André Vizinho, David Avelar, Ana Lúcia Fonseca, Silvia Carvalho, Leonor Sucena-Paiva, Pedro Pinho, Alice Nunes, Cristina Branquinho, Ana Cátia Vasconcelos, Filipe Duarte Santos, Maria José Roxo, Gil Penha-Lopes, Framing the application of Adaptation Pathways for agroforestry in Mediterranean drylands, Land Use Policy 104, https://doi.org/10.1016/j.landusepol.2021.105348.

Framing the application of Adaptation Pathways for agroforestry in Mediterranean drylands

Abstract

Adaptation Pathways is a decision support tool designed to create adaptation policies under different climate change scenarios. This tool has been used successfully in several sectors and contexts such as coastal and river adaptation, urban heat waves, floods and rural livelihoods but its use in natural resource management, has faced several challenges and limitations. In the sector of agroforestry its use has seldom been done or documented and one of the reasons for this may due to some of its specific challenges. In this study, these challenges were addressed when using the Adaptation Pathways for the adaptation planning of three case studies in the semi-arid Alentejo region, a Mediterranean dryland of southern Portugal. This tool was integrated in a participatory approach combined with the Scenario Workshop method, to plan the adaptation of the agriculture and forestry sector of one municipality (Mértola) and two agroforestry farms (221ha and 1000ha). The methodology included, for each case study, 20 interviews, two workshops, literature review, expert analysis and the use of indicators of efficacy of adaptation measures, to define tipping points. The adaptation process and the resulting adaptation plans were evaluated by questionnaire and expert review. This combination of methods has supported the choice of effective adaptation measures for the case studies and when combined with several adaptation pathways and a landscape approach it supported the creation of integrated climate change adaptation plans that are now in implementation. We discuss how this combination of methods deals with limitation to Adaptation Pathways identified in the literature, conclude that the method was able to create adaptation plans that are now under implementation and present avenues for future research.

Keywords: *Adaptation planning; Farm Adaptation; Scenario Workshop; Climate Adaptation; Agriculture management; Participatory Planning.*

1. Introduction

With the increased knowledge on climate change, scenarios, projections, impacts and vulnerabilities there is a growing need for knowledge on climate adaptation, climate adaptation planning and decision making support tools (Howden et al., 2007; Vilà-Cabrera et al., 2018a). On the contrary to climate mitigation, in which the response is only effective if implemented at a global scale, climate adaptation can reduce (but not totally) climate vulnerability at the local level (Füssel, 2007; Vermeulen et al., 2013). Adequate planning can significantly improve the efficacy and cost-benefit ratio of adaptation efforts (Campos et al., 2016; Füssel, 2007). Adaptation planning deals with complex and vast scientific information, uncertainty and also a plethora of possible responses, when dealing with adaptation in complex systems such as those that include ecosystems and humans, namely agroforestry systems (Bizikova et al., 2014; Fei and McCarl, 2018; Vermeulen et al., 2013; Zandvoort et al., 2017). Although several climate adaptation frameworks have been developed to support adaptation planning (Bours, D. et al., 2013; Hernández-Morcillo et al., 2018; Mitter et al., 2018; Robert et al., 2016; Vermeulen et al., 2013; Vilà-Cabrera et al., 2018b), few studies have reported and discussed adaptation planning methods for the agriculture and forestry at the farm level or municipal level from a multidisciplinary perspective (de Frutos Cachorro et al., 2018; Robert et al., 2016). The complexity associated with climate adaptation of agriculture and forestry requires a tool that is field adequate, effective in reducing vulnerability, flexible or dynamic and also capable of engaging farmers and stakeholders in a planning process that goes beyond incremental adaptation and mere management of present risks and climate variability (Halofsky et al., 2018; Robert et al., 2016; Vilà-Cabrera et al., 2018b). Dynamic Adaptive Policy Pathways, most frequently called Adaptation Pathways (AP), have already proven, in other works, capable to be effective in informing and mobilizing decision-makers, creating dynamic adaptation plans, incorporating local knowledge and combining incremental adaptation measures in the short term, with more systemic or transformational measures in the medium-long term (Bloemen et al., 2018). In multi stakeholder contexts, several authors conclude that resolving conflict and, if possible, achieving consensus is an important part of the planning in order to create better plans and maximize the success of implementation (Bosomworth et al., 2017; Innes and Booher, 1999; Uittenbroek et al., 2019). Participatory scenario planning and Scenario Workshops have shown capable of generating consensus while generating robust adaptation plans in areas with high levels of vulnerability and uncertainty (Campos et al., 2016; Schmitt Olabisi et al., 2020). In this study, for the adaptation planning of agroforestry systems at farm and municipal levels, the authors use SWAP − Scenario Workshop & Adaptation Pathways - a combination of the methods Scenario Workshop (Hatzilacou et al., 2007) and Adaptation Pathways (Haasnoot et al., 2013). This approach, already used in other adaptation planning case studies (Campos et al., 2016; Vizinho et al., 2017a), was adapted and refined, thus proposing several add-ons, essential to deal with the complexity of the agroforesty sector at these levels. The aim of this study is to frame the application of the Adaptation Pathways tool in the adaptation planning of agriculture, forestry and agroforestry systems, answering the question: How can Adaptation Pathways be used to create robust science-based adaptation plans of agroforestry systems?

Climate Adaptation Planning in Agroforestry

Climate change projections for years 2070-2100 indicate very significant changes for global climate (IPCC, 2014), namely for the Mediterranean region where significant increases in temperature and droughts, decreases in precipitation and water availability are projected (Ruti et al., 2015; Mariotti et al., 2015; Dubrovský et al., 2014; Planton et al., 2012; Xoplaki et al., 2012). The Mediterranean region is in a transition zone located between North of Africa, with an arid climate, and Central Europe, which is temperate and rainy. Thus, even small modifications in the interactions between tropical and mid-latitude processes can considerably affect Mediterranean climates. In vast areas of the Mediterranean, the maximum climate shift projected for year 2100 using IPCC climate scenarios can lead to a change of climate according to Köppen-Geiger's classification system, from more temperate to more arid, namely from Temperate Mediterranean with hot and dry summers (Csa) to Arid Hot Steppe (Bsh) (Rubel and Kottek, 2010). These projections show very significant negative impacts on the rainfed agriculture and forests of the Mediterranean climate region (del Pozo et al., 2019; Lionello et al., 2014; Xoplaki et al., 2012). The direct impacts in the agriculture, forestry and agroforestry systems in the Mediterranean climate region, in particular the areas without irrigation, can be several: droughts can reduce up to 100% the productivity of cereals and annual crops (Daryanto et al., 2017); reduction of precipitation reduces productivity of crops and trees and can lead to tree mortality, destruction of ecosystems and desertification; water scarcity can lead to animal mortality or disease, migration of biodiversity, difficulty in fire combat; heat waves can destroy flower and reduce fruit productivity, create fires, increase mortality; increase in temperature can result in increased mortality (del Pozo et al., 2019). On the positive side, the projected decrease of frost can increase the potential areas for frost sensitive species, either they are autochthonous species, exotic fruit trees, or horticulture crops. Furthermore, the increase in temperature and atmospheric CO_2 can generate an increase in productivity if water is available and if overheating, or other limiting factors are not a problem (del Pozo et al., 2019). These impacts on agricultural productivity can generate systemic socio-economic impacts at the local, national and international levels (Wiebe et al., 2015). The increase in vulnerability (and also the potential opportunities) calls for effective adaptation investments, planning and management (Vilà-Cabrera et al., 2018a; Rickards and Howden, 2012; Pedersen, 2013; Vermeulen et al., 2013). Farms and rural territories frequently combine agricultural annual and permanent crops, forests, pastoralism, hunting, animal grazing, agroforestry systems and natural areas. In the context of climate change, potential impacts and vulnerability increase, farmers can make reactive or proactive decisions, both on the short term (tactical) or on the long term (strategical) (Robert et al., 2016). These decisions can be affected by agronomic, economic or social factors (Robert et al., 2016), by farmers beliefs, experience, farm attributes and characteristics (Castellano and Moroney, 2018) or even by psychosocial factors such as perceptions, cognitions, motivations, age or lifestyle (Mankad, 2016). Social factors, such as the presence of heirs, can also significantly influence the long term vision of the farm and thus influence the choice of adaptation strategies (Castellano and Moroney, 2018). Based on extensive literature on farmers decision making, Mankad (2016) concludes that each farmer will make decisions in a nuanced way influenced by unique social, psychological and contextual factors. When planning more than one farm, such as a group of farms, a cooperative, village or municipality, the context of decision making is that of a community, thus bringing other factors on decision making, such as relationships, power, leadership, conflict (Phillips and Pittman, 2014), social responsibility, perception of "everyone is doing it", fear of being criticized, (Mankad, 2016) shared perceptions of risk (Van Aalst et al., 2008), Therefore, planning the climate adaptation of farms and territories calls for an integrated framework and decision support tool (Howden et al., 2007), that can include the individual, social and community factors together with the climatic, agronomic and economic ones.

Dynamic Adaptive Policy Pathways is a decision support tool designed to create adaptation policies under different climate change scenarios (Haasnoot et al., 2013) and has been gaining research interest and attention due to its communication potential and dynamic character (Fazey et al., 2016; Bosomworth et al., 2017). This tool has already been used for adaptation planning in several sectors and contexts such as coastal and river adaptation (Campos et al., 2016; Vizinho et al., 2017a; Kwakkel et al., 2015; Haasnoot et al., 2012), urban heat waves (Zandvoort et al., 2017), rural livelihoods and remote communities (Butler et al., 2014; Maru et al., 2014). In the field of agriculture, forestry and agroforestry its use has faced some challenges and has not been clearly framed on how it can be applied successfully (Bosomworth et al., 2017). Some of the reasons could be related with the several challenges that need to be addressed when using Adaptation Pathways in this sector namely: i) an agroforestry system has several species and crops and each of them have different climate change vulnerabilities, not always with already available information; ii) defining tipping points for adaptation measures implies the knowledge of their efficacy (Haasnoot et al., 2013), which is also not available for all the adaptation measures nor or all existing situations of slope, soil type, crops, and techniques; iii) an agroforestry system is composed of several species and crops that have different pathways and tipping points for the same adaptation measure; iv) several adaptation objectives can coexist in an multifunctional agroforestry system and thus there are many ways to perform the adaptation; v) as mentioned above, decision making by farmers involves plenty of ambiguity and dealing with this ambiguity involves increasing the participatory dimension of AP, which is a field in which more information is needed, as shown by Bosomworth and Gaillard (2019) .

The use of AP in the field of Natural Resource Management has been documented (Bosomworth et al., 2015; Moffat et al., 2014) and several limitations and challenges have been identified (Bosomworth et al., 2017, 2015; Bosomworth and Gaillard, 2019). According to Bosomworth and colleagues, the challenge of dealing with complexity in Natural Resource Management is not fully addressed in AP, namely it "doesn't accommodate thinking beyond individual species particularly well" and it's utility is limited at more complex scales, such as multiple species interactions or ecosystem functions. These authors also highlight the difficulty in identifying trigger and tipping points in Natural Resource Management (Bosomworth et al., 2017), a crucial aspect feature of the Adaptation Pathways tool, to be addressed in this study.. Other limitations of AP identified by Bosomworth and colleagues, such as the difficulty in dealing with transformative forms of adaptation, dealing with ambiguity, ignoring the institutional dimensions of governance or focusing on the creation of consensus-based plan instead of focusing on the comparison of adaptation pathways, have been addressed by other studies or case-specific applications of the tool (Bloemen et al., 2018; Campos et al., 2016; Hermans et al., 2017; Lawrence and Haasnoot, 2017; Michas et al., 2020).

Some of the AP limitations have been addressed by specifically paying attention to the specific needs of the context and adjusting the tool to respond effectively. Bosomworth and Gaillard argue that there is a need for those working with adaptation planning and AP to make available "the details of their process, including methods and tools, governance, what worked, what did not, and its benefits and challenges"(Bosomworth and Gaillard, 2019) Since in the field of agriculture and forestry, the past experiences of AP have very few and exploratory, we argue that the application of AP in this field particularly needs detailed information, adjustment and discussion. As authors such as Bosomworth and Sharpe argue, a combination of methods can also be an effective solution to deal with the limitations of a method and significantly improve the adaptation planning process (Bosomworth et al., 2017; Sharpe et al., 2016).

