D4.1

Climate risk assessment and initial risk management plan

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Land-use based Mitigation for Resilient Climate Pathways

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Changes with respect to the DoA	*No changes*
Dissemination and uptake	*The target audience for this deliverable are researchers working on model (sets) and stakeholders*

Short Summary of results
97 interviews with stakeholders were performed to discuss the climate-change-related risks and effects on the environment linked to the implementation of LMTs. The most mentioned climate risks for most LMTs are droughts (as in increased irregularity of rains), heatwaves (especially out of the normal heat season), increasingly heavier rains, erosion (as a consequence of the beforementioned points) and increased incidence of pests. The global south is on average more exposed to these climate risks than the global north because of climatic and infrastructural reasons. Most LMTs are reported to bring large benefits in climate resilience, climate change adaptation and sustainability, such as increased soil water and nutrient retention, increased plant and animal diversity, increased resilience to pests, increased resilience to droughts and heatwaves and increased resilience to heavy rains and strong winds. Carbon sequestration and emissions reductions are also two of the most widely reported effects, but they just constitute a part of the general picture of environmental benefits stemming from the application of LMT practices.
Evidence of accomplishment
This report includes the aggregated data from the interviews in Annex. The individual interview reports can also be accessed upon request.

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Preface

Negative emission solutions are expected to play a pivotal role in future climate actions and net zero emissions policy scenarios. To date most climate actions have focussed on phasing out fossil fuels and reducing greenhouse gas emissions in, for example, industry, electricity, and transport. While zero emission trajectories in these sectors will remain a priority for decades to come, it is expected that residual GHG emissions will remain. To be able to fulfil the Paris Agreement and meet the world's climate goals research, policy and markets are increasingly looking at negative emission solutions.

This is why the nineteen LANDMARC consortium partners work together in order to:

- Estimate the climate impact of land-based negative emission solutions, in agriculture, forestry, and other land-use sectors
- Assess the potential for regional and global upscaling of negative emission solutions
- Map their potential environmental, economic, and social co-benefits and trade-offs

LANDMARC is an interdisciplinary consortium with expertise from ecology, engineering, climate sciences, global carbon cycle, soil sciences, satellite earth observation sciences, agronomy, economics, social sciences, and business. There is a balanced representation of partners from academia, SMEs, and NGOs from the EU, Africa, Asia and the Americas, which ensures a wide coverage of Land Mitigation Techniques (LMTs) operating in different contexts (e.g. climates, land-use practices, socio-economic etc.) and spatial scales.

The LANDMARC project consortium:

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Acknowledgements

The authors would like to thank all case study leads and every colleague who has participated in the very time-consuming stakeholder interviewing process.

We would also like to acknowledge the time and interest of all interviewees, who altruistically dedicated us their time, and from whom we have learned a lot. Their knowledge will hopefully help shaping a future of better practices.

Disclaimer:

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Summary and Conclusions

The following deliverable assesses the climate risks Land-based Mitigation Techniques (LMTs) face and the effects on the environment linked to their implementation. Within the LANDMARC project there are 13 case study countries in which a broad spectrum of assessment work in relation to LMT portfolios of is being conducted. This report covers the results of qualitative (climate) risk assessment work conducted within the 13 LANDMARC case study countries covering **consultations with 97 stakeholders in the 13 countries for each of the LMTs in the national LMT portfolios**.

This document includes three sections:

- Chapter 1**; Introduction**, where a literature review is performed, and the approach and method to the risk consultation are explained.
- Chapter 2; **Climate Risk Assessment in LMTs**, where the interview responses on climate risks and effects on the environment of LMTs are disclosed and analysed.
- Chapter 3; **Climate Risk Management**, where approaches to deal (climate change related) risks and organise the risk management process, as well as a climate risk management tool for LMTs are discussed.

Partly as a result of COVID-19 (e.g., lock-downs) **most of the consultations consisted of video calls** held by case study leads with selected stakeholders. **These interviews discussed the climate related risks and effects on the environment** (part of this deliverable) and socio-economic effects (that will be addressed in another upcoming deliverable 5.2), as perceived by the stakeholders. Some consultations were also carried out in a workshop format.

