourse[q.sample,]  # only add sampled rows from concourse
  q.set <- as.matrix(q.set)
  message(paste("Build a q.set of", nrow(q.set), "items."))
        return(q.set)
}
```

Q-Methodology Figures and Tables

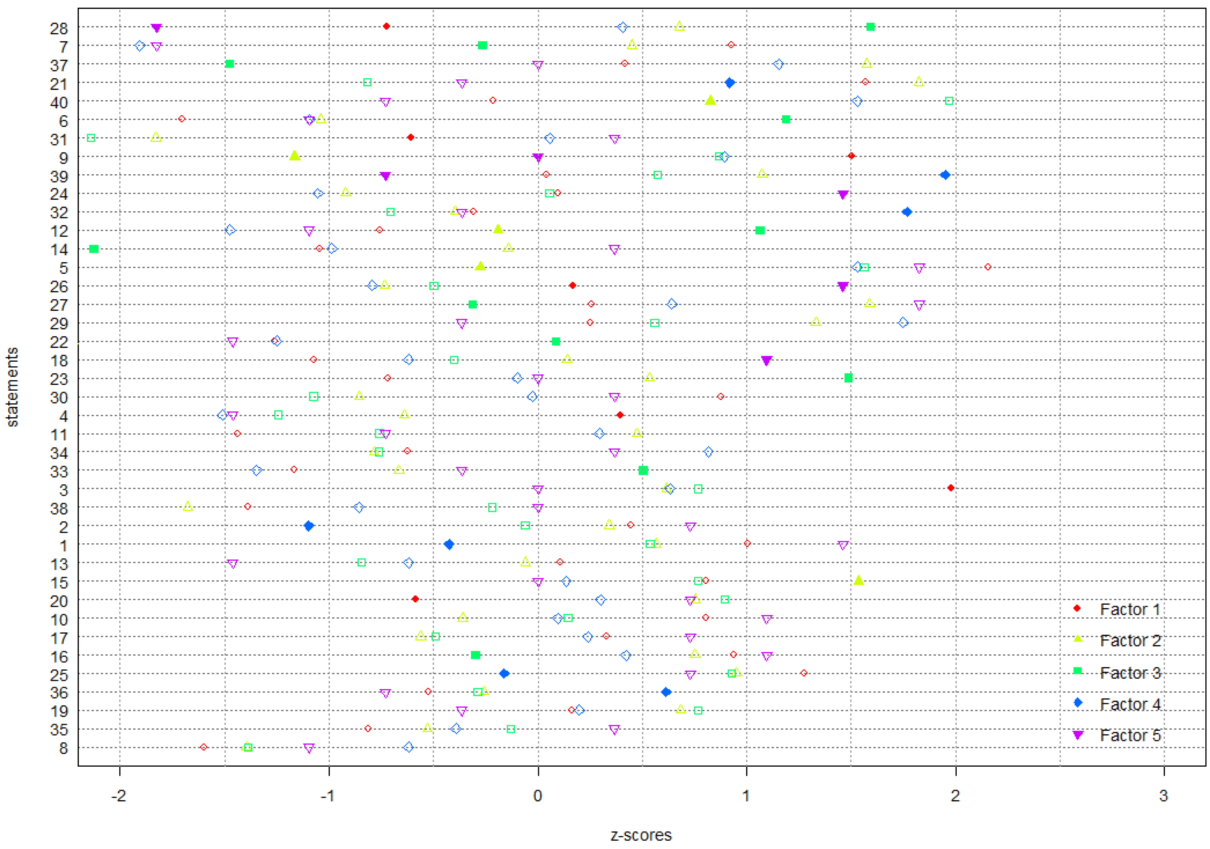

Figure 12.1: Plot of z-scores for statements (Q-set)

Q-sort values - Factor 1

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
6	11	14	12	20	13	4	2	1	9	3
8	22	18	23	31	19	17	10	7	21	5
	38	33	28	32	24	27	15	16	25	
			35	34	26	29	30			
				36	39	37				
					40					

Figure 12.2: Q-sort values for Factor 1

Q-sort values - Factor 2

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
22	8	6	4	5	2	1	16	25	15	21
31	9	24	26	10	13	3	19	39	29	27
	38	30	33	17	14	7	20	40	37	
			34	32	15	11	28			
				35	18	23				
					36					

Figure 12.3: Q-sort values for Factor 2

Q-sort values - Factor 3

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
14	4	13	11	16	2	1	3	12	5	28
31	8	21	26	17	7	10	9	20	6	40
	37	30	32	18	22	29	15	25	23	
			34	27	24	33	19			
				36	35	39				
					38					

Figure 12.4: Q-sort values for Factor 3

Q-sort values – Factor 4

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
4	12	2	8	1	10	11	3	9	5	32
7	22	6	14	13	15	16	27	21	29	39
	33	24	26	18	19	17	34	37	40	
			38	25	23	20	36			
				35	30	28				
					31					

Figure 12.5: Q-sort values for Factor 4

Q-sort values - Factor 5

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
7	4	6	11	19	3	14	2	10	1	5
28	13	8	36	21	9	30	17	16	24	27
	22	12	39	29	15	31	20	18	26	
			40	32	23	34	25			
				33	37	35				
					38					

Figure 12.6: Q-sort values for Factor 5

Table 12.1: Q-Sort factor loadings

	f1	f2	f3	f4	f5	
FAR1	0.68	-0.02	0.09	-0.05	0.17	
FAR2	0.22	0.35	0.35	-0.29	-0.30	
FAR3	0.72	0.02	0.15	0.01	0.05	
FAR4	0.56	-0.15	0.28	0.34	0.30	
FAR5	0.24	0.02	0.68	0.02	-0.17	
FAR6	0.56	0.25	0.02	0.28	0.28	