Following the experience of Campos et al (2016) and (Vizinho et al. (2017a) we propose the combination of Scenario Workshops with Adaptation Pathways (SWAP), to strengthen the participatory dimension of AP and furthermore include some approaches and addons from methods to adequate the process to the needs of decision making by farmers and communities.

The following section (section 2) thus proposes a specific combination of methods that attempts to deal with these limitations in the process of adaptation planning of agroforestry systems. Section 2 presents the SWAP method used, describing in general its eight steps. In section 3, we present the results of a detailed SWAP application in three case studies and the evaluation of the method by the participants. Finally, in section 4, we discuss the method and its results, comparing our results with the literature review. Section 5 offers some conclusions and avenues for future research.

2. Methodology

The objective of this article is to present and discuss the framing and use of SWAP - Scenario Workshop and Adaptation Pathways. An extensive evaluation of the method of adaptation planning can, in rigor, only be performed by assessing if the system that was planned is climate-proof and less vulnerable. This assessment cannot be done before the future climate impacts unfold and therefore its evaluation must be based on a discussion based on theoretical validation of the resulting adaptation plan. Furthermore, because the method of planning is participatory and it is applied to complex socio-economic systems, the evaluation also includes the evaluation of the method by relevant stakeholders.

SWAP - Scenario Workshop & Adaptation Pathways approach for agroforestry systems

Five concepts are pillar of the Scenario Workshop & Adaptation Pathways (SWAP) approach discussed in this study: the Scenario Workshop planning method (Andersen and Jæger, 1999; Street, 1997), the Dynamic Adaptive Policy Pathways (Haasnoot et al., 2013), the Participatory Action Research (PAR) approach (Kindon et al., 2007), the Vulnerability framework (Fritzsche et al., 2014) and the Drivers, Pressures, State, Impact, Responses (DPSIR) framework (Kristensen, 2004). This combination of methods has been used for the first time for coastal adaptation (Campos et al., 2016; Vizinho et al., 2017a) and its use for agroforestry adaptation planning required revision and additional steps that in this paper and case studies use are described and discussed. Figure 1 illustrates the stepwise approach mentioned above and described below.

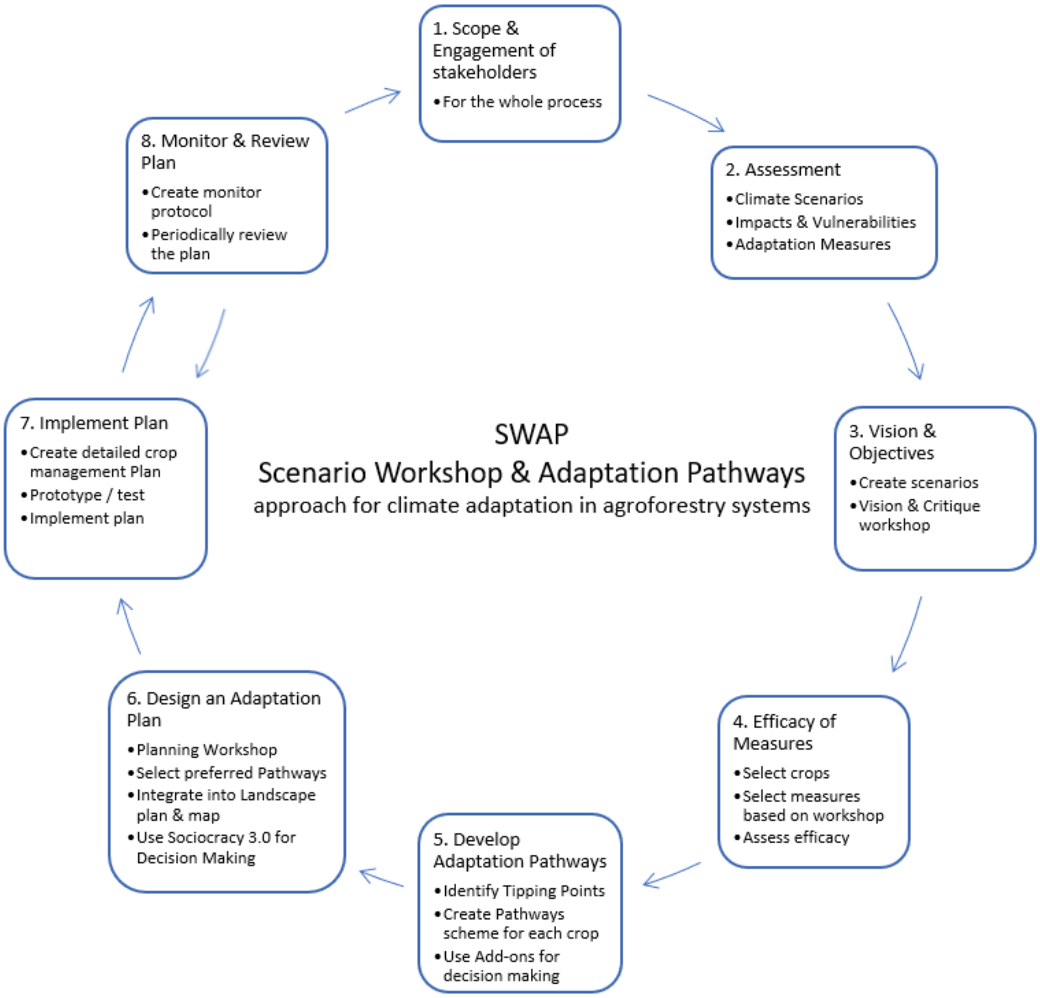

Figure 1 – Stepwise approach of SWAP - Scenario Workshop & Adaptation Pathways for adaptation planning of agroforestry systems. Approach is based on Campos *et al* 2016 and combines Adaptation Pathways with Scenario Workshop

Step 1, Scoping and Engagement of Stakeholders, is done in the very beginning of the process, when only the intention of creating an adaptation plan exists. The first step of the SWAP process consists in engaging the relevant stakeholders, whether the case is of a single farm, a group of farms, cooperative or larger territory, like a municipality.

In the case of farm level adaptation planning, this step is the first co-creation moment with the farmer / farming company, that is essential to generate trust and help define how deep, extensive, detailed, informed, participated and transformative will the adaptation planning process be. In this case, the planners/researchers supporting the planning process start by presenting the farmer/farm managers the planning approach, the climate scenarios, potential impacts, vulnerability, challenges and opportunities in adaptation, exploring stories of what could happen and identifying the interdependence of the farm with external factors, therefore making connections and finding opportunities, support or obstacles outside the farm. The first encounters with farmer/farm managers help the managers understand what is the proposed approach to adaptation planning and also who are relevant people to invite, in order to enrich the adaptation process in specific moments such as the Vision & Critique workshop (Step 3.2) and the workshop for designing a strategic plan (Step 6). The bigger the size of the farm, the higher the responsibility with the territory and more relevant becomes to include more stakeholders.

In cases where the territory is managed by several people, such as a territory with several farmers, a cooperative, a joint initiatives of landowners or collective management initiatives, the process of climate adaptation can be compared to that of community development (Phillips and Pittman, 2014; Reid, 2009). In this context, and as reminded by the literature on best-practices of community development experiences (Phillips and Pittman, 2014), the first step of the SWAP process does not intend to be blue-print but rather a general structure and guideline for a flexible process of stakeholder engagement and community development based on the Scenario Workshop method (Andersen and Jæger, 1999) and inspired by ABCD - Asset Based Community Development (Cunningham and Mathie, 2002; Haines, 2009; Mathie and Cunningham, 2003; Winther, 2015) and Regenerative Development (Gibbons et al., 2018; Mang et al., 2016; Mang and Reed, 2012) approaches.

Despite the challenges posed by climate change in many regions, the adaptation planning should, if possible, be a generative process, based on the place and its potential, its assets and resources, empowering the stakeholders to take ownership over the adaptation planning, implementation and monitoring process.

If stakeholders are to be properly engaged in planning, implementing and monitoring, they need to be involved since the beginning, in defining the scope and limits of the system, as well as who should be part of the process and making these decisions (Arnstein, 1969; Carpentier, 2016; Prieto Martín, 2010; Reid, 2009). The definition of scope should be done with a small core group of stakeholders, the vision and adaptation planning workshops is done with more stakeholders, typically less than 35 selected, personally invited stakeholders (Andersen and Jæger, 1999). Complementarily, before the workshops, other moments, such as public debates, surveys, interviews or other participatory tools, can be organized with an open public to receive more knowledge and opinions, map resources, collect stories and help design the next steps of the process. By including relevant stakeholders, more relevant knowledge, assets and resources are present in the adaptation process, thus improving the quality of the results in its several phases (Haines, 2009), given adequate strategies are put in place to deal with some of the challenges of co-production of knowledge for adaptation (Cvitanovic et al., 2019).

In the case of municipal or regional level adaptation planning, when adaptation plans will have an impact on policies or measures intended to educate, mobilize or increase the adaptive capacity of farms, this participatory approach also attempts to reach the higher level possible of the participation ladder, as defined by Arnstein (1969), OECD (2001) or IAPP (2018), in order to find legitimacy and prevent the illusion of inclusion in climate adaptation, as discussed by Few et al (2007), Prieto Martín (2010) and Carpentier (2016) . Furthermore, this step also increases the social justice and democracy level of the decision making process, therefore reducing the resistance of some stakeholders to the implementation.

Although it is the first step, engagement of stakeholders is not to be implemented only in the beginning of the planning process, but rather throughout the whole planning process (see Appendix A). These objectives and values are part of the PAR approach and their relevance, pertinence and effectiveness are described and discussed by several authors (Dawit and Simane, 2017; Few et al., 2006; Nelson et al., 2016) . Participation and inclusion are important but its practice must be sensitive to existing critiques of participatory processes in order to avoid unnecessary tensions and adequately deal with identified possible issues or paradoxes such as, for example, complexity of information and tools, facilitation skills, hierarchy, adaptation mandate, availability to question assumptions and even manipulation or tokenism (Carpentier, 2016; Cvitanovic et al., 2019; Few et al., 2007; Sprain, 2017; Uittenbroek et al., 2019; Van Aalst et al., 2008).

This first step of SWAP, the strong participatory approach from the beginning, the use of Scenario Workshop method and its impact on the next steps of the process, namely the Vision & Critique workshop in step 3 and the setup and method of planning workshop on step 6, are the main differences from the Adaptation

Pathways method has proposed by Haasnoot et al., (2013). The other main differences and changes presented and noticeable on the other steps of SWAP are mostly a result of the implications of the participatory approach in addition with the specific details of framing of the AP tool to the sector of agriculture and forestry.

Step 2, Assessment of climate scenarios, potential impacts, vulnerabilities and adaptation measures, including adaptive capacity, is framed using the mentioned vulnerability and DPSIR frameworks and have specific details in the sector of agroforestry, given the diversity of species, crops, practices and variables that are included in the system (Fritzsche et al., 2014; Kristensen, 2004; Vizinho et al., 2020). In order to assess and communicate the potential impacts on crops or species and, later on, support the identification of tipping points, in this step we make use of the Climate Envelope concept. The concept of Climate Envelope (Brandt et al., 2017; Hijmans and Graham, 2006; Jiguet et al., 2007; Wilson et al., 2018) refers to the threshold of maximum and minimum values between which a species or crop can survive, defining therefore its spatial distribution or a satisfactory survival rate or productivity level. Many agriculture and forestry crops still do not have their climate envelope well characterized and the variables that are most relevant for its characterization are still an issue of research (Brandt et al., 2017). Several variables can be useful to support decision making and adaptation planning such as: minimum temperature of coldest month and maximum temperature of warmest month; annual mean temperature; resistance to frost; minimum and maximum rainfall; precipitation in wettest month; precipitation in driest month; altitude etc. (Brandt et al., 2017). In order to use the climate envelope of species in the adaptation planning, a literature review must be done to identify what robust information exists, on what variables, that can generate climate envelopes usable for the specific context.

