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Perceptions and Climate Adaptation: Case Study of Agroecology in Crete

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1. Introduction

1.1. Background

Climate change is already having substantial impacts on our world. Increased temperatures, decreased water availability, and more frequent and unpredictable extreme weather events are just a few of the multitude of impacts that will continue to occur globally. The Mediterranean region in particular is already experiencing climate change at a higher rate than the global average; as one of the world's biodiversity hotspots, this is particularly troubling.

Agriculture is exceptionally important to society due to it providing food sustenance for a growing global population. At the same time, agriculture is especially vulnerable to climate change. It is predicted that increasing temperatures will change the duration of growing seasons as well as geographic suitability for crops; extreme weather events will cause crops, especially those under monoculture cultivation, to be more susceptible to pests and diseases and thus vulnerable to large-scale failure; and decreasing water availability will make it more difficult for crops to grow, impacting the quantity and quality of yields.

While climate change imposes significant threats, the industrialisation of agriculture has also implicated itself by engaging in environmentally-intensive practices, as it has systematically depleted on a mass scale the very resources it requires to remain viable in the future. The primary objective of conventional agriculture, maximisation of production, has undoubtedly led to the exploitation of resources as well as numerous negative externalities. Practices such as monoculture, intensive tillage, and widespread use of chemical agricultural products have resulted in reduced soil quality, reduction of biodiversity, and increased risk of crop failure (Gliessman, 2015).

As a result of these and other industrial practices, which are compounded by climate change impacts, the future viability of agriculture is compromised; thus, alternative approaches are needed. Agriculture's function of providing food to society is essential, and changes to the system have far-reaching socio-economic impacts. While conventional agriculture is a primary driver of anthropogenic climate change, it is also highly dependent on climate and consequently

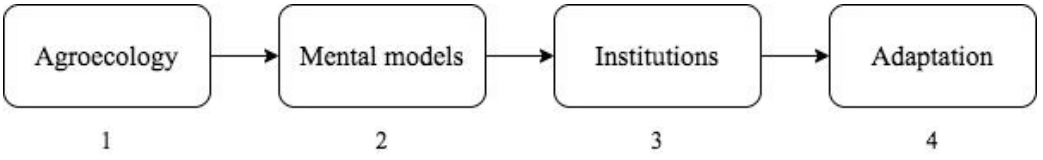
susceptible to peterbations. Therefore, finding sustainable adaptation options for agriculture is necessary.

Agroecology is one of these sustainable adaptation options. Agroecology is an alternative form of agriculture that aims to optimise ecological processes and ecosystem services within agricultural ecosystems. Agroecology employs practices from several other approaches to sustainable agriculture, e.g. biodynamic and organic soil management practices, as well as agroforestry. Overall, agroecology aims to emulate natural ecosystems, focusing particularly on diversification as a means of both enhancing production, environmental conditions, and farmer livelihoods.

It is for these reasons that agroecology is being considered here as a viable option for climate change adaptation. Adaptation in this context is defined as a modification that is made in response to or in preparation for climatic changes or their associated impacts. Adaptation will need to occur at both the individual and collective levels. The impacts of climate change are so vast both spatially and temporally, that individual actions will not be sufficient to fully progress towards a viable future, highlighting the importance of people working together in groups on many scales. To this end, the field of institutional economics has shown that institutions are crucial for establishing shared rules and norms for the goal of optimising the collective benefits of the group.

At the same time, institutions are based on shared experiences and beliefs, also known as mental models. Mental models are formulated over time and based on individual experiences and perceptions. To understand why people take certain actions and not others, it is important to understand how they perceive problems and estimate risk and uncertainty. Therefore, in the context of climate change adaptation, comprehending the influence of mental models on adaptation-relevant behavior is crucial.

Figure 1: Conceptual framework



1.2. Problem statement

Because climate change will have significant impacts on agriculture, alternative cultivation methods will be required for adaptation. The extent to which adaptation is undertaken is in part determined by one's individual perceptions of how the world operates, also known as mental models. Research in the field of institutional economics, among other disciplines, has found that cognitive barriers often prevent comprehension and subsequent action related to climate adaptation. However, less is known about how perceptions can facilitate climate adaptation.

An improved understanding of the connection between mental models and adaptation-relevant behavior could help to inform better policy creation to reduce vulnerabilities to climate change impacts. An individual's perceptions are important indicators for actions. Therefore, understanding which worldviews are more conducive to adaptation than others could offer additional insights into how to better educate and prepare populations for climatic changes.

The aim of this study is to investigate mental models and adaptation-relevant behavior among agroecological farmers in Crete. Qualitative methods were used to understand which mental models related to agroecology lead to particular actions that reduce vulnerabilities to climate change impacts. This data will be situated within the context of recent literature on mental models as well as the local conditions of the study.

1.3. State of the art

Adaptation to climate change is defined by the International Panel on Climate Change (IPCC) as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (2012, p. 36). The extent to which adaptation is able to occur, known as adaptive capacity, is based on both biophysical and socio-economic drivers of vulnerability, or the predisposition to be negatively affected (IPCC, 2014). Adaptation can be inhibited by what are known as limits and barriers in the climate change literature. They are differentiated from each other insofar as limits are absolute obstacles which cannot be overcome, while barriers are malleable obstacles which can hypothetically be surmounted (Moser & Ekstrom,

2010). Barriers can include contextual barriers, in which the conditions of the location (e.g. biophysical, political, institutional, economic, and cultural characteristics) dictate the extent to which adaptation is able to occur. Barriers also include an individual's barriers to adaptation, which are known as cognitive or psychological barriers to assessing risk. These barriers consist of ways in which people incorrectly rationalize the extent to which climate change will affect them (risk appraisal) and their perceived abilities to deal with change (adaptation appraisal) (Grothman & Patt, 2005).

While there is a wealth of literature about cognitive barriers to adaptation, less is known about how individual perceptions can help to facilitate climate adaptation. If climate change adaptation is to be more widely adopted and implemented, it is important to understand not only what impedes adaptation, but also ways of thinking that encourage it. Perceptions about climate change have been widely addressed by scholars (Weber, 2010; O'Connor et al., 1999). More specifically, these interpretations or worldviews can be understood in terms of mental models, which are internal constructions, explanations, and assumptions about how the world operates. Mental models have been examined in the literature within different disciplines and levels of complexity (Genter and Stevens, 2014; Johnson-Laird, 1989). The mental models concept has been applied to climate change more sparingly, but still provides an adequate foundation, with scholars finding that mental models are important indicators for understanding risks associated with climate change (Bostrom et al., 1994; Sterman, 2011).

For the purposes of this paper, the relationship between mental models and climate adaptation will be explored in the context of agroecology. Agroecology has gained more exposure in recent years, particularly from the Food and Agriculture Organization of the United Nations (FAO), as a potential strategy for addressing climate change vulnerabilities through their food security, nutrition and rural poverty programs. The FAO began facilitating symposiums and other related gatherings in 2014 to bring together stakeholders relevant to building more sustainable food systems (FAO, 2020). These international dialogue efforts have been supported by scholarly research dating back to the

seminal works of Altieri (1995) and Gliessman (1998); however it should be noted that agroecology gives significant credence to traditional and indigenous agricultural practices, which undoubtedly originate much earlier. More recent literature has begun to link agroecology to climate change, finding that the central premise of modeling agricultural ecosystems after natural ecosystems via e.g. diversification, inherently reduces vulnerabilities to climate change, among other benefits (Altieri et al., 2015).

1.4. Research question

This research will explore the relationship between the concepts of climate adaptation, mental models, and agroecology. Ultimately, the aim is to understand if agroecology, and it's associated mental models, can be a viable form of climate change adaptation in the future. This leads to the research question: Does agroecology lead to climate adaptation?

1.5. Summary and structure of the thesis

This section aimed to provide a foundation for the concepts that will be explored in this paper. To summarize, adaptation in the agricultural sector is imperative for it to persist in the face of climate change. Individuals' mental models have been found to be important indicators for action connected with adaptation. Agroecology represents a sustainable alternative to conventional agriculture and potential adaptation approach. This paper thus endeavors to examine if agroecology and its related mental models can lead to adaptation-relevant behavior.

The rest of this thesis will be presented as follows. Section 2 introduces the theoretical framework that will be introduced, examining in-depth the literature on the concepts of climate adaptation, mental models, and agroecology. In Section 3, the materials and methods will be exhibited, illustrating the case study method as well as the data collection and analysis approaches that were employed. In Section 4, the case description will be provided in an effort to contextualize the forthcoming empirical evidence. In Section 5, the results of the study will be described. Lastly, Section 6 presents a discussion of the results and their implications for research and policy will be put forth.

2. Theoretical Framework

2.1. Objectives of this chapter

The objective of this chapter is to outline the theoretical foundation of this paper. First, the concepts of climate adaptation and institutions are introduced, followed by the theory behind perceptions and mental models. Next, agroecology as a discipline is explained. Finally, a review of the state of the art on these ideas is described, leading to the general proposition of the paper.

2.2. Concepts and general proposition

2.2.1. Climate adaptation

Adaptation to climate change impacts will be required for society to remain viable in the future. Smit and Pilifosova define climate adaptation as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts" (2003, p. 879). The purpose of undertaking adaptation then is to reduce the vulnerabilities of people and also proactively minimize costs of the impacts (Grothmann and Patt, 2005; Pielke, 1998). Alternatively, it can also refer to efforts to take advantage of climate change impacts for beneficial purposes. Adaptation is highly dependent on the ability of the ecological, social, and economic context of a place to handle changes to its systems and is thus quite variable geographically; this is referred to as adaptive capacity (Smit and Pilifosova, 2003). It is crucial then, for adaptive capacity to be enhanced in an effort to reduce vulnerabilities to climate change impacts.

2.2.2. Institutions

Because the impacts of climate change will impact the availability and accessibility of public good resources and affect systems and people on numerous scales, resources will need to be managed. This management of resources cannot be done by individuals in isolation, but rather collective action will be essential for effective adaptation. Moreover, the roles of interdependent resource users will need to be renegotiated. Indeed, Adger argues that societies have "inherent capacities to adapt to climate change" that are "bound up in their ability to act collectively" (Adger, 2003, p. 327).

For these reasons, the role of institutions is critical for adaptation. Institutions are defined as the "rules of the game of a society and consist of formal and informal constraints constructed to order interpersonal relationships" (Denzau & North, 2000, p. 4). As such, they can perform several functions. First, they can set rules to define and enforce rights or limits to resources (Bromley, 2006). Second, due to their formation based on shared values and beliefs, they can be used to perpetuate these existing beliefs or attempt to shape new beliefs (Ostrom et al., 1992; Knight & North, 1997). These roles of institutions make institutional economics well-suited for examining the nexus between the social complexity of managing natural resources with the economic issues of distribution and allocation (Roggero, 2015; North, 1991).

Since climate adaptation is a collective endeavor, institutions can therefore shape climate adaptation. Scholars have approached the connections between institutions and adaptation in numerous ways. Pahl-Wostl (2009) developed a framework for the analysis of governance in the context of resource management, and particularly on the role of formal and informal institutions in these regimes, finding that informal networks are particularly important to societal learning processes. In addition, Urwin & Jordan (2008) explore the institutions and networks involved with both top-down and bottom-up approaches to climate policy integration, while Adger (2003) focuses on the role of social capital in building adaptive capacity, specifically in terms of trust and reciprocity.

2.2.3. Perceptions and mental models

Before they can be used for addressing collective action issues, however, institutions are first formed by people's perceptions of the world around them. Conventional economic theory assumes that people act rationally and make decisions that optimize their well-being (Denzau & North, 2000). However, in reality, often decisions are rather made through beliefs and ideologies (Knight & North, 1997). Vatn (2005) also asserts that decision-making depends on values, which vary between societies.

Over the course of history, humans have often constructed narratives (e.g. myths, religions) to rationalize how the world operates. These beliefs are formed

by how individuals have learned from their environment (e.g. culture, experiences, socio-economic attributes) over time, eventually forming patterns of learning that are stored as memory (Rouse & Morris, 1986). Perpetually updating as new information is received, these patterns then continue to inform future interpretations of the environment (Denzau & North, 2000). In this way, they are used as a heuristic by pulling the most important features of the model to inform decision-making in the present (Converse et al., 1993).

These patterns of interpretation can be understood in terms of mental models. The concept of mental models transcends several disciplines in the social sciences and has particularly become relevant to the management of natural resources (Jones, 2011; Halbrendt, 2014; Armitage, 2003; Kellert et al., 2000). In this paper, mental models will be viewed through the lens of institutional economics. As such, mental models are defined by Denzau & North (2000) as "internal representations that individual cognitive systems create to interpret the environment." As it would be impossible for humans to fully understand completely how all the world's systems operate, models simplify and act as a framework of these real-life systems. Since people perceive their environment in different ways, contrasting cognitive interpretations are formulated as mental models. Conversely, people with similar backgrounds will thus share more homogenous mental models. It is through these shared mental models that institutions can then be formed (Denzau & North, 2000). It can be fathomed, then, that due to their importance in forming institutions, that mental models are also crucial for climate adaptation.