FAR7	-0.09	0.15	-0.30	0.69	0.07	
FAR8	0.29	0.12	-0.08	0.01	0.85	
FAR9	0.13	0.63	0.10	0.17	0.12	
FAR10	0.29	0.12	-0.08	0.01	0.85	
AD1	0.72	0.25	-0.12	0.24	-0.11	
AD2	0.47	0.36	0.37	0.00	0.20	
AD3	0.37	0.33	-0.17	-0.11	-0.38	
AD4	0.01	-0.11	0.65	0.12	-0.08	
AD5	-0.10	0.27	0.65	-0.04	0.12	
EO1	0.69	0.37	0.28	0.11	0.03	
EO2	0.47	0.39	-0.19	-0.01	-0.07	
EO3	0.15	0.48	0.22	-0.10	0.15	
EO4	0.23	0.69	-0.07	0.11	-0.04	
EO5	0.33	0.21	-0.06	0.50	-0.22	
IR1	0.21	0.37	0.11	0.59	0.10	
IR2	-0.12	0.36	0.55	0.06	0.07	
IR3	0.10	0.09	0.27	0.82	0.12	
IR4	0.37	0.09	0.46	0.56	-0.12	
IR5	0.57	0.33	-0.08	0.06	0.18	
PM1	0.04	0.45	-0.32	0.16	0.08	
PM2	0.01	0.74	0.31	0.25	-0.13	
PM3	0.10	0.72	0.26	0.39	-0.03	
PM4	0.39	-0.06	-0.14	0.17	0.25	
Eigen	4.4	3.7	2.9	2.8	2.2	
%Ex Var.	15	12.9	10	9.5	7.8	**55.2**

Table 12.2: Distinguished and Consensus statements

	dist.and.cons	f1_f2	sig_f1_f2	f1_f3	sig_f1_f3	f1_f4	sig_f1_f4	f1_f5	sig_f1_f5	f2_f3	sig_f2_f3	f2_f4	sig_f2_f4	f2_f5	sig_f2_f5	f3_f4	sig_f3_f4	f3_f5	sig_f3_f5	f4_f5	sig_f4_f5
Sta_1	Distinguishes f4	0.439		0.469		1.433	***	-0.455		0.0304		0.994	**	-0.894	*	0.963	**	-0.924	*	-1.8875	***
Sta_2	Distinguishes f4 only	0.106		0.509		1.545	6*	-0.283		0.4032		1.439	***	-0.389		1.036	**	-0.792		-1.8281	***
Sta_3	Distinguishes f1 only	1.361	6*	1.21	***	1.347	***	1.978	6*	-0.1503		-0.014		0.618		0.137		0.768		0.6315	
Sta_4	Distinguishes f1	1.037	***	1.638	6*	1.908	6*	1.858	6*	0.6013		0.871	**	0.821	*	0.27		0.22		-0.0505	
Sta_5	Distinguishes f2	2.432	6*	0.594	*	0.624	*	0.328		-1.8381	6*	-1.807	6*	-2.104	6*	0.031		-0.266		-0.2966	
Sta_6	Distinguishes f3	-0.665	*	-2.892	6*	-0.611	*	-0.608		-2.2268	6*	0.054		0.057		2.281	6*	2.284	6*	0.0025	
Sta_7	Distinguishes f3	0.476		1.193	***	2.834	6*	2.754	6*	0.7167	*	2.358	6*	2.277	6*	1.641	***	1.561	***	-0.0807	