Step 3, Defining the future vision and defining adaptation objectives is done in this approach using the first stakeholder workshop of the Scenario Workshop method entitled Vision & Critique, in which different future scenarios are presented. Anticipatory or normative scenarios are built on the basis of different visions for the future and exploratory scenarios are built based on observed trends leading to a likely future (Godet and Roubelat, 1996). In this method, three or four scenarios are developed to explore the future consequences of three or four fundamentally different adaptation options under one specific climate scenarios, typically RCP

8.5 or RCP 4.5; more detailed information on climate scenarios, named RCPs (Representative Concentration Pathways) can be found in van Vuuren et al. (2011). The use of scenarios in the visioning workshop allows, on one hand, the choice between incremental, transition or transformative adaptation (Roggema et al., 2012) embedded in the choice of adaptation option and, on the other hand, the definition of adaptation objectives. During this workshop, participants are informed about climate scenarios, impacts and adaptation measures. Then they are presented with the three or four scenarios that explore different adaptation options for they system. As mentioned in section 1, decision making by farmers is affected by psycho-social factors as well as agronomic and economic factors. These different scenarios should therefore be able to connect in different ways with the perceptions, beliefs, lifestyles and motivations of stakeholders while, at the same time, expose the future consequences of choosing and implementing different adaptation option and strategies, in the context of climate change. If scenarios are properly constructed and communicated, and the workshop facilitation allows it, stakeholders will be able to engage in a discussion that bring together logic, values, emotions and personal vision for the future, thus integrating the most possible factors when they are asked to critique these scenarios and create their own vision, defining concrete objectives of adaptation. In the second part of the workshop program, typically after lunch, stakeholders are asked to put their vision onto the map, which starts a discussion on adaptation strategies and measures. In the end of the day, a common vision is agreed by all, by identifying what is common among all stakeholders, finding space also for experimental measures and measures needing more information. The overall method for achieving several decision in group in a short time is that of Sociocracy 3.0 (Bockelbrink et al., 2015). This first workshop also supports and simplifies the following steps of assessment of efficacy of adaptation actions, since it includes and excludes several actions and often places measures on the map, meaning that some measures will no longer have to be assessed, since they are discarded by stakeholders.

Step 4, assessing the efficacy of adaptation measures is essential to support a robust and science-based informed decision-making process. It implies selecting the crops or species that are relevant for the farm or territory, since the adaptation actions have different efficacy and relevance depending on the crop or agricultural practice.

Step 5, developing the adaptation pathways, is done separately for each main crop or species. An Adaptation Pathways scheme is developed by, first, identifying a tipping point for the Business As Usual (BAU) management on the crop or species. After the BAU Tipping Point is defined, adaptation measures and their tipping points can be included in the scheme. Defining tipping points is based on the efficacy of the adaptation measures and this can be done by computed modelling, by using general literature efficacy values or with the use of expert knowledge. The adaptation pathway scheme is then ready to present or choose different adaptation pathways, using a train line analogy, moving from measure to measure as tipping points are reached. Since many options are possible, decision makers choose or design a new pathway based on several presented criteria or their own. If relevant and possible, further add-ons such as multicriteria information or cost-benefit analysis can be added to support decision making.

Step 6 is the strategic adaptation planning moment that is based on the second stakeholder workshop. In this workshop the stakeholders are presented with one adaptation pathway scheme for each main crop. For each crop, they have to choose one of the presented adaptation pathways or design a new adaptation pathway. A new adaptation pathway for one crop is designed whenever the stakeholders want to join or add more adaptation measures in a single pathway or also if they decide to create different pathways for different situations (e.g. different areas in the map, different microclimates, different management of the crop). Since this is a participatory process of planning, it is assumed that the team of planners, responsible for developing the adaptation pathways, cannot limit the options of the farmers/ stakeholders/ practitioners/ decision makers, but rather inform, using the best decision support tool available. In a second stage they must integrate the pathways of the different crops in a map, or zonal plan, that integrates crop management with spatial and farm management. The resulting adaptation plan has several adaptation planning schemes, one for each crop/species, but also one map, with several zones defined and a set of management measures for each zone. The same crop can have different adaptation pathways for different areas of the farm /territory due to different microclimates or conditions (e.g. availability of irrigation). On the other hand, one zone can have several species/crops (e.g. in a agroforestry system) and their interaction can generate different conditions, farm practices and adaptation measures. The map and the zones thus integrates all this information.

Step 7 is dedicated to implementing the strategic plan, which, at the farm level, implies a detailed stage of budgeting, defining materials, densities, field implementation, which is to be made, not on the context of a stakeholder workshop, but on a working group, the farm implementing team. If new measures are to be implemented, experimenting or prototyping is recommended. At the municipal level, implementation has to be done at the farms but ideally also at the municipal level, with measures that increase the adaptive capacity.

Step 8 has monitoring and periodic evaluation plan as the main objectives and, as recommended by Haasnoot and colleagues (2012), should have triggers that originate reassessment, corrective actions, defensive actions, and capitalizing actions. Since climate variability is typically measured on periods of 30 years (IPCC, 2013), there is a tension between measuring and monitoring the impacts of present climate variability versus the impacts of climate change. On the other hand, since the resilience of farms and farmers depends often on annual variability (less of forestry and more on agriculture), it is essential to continuously monitor how the adaptation measures are reducing farm vulnerability by reducing exposure, improving the state/reducing the sensitivity of the farm, protecting against potential impacts and increasing the overall adaptive capacity.

This last step of the cycle of SWAP − Scenario Workshop & Adaptation Pathways is built on the experience of monitoring adaptation pathways, discussed by authors such as Hermans et al., (2017) or Bloemen et al. (2018) and is essential to trigger the detailed planning and implementation of adaptation measures in time. According to these authors, a monitoring program should be transparently linked to the decision-makers and a dedicated structure that bring together experts and decision makers should be responsible to follow up on the adaptation plan. The first step can be to analyze the adaptation plan and identify the important assumptions and also causal relations between objectives, actions, elements of the system and external factors. These causal relations and assumptions help identify what needs to be monitored (signposts or indicators) and what are the measurable values that are associated with tipping points and trigger the implementation of other adaptation measures (triggers) (Hermans et al., 2017). The monitoring of key indicators will inform a periodic review of the adaptation plan, which in other experiences with AP has been undertaken every 5 or 10 years (Bloemen et al., 2018), starting again the adaptation planning cycle.

3. Results

Application of SWAP in three agroforestry case studies

Step 1 Scope and engagement of case studies

Step 1.1 Scoping of case studies and study area

This study is developed within the context of two projects in which three case studies were signaled as key areas where climate change adaptation plans would be developed using the SWAP approach: the agriculture and forestry in the Municipality of Mértola; a Montado agroforestry farm of Herdade da Ribeira Abaixo; and the Nature Park of Noudar / Montado agroforestry farm of Herdade da Coitadinha, all located in Alentejo region in the south of Portugal. While diverse landscape structures exist within the areas of the three case studies, Montado agroforestry systems are the main landscape unit present in the case studies and case study region of Alentejo, south of Portugal (Pinto-Correia et al., 2011).

The Alentejo region, in the south of Portugal, has a Mediterranean climate, with dry hot summers and an average accumulated annual precipitation of 630 mm, which is projected to decrease around 18% by the end of the XXI century, under the RCP 8.5 scenario, and based on an ensemble of 9 Regional Climate Models (IPMA, 2018). Particularly in its southern area (Baixo Alentejo - NUTSIII), the annual precipitation is projected to decrease from 500 mm to 400 mm, under the same scenario. Regarding the temperatures, in the same period of 2071-2100, the annual mean is projected to rise by 4 ^{o}C, while the increase of maximum temperatures could reach 6 ^{o}C. Particularly in August, the average maximum temperatures are projected to increase from 31.3^{o}C in the 1971-2000 period to 36^{o}C in the end of the century (2071-2100).

	Case study Mértola	**Case study Noudar**	**Case study HRA**
Context variables			
Governance descriptors	Municipality level. Land owned mostly by farmers. Presence of Natural Park and management plan.	Farm level owned by public company EDIA (managing entity of large irrigation infrastructures)	Farm level owned by Ministry of Agriculture, managed by the Faculty of Sciences of the University of Lisbon (with rental)
Area (hectares)	129287	991	221
Main crops/farm activities	5 typical farms were used in the plan: 600ha Montado agro-silvo-pastoral systems, 1000 ha of pastures for animal grazing (sheep, cows,	Montado agro-silvo-pastoral system, Organic cattle, biodiversity conservation projects, eco-tourism, education	Montado agro-silvo-pastoral system, Cork, research and education

	black pigs), 200 ha of Stone pine, 1000 ha of shrubs for hunting, 50 ha irrigated yards of vine and olive. Biodiversity conservation is also a major activity.		
Initiative for adaptation plan	Consortium of EEA grants funded "Adapt*For*Change" project included University, Mértola NGO (ADPM) and National Institute of Forestry and Conservation (ICNF)	Consortium of LIFE funded "Montado & climate" project including owner EDIA	Consortium of LIFE funded "Montado & climate" project including manager entity FCUL
Stakeholders involved	Municipality, ICNF, Ministry of Agriculture, farmers cooperative, 15 farmers, universities, professional school, consultant companies, several NGOs (local and regional development, hunters, forestry)	EDIA representatives, farm workers, beekeeper, local fire department, Municipality, ICNF, Ministry of Agriculture, neighbour farmers, other farmers partner in LIFE project, universities, national institute of farming research (INIAV), ADPM, local farmers association.	FCUL managers, FCUL researchers, neighbour farmers, sheep herder, agro-forestry company/experts, municipality, local farmers association, local farmer cooperative, local school, association of cork producers, ICNF, ADPM, INIAV
Adaptation Objectives (result of participatory process, Step 3 - Vision & Objectives)	Make this vulnerable territory attractive, valuing its landscape, biodiversity, hunting, gastronomy, culture, history, heritage and agriculture. Promote permanent pastures and regenerate forest in microclimate; Diversify species; improve soils and water retention; manage hunting sustainably; promote local entrepreneurship	Preserve biodiversity, the Montado, riparian galleries, shrublands and agro-silvo-pastoralism in an organic farming mode. promote pilot experimental zones. Increasing the vitality of the Montado system even in a climate change context, possibly resorting to complementary species.	To be a sustainable farm, an example of Montado´s good management in the region, both ecologically and economically. Simultaneously, dedicate 60% of the property area to biodiversity conservation, with a minimum of human intervention, to support climax communities in riparian and cork oak forest areas.
Crops used in AP scheme			
1. Quercus suber	x	x	x
2. Quercus rotundifolia	x	x	x
3. Arbutus unedo	x	x	x
4. Olea europeae	x	x	x
5. Ceratonia siliqua	x	x	x
6. Permanent pastures	x	x	x
7. Triticum spp	x		
8. Pinus pinea	x		
9. Rosmarinus officinalis		x	x
10. Juglans regia		x	x
11. Fraxinus excelsior		x	x
12. Prunus dulcis		x	x

Table 1 - Comparison of three case studies , context variables, adaptation objectives and crops used in the Adaptation Pathways schemes.

First case study - Municipality of Mértola.

The first case study is the municipality of Mértola. The territory of Mértola has an area of 1.292 km^2, a population density of 5,3 Inhabitants / km^2. 70 % of its area is dedicated to agriculture, with only 614 farms and an average area of 147 ha per farm. The Irrigation area is only 0,7% of (649ha) of all the farming area in this municipality, meaning that the vast majority of farming is rainfed farming (INE, 2009). Land use practices consist mainly of cereal crops and pastures, agroforests with holm oak, shrubs and monoculture forests (CAETANO et al., 2010). Mertola's climate is one of the driest and warmest in Portugal, with an average of 483 mm of accumulated annual precipitation and an average maximum temperature in August of 33.1ºC (average of records for the 1976-2005 period). Climate projections analyzed within the Adapt*For*Change project (AdaptForChange, 2016), indicate by 2100 an average of 228 mm of accumulated annual precipitation and an average maximum temperature of 39.5 ºC in August (Calheiros, T. et al., 2016); these projections were obtained based on one of the climate models (EC-EARTH-KNMI_RACMO22) with the best performance for precipitation in our studied area (see Soares et al., 2017). This climate projections are beyond the threshold of survival of several tree species in the region, namely *Quercus Ilex rotundifolia*, *Quercus suber*, *Pinus pinea, Arbutus unedo, Ceratonia siliqua* and *Olea europaea* (Gonçalves Ferreira et al., 2001; Oliveira and Correia, 2003; Saramago, 2009) .

The main objective of Mértola's case study was to develop a participatory strategic plan for climate change adaptation of the agriculture and forestry of the territory of the Municipality. This plan was developed within the context of the Adapt*For*Change project and 30 stakeholders were involved in the planning process, resulting in a final commitment letter signed by the mayor of Mértola municipality, the Nature Park of the Guadiana Valley, the Cooperative of farmers of Mértola and the local development NGO.

Second case study - Nature Park of Noudar / Herdade da Coitadinha Farm.