More recently, scholars have written on the role of perceptions and cognition particularly as it relates to climate adaptation. In this respect, Grothmann & Patt (2005) identify two primary cognitive factors of perceived risk perception and perceived adaptive capacity. Perceived risk perception refers to the informal cost-benefit analysis of how severely an actor would be affected by climate change impacts. Perceived adaptive capacity refers to the belief of the actor if they can handle those impacts (Grothmann & Patt, 2005). Often, these perceived risks and capacities are under-estimated. Since mental models are simplified

representations of reality, they can lead to predictable errors (Tversky & Kahneman, 1974; Bazerman, 2006).

These errors in decision-making are also known as cognitive or psychological barriers. Cognitive barriers or psychological barriers refer to psychological processes that cause errors in decision-making, and can thus limit climate-related action. There are a multitude of cognitive barriers as they relate to climate adaptation (Gifford, 2011); here the focus will be on three outlined by Shu & Bazerman (2010).

First, discounting the future is a common decision-making error whereby short-term considerations are given higher priority than those that are in the future, despite a potential for cost savings or improved well-being in the long-term (Loewenstein & Thaler, 1989). Discounting often occurs when the future seems distant and uncertain, as well as when distribution of resources over several generations is involved (Wade-Benzoni, 1999). As an example, it can be easily seen in the over-depletion of common-pool resources (e.g. freshwater supplies) at the expense of them being less-available in the future.

A second common decision-making error is having positive illusions about the future. Taylor & Brown (1989) found that people tend to view themselves and the world more positively than is actually true in reality. Two primary types of positive illusions come under the categories of the illusion of control as well as unrealistic optimism. These cognitive errors can in fact be detrimental to decision-making in regards to the quality as well as the timing (Bazerman, 2006). Moreover, they can limit action in regards to climate change adaptation.

As a third cognitive barrier, egocentrism refers to a bias that benefits the individual by way of diverting blame away from oneself (Messick & Sentis, 1983; Babcock & Loewenstein, 1997). When approaching a decision, people tend to already be subconsciously predisposed to one option, then attempt to justify this proclivity by making an argument about fairness. But in reality, this justification is biased toward the individual rather than the collective. Moreover, uncertainty can lead to further obscurity of the issue at hand. This can be seen in the reaction to climate change that humans are not responsible (Shu & Bazerman, 2010).

Undoubtedly, the highly uncertain nature of climate change allows for cognitive difficulties in processing information and making decisions. It has thus been made clear in the literature that people's perceptions (i.e. mental models) can inhibit adaptation through the aforementioned cognitive barriers. In contrast, the literature is more limited in terms of how mental models can shape, rather than limit, adaptation-relevant behavior. This allows for further specification of the research question: can mental models act in a way that foster adaptation rather than hinder? The field of agroecology will herein be examined in an attempt to answer this question.

2.2.4. Agroecology

2.2.4.1. What is agroecology?

The roots of agroecology reach back to the beginning of agriculture, as its principles draw on traditional and indigenous agrarian practices. In this way, the contemporary terminology, which emerged in the 1970s, refers to a recent rediscovery of these practices by modern science. Agroecology also draws upon the disciplines of agricultural sciences, environmentalism, ecology, indigenous production systems, and development studies (Hecht, 2018). Owing to this interdisciplinarity as a field and its evolution over time, agroecology can be defined in different ways and with similar terminology (e.g. biodiversity-based farming systems, diversified farming systems, ecoagriculture, permaculture) (Rega et al., 2018). For the purposes of this paper, agroecology is defined as an integrated approach to agriculture and food systems that "seeks to optimize the interactions between plants, animals, humans and the environment while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system" (FAO, 2018, p. 1). The emphasis here is specifically on this optimisation of ecological processes and on the use of ecosystem services. Disciplinarily, its components have recently been outlined as a science, a practice, and a movement. The science component refers to the study and understanding of agricultural ecosystems; the practice component refers to the application of this knowledge by farmers to cultivate in sustainable ways; and the movement component refers to the social aims of agroecology to focus on

the welfare of the farmer and the viability of the food system as a whole (Gliessman, 2015).

2.2.4.2. Agroecology in the scope of this paper

The FAO has outlined 10 Elements of Agroecology to guide a common understanding of these vast topics. This paper will narrow this framework into two categories with five themes, as outlined in Table 1. Four primary adjustments were made to this framework to better fit the research. First, the theme "common characteristics of agroecological systems, foundational practices, and innovation approaches" was simplified to "environmental characteristics." This conceptualisation is in line with how the FAO has divided climate change impacts on agriculture (biophysical and socio-economic impacts) (FAO, 2007). Second, the overarching categories of "environmental characteristics of systems" and "social context features" were chosen as focal points. The category of "enabling environment" which includes the themes of "responsible governance" and "circular and solidarity economy", while relevant and important, was deemed to be beyond the scope of this paper. Third, "synergies", "efficiency", and "recycling" were combined into one theme due to substantial overlap between these concepts in the context of this research. Fourth, "co-creation and sharing of knowledge" was moved into the category of "social context features" due to its focus on social rather than environmental topics. The following section will elucidate the meaning of each of these themes.

Table 1: FAO's 10 Elements of Agroecology and selected themes for this paper

FAO's 10 Elements of Agroecology	**Agroecology themes in this paper**
Common characteristics of agroecological systems, foundational practices, and innovation approaches	*Environmental characteristics*
Diversity	Diversity
Synergies	Synergies, efficiencies, recycling
Efficiency	
Resilience	
Recycling	
Co-creation and sharing of knowledge	
Context features	*Social context features*
Human and social values	Human and social values
Culture and food traditions	Culture and food traditions

Enabling environment	Co-creation and sharing of knowledge
Responsible governance	
Circular and solidarity economy	

2.2.4.3. Environmental characteristics of systems

2.2.4.3.1. Diversity

Diversity in agroecology is primarily defined by employing biodiversity in cultivation. Biodiversity in agriculture provides multiple benefits to the farmer and the environment. First, biodiversity helps to promote the functioning of ecosystem services, for example the quality of the soil and pollination. It can also increase the efficiency of biomass and water harvesting, thus helping to optimise resource use (FAO, 2018). The genetic diversity of local varieties also makes them better-suited to the local environment and have more potential for future adaptation.

Diversification can go beyond biodiversity, however. Crop-livestock systems optimize mutual benefits between plants and animals that are adapted to local environments. Spatial diversification is practiced through intercropping, which involves the pairing of certain crops to be planted near each other so that they can benefit each other nutritionally. Lastly, temporal diversity is employed through the practice of crop rotation, which often helps to improve quality of the soil between seasons (FAO, 2018).

Diversification can also have socio-economic benefits for the farmer. By having a variety of products for sale, this helps to ensure financial stability in the case of crop failure due to pests, diseases, or extreme weather events. (FAO, 2018)

2.2.4.3.2. Synergies, recycling, and efficiency

Synergies, recycling, and efficiency are presented as separate themes by the FAO, but due to significant overlap, I have grouped them together for the purposes of this paper. These concepts are based on the premise that “waste is a human concept - it does not exist in natural ecosystems” (FAO, 2018, p. 7). Agroecology thus tries to emulate these natural ecosystems to optimise resource use. Synergies in agroecology refer to the deliberate selection of certain ecosystem elements to work together in an effort to optimise biological and ecological processes.

There are several examples of ways in which this can be achieved. For example, planting legumes as part of a crop rotation not only provides an additional income source for the farmer, but also improves the health of the soil and reduces fertilizer due to the nitrogen fixation that occurs (FAO, 2018). Moreover, the concept of Land Equivalent Ratios has been used to demonstrate that the practice of intercropping in agroecological systems consistently leads to higher yields than individually-grown crops (Mead & Willey, 1980). In addition, 51% of the economic value of non-provisioning ecosystem services can be contributed to nutrient cycling (FAO, 2017). As an example, crop-livestock systems allow for the recycling of manure to be used as fertilizer. Recycling of water and biomass can also occur, for example the process of leaving plant debris on the ground to complete their life cycle allows for the decomposed plants to fertilize the soil and retain soil moisture. As a result of these processes, resources are used more efficiently thus reducing overall consumption, costs, and dependence on external inputs, allowing for greater independence and reduced vulnerability for the farmer (FAO, 2018).

2.2.4.4. Social context features

2.2.4.4.1. Co-creation and sharing of knowledge

Agroecology emphasizes that knowledge is localized and thus the practices employed will vary by location and depending on the context. It is advocated that this knowledge be integrated with the practical knowledge of farmers as well as modern science. Even more so, local, traditional, and indigenous knowledge plays an important role in knowledge creation, particularly in the understanding of the local biodiversity and also local institutions. As an extension of this, participatory processes are encouraged. The open sharing of this co-created knowledge is also a major facet of agroecology. Altogether, this "decentralized, locally-developed agronomic knowledge is central to the continuing performance of these production systems" (Hecht, 2018, p. 1). The *campesino* movement in Latin America is the quintessential example of horizontal, rather than top-down, knowledge-sharing through farmer networks (Holt-Giménez, 2006).

2.2.4.4.2. Human and social values

The principal human and social values that are espoused by agroecology are "dignity, equity, inclusion, and justice" (FAO, 2018). Agroecology focuses especially on producers and their well-being, rather than on farming as a means to an end of commodification. It also centers on the role of the farmer in the food system as providing healthful sustenance for the community. By employing principles of organic farming, agroecology promotes both nutrition and consideration for the environment. Sharing both knowledge and resources within the community is another practice that echoes the values of equity and inclusion. The value of justice is illustrated through campaigns for food sovereignty and the right to food (FAO, 2018).

2.2.4.4.3. Culture and food traditions

The fifth theme of focus in this paper is culture and food traditions. It is well-known that culture is shaped by historical events and geography. Looking to the past, we find that culture and food traditions are also derived from the environmental landscape in which they originate. Due to their highly-localized nature, crops that were specifically-suited to certain climate zones thus bore culinary traditions that reflect that environment. Often, these traditions reflect rich biodiversity as well as traditional knowledge about cultivation practices. The modern food system, however, due to the industrialization of agriculture and global trade, has led to a general lack of understanding about where and how food is produced. Looking to the future, culture and traditions provide additional motivation for people to reconnect to their landscapes through the cultivation and preparation of traditional foods (FAO, 2018).

2.2.4.5. Mental models: conventional agriculture vs. agroecology

It may already be apparent that the practices of agroecology described above contrast significantly with modern industrial agriculture. In terms of the mental models related to conventional agriculture, Norgaard & Sikor (2018) differentiate it from agroecology by asserting the philosophical premises of the two approaches. They assert that conventional agriculture subscribes to the "dominant premises of modern science" while agroecology falls under "alternative premises" (Norgaard & Sikor, 2018, p. 21; see Table 2). The first

premise of atomism refers to the notion that agriculture can be understood separately from its social and environmental context. Moreover, the discipline is divided into many sub-disciplines and rarely understood in terms of how they work together. The second premise of mechanism refers to the notion that the parts of the system remain stable over time. The third premise of universalism refers to the notion that complex systems can be deduced to simple scientific laws. The fourth premise of objectivism implies that it is possible to understand problems without bias. The fifth premise of monism refers to the notion that our diverse conceptualisations are coming closer to a common understanding (ibid.). Altogether, these premises form what can be understood as the mental models behind conventional agriculture.

Table 2: "Dominant premises of modern science and alternatives" applied to conventional agriculture and agroecology (Norgaard & Sikor, 2018, p. 23)

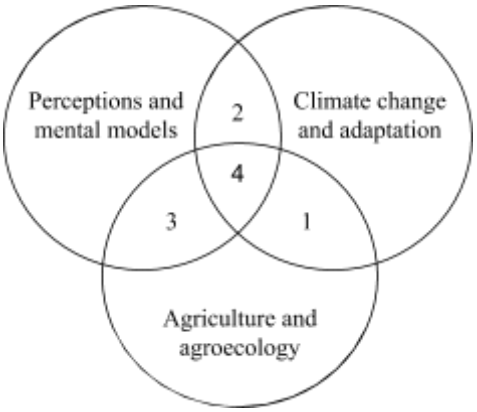
Dominant premises (conventional agriculture)	**Alternative premises (agroecology)**
Atomism	Holism
Mechanism	
Universalism	Contextualism
Objectivism	Subjectivism
Monism	Pluralism

Agroecology is thus proposed as an alternative. Philosophically, holism is first put forth as the alternative to atomism, meaning that the "parts cannot be understood apart from their wholes and wholes are different from the sum of their parts" (Norgaard & Sikor, 2018, p. 23). Second, in contrast to universalism, the notion of contextualism highlights the impacts of local conditions on the same phenomenon. Third, subjectivism differs from objectivism by acknowledging the inherent bias that all people bring to situations. Fourth, pluralism is offered as the alternative to monism in that systems can be understood in many different ways (ibid.). Altogether these premises form what can be understood as the mental models that inform agroecology.

2.3. State of the art on concepts and general proposition

The relationships between climate change and adaptation, perceptions and mental models, and agriculture and agroecology have been approached in the literature in different combinations. This diagram illustrates these combinations with the respective sections numbered. The center of the diagram indicates the effort of this paper to examine all of these concepts; accordingly, the general proposition is addressed in section four.