A questionnaire including climate and environmental parameters was used during the consultations to guide the interviewee through relevant parameters for the assessment of LMTs in the LANDMARC project. The objective was to ask respondents to elaborate further on these parameters and – where possible - provide thresholds and past events when applicable. This questionnaire was developed throughout a series of co-creation sessions involving relevant task leaders, as well as selected case study leads to carry out a pilot test and validate the suitability of the final questionnaire. Also, a 1-2 pager report was written after each interview to record those insights and perspectives that did not fit within the questionnaire format.

For the analysis of the results, the responses to the questionnaires were coded in a matrix and represented in graphs, distinguishing and comparing regions and LMTs to support the assessment of the results.

From the climate risk assessment, it can be highlighted that:

- **Droughts (and heat waves), heavy rains, strong winds and erosion are consistently mentioned as the main climate risks for most LMTs and in most assessed climate regions.** Heatwaves and droughts are often mentioned together as they often happen jointly, but it is droughts that are considered to cause the most damaging effects. Despite the same parameters being mentioned for all regions, **the risks posed by these climate hazards in the global south appear to be perceived as higher risk than in high-income countries in the Global North**. This could be linked to the generally warmer and dryer climates, but may also refer to underdeveloped climate adaptation infrastructure.

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- **Droughts do not necessarily refer to a decrease in average rainfall, but to a more irregular distribution of rains, concentrating shorter, heavier, difficult-to-predict rainfall periods between longer dry periods. This is perceived as the biggest threat to most LMTs**, whereas mild or even moderate decreases in total rainfall do not appear to be perceived as a major concern in most cases long as these periods are predictable and well-distributed through time. A similar notion applies to heat waves, where stakeholders indicate that higher temperatures are not necessarily the main problem, but rather the timing and distribution of heat events.
- Linked to the last point, an important finding is that (soil) **erosion is considered one of the main threats**, while at the same time most LMTs can play a very significant role in erosion reduction by a series of cascading effects. The increasingly common **heavy rains** between dry periods create run-offs that **remove nutrients from the soil, resulting in lower plant coverage**. A low plant coverage leaves the soil more exposed to erosion by heavy winds and **results in a lower water retention capacity, producing further run-offs when heavy rains happen**. **Stopping such cycles is crucial for climate change mitigation and adaptation**.
- A climate change related risk that was not initially contemplated in the questionnaire but was often mentioned by the interviewees is pests**. Climate change allows parasites and plagues to proliferate in environments that were not previously favourable for them**. Such pests are particularly problematic in ecosystems that do not have the capacity or resilience (such as predators) to keep them under control. Also, decreased plant health due to droughts or soil impoverishment leaves them more exposed to damaging pathogens, parasites, fungi, insects, etc. Stakeholders repeatedly raised that **monocultures create a favourable environment for the proliferation of pests**, which can more rapidly cascade into a loss of ecosystem functions and services (e.g., food security).
- Despite being linked to droughts and heatwaves, the – based on the results from the consultations – the incidence of **forest fires appears to be more closely related to land use, ecosystem design and human factors than to climate extremes**. This may suggest that stakeholders think that forest fires are to a relatively high degree controllable or manageable, and that by continuing poor forest management practices significantly contributes to creating the conditions for larger and more destructive fires (enhanced vulnerability).

An overview of the climate risks can be seen in Table 1.

The main remarks about the effects of LMTs on the environment are:

– Stakeholders mentioned **very few negative effects on the environment derived from the implementation of LMTs**, with the exception of an increased risk of pests for dry-seeded rice and poorly planned afforestation/reforestation, and a potential increase in soil temperature for biochar. This ‘bias’ may suggest that other non-climate related co-benefits are a key (perceived) driver for LMTs implementation and acceptance.

– Despite being the main objective of LMTs, **carbon sequestration was not often reported as the main** driver or co-benefit (except for peatland rewetting, where emissions mitigation is considered very large by stakeholders). Also, negative emissions do not (yet?) appear a major driver for LMT implementation, as land users - who may lack familiarity with the concept – may give priority to other co-benefits or risks.