The climate projections analyzed for this farm (Carvalho, 2017a) show for the 2071-2100 period, considering the scenario RCP 8.5, a decrease of 107mm in accumulated annual precipitation, bringing it to around 483 mm, which is the minimum precipitation that supports a good productivity of the main tree in the landscape, the *Quercus ilex rotundifolia* (Oliveira and Correia, 2003). Regarding maximum temperatures in the month of August, projections for the 2071-2100 period indicate an increase in 5ºC, bringing it to 37 ºC which is far beyond the upper threshold of survival for *Quercus suber*, another common tree found in the landscape (Gonçalves Ferreira et al., 2001).

The Nature Park of Noudar, which is also a farm, manages an area of nearly 1000 hectares, is owned by a public company, EDIA, and has most of its area dedicated to the conservation of the holm oak montado agro-silvo-pastoral system. In spatial distribution, some areas of the Herdade da Coitadinha Farm are covered mostly by pastures for cattle, while the majority is dominated by holm oak trees with the understory as pastures and, finally, some areas are allowing the wild development of forests with large trees and shrubs with the major role of wildlife conservation.

Third case study - Public farm of Herdade da Ribeira Abaixo (HRA).

This 221 hectare farm is dedicated to the conservation of the *Quercus suber* (cork oak) montado agro-silvo-pastoral system and its associated biodiversity. The climate projections analyzed for this farm (Carvalho, 2017b) show for the 2071-2100 period, considering the scenario RCP 8.5, a decrease of 179mm, bringing it to around 649 mm of accumulated annual precipitation. Regarding maximum temperatures, in the month of August, the projections for 2071-2100 period indicate an increase in 4^{o}C, leading to temperatures up to 34.5 ^{o}C , which is 3,5 ^{o}C above the upper threshold of survival for *Quercus suber*, the main tree in the landscape (Gonçalves Ferreira et al., 2001).

The objectives of the second and third case studies were to develop climate change adaptation plans at the farm level and implement them in the following two years with monitoring indicators and the support LIFE Programme of the European Commission (LIFE Montado, 2017).

Step 1.2 Stakeholder engagement

In the three case studies, the stakeholders were identified based on the criteria mentioned above namely: land owners/ farmers; local, regional and national experts or scientists; local, regional or national institutions, such as local development associations, municipality, regional public administration on agriculture, institute of nature conservation, local school, farmers associations and local companies. At the local level, especially when planning at the municipal level the approaches used for identifying farmers and stakeholders, was an adapted snowball technique (Atkinson and Flint, 2001; Sadler et al., 2010) used in combination with an approach inspired by the Asset Based Community Development (ABCD)(Mathie and Cunningham, 2003) and the Law of the Few by Gladwell (Gladwell, 2006) that focuses on working with members of the community that are connectors, experts and networkers that can further spread the "message", in this case the climate adaptation plan. Furthermore, stakeholders were engaged to: support the whole planning process; contribute to the identification of present and future vulnerabilities; identification of adaptation measures and strategies; assess the adaptive capacity, opportunities and obstacles; and also provide information necessary to support the creation of the anticipatory scenarios that are used in the Vision & Critique workshop. Before the workshops, individual interviews or group meetings with the identified stakeholders were performed to gather some of the information identified above and pre-invite and select participants for the workshops. The information obtained in these interviews or meetings was recorded in audio or researcher notes. The total of 70 participants in the case study workshops were 24 people from workshops in Mértola municipality, 26 people in Herdade da Coitadinha/Noudar nature park and 20 people in HRA farm. In all the case studies together, when asked if the stakeholders present in the workshops were sufficiently diverse to represent the territory in this topic, 90% of participants answered they were totally or quite satisfied and 10% answered they were only reasonably satisfied.

Step 2 Assessment

Step 2.1 Assessment of Climate Scenarios

Defining the climate variables that are relevant for climate adaptation in the sector of agroforestry is an important step that is connected with the available information for the specific vulnerability of crops in these parameters. In this case, due to the context of funded projects, the authors were able to calibrate regional models for the farm or municipal locations and select the most relevant variables. In the three case studies we have considered the climate scenarios RCP 4.5 and RCP 8.5.

Step 2.2 Assessment of Present and Future Vulnerabilities

After identifying the main agriculture practices, crops and species, the case study vulnerabilities were assessed based on the stakeholder interviews, plus by compiling the existing information namely on soil quality, aridity index, potential solar radiation, GIS, land cover and land use, history of the territory/farm, literature review and information on previous studies in the region and similar agro-silvo-pastoral practices. For the three case studies the future vulnerabilities include increased risk of fire, increased mortality of trees (in particular *Quercus suber* and *Quercus rotundifolia*), decrease in pasture productivity, especially in drought years, increase of water scarcity, namely water for animals, biodiversity loss, destruction of the Montado agro-silvo-pastoral system (Pinto-Correia et al., 2011), soil desertification and rural abandonment (MAMAOT, 2013).

Step 2.3 Assessment of Climate Envelope of species / crops

In this study, after identifying the crops and species that are more relevant in the case studies, we have chosen to define the climate envelope using the following climate variables: minimum and maximum accumulated annual precipitation, average maximum temperature in the month of August and resistance to frost in days. This choice was done based on the relevance of climate variables but also on the best available information for the identified crops/species. Figure 2 illustrates the visualization of climate envelopes in relation to climate projections.

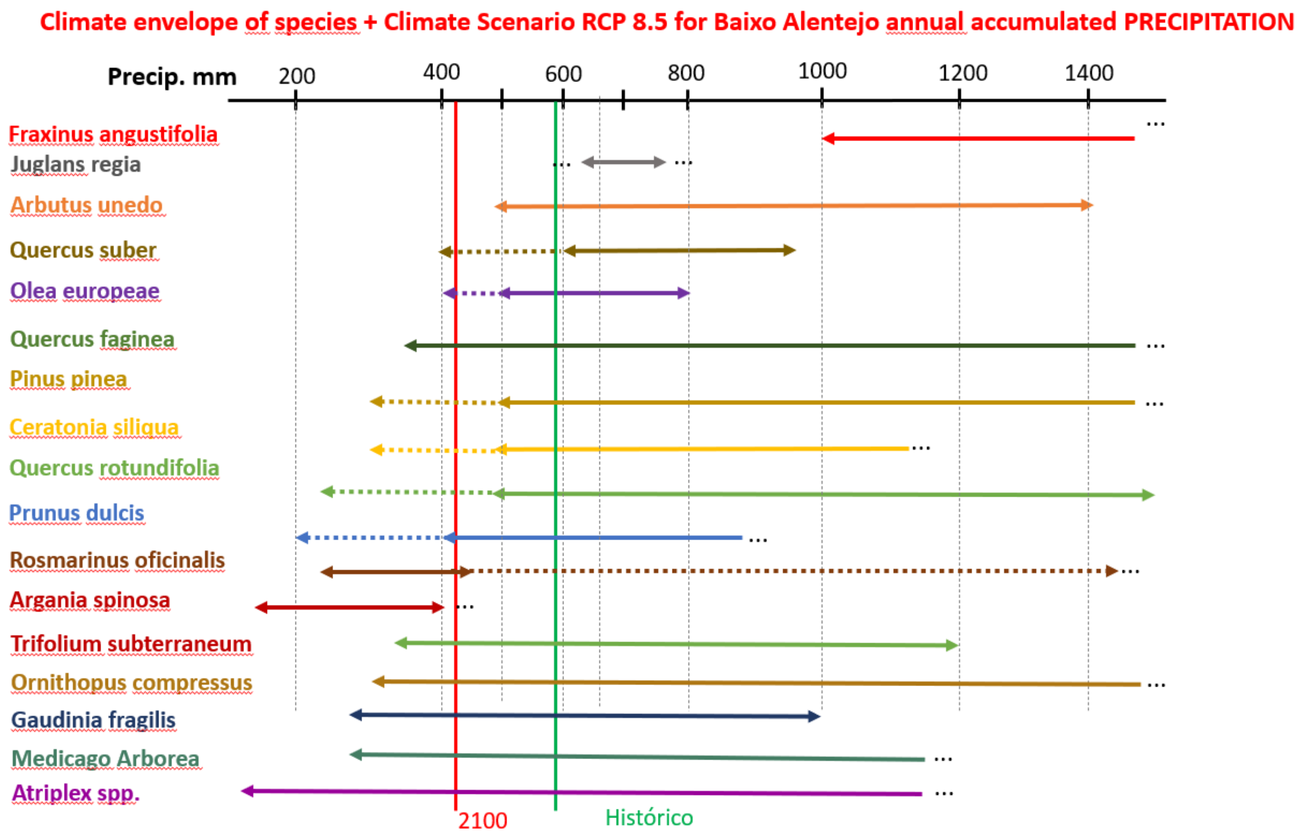

Figure 2 - Illustration of species Climate Envelope together with climate projection of annual accumulated precipitation for the region of study (Baixo Alentejo NUTS III) using RCP8.5 scenario (Source: IPMA, 2018)

The resulting schemes and respective references are presented are available in Appendix A.

Step 2.4 Assessment of adaptation strategies and measures

In the adaptation pathways scheme each adaptation strategy or measure has its own line and a tipping point. In the Portuguese Adaptation Strategy for Agriculture and Forestry sector alone, 237 measures were identified (MAMAOT, 2013). It is therefore essential to understand, organize, and create the hierarchy between adaptation strategies and measures, so that stakeholders can discuss and select strategies and measures that later on can be introduced in the adaptation pathways. This identification of the most relevant measures to consider or exclude was done by stakeholders, in the visioning workshop,

<u>Step 3 Vision and Objectives</u>

Step 3.1 Create scenarios

In the Mértola case study we have developed four scenarios and presented them to stakeholders in a narrative read by different facilitators in the Vision & Critique workshop. For each of the Noudar park and HRA farm case studies we have developed three scenarios and the presentation of the narrative was made in one short video (around 5 min) for each scenario, and the videos were developed by students of a local professional agriculture high school, coordinated by the research team and one school teacher. Written narratives (in Portuguese) for all three case studies and links for the videos are available in the case studies adaptation plan reports (Vizinho et al., 2016; Vizinho et al., 2017a, 2017b).

Step 3.2 Vision & Critique Workshop

In order to clarify the vision and adaptation objectives we use the stakeholder workshop in which the a synthesis of the assessment is made, then the anticipatory scenarios are presented and the stakeholders work in groups, not to choose one of the scenarios as their vision but rather to create their own vision of adaptation based on their reflections, starting from a critical discussion around the presented scenarios and then creating their own vision. In order to reach a common vision from the several working groups that are formed in the workshop, each working group presents their vision and adaptation objectives and a common denominator is found between all the groups, using a consent decision making process, based on a Sociocracy 3.0 method (Bockelbrink et al., 2015). In all the three case studies we obtained a shared common vision and in addition several issues that were not agreed were set aside, potentially to be addressed in future studies or discussions. The shared vision for the adaptation of each case study, included values, adaptation options, objectives and also included and excluded some adaptation strategies and measures, therefore supporting the research team in the preparation and facilitation of the next steps of the adaptation planning processes. Figure 3illustrates the scenarios used in the case study of Mértola.

Accommodate and change

Human/Nature focus

Technological/Financial focus

ALTERNATIVE A: **Convert into Pastures and Shrubs.** Accept the landscape change. Let go from trees and invest in shrubs, pastures and biodiversity

ALTERNATIVE B: **Invest in monocultures of adapted species and precision farming.** Focus in exporting, modernization and precision farming.

Protect and regenerate

ALTERNATIVE C: **Regenerate the Montado agroforest and re-localize agriculture.** Promote agriculture that creates more jobs and use microclimates for a diversified and proximity farming

ALTERNATIVE D: **Protect Montado Agroforests, Afforestation and irrigation at all cost.** Support major investments for water management. Fight plagues and diseases.

Figure 3 - Titles and subtitles of scenarios used in the Vision & Critique workshop of the case study of Mértola municipality. The scenarios, also called Alternatives, were designed according to the axis of the adaptation options "Accommodate and change" vs "Protect and regenerate" and also using a "Human/Nature focus" vs a "Technological/Financia focus". These scenarios are used to generate a discussion that includes values and objectives, together with a more technical discussion focused on measures and strategies.