Figure 2: Connections between concepts in the literature



2.3.1. Climate adaptation and agroecology

In regards to climate adaptation, agroecological practices are particularly better-suited to deal with environmental changes than conventional agriculture. A comprehensive literature review of agroecology research presented to the United Nations Human Rights Council in 2011 found that a transition to agroecological systems can not only mitigate climate change impacts, but also has the potential to double food production in ten years, helping to reduce rural poverty and increase food security (De Schutter, 2011).

Altieri (2015) contends that diversification in agroecological systems is the defining factor that differentiates it from conventional agricultural systems and helps to reduce vulnerabilities to climate change impacts. Diversification can be categorized in two ways: functional diversity, which refers to the biodiversity of a system; and response diversity, which refers to the variety of reactions to changes in the environment from species that offer the same function in an

ecosystem (Loreau et al., 2001; Cabell & Oelofse, 2012). It is the latter, response diversity, that would help an agroecosystem be less vulnerable to shocks to the system. This is due to the fact a rich ecosystem has levels of redundancy built into it by multiple organisms performing similar functions. Therefore, if a shock to the system damages one species, another similar one can still carry out the necessary functions that would allow the ecosystem to persist and adapt to the changes (Altieri, 2015; Lin, 2011). As previously stated, this helps to reduce the vulnerability of the crop to failure due to pests, diseases, or unpredictable and extreme climatic changes. This is particularly important as these incidences are expected to increase in the face of climate change.

Scholars have found many examples of agroecology reducing vulnerabilities through diversification. For example, a case study in China found that the utilization of several different rice varieties experienced less disease incidence and higher yields than monoculture fields (Zhu et al., 2000). Moreover, a case study in Kenya found that certain crops can be used in combination to create a push-pull effect to simultaneously manage pests (Kahn et al., 1998). In addition, a comparative study in Bolivia, China, and Kenya found that the cultivation of multiple traditional varieties as well as seed-saving practices contributed to adaptation of farmers (Swiderska, 2011).

Beyond diversification, agroecological practices can contribute to reducing vulnerability to climate variability in other ways. Organic soil management and water conservation and harvesting are two primary ways in which this can be carried out. Managing and enhancing soil organic matter is important not only for having biologically- and texturally-productive soil, but also for improving the capacity for water retention. This is particularly important for improving a crop's tolerance to drought, as well as resisting erosion due to extreme weather events (Magdoff & Weil, 2004; Altieri, 2015). Moreover, soil organic matter can be improved through green manures and cover crop mulching. A study in Honduras found that these practices not only doubled corn yields, but also reduced weed growth and erosion, and in turn reduced costs to the farmer (Milton, 1989). In addition, the precarious nature of the future of water availability makes water conservation and harvesting crucial. Zougmore et al.

(2004) reports the use of a system in Mali and Burkina Faso that involves the digging of pits in the ground, filling them with manure, capturing the rainfall, then planting sorghum and millet directly in the pits. This allows for the efficient use of both manure and water and allows for higher yields (Reij, 1991).

In conclusion, there are an abundance of ways in which agroecological practices can be employed to reduce vulnerabilities to climate change, of which only a selection is presented here. An analysis of 60 case studies over 15 years of sustainability assessments of small-holder farmers in Latin America has also echoed many of these findings (Astier et al., 2012).

2.3.2. Mental models and adaptation

Mental model research has been approached in a range of different ways using both qualitative and quantitative analysis. Qualitative analysis of mental models has relied more on interview material and thematic analysis. For example, a "mental models approach" was developed by Morgan et al. (2002) in writing about risk perception, in which the aim of the method is to determine knowledge gaps by comparing expert knowledge to public knowledge via qualitative interviews. In contrast, analysis of mental models can be more technical, involving the mapping of the models as well as modelling itself. This literature review will focus more on qualitative methods as that was what was employed for this research.

Research on perceptions about climate change is particularly varied for several reasons. First, due to the vastness, uncertainty, and complexity of climate change, people generally have a more difficulty expressing their thoughts about it (Ungar, 2000). Moreover, data collection and analysis varies between studies, such as by the content of the question, the geographical context, as well as the socio-political context at the time of data collection, which has the potential to over- or under-emphasize certain issues (Lorenzoni & Pidgeon, 2006; Kasperson, 2005).

Several authors have explored the connection between mental models or perceptions and climate change. Lorenzoni & Pidgeon (2006) put forth an extensive literature review of studies that compare viewpoints on climate change between Europe and the United States. Bostrom (1994) used qualitative,

open-ended interviews and a questionnaire to gauge public understanding of climate change. The term "mental model" was used prominently but not explicitly defined, however, thus employing a more general use of the term. The use of open-ended interviews was employed to explore the mental models of the participants and drew on prior research from cognitive anthropologists such as Kempton (1997), who proposed the concept of cultural models, referring essentially to shared mental models that a culture has in common.

Turning the focus toward climate adaptation, Otto-Banaszak et al. (2010) conducted interviews with climate change adaptation experts across various industries and disciplines in Europe. Employing a thematic analysis, the authors found that depending on the field in which the expert worked, there were different mental models exhibited and thus different interpretations of which prescriptive adaptation measures should be employed (Otto-Banaszak et al., 2010).

Coming closer to the focus of this paper, some scholars have focused specifically on farmers' perceptions of climate change and adaptation. Jacobi et al. (2013) employed focus groups, workshops, and semi-structured interviews in Bolivia in combination with environmental data to inform resilience indicators. Chalise et al. (2015) investigated the views of farmers on adaptation in Nepal by conducting three case studies, and gathered data through a questionnaire and the facilitation of focus groups. Additionally, Gbetibouo (2009) combined a quantitative analysis of environmental conditions with a household survey of farmers in South Africa to determine factors for adaptive capacity.

2.3.3. Agroecology and mental models

The literature on perceptions and mental models related to agroecology is more limited, but there are still a few relevant examples thus far. Rivera-Ferre (2018) conducted a lexicometric analysis of policy related to agroecology and found competing narratives on which elements of agroecology should be emphasized and at which scales. This confirms the earlier assertion that agroecology's breadth necessitates focusing on some elements more than others, as this case study does. Blesh & Wolf (2014) explored motivations of farmers to transition to agroecological farming methods in the United States, and what resources they

operationalized to begin the transition, using qualitative interviews and participant observation. The study highlights the complexity of any system change, which is also applicable to understanding climate change adaptation. Saillou (2017) conducted semi-structured and open-ended interviews with French farmers to understand their mental models about the agroecological practice of using insects and pests as a biological control measure. Considering resources as social constructions allowed for an exploration of how resources can be perceived in different ways by stakeholders. Finally, Van Hulst et al. (2020) comparing expert and farmer perceptions of agroecology in Scotland by using a cognitive mapping approach, found that farmers were less familiar with the term despite still employing some of its practices. The researchers declared a need for further explicating the connections between agroecology's practices and its multiple benefits, which is what this case study aims to accomplish.

2.3.4. General proposition: mental models, adaptation, and agroecology

As illustrated above, there have been numerous pertinent studies related to the concepts that this research aims to address. First, agroecology has shown promise as a form of climate adaptation in agriculture due to its focus on diversification, which helps to reduce vulnerabilities. Second, mental models have been shown to be relevant to adaptation primarily in terms of their influence on inhibiting adaptation-relevant behavior through cognitive barriers. Third, perceptions and mental models related to agroecology have shown how these perceptions can lead to certain agricultural actions.

The aim of this paper, then, is to relate mental models about agroecology to climate change adaptation, which has not been specifically addressed in the literature thus far. We know that mental models can influence decisions in how to adapt, and agroecology is an approach for implementing adaptation. This then leads to the proposition: Do mental models associated with agroecology lead to adaptation-relevant practices?

2.4. Summary

In summary, this paper is informed by existing theory and literature about mental models and agroecology as they relate to climate adaptation. Mental models are important for climate adaptation as they are the basis for taking

particular courses of action. The case of agroecology is thus examined here as an approach to adaptation not only through the use of certain adaptation-relevant practices, but also through the perceptions that inform those practices. This section has therefore provided the theoretical framework for the forthcoming empirical analysis.

3. Materials and Methods

3.1. Objectives of this chapter

The objective of this chapter is to lay out the methodological approach to this paper. First, the theoretical foundations for the case study method, followed by methods for qualitative interviewing and participant observation, are described. Second, the operationalization of the construct is outlined, followed by the strategy for analysis.

3.2. The Case Study Method

A case study is a type of qualitative research method for studying complex, modern phenomena in their real-life setting. It is useful for studying phenomena that are closely related to their surroundings, making the gathering of contextual evidence imperative for analysis. Moreover, it employs multiple sources of data as a means of triangulation and validation (Yin, 2003). Consequently, the resulting empirical evidence can provide a more authentic and nuanced representation of the phenomenon of interest (Bhattacherjee, 2012). The case study method was therefore chosen for this research because the issue is contemporary in nature and the context is necessary for understanding the phenomena at stake. Moreover, since case studies attempt to "illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (Schramm, 1971 in Yin, 2003, p. 17), it is suitable for this research in particular as it attempts to determine a connection between beliefs and the decision to act on those beliefs.

The case study method is an iterative and interpretive method that can be used for theory building, as additional points of interest often tend to emerge from the data while it is being collected. As a result, the research question can change over time if more relevant issues arise during the research process (Bhattacherjee, 2012). Due to its in-depth nature, relationships and insights that may otherwise remain hidden with other less-immersive research methods may be illuminated (Creswell, 2014).

A single-case design was chosen as the research design for this study. Since the connections between climate adaptation, mental models, and agroecology is not yet clear, a single-case design allows for the high degree of contextualization of

the data in order to ascertain a nuanced understanding of the results (Yin, 2003). As is common with qualitative research, the case was selected purposefully rather than representatively. Although the case was purposefully chosen prior to fieldwork, case study research necessarily allows for some room for changes while the research continues as more information is gathered. For this reason, conceptually-driven sequential sampling also occurred, meaning that the sample evolved during fieldwork as more relevant information arose and additional participants were referred to the study via snowballing (Miles et al., 2014; Naderifar et al., 2017).

Defining the unit of analysis is also critical for case study research. The unit of analysis is the individual, group, or object that is the focus of the research question, and can also be understood as the case itself (Bhattacherjee, 2012; Miles et al., 2014). In this case, the farmers that were interviewed are members of an agroecological social cooperative enterprise. An earlier phase of this research planned to analyze the cooperative as a whole. During data collection, it was found that the social interactions between the members were not as strong as expected, so the initial intention to investigate a collective action issue became less relevant. For this reason, this case instead focuses the unit of analysis on the individual farmer rather than the group.

3.3. Data Collection

For case study research, multiple types of data can be used to inform the research. This multiplicity of data provides a variety of sources of evidence for not only analysis of the research question, but also a source of contextual information to understand the nuanced nature of the evidence. The use of several data sources also triangulates the data, strengthening its validity. Here, I outline the types of data and the respective collection methods that were employed in this research.

3.3.1. Primary data

3.3.1.1. Qualitative interviews

For this research, qualitative interviews were the predominant source of data. Interviews are useful for answering complex questions that require equally detailed explanations (Rubin & Rubin, 2011). Interviews are unique in that the

information is not solely extracted from participants, but rather it is a dynamic social conversation in which the knowledge is produced jointly and interpreted at a later point in time. Moreover, the interpretation of meaning in addition to the analysis of content also differentiates interviews from other data collection methods (Kvale, 2008). Interpreting the meaning was especially relevant for this case, as the beliefs of the participants were one of the focal points of the study. As Fujii explains, "The value in these data lie not in their factual accuracy, but in what they convey about the speakers' worlds, and how they experience, navigate, and understand them" (2017, p. 1). For this research, semi-structured and open-ended interviews were employed. These interview methods are appropriate for mental models research as they allow for the interviewee to freely express themselves and thus display their cognitive functioning (Jones et al., 2011). As much as possible, an interview protocol (see Appendix) with the main themes was used as a guide for the semi-structured interviews. Sometimes, however, the interviews became more open-ended in nature when the interviewees wanted to elaborate on certain topics.

3.3.1.2. Participant observation

Participant observation was another primary data collection method employed for this research. Participant observation is a type of observational technique whereby the researcher is actively involved in the data collection (in contrast to direct observation, which is passive) and thus allows for the possibility of influencing the phenomenon of interest (Bhattacherjee, 2012). Participants are observed in their natural settings and the researcher takes notes about the behavior, activities, and comments of the participants (Creswell, 2014). Direct observation was also employed, but it was often less feasible to stay completely removed from the subjects of interest.

3.3.2. Secondary data

Additional secondary sources of data were also used to inform this research as a means of triangulation. Documentation such as printed documents and promotional material (e.g. informational pamphlets, reports), as well as digital material (e.g. websites, online news articles), from related stakeholders were

analysed. Moreover, academic research papers were used to more fully enrich the analysis (Creswell, 2014).

3.4. Operationalization of the construct

As previously stated, the case was selected purposefully because Crete is particularly well-suited for addressing the research question. First, due to Crete's isolated nature as an island, its resources are constrained geographically. Second, the Mediterranean region being more severely impacted than the global average in terms of climate change impacts. Third, agroecology represents an alternative and unconventional approach to agriculture that could be utilised for adaptation. Regarding the selection of the case participants, the individuals were initially located due to their involvement in an agroecological social cooperative enterprise. Rather than analysing the collective actions of the group, however, the focus of this study is rather the shared mental models of the individuals involved.