Sta_8		-0.204		-0.213		-0.98	***	-0.504		-0.0085		-0.776	*	-0.3		-0.767	*	-0.291		0.476	
Sta_9	Distinguishes f1 Distinguishes f2 Distinguishes f5	2.669	6*	0.636	*	0.612	*	1.505	***	-2.0324	6*	-2.056	6*	-1.164	**	-0.024		0.868	*	0.8922	*
Sta_10		1.165	***	0.661	*	0.709	*	-0.291		-0.5038		-0.456		-1.457	***	0.048		-0.953	*	-1.0006	*
Sta_11		-1.911	6*	-0.679	*	-1.731	6*	-0.707		1.2323	***	0.179		1.204	**	-1.053	**	-0.028		1.0249	*
Sta_12	Distinguishes f2 Distinguishes f3	-0.565	*	-1.819	6*	0.719	*	0.34		-1.2542	***	1.283	***	0.905	*	2.538	6*	2.159	6*	-0.3786	
Sta_13		0.168		0.954	**	0.727	*	1.571	***	0.7853	*	0.559		1.402	***	-0.227		0.617		0.8436	*
Sta_14	Distinguishes f3	-0.901	***	1.083	***	-0.056		-1.41	***	1.9839	6*	0.845	**	-0.509		-1.139	***	-2.493	6*	-1.3541	**
Sta_15	Distinguishes f2	-0.731	**	0.041		0.671	*	0.807	*	0.7721	*	1.403	***	1.538	***	0.631		0.766		0.1354	
Sta_16	Distinguishes f3 only	0.184		1.236	***	0.516		-0.159		1.0522	***	0.332		-0.344		-0.721	*	-1.396	***	-0.6751	
Sta_17		0.887	***	0.816	**	0.087		-0.404		-0.071		-0.8	*	-1.291	***	-0.729	*	-1.22	**	-0.4913	
Sta_18	Distinguishes f5	-1.21	***	-0.668	*	-0.452		-2.167	6*	0.5424		0.758	*	-0.957	*	0.216		-1.499	***	-1.7155	***
Sta_19		-0.518	*	-0.601	*	-0.032		0.53		-0.0829		0.486		1.048	**	0.569		1.131	**	0.5624	
Sta_20	Distinguishes f1 only	-1.34	6*	-1.477	6*	-0.883	**	-1.315	***	-0.1365		0.457		0.025		0.593		0.162		-0.4315	
Sta_21	Distinguishes f4	-0.255		2.387	6*	0.651	*	1.936	6*	2.6417	6*	0.906	**	2.19	6*	-1.736	6*	-0.451		1.2844	**
Sta_22	Distinguishes f2 Distinguishes f3	0.966	***	-1.348	***	-0.011		0.2		-2.3145	6*	-0.977	**	-0.766	*	1.337	***	1.549	***	0.2116	
Sta_23	Distinguishes f3	-1.251	***	-2.203	6*	-0.618	*	-0.717		-0.9523	**	0.633	*	0.534		1.585	***	1.486	***	-0.0988	
Sta_24	Distinguishes f5	1.02	***	0.044		1.153	***	-1.363	***	-0.9761	**	0.133		-2.383	6*	1.109	**	-1.407	***	-2.5155	6*