Step 4 Efficacy of measures

Step 4.1 Select crops and species

For all the three case studies a maximum of eight or nine crops and therefore adaptation pathways schemes was defined, so participants would have time to review and discuss during the full day of the planning workshop. This means having to choose crops, despite the fact that some farms use and value more than eight or nine crops in their agroforestry systems. There were six crops that were used in the adaptation pathways of the three case studies: holm oak (*Quercus ilex rotundifolia*), cork oak (*Quercus suber*), strawberry tree (*Arbutus unedo*), olive tree (*Olea europeae*), carrob tree (*Ceratonia siliqua*), and permanent pastures. The other crops/species that were also used in adaptation pathways are wheat (*Triticum spp*), umbrella pine (*Pinus pinea*), rosemary (*Rosmarinus officinalis*), whole nut tree (*Juglans regia*), narrow-leafed ash tree (*Fraxinus angustifolia*) and almond tree (*Prunus dulcis*).

Step 4.2 Assess efficacy of adaptation measures

To assess the efficacy of adaptation measures, in the Mértola municipality case study, we have used expert knowledge. In the other two case studies we have chosen a set of indicators and used literature review to look for quantitative evaluation of adaptation measures that could support the efficacy assessment. This table of efficacy is available in Appendix A.

Step 5 Develop Adaptation Pathways

Step 5.1 Define a generic adaptation pathways scheme

The generic adaptation pathways scheme used (see Appendix A) was based on the original by Haasnoot and colleagues (2012) and adapted to include the specific information mentioned on the methodology, namely species and the possibility of stakeholders to introduce a combination of measures in the scheme, estimating a tipping point based on the information available and presented at the planning workshop. This is an important part of the methodology since several authors use adaptation pathways schemes that are more generic, strategic, policy oriented and/or qualitative (Bosomworth et al., 2015; Bosomworth and Gaillard, 2019; Butler et al., 2014; Colloff et al., 2016), rather than crop specific and as more quantitative and objective as possible, the latter being the choice used in this study.

Step 5.2 Identify baseline Tipping Points

In order to design the adaptation pathways for each species we needed first to identify the tipping points to each species/crop in the landscape, based on the present management and agricultural practices, i.e. in the baseline / Business As Usual situation, without (additional) adaptation measures and planning. Different tipping points may be identified for the same crop and adaptation measure if different micro-climates exist in the landscape. Due to this fact we have identified and classified the microclimate zones in the landscape and determined different baseline tipping points for the shaded slopes and for the sunny slopes. For the sake of simplification and usability of the pathways scheme we have presented this information to the stakeholders but in the pathways' scheme have only used the baseline tipping point for the sunny areas and not for the protected microclimate areas, such as riparian areas or north facing slopes, otherwise the number of AP schemes would double or triple. When designing adaptation pathways for each crop (Step 5.3), stakeholders ended up, for some crops, identifying the different situations that may be defined due to microclimate, zoning or management and finally designed a specific adaptation pathway for each of these identified situations. Figure 4 illustrates the different tipping point of *Arbutus unedo* (strawberry tree) in Mértola municipality present and future climate in the RCP8.5 scenario. Under this scenario, this species is only possible to survive and thrive until around year 2040 if located in microclimates, such as north slopes or riparian areas. The stakeholders have thus defined two situations, one located in microclimates and another located in the rest of the territory, needing deficitary irrigation and other adaptation measures, that only compensate if the crop is set up in an orchard management and not the natural way that leads to a natural classified habitat of shrubs and forest.

Step 5.3 Design the Adaptation Pathways scheme for each crop

Since each species / crop has its specific tipping point and different relevant adaptation measures, a dedicated adaptation pathways scheme was made to each crop analyzed for each study. In order to design the adaptation pathways, the tipping point for each adaptation measure must be defined according to the efficacy of each adaptation measure. As mentioned above, in the case study of Mértola municipality this task was performed using expert knowledge and in the other case studies it was based on literature review. Nevertheless, since the quantitative information available in the literature is often specific to the context of the research, expert knowledge was again used to transform and adapt this efficacy indicators into the tipping points for every adaptation measures on the different crops. For example, if the tipping point of the baseline of *Arbutus unedo* (strawberry tree) is defined due to the projected low level of annual precipitation, the adaptation measure of deficitary irrigation can be 100% effective in reducing the water scarcity and therefore the tipping point is eliminated.

The tipping point of all crops was defined according to a specific objective: prevent increase in tree mortality and prevent productivity decrease above 50%. For example, the species *Q. suber* is described in the literature to survive and produce above 600 mm and below this to have reduced levels of survival and productivity which can occur until 400 mm. On the other hand, the average maximum temperature in which it thrives is 31 ^{o}C. The tipping point for *Q. suber* without additional measures was defined in the moment in time when annual accumulated rainfall is projected to decrease bellow 600 mm or the average maximum temperature of August is projected to increase above 31 ^{o}C. In this case, in order to eliminate the tipping point, an adaptation measure must increase soil moisture (for example, 3,8cm of straw mulch reduce soil evaporation by 35% compared to bare soil (Chalker-Scott, 2007)), in order to compensate for the reduced precipitation. If maximum temperature is the limiting factor, then measures that decrease temperature and alter micrometeorological conditions (for example, increasing the tree densities in Montado landscapes can reduce average temperature by 3,42 ^{o}C (Godinho et al., 2016)), can diminish the exposure to increasing temperatures. If no measure is sufficient to eliminate the tipping point then changing species / crop is the only measure that can be resilient and protect the farm against the projected climate change.

Step 5.4 Use Add-ons to Adaptation Pathways

The use of Adaptation Pathways schemes to support adaptation planning and decision making can be complemented and combined with other tools. In this study we have used Multi Criteria Analysis (MCA), maps (with different information such as aerial photos, microclimates, soil quality, land use, existing forest management plans, natural park management plan), participatory mapping and also sets of cards on the possible adaptation measures (with photo, description and MCA information). This information is produced in the language of the case studies (Portuguese) and several maps and schemes can be found in the final adaptation plans/ reports of the case studies of Mertola, Noudar and HRA (Vizinho et al., 2016, 2017c, 2017b).

Step 6 . Design Strategic Adaptation Plan

Step 6.1 Select preferred Pathways

In each case study, this step was made in the second workshop of the Scenario Workshop method, designed for Planning. The participants used the best available information and choose the combination of adaptation measures in time, creating a final adaptation pathway. For this, the participants were allowed to add new adaptation measures and to combine several adaptation measures into one adaptation pathway. Figure 4 shows the base adaptation pathway scheme for the crop of *Arbutus unedo* and the selected preferred pathways in the case study of Mértola municipality. In this specific crop and case study participants decided to select and design two pathways since the species can be managed in different ways according to its location or management objectives (more conservation or more productive).

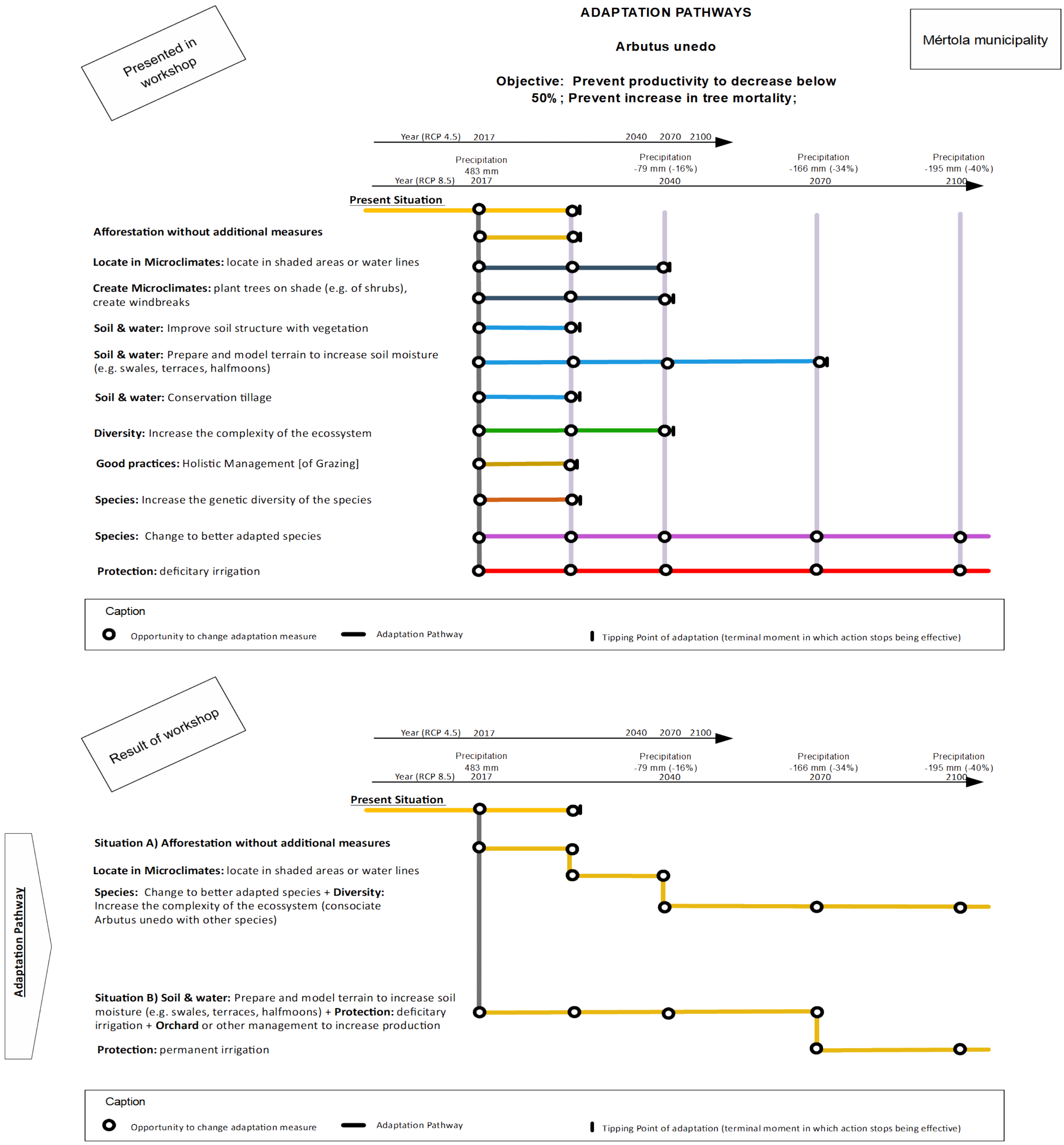

Figure 4 - Adaptation Pathways for *Arbutus unedo* in the case study of Mértola Municipality. The figure considers two RCP scenarios (8.5 and 4.5) with different temporal scales and three pathways (BAU, Situation A) and Situation B)).

For the sake of comparison and overall analysis we compile in a simplified adaptation pathways scheme for the case studies of Mértola (Figure 5), Noudar park and HRA farm, the adaptation pathways of the six species common to the three case studies.

The analysis of Figure 5 shows that the adaptation pathways schemes illustrate very clearly the unsustainability of the business as usual management for all the crops except *Quercus rotundifolia*. For all the other crops a combination of adaptation measures is needed if the crop is to be maintained in the landscape until year 2100, with acceptable levels of productivity and survival. In the context of this case study, the crops have different adaptation measures if they are in a rainfed or irrigation situation and inside the rainfed, they also have significantly conditions and adaptation measure according to their microclimate, such as, for example a shaded north facing slope (with lower Potential Solar Radiation (Príncipe et al., 2014)). By identifying different situations where different microclimate conditions or different structural management choices occur and creating different pathways for each situation, the adaptation pathways tool was able to accommodate and deal with the challenges of landscape complexity.