Data was collected on the island of Crete in Greece, primarily at agroecological farms in the Messara Plain in the Heraklion region, in October and November 2019 (an exception being one expert interview in Athens in September 2019). Participant observation and qualitative semi-structured interviews were conducted with ten agroecological farmers and three experts during this time period. Farmers were observed working on the farms, participating in community and cooperative meetings, processing products and seeds from the farms, organizing the seed bank, teaching agriculture courses at the local school, guiding tours of the farms for visiting students, and interacting with other people in the local community at establishments such as tavernas.

Interviews were conducted on a voluntary basis and recorded when verbal consent was provided by the interviewees. For confidentiality purposes, the identities of the participants are presented anonymously. Interviews were transcribed within twenty-four hours in an effort to retain contextual details. Notes were also taken during recorded interviews for the purpose of highlighting important quotes, observations, or body language (Bhattacherjee, 2012). Much of the data was also collected through participant observation and informal conversations; in these cases, detailed notes were hand-written and subsequently

typed, or typed as a note on a cell phone, with as many contextual details included as possible.

Table 3: Involvement of study participants

Interview	Participant role	Recorded interview	Conversation notes	Participant observation
01	Farmer		x	x
02	Farmer/Expert	x	x	x
03	Farmer	x	x	x
04	Farmer	x	x	x
05	Farmer	x	x	x
06	Farmer	x	x	x
07	Volunteer		x	x
08	Farmer		x	x
09	Farmer		x	
10	Farmer/Expert		x	
11	Expert		x	
12	Expert		x	
13	Expert	x	x	

For the semi-structured interviews, which lasted approximately an hour on average, a general protocol (see Appendix) was followed to ensure all topics were addressed. In general, participants were asked about their motivations for practicing agroecology, the agroecological methods they employ, and their impressions of the social and environmental context. Depending on how much the interviewee had to say about the topics at hand, interviews required more or less improvisation on the side of the interviewer and as a result some interviews were more open-ended in nature.

3.5. Analytical strategy

Braun & Clark's (2012) six phases of thematic analysis were used as an overarching analytical framework for this case. Thematic analysis is a systematic method for identifying "patterns of meaning (themes) in a dataset" (Braun & Clark, 2012, p. 57). Thematic analysis is valuable because it can balance both inductive and deductive approaches to analysis. This means that while some general themes can be brought into the analysis by the researcher (deduction), it is combined with themes that arise purely from the data itself

(induction). This was also true for this paper, as the theoretical lens of institutional economics was used to deductively interpret the data, especially to understand issues that were not explicitly articulated by the participants, while inductive interpretation allowed for the participants' experiences to contribute to the theme generation.

The first phase of thematic analysis began with the familiarisation with the data. The data was first organised and prepared for further analysis by ensuring all notes were completely transcribed, and organising the metadata for each interview (e.g. date of interview, interviewee, etc.). An initial review of the all of the data was then conducted to gain an understanding of the overall meaning and general picture. An attribute table of all participants was maintained and updated throughout the course of the analysis. Critical notes about content and context were also made during this phase (Braun and Clark, 2012).

The second phase of thematic analysis involved the generation of initial codes. Coding is a method of labelling or tagging the data with key words or phrases that are potentially relevant to the research question. Codes can be descriptive or analytic in nature. They can also be reflective of the researcher's perspective or theoretical framework, or of the participants' experiences or language (Creswell, 2014; Tesch, 2013; Bhattacherjee, 2012; Braun & Clark, 2012). To begin coding, the raw textual was imported into a qualitative data management and analysis software (MAXQDA). One coding process that was drawn upon for this analysis was that of grounded theory, which is an inductive method for theory formulation that is "grounded" in observed empirical data (Glaser & Strauss, 1967; Strauss & Corbin, 1998). While a full grounded theory analysis was not applied in this case, as a theoretical framework was determined separately from the empirical data, the grounded theory technique for coding was employed. First, open coding was used to compile a master list of all concepts that arose in the interviews. The codes were created while the raw textual data was thoroughly examined. As codes began to formulate, characteristics of the codes were also differentiated when feasible (e.g. positive/negative, high/low, etc.), for the purpose of grouping codes in the next step (Bhattacherjee, 2012).

Phase three initiates the search for themes based on the generated codes. Braun & Clark (2012) make clear that themes do not simply emerge; rather, they are constructed by the researcher based on one's interpretations of the data. To begin this process, codes were grouped into categories. The codes were aggregated and used to form the description of the case and the major themes that arose from the content. For example, codes were combined into both functional theoretical groups (such as "context", "mental models" or "adaptation") and more specific groups (e.g. adaptive practices). Lastly, selective coding was used to narrow the categories to a few central themes, also known as "winnowing" the data (Guest et al., 2011).

In phase four, the potential themes were reviewed for quantity and quality and further refined. The themes were assessed for their relevance to the research question, how much supporting evidence they had, and the boundaries of each theme. This resulted in the amalgamation of some themes and the splitting of other themes (Braun & Clark, 2012). Next, axial coding was employed to draw relationships between those categories (Bhattacherjee, 2012). In the context of this research, I tried to link beliefs (mental models) with behavior (adaptation) in accordance with the agroecology themes outlined in the theoretical framework. These linkages are outlined in the Results section.

There is a degree of overlap between phases five and six. In phase five, themes were named and defined. As part of this, sub-themes were determined along with the selection of quotations for each sub-theme. Necessarily, written interpretations of the quotations began to formulate in an effort to guide the flow of the sections. Phase six involved determining how to represent the derived themes in a narrative form (Braun & Clark, 2012). I chose to present the data by presenting each of the agroecology themes as they were outlined in the theoretical framework, followed by sub-themes with supporting quotations from individuals. For easier viewing and comprehension of the whole, I also presented the themes along with examples of each mental model and adaptation behavior in the form of a table (Creswell, 2014). In addition, this phase also included interpretation of the data and an attempt to derive meaning from the results. I combined my own personal takeaways with those that are present in the

existing literature, and tried to compare how these findings converged and diverged. Furthermore, I reflected on how these findings could be used and improved upon in future research (Creswell, 2014). These learnings are presented in the Discussion.

As an additional layer of analysis, a hypothetical counterfactual of conventional farmers was presented where possible as a means for comparison to the agroecological farmers' perspective. A counterfactual addresses the question, "What would have happened without the cause or intervention?" (Patton, 2014, p. 598). The purpose of this was to sharpen the focus on the shared mental models relating to agroecology as a whole versus conventional farming, rather than seeking the differentiation in beliefs between the interviewed farmers. Conventional farmers were not interviewed for this research due to time constraints, however, due to their viewpoints being part of the dominant global agricultural system, their mental models can be inferred based on the information provided from the agroecological farmer and expert interviews, as well as from the literature.

3.6. Hypothesis formulation

The hypothesis for this research was formulated after several iterations of analysis. First, the empirical evidence was analysed using thematic analysis to derive the primary themes. The existing literature was then revisited with the emergent themes to look for similarities and differences between the case at hand and other cases that had been previously researched. Following this review, the theoretical concept of mental models was determined to be relevant to this case. The hypothesis was thus formulated based on an attempt to correlate the verbally-communicated mental models of the study participants with their observed actions. This led to the hypothesis: Are the mental models from agroecology observed in the interviews consistent with the adaptation-relevant practices observed in the case-study?

3.7. Summary

This section outlined the materials and methods that were employed for this paper. The case study method was used as the overarching approach, using primary data collection techniques of qualitative interviews and participant

observations, and secondary data collection techniques of analogue and digital documentation review. Thematic analysis was subsequently used as the analytical strategy. Following the typical structure for case study research, this paper first presents a detailed description of the setting and context of the case, followed by a thematic analysis of the empirical evidence.

4. Case description

4.1. Objectives of this chapter

The objective of this chapter is to understand the environmental and socio-economic context of the case. First, climate change impacts in the Mediterranean will be reviewed, followed by the existing environmental conditions in Crete. Next, some relevant socio-economic and cultural characteristics of the case will be explored. Finally, the past, present, and future of agriculture in Crete will be discussed.

4.2. Environmental context

4.2.1. Climate change impacts in the Mediterranean

Climate change will particularly impact the Mediterranean region, which is already experiencing climate change at a higher rate than the global average. Average annual temperatures in the Mediterranean Basin have increased by 1.4°C since the late 19th century, which is 0.4°C higher than the global average. In addition, the frequency and severity of droughts have also increased since 1950. In the future, temperatures in the Mediterranean are expected to outpace the global average by 25%, and even more so in the summer months, at a rate of 40% higher than the global average. Occurrences of heatwaves are also expected to increase from once every two years to several times in one year (Cramer et al., 2018).

The Mediterranean region is also experiencing changes in water availability. This is of particular importance to islands like Crete, where water availability has already been a pressing issue prior to global climatic change. Droughts are expected to increase in duration by 7% with a 1.5°C average global temperature increase. Moreover, in non-summer months, rainfall events are expected to amplify by 10-20%. Due to decreased rainfall and increased evapotranspiration associated with global warming, the Mediterranean will be one of the hardest-hit regions in the world in terms of freshwater availability, with an anticipated reduction of 2-15% for 2°C of warming. In Greece particularly, per-capita water availability may hit the threshold for severe water stress by 2030. Rainfall in summer months is expected to decrease by 10 to 30%, causing a potential increase in irrigation demand of 4-22% (Cramer et al., 2018).

4.2.2. Environmental conditions in Crete

The Region of Crete is the southernmost and largest island of Greece, with a total area of 8,336 square kilometers and a population of 623,025 (based on 2011 census). It is located between four seas and three continents (Leontis, 2009). As such, it has a wide variation in micro-climatic zones, allowing for an exceptional range of biodiversity as well as suitable cultivation conditions for a variety of crops. Crete's climate is characterized as sub-humid Mediterranean, with hot and dry summers and cold and wet winters (EC Life, 2016). The island is split by three mountain ranges running from west to east. The northern coast resembles a more Mediterranean climate, while the climate in the south more closely resembles North Africa (Leontis, 2009).

As an island, Crete is a "self-contained microcosm," and can be seen as a system with defined boundaries. Thus by nature, it has several limiting factors. Geographically, it is isolated from the mainland, making the transport of goods, people, and infrastructure more expensive due to far distances. Land and water use is also spatially limited. Socially, public services such as healthcare and education are less available, making the standard of living lower than the mainland. These factors can also drive people to migrate, causing additional problems such as labor shortages. Tourism in particular has contributed to rural-to-urban migration, while also putting intense pressure on water availability (Vogiatzakis, 2008).

The landscape of Crete has changed drastically in the last century. The island became more fragmented as roads and infrastructure were expanded. Tourism has become the primary economic driver in Crete, but it has also had a substantial impact on the landscape by occupying many coastal areas, and putting great pressure on waste management facilities and water supplies (Leontis, 2009).

4.2.3. Climate change impacts on agriculture in Crete

While different parts of the world will experience climate change differently, agricultural systems in southern Europe are expected to experience increased variability, unpredictability and vulnerability, along with decreased crop suitability and productivity (Trnka, 2011). Indeed, climate change is already

threatening agriculture and food production in the Mediterranean (Cramer et al., 2018).

Socio-economically, agriculture is a key activity for much of the Mediterranean's rural population. Despite this, labor shortages are becoming more common in Crete. Migration to urban areas for employment opportunities has increased with the rise of tourism particularly. As a result, agricultural labor is more and more being carried out by the family of the farmers and by farmers helping each other (EC Life, 2016). Agriculture is particularly important in Crete as it is an island and is thus otherwise dependent on imports. Sustainable development of the agricultural sector means that dependency on imports could be lessened while also creating a market for exports (Ventrella et al., 2012).

The EC Life Adapt2Clima Program conducted an extensive SWOT (strengths, weaknesses, opportunities, and threats) analysis for climate change impacts on agriculture in Crete. Several notable findings that are relevant to this paper are as follows:

Table 4: Strengths, weaknesses, opportunities, and threats of climate change impacts on agriculture in Crete (EC Life, 2016)

Strengths - favorable conditions for secondary occupation of farmers - good reputation of products and historical ties - favorable development of organic farming microclimatic conditions	**Weaknesses** - difficult pest and disease management, due to overuse of chemicals - fact that it is an island - lack of an effective crop product promotion network - genetic mixing of local crop varieties with imported ones - high production costs
Opportunities - taking advantage of special and high quality local products - high international demand for local products - change of nutritional standards towards products of high nutritional value	**Threats** - pressures applied to traditional agricultural practices from the new CAP that cause disorientation - pressures exerted on land use and natural environment - gradual decrease of workers and consequent reduction in crops cultivation - further intensification of climate change effects

Climate change impacts have already begun to be felt by producers in Crete, making its way into mainstream media. For example, winegrowers have noticed

an increase in temperatures along with unpredictable rainfall that typically comes in short heavy downpours so that it is not easily absorbed by the soil. Because of these environmental changes, these producers have projected the possibility of having to move their cultivations to higher altitudes for cooler temperatures, and potentially changing the varieties that are grown (Whiting, 2017).

Several interviewed experts and farmers also cited changes they have noticed in agriculture. In olive production, higher temperatures have caused the olives to ripen earlier than usual, requiring harvest closer to August rather than September or October. This timing causes a labor conflict with the tourism industry, as many seasonal laborers are still working in tourism in late summer, thus causing a shortage in available workers to harvest (Interview 12). Experts and farmers also mentioned a decrease in water availability, as they noticed water bodies drying up. This was attributed to the overuse of irrigation which has depleted the groundwater aquifers.