- However**, most stakeholders reported that LMTs can provide major advantages in terms of climate resilience and long-term sustainability of the assessed ecosystems**, particularly in avoiding and reverting the effects of soil degradation. **For the majority of all the assessed LMTs report, stakeholders refer to improvements in water retention, nutrient retention, soil stability and biodiversity in general**. These effects are very valuable for addressing erosion, allowing for sustainable practices and the specific design of LMTs targeting carbon sequestration.
- **Techniques involving trees**, such as agroforestry, afforestation/reforestation and forest management **are perceived to greatly improve the system resilience** by providing protection against soil water evaporation, excessive sunlight, strong winds and by stabilising the soil, improving water and nutrient retention. They also act as hosts for more biodiversity, improving resilience against pests and fostering pollination. Most mature trees are remarkably resistant to climate extremes, so they can protect more vulnerable parts of ecosystems and/or habitats against climate risks to a large extent.
- As a general rule, **the more complex a system is, the more resilient and sustainable it is perceived to become**. **Complex techniques**, such as agrosilvopastoral systems, **provide closed and fast nutrient cycles** that need little or no external input and host different plant and animal species that keep nutrient balance and **avoid pests**, while **increasing resilience against climate extremes**. **Carefully designed agroforestry and multi-crop systems are very resilient and sustainable in the long term**, as opposed to most industrial mono-crops.

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	Dehesas & Montados	Agroforestry	Wetland Rewetting	Afforestation/ Reforestation	Forest Management	Reduced/ No tillage	Organic Fertilisers	Cropland Management	Avoided Grassland Conversion	Biochar
Heat waves	Red	Yellow	Red	Yellow	Red	Red	Yellow	Green	Red	Yellow
Cold waves	Green	Green	Green	Green	Green	Green	Yellow	Green	Yellow	Green
Drought	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow
Forest fire or land fire	Red	Yellow	Red	Yellow	Red	Yellow	Green	Green	Green	Green
Strong winds	Green	Red	Green	Yellow	Green	Green	Yellow	Green	Red	Yellow
Heavy rainfall	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Green	Green
Flash flood	Green	Green	Yellow	Green	Green	Green	Green	Green	Green	Green
Landslides	Green	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Green	Green	Green
Erosion	Red	Red	Yellow	Yellow	Red	Green	Red	Yellow	Red	Green
Pests	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Green	Green	Yellow

Table 1: Overview of climate risks. Red are risks mentioned by >40% of the interviewees, yellow by 15% to 40%, and green by less than 15%. It can be noted that droughts are perceived as a major threat for most LMTs, followed by heatwaves and erosion. On the other side, cold waves are not generally perceived as a major risk, same as flash floods, which can be mitigated to a great extent by the use of appropriate infrastructure.

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Building on the risk assessment methodology and results in Chapters 1 and 2, Chapter 3 continues by providing some background and guidance on performing a risk assessment. We argue that mainstreaming climate change related risks in conventional risk management processes is a crucial element, specifically for economic activities that are closely linked to land-use, such as the implementation of a broad range of land-based mitigation solutions including agro-forestry, afforestation, wetland- and cropland management, etc.

Mainstreaming (or embedding) climate risk management within existing risk management processes that are operated by e.g., countries, companies and/or communities will improve the effectiveness of LMTs as it can limit the exposure or vulnerability of a specific LMT to climate change related risks, such as droughts, and floods.

Within Chapter 3 we recommend those entities that aim to host risk management process to carefully select and manage the stakeholders that are relevant for and/or affected by the implementation of specific LMT or risk management implementation actions. We consider a robust and inclusive stakeholder selection and engagement process a vital prerequisite for effective (climate) risk management.

We introduce the concept of a risk management ecosystem, with the aim to create awareness about other ongoing iterative and participatory risk management processes that operate at a different level or scale (e..g., company level, supply chain level, country level). We argue that a basic understanding of the broader risk management ecosystem (outside ones own risk management process) has significant synergy potential, for example in terms of sharing data, resources and information (to also avoid unnecessary overlaps, potential conflicts and counter-productive measures to be implemented). The notion of a risk management ecosystem may also open the dialogue amongst risk managers about subsidiarity (which climate risk should be managed by whom? And who is responsible/liable for addressing a specific risk?) and can also aid in identifying gaps or biases in the risk management processes (e.g., not sufficiently participatory, inclusive).