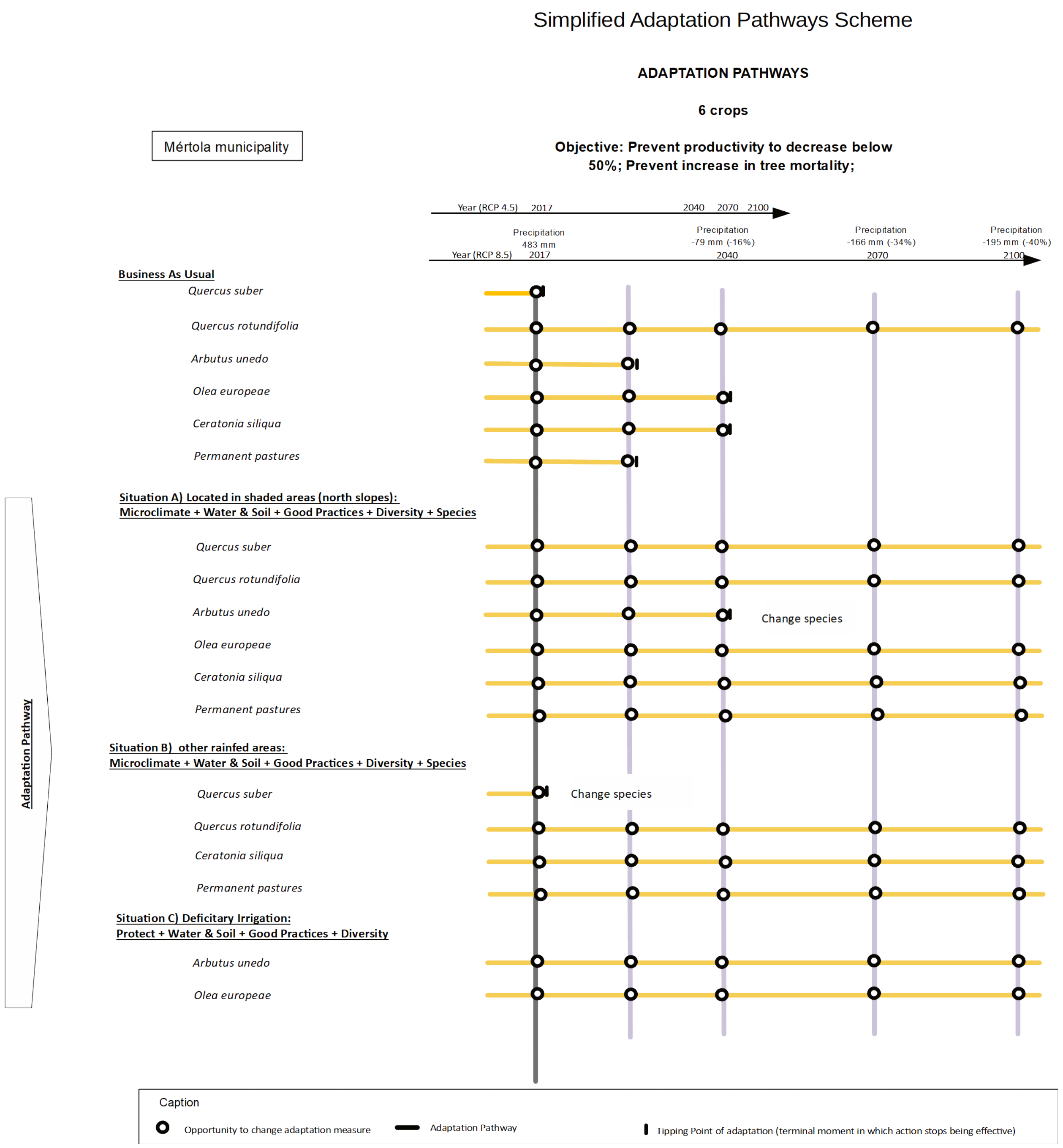

Figure 5 - Adaptation Pathways for 6 crops in the case study of Mértola Municipality. The Adaptation Pathway chosen is different for Situations A) , B) and C), which are complementary. These situations correspond to different areas in the landscape or different technological possibilities or management choices, namely irrigation.

Step 6.2 Integrating Adaptation Pathways into a landscape plan

Since a farm or a landscape is not the simple composition of several crops and species, there are interactions, mixed systems, location and different management practices, then an adaptation plan must introduce the several crops in a zonal plan and use complementary tools to do so. In the case studies Noudar and HRA, a zonal plan was developed on the map and each zone had, not only the combinations of species to use, but also complementary adaptation measures that are relevant and specific to the integrated management on the crops and species in a given location. Figure 6 illustrates one of these maps that serve as the base for the zonal plan, in this case for nature park of Noudar / Herdade da Coitadinha farm. In the zonal plan, each of this zones has a specific management plan that integrates normally more than one crop (e.g the area of Nuts includes grazing pastures).

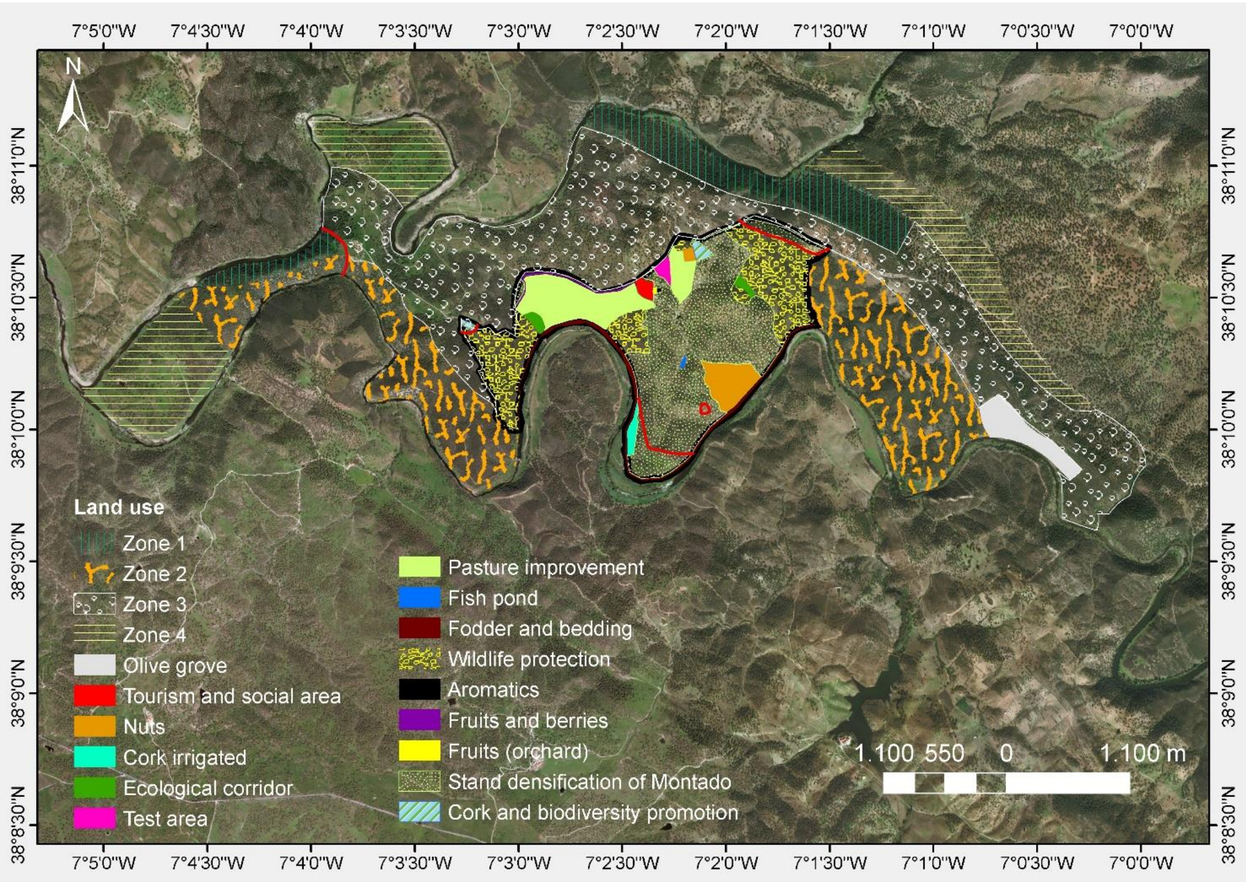

Figure 6 - Zonal Plan of Noudar Park / Herdade da Coitadinha farm. To each zone and land use there is a specific description of measures and management to implement, according to Adaptation Pathways dynamic timeline

In the case of Mértola municipality, since the area was understood as too large to perform a zonal plan with the relevant detail and in only two workshops, the method used was the creation of 5 classes of farms or typical land uses that are frequent in the municipality: i) 100 hectares of monoculture of *Pinus pinea*; ii) 600 ha of Montado agro-silvo-pastoral system of *Quercus rotundifolia* and *Quercus suber*; iii) 1.000 ha of pastures and grazing; iv) 1.000 ha of shrubs and hunting area; v) 50 ha of irrigated agriculture with olive trees and vineyards. For each of these five types of farms, a zonal adaptation plan was developed inside the participatory workshop. One of these zonal plans is illustrated in Appendix A.

Step 6.3 Reviewing and finalizing Plan

After the workshops when adaptation pathways are chosen and zonal plans are agreed, a final document with an adaptation plan is built and revised by relevant experts and stakeholders.

Step 6.4 Evaluation of Results

The study of framing of the adaptation pathways and its implementation in the adaptation planning using the SWAP method (Campos et al., 2016; Vizinho et al., 2017a), was developed using a Participatory Action Research (PAR) approach (Borda, 2001; György et al., 2013; McIntyre, 2007; McNiff, 2013) which implied the creation of a working group but also the engagement of local relevant stakeholders in the definition, discussion and evaluation of all phases of the work. The adaptation pathways were thus used in combination with the Scenario Workshop process, interviews, preparatory meetings and other tools such as maps, schemes and presentations that supported the planning process and integrated complexity, overcoming some of the limitations of Adaptation Pathways (Bosomworth et al., 2017) for adaptation planning. In the participatory planning process, the proposed Adaptation Pathways were revised, edited and chosen by the participants and decision makers. In the end of the vision and planning workshops, an evaluation questionnaire was presented to the 70 participants obtaining 55 responses, 14 for Herdade da Ribeira Abaixo farm, 18 for Coitadinha farm and 23 for Mértola municipality (see Appendix B). The participants were asked how they evaluated the overall quality of the workshops, ; the results obtained; the content; the quality of presentations, materials provided, speakers and facilitation; the quality and quantity of the stakeholders involved; logistics; expectations; future engagement and suggestions of improvement. In a score of 1 (poor) to 6 (excellent), the average of the evaluation of all the responses to all the case studies was 5,4 (very good) and all the answers ranged from good (4) to excellent (6).

<u>*Step 7. Implement plan*</u>

In the two farm case studies, HRA and Noudar, after the strategic adaptation plan was developed, a detailed field implementation plan was developed which includes further detailing zones, plant densities, plantation and management techniques (which include adaptation techniques), budgets and coordination of field implementation. The field implementation in itself implies adjustments to the field implementation plan since during the implementation, immediate feedback is obtained from detailed on site observation or from immediate consequences and monitoring of plantations and management by field workers or farm managers/coordinators. The field implementation plans of these two farms was developed and is being monitored, within the context and funding of the project LIFE Montado & Climate: a need to adapt (LIFE Montado, 2017). These detailed plans were developed and started being implemented in 100 hectares for HRA (45% of the farms area) and 208 hectares for Noudar nature park (20% of the farms area). The plans are also being implemented in the rest of the farms area but without this specific funding and therefore less investment. The HRA results of first year's plantation in 100hectares are already available and one of its highlights can be summarized in the plantation of 6.700 plants and an average survival rate of 91%.

At Mértola municipality, implementing the plan is a more complex task since the public owned agroforestry areas are residual and the municipality does not own or manage the private agroforest areas. The implementation of a strategic adaptation plan for the agroforestry sector on the municipal level is therefore dependent on the use of public policy instruments or on the voluntary adaptation of the chosen measures by farmers and other relevant stakeholders. The 15 farmers that were present in the adaptation planning process, at the time of the first interview and meeting before the planning workshops, they were all already implementing some climate adaptation measures. This information suggests that the farmers that participated will continue to adapt, adjusting their adaptation actions based on the best information available to them, their adaptive capacity and the other several factors that influence farmers decision making on the environmental, economical, social and psychological dimensions, as discussed above. Accompanying the adaptation action of farmers and stakeholders that took part in planning process is an essential part of the monitoring step that should be done periodically and is relevant for future research but in the municipality of Mértola, in year 2009 there were 711 farms and farm managers (of which 589 and 122 women) (INE, 2011). This means that there is a significant effort that needs to be done by institutions in order to reach out and promote the adaptation measures. Some of the possible measures in this field are identified and agreed in the adaptation plan as part of the promotion of the adaptive capacity. In the Mértola adaptation plan, eight measures were proposed and agreed to promote adaptive capacity in the municipality. The four measures focused on training and dissemination (Integrated training on schools; Transfer of knowledge with farmers; Promote meetings and visits with farmers; production of local technical and scientific knowledge and its transfer) are all being implemented by different stakeholders, such as the local NGOs, the professional school and the Municipality executive. The four measures focused on governance (Forest Management plan of public forest; Lobbying for some of the proposed measures; Attract new population and keep existent; Promote effective articulation between local and regional stakeholders) have also started being implemented by the local stakeholders despite the challenges identified.