4.3. Socio-economic and cultural contexts

4.3.1. Socio-economic context

The economic crisis of 2008 left an indelible mark on many parts of Greek society. One of these marks is that of demographic changes in cities and rural areas. While rural-to-urban migration has been an issue contributing to the decline of rural areas globally for the last several decades, the recent economic crises have caused some people to reconsider their urban lives and retreat back to the country. Especially in Greece, urban-to-rural migration has increased since 2008 (Gkartzios, 2013). One possible explanation for this is that Greeks were faced with imagining the possibility of leaving the Eurozone and needing to be less reliant on imports (Interview 11). In this way, growing your own food in the countryside became a more attractive option than living in cities with rising unemployment. These positive perceptions of rural living, referred to as the “rural idyll”, can be attributed to perceived potential improvements in environmental and social conditions. The type of migration in this case can be categorized as “anti-urbanisation” since the movement is motivated by an aversion to the city (e.g. the economic “rat-race”) (Mitchell, 2004). Moreover,

the choice to undertake urban-to rural-migration is often exhibited by both push (anti-urban) and pull (pro-rural) dynamics (Gkartzios, 2013). The crisis therefore allowed for both of these sentiments to grow for some Greeks, and has since changed the social fabric of rural areas.

4.3.2. Cultural context

This history of Crete has led to Cretans having a unique cultural identity, even among Greeks themselves. Cretans distinguish themselves by their candor and toughness that arose from their contentious history. Due to its strategic geographic locations, Crete has survived numerous invasions over centuries, most recently and memorably for many Cretans being the invasion by Germany in World War II. Having been prepared by previous invasions, they fought back as they had in the past, which serves as a source of great pride for Cretans today (Leontis, 2009). This mentality of self-defense has been translated into not only self-preservation, but also self-sufficiency. When considering the factors of the isolated nature of Crete as an island, combined with the economic crisis and potential of leaving the Eurozone, it can be fathomed how this cultural identity came to be, and how it could influence other aspects of life there.

4.4. Agricultural context

4.4.1. Background of agriculture in Greece

"Traditional" agricultural production was commonplace in Greece for thousands of years. By the fifteenth century and the rule of the Ottoman Empire, what we would now consider to be "traditional" practices included collective management of resources, intercropping of grains and legumes, crop/livestock systems, and diversification in both land uses and production (Kizos and Vlahos, 2012; Damianakos, 1999; Horden and Purcell, 2000). Especially on the islands, "production was oriented towards self-sufficiency by diversifying production" (Kizos and Vlahos, 2012, p. 8).

These traditional practices were already deemed to be outdated and even "oriental" leading up to the industrial revolution in the late nineteenth century (Mouzelis, 1978). Even still, 54% of the population were engaged in agriculture prior to World War II (Leontis, 2009). Intensification of agriculture in Greece began in the 1950s and accelerated in the 1970s (commonly referred to as the

Green Revolution in interviews) through the use of mechanisation, irrigation, and chemical fertilizers and plant protection products. (Kizos & Vlahos, 2012; Pratt & Funell, 1997). However, intensification was not as widespread in mountainous areas and on the islands due to their geographic conditions, which made these farmers less competitive and ultimately contributed to the decline of farming in these regions in the last several decades (Kizos & Vlahos, 2012). While this is true for some parts of Crete, its much larger size (compared to other Greek islands) allowed for the existence of the Messara Plain, which became a highly-intensified area for commercial olive production.

4.4.2. Policy context

The Common Agricultural Policy (CAP) of the European Union (EU) has substantially shaped the current state of agriculture in Greece. Since Greece joined the European Union in 1981, agricultural production became tailored to subsidies rather than the market. As a result, production of subsidized crops such as wheat and cotton surged, while non-subsidized crop production declined (Kizos & Vlahos, 2012; Karantininis, 2017). These conventionally-grown crops (e.g. cotton) were input-intensive and taxing on the landscape, and also diverted cultivation away from traditional varieties and practices that were adapted to local conditions. Particularly in the Cretan context, an interviewed expert also cited the CAP as problematic especially for the incentivization of not only olive monoculture but also goat production (Interview 12). As an example, goats are especially destructive, as they eat more and also climb higher up the mountains than sheep. The introduction of the CAP has increased the goat population such that locals believe it has exceeded the carrying capacity of the landscape (Interview 12). Several interviewed farmers complained about the lack of control of the goats, particularly that they are able to seemingly roam freely, which has denigrated the landscape and removed groundcover, thus contributing to erosion issues (Interview 3, 4; Kizos & Vlahos, 2012).

4.4.3. Current state of agriculture

Currently, Greece's total agricultural production is valued at 9.6 billion Euro, placing it tenth out of the 27 EU member countries. Its contributions towards the EU's total agricultural output comprised 2.6% in 2015. Despite Greece's

agricultural sector being small compared to other countries in the EU, it is quite significant domestically. Greek agriculture has proven to be its most resilient sector, particularly following the recent economic crisis of 2008. This is evidenced by the agricultural sector being the only industry to grow in size since 2008, while other sectors' sizes reduced by 30%. Moreover, agriculture's share of Greece's GDP was 3.8% in 2008 and rose to 5.5% by 2015 (Karantininis, 2017).

Agriculture in Greece is characterized primarily by small farms. Data from 2013 indicated that 53% of farms are less than 2 hectares in size, while 95% of farms are less than the EU average of 14.6 hectares (Karantininis, 2017). The distribution of farms in Greece is also skewed geographically due to the diversity of the landscape. Crete has the largest share of small farms in Greece (ibid.). These already-small farms are often split between several parcels; on average, farms are split into five parcels. This is due in part to the fact that land is commonly passed down through families, which is incentivized by tax breaks of up to 50%. In general, land is rarely put up for sale, as it is seen as a type of insurance asset, back-up plan, or retirement option for Greeks that have moved to more urban areas. As a result, parcels appear to be abandoned and eventually overgrown by shrubland, and sometimes used as a dumping facility (Kizos & Vlahos, 2012; Karantininis, 2017). These national trends were also evident in the localized empirical data (Interviews 1, 2, 3, 5, 6, 8, 9). Moreover, whereas it is common for many Cretans to own a parcel of land, their small size means that farming often has to be supplemented with other incomes, such as tourism.

4.4.4. Agriculture in Crete

Agriculture comprises 13% of Crete's GDP and employs 12% of the workforce in Crete (EC Life, 2016). In terms of agricultural land use there, utilised agricultural area occupies 653,305 hectares of Crete's land, comprising 70% of the total surface area. Specifically, heterogeneous agricultural areas comprise 19%, while permanent crops comprise 23%. The primary crops that are cultivated are olives, wine grapes, and tree fruits (ibid.).

This research will focus on the Heraklion prefecture as it is where the selected case is located. The Heraklion prefecture has the most agricultural activity in the

region, encompassing 39% of the island's utilised agricultural area. Within the Heraklion prefecture, tree crops comprise 46% of land, while meadowlands and pastures comprise 41%, followed by vines with 8%, and annual crops with 4% . Regarding land holdings in the Heraklion prefecture, there were 41,221 land holdings covering an area of 153,538 hectares in 2010. The vast majority of these holdings are small and fragmented, less than 5 hectares in size per holding (EC Life, 2016).

Since the accession into the EU, olive monoculture has proliferated in Crete, primarily in the Messara Valley, the island's most fertile region stretching west from Heraklion down the center of the island. Olives are the most widely-cultivated crop in Crete. Of the 60.8% of total cultivated area that is fruit production, olive orchards comprise 89% (Chartzoulakis et al., 2001). Vegetables are also cultivated, albeit to a lesser degree, but primarily include tomatoes, cucumbers, potatoes, eggplants, and onions (EC Life, 2016). Wine grapes, along with wheat and barley, are the other prominent crops in the Heraklion prefecture.

In terms of environmental footprint, agriculture is the primary beneficiary of water usage in Crete, comprising 84.5% of total consumption, and 42.3% of cultivated land is irrigated (EC Life, 2016). Drip irrigation is predominantly used for olive production. Due to such high water demands, the Messara Valley is threatened by groundwater pollution, water scarcity, and soil erosion (Chartzoulakis et al., 2001). These issues lead one to wonder what other options there are for the future of agriculture in Crete.

4.4.5. Sustainable agriculture in Crete

Agroecology is a term that has only recently started to be used more prominently, but has its roots in organic and ecological farming which have been in public discourse much longer. The organic agriculture and environmental movements originated in Greece in the 1980s, prompted by international demand for olives and olive oil. Initially, the methods employed were more experimental in nature, with data on organic agriculture not becoming available until 1992 (Migliorini et al., 2018). According to data from 2018, organic agriculture comprises 492,627 hectares, approximately 3.3% of all usable

agricultural area in Greece (EC Life, 2016). Clearly, this leaves some room for growth.

Agroecology is still a small field but is operating within a growing network of sustainable agriculture initiatives in Greece (Migliorini et al., 2018). I was introduced to many of these organizations during fieldwork at the second Agroecology Europe Forum in Heraklion. The organization of Agroecology Europe is itself working to facilitate connections between academia and farmers. In Greece, non-profit organisations such as AEGILOPS (Greek Network for Biodiversity and Ecology in Agriculture) focus on the restoration of local varieties, breeding of organic varieties, and seed education for farmers. In addition, AGROECOPOLIS (Hellenic Network for Agroecology, Food Sovereignty, and Access to Land) advocates for community-supported agriculture in Greece as means of achieving food justice. EU-funded initiatives such as LIFE IGIC (Improvement of Green Infrastructure in Agroecosystems) are researching sustainable farming practices for olive orchards in Crete. Civil non-profit companies such as PLOIGOS, which is in part funded by local municipalities, is an education and developmental company that works to improve environmental, social, and economic outcomes for farmers in Crete. The farmers involved in this study particularly benefited from the Οικοτεχνία ("cottage industry") program, which helps them to sell as an additional income source high-quality, organic, locally-made and culturally-relevant products made in their home from produce grown in their cultivations.

As was mentioned in the Methods section, the sample chosen for this case was originally based on a social cooperative enterprise that advocates for and practices agroecological cultivation. The cooperative was formed in 2016 by like-minded individuals who were already practicing agroecology in their own cultivations, facilitating educational programs at the local school, and organizing a local seed festival since 2012. They formed the cooperative to expand on these efforts by focusing on improving the livelihoods of farmers through education on cultivating traditional varieties and saving seeds. The cooperative's primary aims are to improve the quality and health of both the environment and community. Members also draw on their ancient Minoan heritage as a source of

inspiration and motivation. As a group, they pool the products that they produce (herbs, olive oil, honey), sell it under a common label through community-supported agriculture, and split the profits amongst themselves, as well as retain a percentage within the organization for re-investment. Beyond that, however, there was not enough evidence observed during fieldwork about which a substantial argument could be made about collective action in the cooperative. For this reason, it made more sense to focus the unit of analysis of this research on the farmer rather than on the cooperative entity.

4.5. Summary

This section explored the environmental, socio-economic, political, and cultural context for this case study. An environmentally-diverse region with a strong culture tied in history, Crete's agricultural sector is a reflection of these qualities. While primarily dominated by conventional agriculture in the form of olive monoculture, there is growing interest for sustainable agriculture, in which agroecology is a part. The next section will explore how these ideas about agroecology were found to be connected to climate-adaptive practices in the case at stake.

5. Results

5.1. Objectives of this chapter

This chapter will explicate the empirical evidence that was gathered through qualitative interviewing and participant observation. It is organized in accordance with the agroecology themes that were put forth in the theoretical framework. Each theme first explains the relevant mental models followed by the associated adaptation behavior. The hypothetical counterfactual is presented where possible and offers the contrasting viewpoint of prevailing conventional mental models and behavior. It should be noted that due to the interrelatedness of the themes, some topics arise under several themes. Finally, an overview of observed climate change perceptions is presented.

Table 5: Agroecology themes with corresponding observed mental models and adaptation-relevant behavior

Agroecology theme	**a) Mental model**	**b) Adaptation**
Environmental characteristics		
Diversity	Holism, connection with nature	Biodiversity, traditional seeds, livestock/wildlife
Synergies, efficiencies, and recycling	Nature balances itself, resources are finite	Water saving, intercropping, nutrient recycling
Social context features		
Co-creation and sharing of knowledge	Need to change conventional public perception, set a good example	Seed festival, education programs
Human and social values	Healthy relationships, reciprocity, respect, responsibility	Sharing resources, community involvement, reduced resource use
Culture and food traditions	Cretan historical heritage, nostalgic family memories, self-sufficiency	Traditional seeds

5.2. Environmental characteristics of systems

5.2.1. Diversity

5.2.1.1. Mental models

Mental models about diversity were primarily exhibited through beliefs about the interconnectedness of humans with nature. The belief that all living things are connected is related to the premise of biodiversity that ecosystem components give and take from each other while providing each other essential beneficial services. The focus on diversity in agroecology aims to use these ecosystem services for the benefit of both the ecosystem and the farmer through synergetic systems. I found this belief to be exhibited through explicit expressions of connections with nature and desires to live closer to nature as a motivation for engaging with agroecology.