Sta_25	Distinguishes f4 only	0.325		0.35		1.439	6*	0.547		0.025		1.113	***	0.221		1.088	**	0.196		-0.892	*
Sta_26	Distinguishes f1 Distinguishes f5	0.903	***	0.668	*	0.963	**	-1.293	***	-0.2351		0.06		-2.196	6*	0.296		-1.961	***	-2.2563	6*
Sta_27	Distinguishes f3	-1.329	6*	0.574	*	-0.382		-1.567	***	1.9036	6*	0.947	**	-0.238		-0.956	**	-2.142	6*	-1.1854	**
Sta_28	Distinguishes f1 Distinguishes f3 Distinguishes f5	-1.401	6*	-2.314	6*	-1.126	***	1.106	**	-0.9135	**	0.275		2.507	6*	1.188	***	3.42	6*	2.2321	6*
Sta_29		-1.079	***	-0.307		-1.496	6*	0.617		0.7718	*	-0.417		1.696	***	-1.189	***	0.924	*	2.1133	6*
Sta_30		1.733	6*	1.952	6*	0.904	**	0.513		0.219		-0.83	**	-1.221	**	-1.049	**	-1.44	***	-0.3909	
Sta_31	Distinguishes f1	1.223	***	1.538	6*	-0.661	*	-0.97	**	0.3144		-1.885	6*	-2.194	6*	-2.199	6*	-2.508	6*	-0.3088	
Sta_32	Distinguishes f4 only	0.089		0.399		-2.075	6*	0.059		0.3097		-2.164	6*	-0.03		-2.474	6*	-0.34		2.1342	6*
Sta_33	Distinguishes f3	-0.498		-1.668	6*	0.184		-0.799	*	-1.1702	***	0.682	*	-0.301		1.852	6*	0.87	*	-0.9829	*
Sta_34		0.162		0.14		-1.438	6*	-0.987	**	-0.0223		-1.6	6*	-1.149	**	-1.578	***	-1.126	**	0.4512	
Sta_35		-0.281		-0.678	*	-0.417		-1.175	**	-0.3972		-0.136		-0.894	*	0.261		-0.497		-0.7579	
Sta_36	Distinguishes f4 only	-0.267		-0.238		-1.14	***	0.206		0.0292		-0.873	**	0.473		-0.902	**	0.443		1.3453	**
Sta_37	Distinguishes f3	-1.155	***	1.896	6*	-0.732	*	0.42		3.0508	6*	0.423		1.575	***	-2.628	6*	-1.476	***	1.1522	**
Sta_38		0.289		-1.167	***	-0.53		-1.386	***	-1.4564	***	-0.819	**	-1.676	***	0.637		-0.219		-0.8566	*
Sta_39	Distinguishes f4 Distinguishes f5	-1.033	***	-0.533		-1.911	6*	0.771	*	0.4998		-0.877	**	1.805	***	-1.377	***	1.305	**	2.682	6*
Sta_40	Distinguishes f2	-1.042	***	-2.184	6*	-1.745	6*	0.516		-1.1425	***	-0.703	*	1.557	***	0.439		2.7	6*	2.2603	6*