We continue Chapter 3 by applying the basics of risk management and the concept of risk management ecosystem to specific LMT cases that are exposed to climate change. We conclude with a brief discussion on an IT enabled tool - developed by a group of Master students, from Wageningen University – that could support (online and offline) stakeholder engagement for doing climate risk assessments for LMTs. This tool (beta version) that could structure and streamline climate risk management for LMTs was piloted with local LANDMARC partners in Spain and Portugal. The further development of such tools may aid other stakeholder groups with initiating and planning climate change risk management processes.

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1. Introduction

1.1 Context

With the 2015 Paris Agreement (PA), the international community agreed to limit the rise in global temperature at least to below 2ºC. Mid-century net-zero or net negative climate scenarios, particularly those that focus to limit global temperature rise to 1.5ºC, rely on the large-scale deployment of so-called negative emission technologies and practices (NETPs) that can remove CO_2 from the atmosphere. NETPs or carbon dioxide removals (CDR) are primarily needed to compensate for any residual emissions in 'hard to decarbonize' sectors, like international aviation and agriculture. NETP solutions can include both land- and ocean-based technologies and practices that can remove CO2 from the atmosphere. However, there is a real risk that any shortfall or delay in robust mitigation efforts will result in a stronger reliance on negative emission solutions (Roe et al., 2019)(IPCC, 2022b). also states (high confidence) that CDR deployment at scale is unproven, which poses *"a major risk in the ability to limit warming to 1.5ºC."*

The latest IPCCC scenarios also rely on the significant deployment of NETPs, many of which are so-called Land-Based Mitigation Techniques (LMTs). A broad range of LMTs can be deployed to both reduce CO2 emissions as well as remove them from the atmosphere. LMTs include nature-based solutions, where more carbon or CO2 is stored in vegetation (trees) and soils. Some of the better-known LMTs are agroforestry, rewetting or (organic / peat) soils, afforestation, etc.

In the latest IPCC report, there are 116 climate scenarios with >66% probability of limiting global warming to below 2oC. About 87% (101) of these scenarios are considering significant deployment of NETPs (Smith et al., 2016). However, to date, the inclusion of NETPs and LMTs techniques in countries' Nationally Determined Contributions (NDCs) remains limited (Annex 1; LMTs and climate risk management in NDCs). It is, therefore, necessary to assess how NDCs deal with LMTs and what policy strategies and approaches are proposed to limit the exposure of NETPs and LMTs to climate and environmental risks associated with their implementation and upscaling.

Ongoing integrated assessment climate scenario modelling (IAM) efforts are continuously improved to include a broader and more detailed portfolio of NETPs and LMTs. Current IAM modelling efforts rely heavily on BECCS and afforestation as key options, while other solutions like biochar, soil carbon enhancement, and more behavioural / land management practices (e.g. forest fire management, reduced tillage, extending thinning cycles) are generally less well covered in modelling assessments (Smith et al., 2016). The same 'gap' can also be observed in the NDCs, where BECCS and afforestation are the dominant NETP solutions included.

Aside from a better and broader 'coverage' of NETPs/LMTs in integrated assessment modelling, there is also a need to deepen our understanding and management of *"trade-offs with other sustainability objectives (IPCC SR15 Ch 2)*". (IPCC, 2022a) indicates the following:

"Co-benefits and adverse side effects of mitigation could affect the achievement of other objectives such as those related to human health, food security, biodiversity, local environmental quality, energy

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access, livelihoods and equitable sustainable development. The potential for co-benefits for energy end-use measures outweighs the potential for adverse side effects whereas the evidence suggests this may not be the case for all energy supply and agriculture, forestry, and other land use (AFOLU) measures. "

A better understanding of such trade-offs/co-benefits related to NETPs/LMTs will help to develop more realistic, and more spatially explicit scaling scenarios. Relevant trade-offs and co-benefits can include impacts on e.g.:

- Biodiversity,
- Ecosystem performance,
- Air quality (NOx, fine particles)
- Water use, availability and quality,
- Land-use change/land degradation/soil quality,
- Evapotranspiration effects,
- Animal health/welfare,
- Human health/well-being,
- Surface albedo,
- Adaptation capacity,
- Land rights/conflicts,
- Food security/prices,
- Local communities / rural livelihoods,

The abovementioned (non-exhaustive listing of) trade-offs (and co-benefits) can pose a risk (or opportunity) for LMT scaling in AFOLU sectors. Such risks are often variable through time and space, and are typically highly context-specific, as they are specific to local earth systems (e.g. soil type, hydrological conditions, weather conditions, habitat type, etc.) as well as human systems (e.g. institutions, governance, degree of automation/industrialisation, land/forest/farm management practices,) conditions.

NDC documents are generally developed via a top-down approach. A specific mitigation goal is set and then a strategy with a broad range of reduction and removal technologies and practices is defined based on this target. The LANDMARC project uses a more disaggregated, bottom-up approach, where information for a broad range of LMTs is gathered within eleven of the thirteen LANDMARC case study countries (The Netherlands, Germany, Spain, Portugal, Switzerland, Burkina Faso, Kenya, Vietnam, Nepal, Indonesia, Venezuela, and Canada) spanning across five continents (Table 2). Within LANDMARC data/information from Earth Observations (EOs), consultations with stakeholders, model simulations and literature are collected to understand the context-specific, scaling potential, barriers and risks for LMTs implementation.

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Sub-category	LMT	National Portfolios (short-lists)												
		NL	DE	CH	VE	BF	KE	CA	SE	ID	ES	VN	NP	PT
Wetlands	Peat soil rewetting, Paludiculture, wetland restoration and conservation	x	x					x		x				
Cropland	Reduced/no-tillage			x			x							
	Cropland management		x			x	x						x	x
	Organic farming	x								x		x	x	
	BECCS	x		x				x	x					
	Biochar			x				x	x			x		
	Agroforestry			x			x						x	
Grassland	Avoided grassland conversion													
	Grassland management for carbon sequestration		x					x			x			x
	Agroforestry	x									x		x	
Forest land	Avoided deforestation					x	x							
	Afforestation/Reforestation	x	x			x	x	x		x	x	x	x	
	Forest management (incl. fire management)		x		x	x		x	x	x	x		x	x
	Agroforestry				x	x				x		x	x	

Table 2: Countries and LMTs in the LANDMARC project

The risk assessment done within the framework of the LANDMARC project for this report is intended to expand our understanding of the climate change-related risks and the effects on the environment stemming from the implementation of LMTs at the local level. The results and findings could be used to inform and strengthen future climate change mitigation and adaptation plans, as well as LMT scaling scenario modelling with the help of IAM modelling.

1.2 Understanding Climate Change Risk

Risk is broadly defined as **"the potential for adverse consequences"** (Reisinger et al., 2020). The word "potential" explains that **uncertainty** (or incomplete knowledge) is a key element of the concept of risk. The word "adverse" clarifies that the concept of risk **refers only to negative consequences** (the same approach applied to positive effects is known as "opportunities").

It is important to make a distinction **between direct and indirect risk**, as climate change is a complex issue with countless interacting factors:

- **Direct risks** are those where there is a **direct link between a hazard and an element at risk** that is exposed and vulnerable. For example, storms and flooding damaging buildings and infrastructure, droughts leading to crop failure, or extreme temperatures causing heat stress.
- **Indirect risks are further removed from a hazard** – for example, impacts on mental health, disruptions to supply chains, migration, social wellbeing, changes in policy, etc. They are the result of direct risks elsewhere, which can be local or distant (Ministry for the Environment, 2021).

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Within the LANDMARC project, we have performed a risk assessment to identify a broad variety of risks for LMTs scaling, these include risk categories such as climate, environmental, social, and economic risks to LMTs. Within this report, we focus on 'earth system' risks. We especially target climate change-related risks but also included other environmental risks. The results of the risks assessment of other risk categories (e.g., policy, social, and economic risks) are presented in a complementary report (Deliverable 5.2: Results from risk, co-benefit, and trade-off assessment; forthcoming app. March 2023).