5.2.1.1.1. Connection between humans and nature

First, prevalent in the mental models of respondents were ideas about the connection between humans and nature. Interviewees saw themselves as being part of nature rather than outside the system. They also expressed the viewpoint of nature as a provider, not only in terms of food production, but also in terms of providing "real" forms of knowledge. Moreover, some interviewees also believed in an innate quality in humans to live in nature:

> *"People are born to live in nature, not in cities." (Interview 01)*
>
> *"You can learn everything from nature." (Interview 01)*
>
> *"I mean this is my dream, to make it a natural ecosystem, as natural as it can be because we are inside also. Us being part of it, not being the rulers of it, being part of this ecosystem." (Interview 05)*

These sentiments illustrate the importance placed on the connection to nature by the farmers and are seen as counter to the prevailing conventional mentality. Conventional agriculture is dominated by beliefs about maximising yield, and thus extraction of products from the land, rather than a reciprocal relationship, as described by one interviewee:

> "*We only see land as what it can give to us rather than what we can give to each other." (Interview 01)*

5.2.1.1.2. Anti-urban, pro-rural

Second, the interviewees' beliefs about being connected with nature were further exhibited by their motivations to "return to nature" by physically relocating themselves geographically and to connect with the land through agroecological farming. Several of the farmers had grown up in an urban setting (Athens) and had expressed disdain for the city as well as possessing an idealised notion of life in the countryside. Indeed, the sentiments expressed by the interviewees are also reflected in the counter-urbanisation literature. In the case of this research, some interviewees' noted both the desire to escape the city (push) as well as a desire to be closer to nature (pull):

> "*This has been a long-lasting dream of ours, mine and my husband. We have always wanted to go back to the land, go back to nature, and live as close to nature as possible." (Interview 05)*
>
> "*We are very happy to be here. I just came back from London, it was good to stay for two, three, four days, but that's about it, no more. It's too tiring, too noisy, too many people. Even Heraklion, not only London; we don't even want to go to Heraklion. We stay away from it as much as possible." (Interview 05)*

5.2.1.2. Adaptation

These mental models connected to several adaptation-relevant behaviors related to diversity. Diversification in cultivation was cited by nearly all interviewees as being one of, if not the most, important aspect of agroecology. The most important forms of diversification cited were the use of biodiversity via traditional seeds, as well as intercropping and crop-livestock integration. In addition, farmers cited the need for better integration of science and practice.

5.2.1.2.1. Biodiversity

Biodiversity in cultivation was the most commonly-referenced adaptation-relevant behavior. All interviewees cited this as being of paramount importance with multiple benefits, such as disease resistance and the ability of the plants to benefit each other. One frequently-mentioned benefit is the ability of biodiversity to boost resistance to disease:

> *"We believe that if there is a big variety of plants, maybe most of the plants help each other to be stronger [against] diseases, so biodiversity is one of our main goals, and of course we talk about organic agriculture without any use of chemicals." (Interview 04)*

This stands in contrast to the prevailing local practice of olive monoculture, which interviewees were strongly opposed to:

> *"The most important is not to have a monoculture, to have multi-culture, to have a lot of different plants and trees so that each one helps the survival of the other, so that they all cooperate together. And it's not only the plants, it's also the animals, because we're talking about bees, we're talking about insects, we're talking about the whole ecosystem." (Interview 05)*

Figure 3: Carob (left) and endemic dictamo (right) as examples of biodiversity

5.2.1.2.2. Use of traditional seeds

Of further substantial importance to the farmers interviewed was the use of local and traditional seeds in their cultivations. As this is a practice with multiple benefits, it will continue to come up in forthcoming sections. Here, interviewees

cited the ability of traditional seeds to be better-equipped deal with climatic changes due to their genetic complexity:

> *"And these materials we use, seeds for example, they have in the genes, they have information of resilience, of a resistance for these changes. They resisting lack of water, they resisting diseases and insects… Hybrids, they have only a small amount of genes so they don't have this ability. But local varieties… have many genes to give their characteristics, so many genes means many possibilities to adapt to some conditions." (Interview 02)*

The interviewees found this to be an important difference from the conventional farming practice of using hybrid seeds:

> *"Hybrids, the plants that they are made in the labs, I don't believe they have a future because they are like antibiotics - the more you develop them in the lab, the less choices you have to keep developing them in the future. So I'm sure that even the scientists that work in this field, they will very soon... try to look back to the local varieties for some new genetic material and to have some material to work for the future." (Interview 04)*

5.2.1.2.3. Other forms of diversification

Other forms of diversification were found primarily through participant observation rather than through oral interviews specifically. Spatial diversification in the form of intercropping served as an important complement to biodiversification for many of the farmers. Through direct observation, it was found that the farmers were growing a large variety of crops intermingled with each other. For example, one farm had tomatoes, cucumbers, herbs, squash, okra, sesame, beans, cabbage, and cotton planted in alternation next to each other. Another farm focused more on fruits, with grapefruit, lemon, prickly pear, banana and papaya plants growing in close proximity. Moreover, crop-livestock diversification was also evident in the form of several farmers citing that sheep manure would be shared among the group from the farmer that had sheep on his farm. Additionally, diversification also meant fostering a hospitable environment for other forms of natural wildlife, as lizards and grasshoppers could be seen

moving about the crops. This is of course also only possible due to the lack of chemicals used on the farms that were surveyed.

Figure 4: Intercropping of fruit trees (fig, pomegranate) with vegetables

5.2.1.2.4. Holistic science and practice

In another vein, the field of agroecology also defines diversity to include the diversification of the discipline itself. This was reflected in the interviews as the farmers also expressed using various ecological farming methods in combination. Farmers mentioned using parts of several ecological farming methodologies, such as permaculture, organic, and biodynamic. Additionally, some felt that science itself should be more transdisciplinary. This is also in alignment with agroecology's aims to better integrate modern science with traditional local knowledge as well as participatory processes.

> *"Science should be holistic, not specialized. Farmers would be better farmers if they were also musicians, for example." (Interview 01)*

5.2.2. Synergies, efficiencies, and recycling

5.2.2.1. Mental models

5.2.2.1.1. Nature's ability to balance itself

Mental models related to synergies, efficiencies, and recycling were first exhibited in beliefs about nature's inherent abilities to function on its own and balance itself despite disturbances. These sentiments partially echo the aforementioned mental model of viewing the agroecosystem in a holistic way, but with more of an emphasis on each component working together as a system. Additionally, there was also a belief and trust that nature will find a way through change, has the ability to balance itself out, and "knows" how to act.

> "*Whatever happens in nature is as it should be." (Interview 01)*
>
> *"Now we have fruits, vegetables, legumes… almost everything, and they work in balance, all of them. I want to have a… food forest, so that nature can work on its own, and you don't have to do much, you don't have to be pumping chemicals all the time so that you kill one pest, other pests or other insects or other living creatures can do the job for you. Permaculture. The idea of nature doing what it knows how to be done." (Interview 05)*

While these beliefs can reinforce the positive use of agroecological methods, they can also reinforce cognitive barriers to climate change adaptation, as one may be less likely to adopt adaptation-relevant behaviors if the assumption remains that conditions will always return to "normal." One farmer, for example, used this as justification for not partaking in any monitoring activities, even informally, because he had full trust in nature.

5.2.2.1.2. Resources as limited

Mental models related to synergies, efficiencies, and recycling were also exhibited in beliefs about the finite quantity of resources on the island of Crete. This was shown in how they differentiated themselves from other people. In their view, there is a lack of awareness and concern from not only conventional farmers but also the general public about the availability and use of scarce resources.

> "*People are not thinking of water collection and preservation, they only think of using it abundantly, because they think that it will always be there, and if they can't find water, they just drill holes, and they think they're going to find water very deeply… and they can't find water deeply, and if they do find water it's all salinated." (Interview 06)*
> "*I don't know if it's climate change. What I would say is it is mostly how we use, it's the use, we are not using the resources properly, we think they are eternal, we think they are forever, but they have a set time limit." (Interview 06)*

5.2.2.2. Adaptation

5.2.2.2.1. Water recycling

Adaptation-relevant behavior related to synergies, efficiencies, and recycling was about conserving finite resources and making the best use of nature's ability to cycle and reuse water and nutrients. Water availability was overwhelmingly brought up by participants as being of high importance. This was exhibited in several ways. First, most farmers used drip irrigation for their cultivations, with some collecting rainwater in barrels. This method of irrigation consumes far less water than conventional methods. Second, terracing was employed as a means for limiting runoff due to the slope of the land, helping to increase water and nutrient retention. Third, in addition to the quality of the product, water availability and requirements also often dictated the varieties of crops to be cultivated. Moreover, particular crops were chosen primarily due to their lower water requirements:

> "*The most important is that these varieties need less water, small amounts of water. Estimate that [a] hybrid needs 3-4 tons of water to give 200 kilos [of tomatoes]. When you cultivate a tomato with traditional seed, [it needs] one liter per plant per day." (Interview 03)*
> *"I can work this land in the best way possible to make a food forest… meaning that you plant in such a way that every plant can benefit from the other plants as much as possible, which also would mean that you plant species that bring up water, because water is an issue here in Crete." (Interview 06)*

Figure 5: Terracing used to retain water and limit runoff

5.2.2.2.2. Nutrient recycling

In addition to water conservations efforts, nutrient cycling efforts were undertaken in an effort to maintain soil health. This was achieved through several methods, such as recycling manure from fellow farmers' sheep. This can also be seen as a synergy between crop-livestock systems, as well as an economic efficiency by reducing the cost of fertilizer inputs. Another way that farmers tried to optimize biological processes was through intercropping: planting particular crops near each other to maximize their benefits, such as nitrogen fixation and improved soil texture. For example, garlic was planted alongside beans for the purpose of acting as a repellent to pests. Additionally, the use of green manure via incorporation of nitrogen-fixing legumes in the cultivation was also practiced. Finally, many of the farmers also aspired to continually add more biodiverse crops to their cultivations.

Another common practice for recycling both nutrients and water was to leave plant debris on the ground after pruning or after the plant had finished fruiting. Rather than clearing it as would be common with conventional agriculture, leaving the plant debris helps to enrich the soil and retain moisture:

> "*One way of preserving water is not to keep the land bare. If the land is covered with organic material, then it needs less water. So this is another clever way of reducing the amount of water that you use. All the matter from the grass, everything that we take out stays on top, so that it keeps the land wet and not dry." (Interview 05)*

5.2.2.2.3. Economic efficiencies

Farmers also found some economic efficiencies through their agroecological practices. For example, the use of salvaged materials for construction of terraced plant beds was observed on several farms, using rocks, wood, and building materials that were found along the road or donated from friends. In addition, by planting a cover crop of legumes, not only is the soil health improved, but it also provides an alternative food or income source by maximizing available arable land. Moreover, non-conventional practices for pest removal can provide similar benefits, which also have shaped cultural practices:

> *"Because ok, it's more difficult without the use of chemicals, you have to fight with many diseases and other insects or snails, they want to try these tasty beautiful plants. For example, snails, we have to collect them by hand, but we can also sell them in the local market (Cretans love snails anyway), or also to offer them as a present to friends so that they can enjoy them." (Interview 04)*

5.3. Social context features

5.3.1. Co-creation and sharing of knowledge

5.3.1.1. Mental models

Mental models related to the co-creation and sharing of knowledge were exhibited by farmers expressing the need for the general public to be better-informed about where their food comes from and how it is produced, as well as a desire to set an example for a more sustainable way of life.

5.3.1.1.1. Lack of understanding from general public

First, the agroecological farmers interviewed believed that the general public is generally unaware about agricultural and food systems. In particular, they think there is a lack of understanding about the consequences of conventionally-grown produce; environmentally, economically, and nutritionally. Moreover, they fear

that the knowledge of traditional agriculture and the use of traditional seeds has been lost, and want to share their knowledge to rejuvenate these traditional methods and varieties.

> "*That's where we have to change the perception of people, the conscious, the idea of people for food. You don't have to eat a lot of useless food, food that gives you nothing. Eat less, but the food that will give you the most of the ingredients you need for your body and food that will give you health. So we have to change the way we are thinking, and then these changes come to the farmer, they will meet. If consumers begin asking for healthy products, then the farmer has to produce healthy products." (Interview 01)*
>
> *"This is the reason why I have been involved and I have been interested in what [the cooperative] is doing, and this is the rejuvenation of the traditional seeds… They should not be lost, they should be shared, and people should be educated to start using them again. If not… broad scale cultivation, at least for their own personal use, for their families. I think this is the most important, number one priority." (Interview 05)*

5.3.1.1.2. Setting a good example

Many interviewees felt that they were uniquely positioned to bridge this knowledge gap by serving as an example of the potential of agroecological farming to the local community. They believed that showing their local community how effective agroecological farming can be, and talking about it in a welcoming way, can help to convince more people about its efficacy. Particularly they hope to resonate with people by connecting over shared traditions and local seeds.