Step 8 Monitor and Review the plan

To extensively evaluate the success of the implementation of the plans, monitoring is essential. Furthermore, to be able to accompany the evolution of climate change and incorporate its pressure and variability in the management of the territory, continuous monitoring of signposts/ indicators and triggers must be implemented to support a periodic revision of the adaptation plan. After the second planning workshop in all case studies it was clearly identified by stakeholders the need to periodically revise the adaptation plan, ideally, every 5 years. The stakeholders considered that after some years there will be more observation and a clearer perception of the impacts of climate change on the landscape, there will be probably more information regarding adaptation measures and finally, the revision of the adaptation plan will support an assessment, monitoring and evaluation of the implementation efforts by the different stakeholders. In the two farm case studies (Noudar and HRA), due to ongoing action-research projects, monitoring is also included, namely until year 2021, in the context of LIFE Montado & Climate project that financed the planning, implementation and monitoring in a plot of 100 hectares, leading to continuous revision of adaptation measures in the field. In the Mertola municipality, the Adapt*For*Change project only financed the adaptation planning and not its implementation or monitoring. Due to the longterm nature of climate adaptation, and based on the experience of these case studies, it is evident that a structure or at least one person in each case study needs to be responsible for ensuring that the continuous monitoring and periodic revision of the adaptation plans is put in place. Since these efforts require significant resources and as

Hermans et al discuss (2017), need to combine experts, practitioners and decision makers, a structure or a group should be created to implement a proper monitoring program in the case studies.

4. Discussion

The Adaptation Pathways schemes, as framed and used in the three study cases, were useful to support the decision making process in the planning workshops, by contributing to communicate to stakeholders the relationship between the climate tolerance of each crop, the projected increase in vulnerability and the response effect of the adaptation measures. This statement is supported by the responses of the participants to the survey after the planning workshop in which they evaluated the general quality of the workshops (average of the three case studies, being 100% the maximum score) as 91,03% , content of workshop as 90,03%, method of the workshop 89,03% and results of workshop with a 87,13% score. Some explicit references on the open questions on the survey to participants also support and clarify this result such as: [one the most useful topics in the process was the] "presentation of adaptation pathways for plant species/cultures" ; "the subject was presented in a pragmatic way, with a presentation of objective results, which is very positive and almost singular, since the issue of climate change is often debated in a theoretical way"; or "Resilience of species to climate change scenarios with references to scientific articles, excellent work !".

The positive evaluation of the method by the participants and the positive concrete references in open questions in the survey show that the objective and quantitative approach of the adaptation pathways schemes and the quantitative information that supported it (climate projections, climate envelope of species and efficacy of adaptation measures) was appreciated and supportive of the participatory adaptation planning process.

The AP method has been evaluated and applied with success in the adaptation planning of several case studies but it has also been analysed and discussed on its limitations (Bosomworth et al., 2017; Bosomworth and Gaillard, 2019; Moffat et al., 2014; Werner, 2013). We thus discuss the use of SWAP in agroforestry using the frame of the previously identified limitations to these methods.

Dealing with limitations of Adaptation Pathways: Tipping Points are difficult to identify in NRM and Agroforestry

The Adaptation Pathways (AP) schemes are a central part of this method because they support the creation of a dynamic plan that relates the adaptation planning objectives to tipping points, which are dependent on specific climate change variables. By using two different RCP scenarios in each AP scheme, this relation is more clear to stakeholders and the decision of when to act /implement an adaptation measure is related to the tipping point itself (Haasnoot et al., 2013).

In several applications of the AP, in other sectors, computer modelling has supported the design of the AP plans in the identification of the tipping points of the business as usual scenario in different climate scenarios (Campos et al., 2016; Haasnoot et al., 2012; Zandvoort et al., 2017). Computer modelling has also been used to model the effectiveness of the adaptation measures in other studies (Haasnoot et al., 2012; Kwakkel et al., 2015). In the sector of agroforestry the use of AP is still innovative and in all cases in which it was applied, computer modelling was never, to our knowledge, used to support the assessment of the tipping points of the adaptation measures. One of the reasons may be the complexity of the ecosystem and the need to perform a tailor made model, which implies significant resources. Colloff and colleagues (2016) used a qualitative conceptual model in which they scored the ecosystem services provided by different types of forest and management and use these scores as a proxy for ecosystem resilience and thus a *decision points* in time in which, in order to keep the ecosystems service level, another set of measures/ forest type/forest management needs to be put in place. The approach of Colloff and colleagues is designed to integrate the complexity of landscape management and planning in the adaptation pathways. In contrast, in our case, we have decided to keep the use of the tipping points, crop or species specific and as more quantitative as possible and then use other tools, such as visioning workshop or zonal planning, to discuss types of forest, species, crops, green corridors, water harvesting, animal grazing and plan the landscape with a systemic perspective, thus using the AP schemes only as a resource for the second stage of planning. Despite the integration of complexity made in our study, the identification of critical thresholds and tipping points remains a challenge since they can be reached by different drivers in different moments in time. For example, the cork oak trees (*Quercus suber*), in the HRA farm, should not be affected by water scarcity until year 2100 if we look only at accumulated annual rainfall, in RCP8.5 scenario, thus no tipping point would be identified in this period. On the other hand, the increase in maximum temperatures will bring this species out of its climate envelope, in this location, before the year 2070, in the RCP8.5 scenario. In this situation the tipping point should be defined according to the temperature and only the measures that aim to reduce exposure to heat, reduce temperature or change the species, can be effective and therefore be placed in the AP scheme. Here the communication to stakeholder of such tipping points and AP becomes more complex, easily loosing the desired simplicity of AP. In our case study, besides measures to address increase in temperatures, we have kept in the adaptation pathways schemes other measures, aimed at reducing water scarcity, improving soil and fighting pests and diseases, although they were not effective in postponing the tipping point. Some of these measures were indeed also chosen by stakeholders, since they perceive water scarcity, soil quality or pests/diseases important aspects to decrease the vulnerability of the farm.

Complementary, if we look at the potential increase in the frequency, duration and intensity of extreme events such as droughts (Dubrovský et al., 2014; Hoerling et al., 2012), the trees in our case studies will be affected (Grant et al., 2010; Leite et al., 2018) but it is not easy to identify a tipping point. As concluded by other authors (Bosomworth and Gaillard, 2019; Moffat et al., 2014), this shows the need to complement the tipping points approach when providing information about adaptation measures for decision makers. In our case studies we have, on one hand, provided information on the potential impacts, the efficacy of adaptation measures and, on the other hand, we have given the possibility for stakeholder to add new measures or combinations of measures in the AP scheme. This option was always used by the stakeholders in the three case studies and in most of the crops/ species.

Dealing with limitations of Adaptation Pathways: increasing levels of system complexity and goal setting

When studying the limitation of AP, Bosomworth and colleagues found that, except when developing AP plans for single species or asset category (e.g. a river or wetland or coastal area), the tool did not support the stakeholders in discussing and defining the main goals and values for the landscape they are planning (Bosomworth et al., 2017). While in protecting a single species the goals are clearer and meaningful dialogues can bring the stakeholders to use their skills for AP planning, at a landscape scale or system level the tool did not provide sufficient guidance, support or frame for the creation of generic pathways and plans. In their study, interviewees explicitly state that it would be important to first develop a discussion on values and goals, since a main objective is to reach a consensual plan, rather than just comparing Adaptation Pathways (Bosomworth et al., 2017). In this context the authors also state that defining a tight biophysical boundary supports the stakeholders in focusing their discussion.

Vermeulen and colleagues argue that it in order to deal with the complexity of impact assessment and also the complexity of economic and social systems, in adaptation planning it is important to combine scientific information from an impact based and adaptive capacity based approach (Vermeulen et al., 2013). The impact based approach includes knowledge on climate projections and crop impacts and the adaptive capacity based approach includes knowledge on socio-economic agricultural systems, adaptive capacities, vulnerabilities and adaptation options (Vermeulen et al., 2013). The SWAP combination of methods used in this study is therefore a combined approach for adaptation planning that has the potential to incorporate the different dimensions of complexity. On the capacity-based approach, the information obtained and used on these aspects is mostly brought by the Scenario Workshop method with its including interviews, preparatory meetings, anticipatory scenarios and stakeholder workshops. The knowledge from the impact based approach is used on: the climate projections; the climate impacts literature and climate envelope of species; the analysis of each case study terrain, soils, microclimates and sensitivity; the analysis of efficacy of adaptation measures and the identification of tipping points. The discussions, definition of objectives and choice of all the adaptation strategies and measures in the multi-stakeholder workshops approach enables the integration of the adaptive capacity and the knowledge on potential impacts, in first-hand, by the stakeholders themselves.

The SWAP method answers these concerns by focusing on the creation of a consent based plan for a clearly bound territory, the definition of goals in a first workshop based on visioning, a second workshop with the design of AP dedicated to single species and finally the integration in a landscape or farm plan of the several AP.

Dealing with limitations of Adaptation Pathways and Scenario Workshops: reaching a consensual plan

Creating a common vision, a set of agreed goals and a consensual plan in a multi-level stakeholder workshop is not a straightforward achievement of participatory methods. Indeed Kallies and colleagues have tested three participatory methods and none of them was able to create a common vision, Scenario Workshop included (Kallis et al., 2006). Yet, in the three case studies presented, the SWAP process was able to produce a common vision, goals and a consent based adaptation plan. Furthermore, in another case study where SWAP was used in coastal adaptation planning, a consensual vision and plan was also achieved (Campos et al., 2016; Vizinho et al., 2017a). We consider that the reason for this success is that in the participatory workshops: i) it was explained that the objective was not to discuss the who or what is more responsible for the problem but rather focus on what we can do for brighter future; ii) the stakeholders were specifically asked to criticize the presented scenarios and create their common vision (workshop 1) and plan (workshop 2); iii) after each groups of participants presents their results, a list of what is common from all the groups is identified and these points are then agreed upon, based on the Sociocracy 3 method: iv) all inputs and ideas are acknowledged and inserted as results and ideas to discuss or study later; v) a trusted workgroup is created to follow up the workshop and further detail, revise and improve its results. In the case studies presented, these follow up workgroups, that finalize the adaptation plan, included the research team and also several participants from the workshop. This goes in line with one of the most important principles, identified by Füssel, for adaptation planning: it ″requires close collaboration of climate and impact scientists, sectoral practitioners, decision-makers and other stakeholders″(Füssel, 2007). During the workshops the facilitators focuses on the concept of consent instead of consensus, as proposed by sociocracy (Bockelbrink et al., 2015). A consent based plan is when all participants consent on the decisions but it does not need to be the ideal plan for everyone. By focusing on what they agree, this approach proposes that a concrete plan is achieved within the available time for planning, which can later and further be improved, by periodic revisions and as knowledge and capacity increases.

Dealing with governance and Incremental, Transitional or Transformative adaptation

The debate on incremental, transitional or transformative adaptation is connected to the method and framework used in the adaptation planning process, since without a process that explores the underlying causes of vulnerabilities, they cannot be addressed and integrated in the adaptation agenda (Bosomworth et al., 2017; Pelling, 2010; Roggema et al., 2012). Simultaneously this debate is not independent from the governance and power dynamics existing in the context of the system being planned. Adaptation Pathways offer flexibility since they allow progressive implementation and changes in the adaptation options (Werner, 2013) but they have been criticized by not offering the space for discussing the fundamental change of system goals (Bosomworth et al., 2017). Presenting the disasters associated with climate change or losses that exceed what is socially acceptable (e.g. recurrent large fires, desertification, massive loss of agricultural production) can generate the context in which the need for a transformational agenda is strong. In the face of climate scenarios and other scientific information that bring into consideration such disasters and losses, the adaptation planning process didn’t limit and controlled the debate to the incremental or transitional agenda. In the Mértola municipality case study, where water scarcity and temperature increases are projected to be higher and have stronger impacts, these issues were relevant. In the survey for the evaluation of the process, stakeholders mentioned that more time is needed to debate the water scarcity and the rainwater water harvesting in the territory. Furthermore, despite the workshops having had one moment for discussing the adaptive capacity, stakeholders mentioned they would need more time on this particular important topic, namely to create a workgroup to continue towards implementation. Since municipalities are not owners of the territory, and other stakeholders have important power, their mandate is limited as governance aspects are of increased importance. Based on the ABCD approach (Cunningham and Mathie, 2002; Mathie and Cunningham, 2003), a protocol session was organised to have some the most relevant stakeholders sign the adaptation plan for the municipality. At this moment several adaptation measures have been put into place but some of the most structural, such as integrating the adaptation plan for agriculture and forestry in the spatial planning instruments have not been put into place. It is therefore reasonable to suggest that the SWAP process could be improved or complemented on the governance and adaptive capacity at municipal level.