> "*So it's up to us, if we try to become even better with what we are doing, and better organized, I think we can give a very good example to many other farmers in Crete and the rest of the country to do similar things." (Interview 04)*
>
> *"Because we also try to give a good example to the society in general, to the local society especially, we like to save old traditions and to try to*

keep the good examples and the good elements of life in the past, and to combine it with modern life." (Interview 04)

"And we are also interested to show our results to other people. Because in general we believe that the best way to persuade somebody to quit the classic way of agriculture with the use of chemicals is not to tell him that you are wrong, but to just to tell him, this is what we do, you are very welcome to come and see our results and what we do and why we do it. And then if you want, you can follow this example or you can change something in the way you do something until today. For me this is the most important." (Interview 04)

5.3.1.1.3. Conventional resistance

The farmers interviewed expressed that their alternative ideas have not been met without resistance, however, from the local community that is used to conventional agriculture. They felt that locals are reluctant to change and not open-minded (Interviews 03, 08, 09, 10). On the side of producers, they expressed dismay that conventional farmers keep doing things the way that they have always been done, but they don't know why they do it anymore (Interview 08). On the side of consumers, they found that locals are generally uninterested in higher-quality or even different products. For example, one olive farmer asserted that "Cretans don't appreciate high quality oil" (Interview 09), while another said that he grew a spelt crop successfully but wasn't able to sell it due to lack of consumer interest (Interview 10). Several farmers also noted that their neighbors made fun of them when they first started trying agroecological methods. But, one farmer noted that while he was teased in the beginning for using a weed-cutting machine instead of spraying, others in his community have since learned from his example and now also use this machine (Interview 03).

Figure 6: Sign indicating organic field that should not be sprayed with chemical fertilisers

5.3.1.2. Adaptation

The farmers' beliefs about a need for education in their communities has been translated into action via the development of education programs and events. The organization of educational activities was the most evident way that the farmers work collectively through their cooperative entity.

5.3.1.2.1. Seed festival

The primary educational outlet for the cooperative is through the organization of an annual seed festival in their village. The founders of the cooperative began to organize the seed festival in 2012, four years prior to the formation of the cooperative itself. The festival brings the local community together, with educational activities for children about the local environment and cultural heritage, to bring attention to the rich biological diversity and heritage of Crete. The cooperative saves seeds from their cultivations throughout the year to be distributed for free to the public. Since starting the festival, they have noticed a difference in their community's awareness:

> "*In our village for example, no one had ever discussed about traditional varieties, and now the whole village discusses about it, the whole area, the whole island, they have a discussion about it, the traditional varieties." (Interview 02)*

5.3.1.2.2. Education programs in schools

Another core part of the cooperative's educational efforts is the organization of programs at schools in the area. Also beginning in 2012, the cooperative was asked by the local municipality and school to take over responsibility of a vacant lot and transform it into a garden to teach the students. They cleared the land of garbage and debris, and constructed raised beds from salvaged materials. They continue to use this land to teach students about all stages of the growing process, and particularly about how to save seeds. They find it important for the children to be exposed to these ideas at an early age:

> "*And this is a main goal for us, to enter in the schools, and pass our message to the kids. Because this is the generation who can change the situation for the environment. Because grown people are very hard, very difficult to take the message and to change the methods they cultivate and the methods they see the environment. We focus on kids in any way." (Interview 02)*

Figure 7: Space on farm (left) and community space (right) for the cooperative's educational events

Members of the cooperative were also working to develop a new education program for farmers specifically about how to cultivate in order to produce high-quality seeds. At the time of interviews, they were working on writing a survey to gauge the baseline knowledge of farmers about this topic. Based on the results of the survey, they planned to host a seminar for farmers, "so that producers will have their own seeds instead of going and buying from chemical companies" (Interview 05).

5.3.2. Human and social values

5.3.2.1. Mental models

5.3.2.1.1. Healthy society

As members of a social cooperative enterprise, human and social values were a critical part of the farmers' motivations for being involved with agroecology. First, a primary goal was to cultivate harmonious and healthy relationships with themselves and society. A common motivation among interviewees was to produce healthy products for themselves and their community:

> "*That's why we're doing this, because it's a matter of what we want for ourselves, we want to eat healthy products, we want to eat products that have no chemicals, we want to have a healthy environment, we want to have healthy relations between us and between society. And we consider that there is not a healthy nation unless you are healthy in your body." (Interview 02)*

5.3.2.1.2. Reciprocity

Interviewees expanded on this notion of fostering a healthy society by also wanting to give back to both their community and the earth. In contrast, the mentality of conventional agriculture tends to see the earth as a commodity from which value should be extracted and maximized. Ideas of reciprocal care for each other and giving to others was a common sentiment among interviewees.

> "*If we want to feel good about what we step on, we know that we need to give back to the environment, not only take from it, and give to neighbors. We all take and we all give." (Interview 03)*
>
> "*On a social level, I think being part of [the cooperative] is our way of trying to help a little bit, add just a tiny bit to society. Trying and helping*

and educating people and talking about all these small things that people are not aware of. Like for example traditional seeds, what they are and what they do. Socially, I believe that making a contribution by entering this group of people that share a similar philosophy, we are trying to help as much as we can, as much as one individual person or nine individual people can. There's not so much that you can do on an individual level, but little by little you can influence at least the people around you." (Interview 05)

5.3.2.1.3. Respect and responsibility

Lastly, many interviewees viewed their relationship with nature as based on the values of respect and individual responsibility. Tying in to sentiments about giving back to the earth and humans' connection with the earth, the agroecological farmers believed that both agriculture as a whole and also people on an individual level need to treat the earth with more respect. Similarly, notions of enacting this respect on an individual level was emphasized as an individual responsibility, serving as an interesting contrast to the more collective sentiments about working together and helping each other.

"*If everybody on this planet would take responsibility, individually, this world would be very different. It's all about taking responsibility. Because if you take responsibility, you start to care." (Interview 06)*

5.3.2.2. Adaptation

Adaptation-relevant behavior related to human and social values are more overarching and underlie many of the other themes, and as such can be seen in previous sections of this paper. A few interviewees did cite specific actions that they had taken personally, such as buying and planting their own trees to improve air quality, reducing plastic consumption, buying organic products, and riding a bicycle instead of driving (Interview 13). Most other relevant behavior can be seen more broadly, however. Their beliefs about reciprocity can be seen through their sharing amongst themselves as well as with the local community, with the sharing of both seeds and knowledge. Their farming practices are also rooted in similar reciprocal beliefs about respecting the earth. Moreover, the

organisation of the seed festival and other education programs is also evidence of a desire to create a better society.

5.3.3. Culture and food traditions

5.3.3.1. Mental models

5.3.3.1.1. Ancient heritage

Mental models related to culture and food traditions were first exhibited through a connection to the farmers' Cretan heritage, both ancient and ancestral. The ancient history of Crete served as a significant source of cultural meaning for many of the agroecological farmers interviewed. To several of the farmers, Crete was seen as the womb of the earth (referred to as the "big mama"). Indeed, Crete is historically home to the Minoans and known as the origin of civilization. This ancient heritage is a source of great pride for Cretans, and is especially embodied in the form of olive trees, for example:

> "*We also have got some very old trees, that one over there that you can see, it's more than a thousand years old, so we're very proud of it, this is our heritage." (Interview 05)*

5.3.3.2. Familial traditions

The farmers also see agroecology more simply as just how farming used to be: traditional agriculture prior to industrialisation, and more personally, how their grandparents used to farm. For example, one of the founders of the cooperative was primarily motivated to start saving seeds, and ultimately form the cooperative, as a means of connecting with his grandmother's spirit. The use of traditional seeds are also seen as connecting with their culture and ancestors, possessing more meaning and significance than hybrid seeds.

> "*Now we call this agroecology, but mainly it's our tradition and what our ancestors always used to do on earth. Our aim is, as human beings, to keep in our hands a part of local seeds, traditional seeds… most of the seeds that we cultivate today come from people who used to keep them with love, these seeds, and they trusted them to us." (Interview 03)*
>
> *"We don't cultivate seeds without a memory." (Interview 03)*

5.3.3.3. Culture of self-sufficiency

Due to the nature of Crete being an island, Cretans have a history of requiring some degree of self-sufficiency, and their mental models reflect this. Self-sufficiency was overwhelmingly cited as the central motivation and benefit of agroecological farming. Growing their own food and being able to provide for themselves in this way was seen as a way to gain independence from and reduce reliance on outside markets and external inputs.

> *"[Traditional seeds] give you the freedom to produce your own food. You are not a slave of a big company that tells you what to do and how to do it. And if the company wants you to eat, then you will eat. You should be able to produce food, and also the very important thing is, we do not know how to cultivate either… And I think this is a knowledge that is lost and that shouldn't be. We should all be able to feed ourselves in one way or another." (Interview 05)*
>
> *"I wanted to do this because I wanted to be independent, having the knowledge on my own, I'm not having to rely on anybody, asking what's the usual way of doing things, because what they do here now is still very commercial farming and permaculture is not like that." (Interview 06)*
>
> *"When your target is to earn a lot of money, from what you're doing, that's the most difficult road, the most difficult way to do things. But if your aim is to earn for you, for each of us, to eat, to have something to eat, and feed ten more families, for example, for me that's the ideal scenario." (Interview 03)*
>
> *"I think the most important is independence. And independence leads into freedom. And you can only do this if you can feed yourself." (Interview 06)*

5.3.3.4. Adaptation

5.3.3.4.1. Resource sharing

Adaptation-relevant behaviors related to mental models about culture and food traditions were first demonstrated through resource sharing and the utilisation of traditional seeds. Independence from external markets was frequently seen by interviewees as a primary benefit of agroecology. For example, one farmer noted

that by sharing with a friend, they are both able to increase their available products and thus improve their self-sufficiency:

> *"My friend has sheep, goats, and takes products from these animals. I give him some of my products, he gives me back some of his products. So, mainly, he has thirty products to give me, and I have thirty to give to him. If he has sixty, I have also sixty. So we altogether are self-sufficient." (Interview 03)*

5.3.3.4.2. Traditional seeds

Even more so, the use of traditional seeds was overwhelmingly cited as being most important to the farmers' agroecological practices. Not only do the seeds provide a source of connection for the farmers to their heritage, but they also provide the very practical purpose of producing their own food. The way this is carried out in practice is by leaving the best fruits to grow to their fullest potential, and harvesting the surrounding fruits, so as to concentrate the nutrients and water in the fruit in which the seeds will be harvested. The fruit is left on the vine for as long as possible, then it is harvested and the seeds are removed, cleaned, and dried. The cooperative is taking their seed-saving actions a step further by formalizing these practices through the organization of a seed bank. By working with testing facilities at the local university, they can help to ensure the quality of the seeds, thereby improving quality and yields for farmers, while also institutionalizing this process and thus helping to ensure the long-term sustainability of the project:

> "*I have already started with organizing our seed bank... I want to write the seeds, give the codes, put them in the refrigerator, and start having these tests and have certain varieties that I can suggest to producers and say this is a good variety of tomato... And at the same time, I come in contact with the university in Heraklion that has already taken some seeds to test them - how they are, the characteristics, how is the product, what yield they give, which is the genes... write down all these information, and to gradually have a serious seed bank from where we can help producers have more yield, healthy yield." (Interview 02)*

Figure 8: Organization of seeds for preservation in seed bank (left) and harvested sesame seeds (right)

5.4. Climate change perceptions

Due to the subject matter being related to climate change adaptation, an additional section on the farmers' perceptions of climate change itself is particularly relevant to this case. Most of the agroecological farmers interviewed for this study believed that climate change is happening, but that it is a natural phenomenon and nature is changing all the time. This echoes their mental models about synergies and efficiencies in regards to nature knowing how to balance itself. Moreover, most also held the belief that humans have no influence over the climate, citing that "we as human beings or as a race, we are not as powerful as we think, to really have such a huge impact that would affect climate change" (Interview 06). In general, interviewees were more concerned about resource scarcity due to overuse and pollution rather than due to climate change, which tied in to previous sentiments regarding individual responsibility and respect for the environment. Additionally, among olive farmers in particular, there was a "good year, bad year" sentiment present, meaning that they would generally expect the production quality and quantity to alternate approximately every year. This could imply a lack of adaptation in the long-term. Lastly, some

also voiced skepticism of the media, government, and science for promoting climate change. Ultimately, however, regardless of the variation in beliefs about the how and why of climate change, one farmer summarized that these agroecological methods are still beneficial to them:

> *"So we can say that climate change is something to happen and we can do nothing for this, so let's keep on doing what we were doing, pollute and spray all this - no. If we protect the environment, we make more length to this change, and of course, we can protect ourselves from this change by using these methods. (Interview 02)*

5.5. Summary

The empirical evidence outlined in this case reflected five focal themes of agroecology; within each of these themes, it was demonstrated how the mental models of the case study participants were correlated with their adaptation-relevant behavior. In particular, the use of traditional seeds was referred to frequently as a practice that found many benefits such as being better adapted to the local environment, contributing to biodiversity, and fostering community and a sense of connection to cultural heritage. Moreover, these mental models and behavior associated with agroecology were differentiated from conventional mental models and behavior where possible (Table 6). The empirical evidence from this case study thus confirms the hypothesis that mental models can shape climate change adaptation. This is of particular importance in the context of this case, as the behaviors beneficial to climate adaptation took place despite the presence of skepticism regarding anthropogenic climate change. This could have important policy and research implications, which will be explored in the next section.

Table 5: Agroecology mental models and adaptation-relevant behavior versus conventional mental models and dominant practices

Agroecology			**Conventional***	
Agroecology theme	*Mental model*	*Adaptation (vulnerability reduction)*	*Mental model*	*Dominant practices (vulnerability maintenance or exacerbation)*
Diversity	Holism, connection with nature	Biodiversity, traditional seeds, livestock/wildlife	Atomism, specialisation	Monoculture, hybrids
Synergies, efficiencies, recycling	Nature balances itself, resources are finite	Water saving, intercropping, nutrient recycling	Unlimited resources, anthropocentric rationale for resource use	Intensive usage of water and chemical inputs
Co-creation and sharing of knowledge	Context-specific, valuing of producer and local knowledge, participatory science	Seed festival, education programs	One-size-fits-all agriculture	Disconnect between science and practice; distrust of science
Human and social values	Equity, responsibility, reciprocity, environmental stewardship	Sharing resources, community involvement, reduced resource use	Human and social values generally not considered	Exploitation of agricultural workers
Culture and food traditions	Heritage, cultural identity, sense of place	Traditional seeds	Year-round and global availability of food; no seasonal or geographic connection	Lack of connection between consumers and origins of food

* hypothetical counterfactual

6. Discussion

6.1. Summary of the results and objectives for this chapter

The previous chapter elucidated the findings of this case study, which aimed to correlate mental models with adaptation-relevant practices. First, mental models about holism were found to be related to practicing biodiversity and using local seeds in cultivation, falling under the diversity theme. Second, beliefs about valuing the natural environment and finite quantities of resources were found to be related to resource conservation practices (e.g. intercropping), falling under the theme of synergies, efficiencies, and recycling. Third, aspirations to change the prevailing conventional mindset were found to have led to the development of community education programs, falling under the theme of co-creation and sharing of knowledge. Fourth, values of reciprocity and responsibility were found to lead to actions such as resource sharing, falling under the theme of human and social values. Fifth, an appreciation for heritage informed the practice of cultivating local seeds, falling under the themes of culture and food traditions. These findings thus confirmed the hypothesis, in that the mental models related to agroecology were found to be associated with actions that would reduce vulnerability and thus enable adaptation.

The objectives for this chapter are to address possible biases of the study and discuss its potential implications for future research and policy development. First, the limitations of the research will be addressed in regards to the materials, method, and proposition. The implications for research, followed by implications for policy, will subsequently be discussed.

6.2. Limits of the research

6.2.1. Limits of the materials

As with any scientific research, this study was limited in several ways. First, the interviews were limited in terms of my own language abilities and thus the sample was skewed towards farmers with English-speaking capabilities, i.e. participants with higher education levels. Exceptions to this include one farmer that spoke very little English and was translated by another participant, and an expert that was aided by impromptu translations from Google Translate to aid in mutual understanding.

Second, the study was limited in terms of time and finances. This led to a restriction of the size of the sample, as well as the duration and quantity of interviews per person. As such, the interviews were thus limited in terms of depth and breadth. Interviews with conventional farmers, which could have further enriched a contrasting analysis, were also not possible for these reasons. Future research would benefit from additional counterfactual material.

Third, because most of the interview participants were involved in the same agroecological cooperative, their viewpoints may be specific to that group and emphasize particular aspects of agroecology more than others. Therefore, the perspectives in which they prioritize may not necessarily be representative of agroecology as a whole. Still, these perspectives are a core part of agroecology as a discipline and thus can be useful for other cases.

The data collection process of participant observation also lent some difficulties to developing the materials. Trying to strike a balance between being a trustworthy and friendly guest, as well as an objective and critical observer, proved to be challenging as a researcher. As a result, the empirical evidence was impacted by how the participants perceived me as both a guest and researcher over the course of data collection.

6.2.2. Limits of the method

The case study method also has some general limitations. Primarily, case studies can be biased due to the necessity for subjective interpretation by the researcher. The same data can be interpreted in different ways by different people. My own background, worldviews, and mental models have thus informed my interpretation of this data. Moreover, a more experienced researcher than myself may find more nuanced patterns in the data (Bhattacherjee, 2012).

Additionally, due to their highly-contextualized nature, case studies can be limited in terms of the extent to which their findings can be extrapolated to other places. This criticism is also true, though, for quantitative studies in which several need to be completed for meaningful conclusions to be drawn (Yin, 2003). As such, case study findings "are generalizable to theoretical propositions and not to populations or universes" (Yin, 2003, p. 10). In this way, the aim of

this case study was to generalize theories through analytic generalization rather than statistical generalization (ibid.).

6.2.3. Limits of the proposition

A critique of agroecology may be that it is quite aspirational in its scope and unclear in its definition. Agroecology has been labelled as a polysemic term that can have multiple interpretations, and thus be approached in interdisciplinary ways (Bellon and Hemptinne, 2012; Dalgaard et al., 2003). Because the scope is so large and attempts to encompass many concepts, both in terms of issues it tries to address as well as the scales in which they occur, agreeing upon definitions and defining measurement mechanisms can be challenging. Moreover, different interpretations of agroecology can lead to differing institutional and political outcomes (Rivera-Ferre, 2018; Rega et al., 2018). In one way, this can be seen as a weakness, however it can also be a strength in terms of policy implementation due to there being many potential uses of agroecology.

6.3. Implications for research

Agricultural systems are inherently complex, requiring consideration beyond the agricultural sciences solely, e.g. with the natural and social sciences. In this respect, this research is in alignment with Norgaard & Sikor's (2018) proposal of "holism" in agroecology as an alternative to the "atomism" associated with conventional agriculture, as was also outlined in the theoretical framework. Similarly, Hagedorn (2008, 2015) asserts that due to being based on biological processes, agriculture is a unique industry that consists of complex interactions which can be understood as nature-related transactions. The efforts of conventional agriculture to operate as an engineered industry, based on production maximisation and specialisation, have led also to atomisation and thus can be considered as a segregative institution in which transaction costs are externalized (ibid.). In contrast, agroecology, representing an alternative pathway for agriculture, can be considered as an integrative institution that internalises transaction costs and more closely aligns with the inherent complexities that are present in agriculture (ibid.).

This concept of integration should also be applied to future research in the field of sustainable agriculture in order to have an appropriately nuanced understanding that accounts for both complexity and uncertainty. Agroecology advocates for research approaches to be more inter- and transdisciplinary, which allows for cross-pollination of ideas between disciplines, allowing for innovation to occur (Gliessman, 2015; Hatt et al., 2016). Interdisciplinary research refers to multiple academic disciplines bringing their respective perspectives to an issue, while transdisciplinary research (also known as participatory research) refers to expanding stakeholder involvement in the research process (Baveye et al., 2014). Indeed, agroecology considers the food production system as a whole, and necessarily then also the people within this system. As such, agroecology gives credit to traditional and indigenous agricultural practices that have historically been overlooked in science (Altieri, 1995). Moreover, these participatory research approaches have provided fertile ground for stakeholders to exchange information and differing viewpoints, allowing for collective social learning (Duru et al., 2015; Vilsmaier at al., 2015; Hatt et al., 2016). Additionally, it can allow for more successful adoption of scientific recommendations, improve management of common pool resources, and empower stakeholders (Biggs et al., 2011; Mendez et al., 2013; Hatt et al., 2016). Therefore, a combination of both practical knowledge from stakeholders, as well as modern scientific knowledge, will be optimal for advancing innovation in sustainable agriculture in the future.

6.4. Implications for policy

This research endeavored to understand how mental models can drive climate adaptation-relevant behavior. An earlier phase of this research was based on the following premise: “From an actor-oriented perspective, however, it is important to examine which of these externally-identified impacts farmers actually perceive, as *only the perception of an impact will lead farmers to take adaptive measures*” (Jacobi, 2013; emphasis added). The results of this research challenge this premise, instead finding that the “perception of an impact” was in fact not a prerequisite for climate adaptation-relevant behavior to occur. Rather, it was found that the multiple benefits (also known in the literature as co-benefits or

ancillary benefits) derived from agroecological practices drove adaptation, even when beliefs in anthropogenic climate change were not present. As Moser and Ekstrom (2010) critically note, “adaptation must consider, but may not be justified by, climate change alone and may be initiated or undertaken in the context of nonclimatic windows of opportunity” (p. 22026). In this way, this indicates a potential for agroecology to provide alternative paths of entry to climate adaptation, since the psychological barriers to accepting climate science have been shown to be significant.

More specifically, one potential pathway and the primary finding of this research was the importance of using traditional seeds as a means of achieving self-sufficiency. Providing multiple perceived benefits to farmers, their use not only can help reduce environmental vulnerabilities by being better adapted to the local conditions, they also allow the farmers to carry on their cultural heritage, foster a sense of community through seed-sharing initiatives, as well as a sense of individual independence free from external inputs. Indeed, the use and sharing of traditional, locally-adapted seeds have been advocated for climate adaptation in the literature (Jarvis et al., 2015; Yadav et al., 2011; Vernooy et al., 2017).

The focus of the EU Common Agricultural Policy (CAP) on modernisation of agriculture is in some ways antithetical to agroecology. This is evidenced by the incentivization of industrialisation in terms of both mechanisation as well as the genetic modification of seeds for high-yielding monoculture. As has already been established, these practices make the food system more vulnerable, particularly in the context of climate change disturbances (Alexander et al., 2015).

The EU Common Agricultural Policy (CAP) could therefore use agroecology principles to better align with the EU Water Framework Directive (WFD) as well as NATURA 2000 (biodiversity policy). These policies seek to address several of the numerous negative externalities associated with conventional agriculture (e.g. water quality, biodiversity, farmer livelihoods), but since none of them address the root cause of monoculture-dominant industrial agriculture,

these externalities can ultimately be only marginally mitigated by these policies (Migliorini, 2018).

The CAP already has measures in place to support sustainable agriculture, such as green direct payments as well as rural development measures. These measures are intended to preserve biodiversity and improve other environmental conditions. However, a report from the European Court of Auditors (2020) found that the current policies in place have in actuality not helped to improve these outcomes. Therefore, incentivisation of agroecological practices such as the use of local varieties and polycropping to enhance biodiversity, as well as using organic soil management methods to reduce chemical runoff and improve water quality, would be beneficial supplements to the upcoming update to the CAP that would then also help to achieve the goals of the EU WFD and NATURA 2000.

Agroecological practices could then supplement these policies to improve not only environmental conditions but also broader food systems outcomes. In the Ten Years for Agroecology (TYFA) project, the Institute for Sustainable Development and International Relations (IDDRI) developed a quantitative model that analyses land use and production methods of a European-wide transition to agroecology by 2050. This model found that, through the phasing-out of chemical agricultural inputs and expanding of green infrastructure, greenhouse gas emissions can be reduced by 40% and food requirements for Europeans can still be satisfied, despite a 35% reduction in overall food production (Poux & Aubert, 2018). By introducing agroecology concepts into the CAP, particularly by emphasizing the use of local seeds, ecological farming practices, and short supply chains, these food systems could become more viable and self-sufficient in the long term.

6.5. Summary

This case study was limited in terms of time and financial resources, the necessary subjective interpretation required in case study research, as well as the vast scope of agroecology as a discipline. Despite these limitations, this study provides grounds for future research and policy development in regards to the use of agroecology to reduce vulnerabilities to climate change.

7. Summary

It is clear that climate change will continue to have vast impacts globally. Effective adaptation to these changes will require collective action coordinated by institutions. Institutions are based on shared mental models, which are formed based on individual experiences and perceptions. Therefore, mental models are also important indicators for adaptation.

At the same time, agriculture is especially vulnerable to climate change. Agriculture is particularly important to society due to it providing the public good resource of food production. Moreover, adaptation in agriculture will be required to continue food production in the future. Alternative forms of agriculture represent opportunities for adaptation to climate change. One of these alternatives is agroecology, which aims to optimise ecological processes and ecosystem services within agricultural ecosystems.

The focus of this paper is thus on agroecology as an example of how mental models can lead to adaptation. A qualitative case study of agroecological farmers in Crete, Greece was carried out, using semi-structured interviews and participant observation to inform data collection. Five themes of agroecology were used as a framework for assessing the data: diversity; synergies, efficiencies, and recycling; co-creation and sharing of knowledge; human and social values; and culture and food traditions. A subsequent thematic analysis of the empirical evidence revealed connections between mental models related to agroecology and adaptation-relevant behavior.

This study therefore shows potential for agroecology to be used both as a set of agricultural practices as well as an alternative approach to policy implementation for climate change adaptation. The stakes are high for the agricultural sector to adapt to climate change in a way that is sustainable both environmentally and socially to ensure food security in the future. The multiple benefits provided by agroecology in both of these realms therefore provide ample appeal to a wide range of stakeholders. Future policy should therefore consider the further integration of agroecology into both environmental and agricultural legislation.

8. Appendix

8.1. Semi-structured interview protocol

- How did you get started with farming?
- Why did you choose an agroecological approach to farming?
- What aspects of agroecology do you find most important from both an environmental and social perspective?
- What opportunities and challenges do you see for practicing agroecology in Crete from both an environmental and social perspective?
- Have you noticed environmental changes in Crete, and if so, what? Do you think it is part of a larger phenomenon or rather isolated incidents?
- Have you changed or are you considering changing any of your farming methods based on any observed environmental changes, and if so, what?

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