Dealing with uncertainties for real world decision making

One of the important questions in adaptation science is to understand if the use of different adaptation planning methodologies is resulting in better informed decisions (Lourenço et al., 2014). In this context, identifying the sources of uncertainty and discussing how it is dealt with and where there is space for improvement is one of the important tasks of adaptation planners and future research.

There are several sources of uncertainty that are relevant for robust adaptation planning, such as Regional Climate Models, Global Climate Models, GHG Scenarios, climate sensitivity, climate impacts and also the climate response or adaptation measures (Fei and McCarl, 2018; Dessai and Hulme, 2007a) . The uncertainties depend largely from context to context and since more robust climate responses imply a higher investment and a need to deal with the complexity of economic and social systems, they need to involve decision-makers and stakeholders. This brings a higher emphasis on the communication of uncertainty and the participatory methods used in the adaptation planning process (Dessai and Hulme, 2007b; Swart et al., 2014). In many circumstances, due to time or resource constraints, decisions need to be made without available robust evidence-base information or before uncertainties can be totally reduced (Van der Sluijs et al., 2008; Walker et al., 2003). Some critics argue that overrating the importance of uncertainty can hinder the urgent need for action, by providing a rationale for delay (Vermeulen et al., 2013) but our mandate when doing participatory action researcher is to attempt to identify, clarify and reduce uncertainties, while at the same moment making decisions possible, in the available time, therefore considering the costs of inaction. In the SWAP process, as in all participatory processes dedicated to decision-making, there is a tension between depth of discussion and time length of the discussion and deliberative moments. With more time, stakeholders can understand better all the information and uncertainty and they can reach better decisions. On the other hand, the time available to dedicate to planning by stakeholders, namely farmers, is frequently limited. The SWAP method presents a balanced frame that has a robust rational combining physical and earth sciences with social sciences, therefore creating the space for continued improvement. Stakeholders mentioned, in the experiences of the three case studies, that more workshop time would be useful and needed to plan the adaptive capacity and the monitoring of the implementation. Nevertheless, its application is considered, by the stakeholders and authors, successful and the plans robust, based on the available knowledge.

From Planning to Implementation

In the two farm case studies of Herdade da Ribeira Abaixo and Noudar Nature Park, the climate adaptation plans were specifically adopted into farm management plans and thousands of trees were planted using specific adaptation measures to increase their success. Furthermore, the overall vision, long term strategy and dynamic plans for the farms are being implemented and motivated the farms teams to invest further in the resilience of their farms, engaging stakeholders and visits, creating what are now demonstration farms for climate adaptation. Since these two farms are state owned or state owned companies, have received specific funding for adaptation and are particularly dedicated to conservation and research, and therefore this success cannot be generalized to other types of farms. Farms are normally more pressured by economic viability, focused on profit and may have less access to funding, may have less motivation to maintain a long term vision of sustainability (as discussed by Castellano and Moroney, 2018) or may have less access to experts, researchers and institutions to support their detailed planning, investments and innovations, when compared to our case studies. On the other hand, we can argue that state owned firms have management challenges of their own, that can limit or create specific obstacles for successful adaptation (Böwer, 2017; Dewenter and Malatesta, 2001). These challenges can be the difficulty in mobilizing investments, bureaucracy, decision making and governance, distance of managers from the field work or, on another hand, not having a necessity to maintain the economic viability of the farm. The context of our two farm case studies, in which the agroforestry system of Montado is the main landscape, has specific challenges of its own (Muñoz-Rojas et al., 2019; de Sampaio e Paiva Camilo-Alves et al., 2013; MAMAOT, 2013) such as the tension between different management paradigms, namely between the conservation of a traditional agro-silvo-pastoral landscape or the innovation for more productive and market oriented farms. Despite these challenges, the method applied in these case studies was able to create robust adaptation plans and mobilize the farms and its managers for adaptation. For other types of farms, such as family farms or farms owned by cooperatives, multinationals, Forest Intervention Areas − ZIF (Valente et al., 2013) or other management structures, the factors concerning decision making are very specific and contextual, together with the location of the farm itself (Castellano and Moroney, 2018; de Frutos Cachorro et al., 2018; Mankad, 2016; Robert et al., 2016; Valente et al., 2013). Thus, the question remains to whether this method will be effective in other types of farms and contexts.

Complementary to the environmental, economic, social and psychological factors that affect decision making by farmers, in the field of climate adaptation, uncertainty and how it is dealt with by frameworks and decision support tools is a major aspect (Capela Lourenço, 2015, p. 207; Fei and McCarl, 2018; Swart et al., 2014). Another major aspect identified by the adaptation science literature is the approach of planning, in which participatory processes that engage stakeholders, involve the actors to realise and perceive the potential climate impacts as well as the uncertainty that is associated (Capela Lourenço, 2015, p. 208). Participatory processes, namely Scenario Workshop, can create empowering event that enhance the consciousness of participants, social learning, networking (Nygrén, 2019) and thus contribute to concrete adaptation actions and replication. On the context of forest management, Nelson et al state that "partnerships between practitioners, policy makers, and science organizations will be key to creating an inclusive environment for collaboration on planning and implementation adaptation measures". The multi-level and multi-scale dimension of adaptation is therefore also present in this sector, in particular for forestry, as policies and regulation can be strong barriers or incentives for adaptation (Nelson et al., 2016). The participatory approach of the SWAP method aims to create these empowering events that not only engages the decision-maker in a process that promotes learning and enhances perception, but also engages several practitioners and stakeholders to increase the possibility that such relevant partnerships and networks are created. The organisation of Scenario Workshops at the municipal or regional level planning also has the potential of integrating policy stakeholders and therefore contributing to specific reflection of barriers and incentives of regulations and policies for agroforestry adaptation. In the case study of Mértola municipality, the 15 farmers that have participated in the adaptation planning workshops are implementing adaptation measures and have declared that the planning process was important for them and the territory. The institutional stakeholders are also implementing the measures aimed at adaptive capacity. The SWAP method of adaptation planning , the framing of the Adaptation Pathways and the adaptation plans contributed, therefore, to the adaptation of all the case studies. Nevertheless, the fact that the farmers that participated in the planning workshops are only around 2% of the total farmers (711) in the municipality, raises the discussion of how can the plan extend beyond the participants to be applied in all the territory. In a top down approach, there are several instruments to promote climate adaptation such as direct regulation, also known as "command and control", education and also economic instruments. The economic policy instruments attempt to influence behaviour by changing the costs and benefits of specific actions. Possible instruments can be subsidies, taxes, tax differentiation, charges, grants, permits, concessions, market creation or even financial instruments (Bräuninger et al., 2011; Buckley, 1991). In the case of Mértola some of these instruments are available, either to the Municipality public administration or to some other institutions present in process such as the natural park, the national institute for forestry, the regional and national administration of agriculture or the Portuguese agency of environment. From a bottom-up approach, a community development approach, or a multi-level participatory approach, the different stakeholders can collaborate, develop partnerships and articulate all possible instruments for the common vision achieved in the participatory planning process. We can argue, as proposed by several authors such as Gladwell or Winther (Gladwell, 2006; Phillips and Pittman, 2014; Winther, 2015) that by engaging a diversity of stakeholders in a community and creating a common vision, when those stakeholders that are leaders, connectors and experts, they become the leaders and the carriers of the plan, implementing the efforts of mobilizing the community by themselves. Since in the SWAP process in the municipality of Mértola we have attempted to implement this approach, we are now observing that several important initiatives, projects (such as the LIFE Montado Adapt project) and partnerships that have meanwhile happened to promote the adaptation in the territory, have been led by participants of the participatory process of adaptation in Mértola. This community and peer engagement, the farmers visits, research and demonstration projects, partnerships, networking, education, economic instruments and eventual direct regulation are mostly all the measures available in the literature to promote adaptation. We thus argue that in order to activate all these instruments together, a robust participatory process of planning, that creates a common vision for adaptation and engages a representative diversity of stakeholders in the community is an effective tool for climate adaptation planning in agriculture and forestry. SWAP was, in the three case studies, efficient in creating a robust adaptation plan, in involving a representative diversity of the community and stakeholders and in activating several implementation actions by different stakeholders. Further research is relevant to understand how can this method work in different contexts, namely in geographical areas where climate vulnerability is less evident for stakeholders than in the municipality of Mértola, in the southeast of Portugal.

5. Conclusion

We conclude that the described method and combination of Scenarios Workshops and Adaptation Pathways was successful in creating participatory robust adaptation plans for the agriculture and forestry of three case studies that are now in implementation, both at farm and municipal levels. Involved stakeholders and authors consider the resulting adaptation plans robust, improving the resilience and reducing the vulnerability of the case studies. This combination of methods has dealt successfully with the limitations, previously identified in the literature, in the use of Adaptation Pathways for Natural Resource Management and one of the success indicators of the methods is that the adaptation plans have started their implementation with positive results, namely the success of afforestation efforts with 91% survival, diversification of crops and several measures of promotion of adaptive capacity. Since the application of SWAP method on the adaptation planning of agriculture and forestry was, until now, only applied in one municipality and two farms that are, one state-owned and another a state-owned enterprise, it is relevant to apply and evaluate the application of the method in other municipalities and other types of farms, in order to ensure its usability and eventually improve or adapt the method. Furthermore, the facilitation of the SWAP process was until now done always by researchers, within the context of action-research projects. To ensure if its replication and usability is as prolific and efficient as in the case studies reported, its use by other planning teams and contexts is a relevant topic for further research. A relevant future research question is how can this method perform and what are its limitations when applied in this sector at different scales, namely regional, intermunicipal, cooperatives, collective agroforest entities, corporate farm or smaller family farms. The combination of Scenario Workshops and Adaptation Pathways has recently been applied for multi-sectoral adaptation planning of the region of Algarve, in the south of Portugal (with 16 municipalities) and is now under application in different private agroforestry family farms. The evaluation of these and other future applications and also how to they deal with the identified limitations of the SWAP process (e.g. need for more time of debate in planning workshops for adaptive capacity and monitoring), namely when comparing with other participatory methods for adaptation planning in this sector are relevant avenues of future research.

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Title:

Framing the application of Adaptation Pathways for agroforestry in Mediterranean drylands

André Vizinho[1], afvizinho@fc.ul.pt, https://orcid.org/0000-0002-0503-3624

David Avelar[1], dnavelar@fc.ul.pt, https://orcid.org/0000-0003-2443-3460

Ana Lúcia Fonseca[1], alfonseca@fc.ul.pt, https://orcid.org/0000-0001-5711-0698

Leonor Sucena-Paiva[1], leonorspaiva@gmail.com ,

Alice Nunes[1], amanunes@fc.ul.pt , https://orcid.org/0000-0002-6900-3838

Pedro Pinho, paplopes@fc.ul.pt,

Silvia Carvalho[1], sccarvalho@fc.ul.pt , https://orcid.org/0000-0002-8414-6503

Hugo Oliveira, hfoliveira@fc.ul.pt ,

Ana Cátia Vasconcelos, anakatia.vasconcelos@gmail.com,

Filipe Duarte Santos[1], fdsantos@fc.ul.pt , http://orcid.org/0000-0001-7316-1479

Cristina Branquinho[1], cmbranquinho@fc.ul.pt , https://orcid.org/0000-0001-8294-7924

Maria José Roxo[2], mj.roxo@fcsh.unl.pt, https://orcid.org/0000-0003-2628-8535

Gil Penha-Lopes[1] gppenha-lopes@fc.ul.pt, https://orcid.org/0000-0002-1024-1954

[1] Centre for Ecology, Evolution and Environmental Changes (ce3c), Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Bloco C2, Piso 5, 1749-016 Lisboa, Portugal

[2] Faculdade de Ciências Sociais e Humanas – Universidade Nova de Lisboa, Avenida de Berna, 26-C, 1069-061 Lisboa, Portugal

Corresponding author: André Vizinho; Email:afvizinho@fc.ul.pt; Tel: +351 965615379, [1] Centre for Ecology, Evolution and Environmental Changes (ce3c), Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Bloco C2, Piso 5, 1749-016 Lisboa, Portugal

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