When the concept of risk is applied to climate change, we encounter the following interacting elements;

- **Climate change hazards** are direct or indirect hazards derived from increasingly extreme weather (eg, cyclones, floods, droughts), or longer terms shifts in precipitation, sea-level rise and other variable patterns.
- **Exposure,** in this case, to which degree LMTs are exposed to climate change hazards (direct or indirect)
- The **vulnerability** of the carbon sequestration potential of the LMTs to the hazards (Switzerland & Barros, n.d.).

These three elements are subject to uncertainty in terms of frequency and magnitude of the hazards, as well as to the degree the reduction or removal potential of the LMTs is exposed and vulnerable to such hazards. Climate risks in this deliverable will be described considering these three elements.

Climate change risks can propagate as **'cascades' across physical and human systems**, expanding these risks across various sectors. Because of the links between natural and socio-economic systems, these interactions can result in feedback loops in which a certain event triggers a reaction with much larger effects. Cascading risks can have significant implications for climate risk management and cannot be foreseen (Lawrence et al., 2018). We will try to identify cascade risks in our assessment.

1.3 Climate Change Risk Assessment and Management

The consideration of direct, indirect and cascade risks aims for a holistic approach to evaluating the climate change-related risk LMTs face. The characterization of climate change risks (CCRs) is a complex task that requires a multi-factorial assessment of parameters from different perspectives. It requires a thorough problem definition and the collaboration of subject matter experts (SMEs) with expertise in different fields.

The LANDMARC project takes a **four-element approach** to CCR management:

a) ***Problem Framing***: potential key hazards and characteristics were identified through a literature review and consultations with experts working on different LMTs, as well as with final users of the results of this exercise (such as modellers). As a result of this co-creation process, a questionnaire including direct, indirect risks and their relationships and thresholds was created to be used at a larger scale with targeted key stakeholders. This questionnaire is designed not only to record CCRs but also opportunities derived from the implementation of the LMTs.

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b) *Risk Assessment:* A series of semi-structured interviews were held with key stakeholders using the questionnaire as a guide, recording qualitative and quantitative data regarding the exposure, vulnerability and hazards the LMTs face because of climate change. Stakeholders were targeted according to their professional roles and demographics to ensure a good representation of the assessment. The dimension of the assessment was 3 to 5 stakeholders per case study country and LMT. These results were analysed, contextualized, and processed to extract relevant findings.

c) ***Risk Management:*** Based on the assessment, the LANDMARC project developed strategies to mainstream CCR management within existing and ongoing risk assessment and management practices performed at different levels.

Simple enough to define in theory, **the distinctions above are often difficult to maintain in practice**. Separation of assessment and management is particularly problematic, while communication and two-way stakeholder engagement is now seen as integral to all stages of the assessment and risk management process rather than something to be adopted separately after risk assessment and management issues have been resolved (Stern & Fineberg, 1996). However, this deliverable aims to address *risk assessment* and *risk management. Risk framing* is explained in more detail in Annex 2; Implementation of the assessment

It is important to consider that the risk assessment – risk management relationship cannot be understood under the problem–solution framework, but from a cost-benefit perspective (Michael Jacobs, 1991). That is, **a solution must be applied only if its benefits outweigh its costs**. While this report does not intend to provide answers to this question, within the LANDMARC project, we do apply a range of different software tools and models (i.e., ALCES, E3ME, LANDSHIFT, DayCent, EC-Earth)(*LANDMARC Tools — LANDMARC Horizon 2020*, n.d.) to simulate a range of socio-economic and environmental consequences of the implementation of LMTs. This quantitative information can be used with qualitative aspects as a basis for the discussion of the upscaling of LMTs. The results of this (ongoing / forthcoming) work will also be published and shared with relevant target groups.

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2. Climate Risk Assessment in LMTs

As mentioned in Chapter 1, a risk assessment on a broad range of risk categories was performed. To benefit from potential synergies between several LANDMARC tasks[1] in data gathering and stakeholder consultation the assessment was integrated, saving time and stakeholder exhaustion, and helping build a consistent storyline between different tasks.

2.1 Method

Figure 1 provides a brief overview of the five-phase methodology applied for the risk assessment within the framework of the LANDMARC project. In Figure 1 each of the five phases are described in more detail.

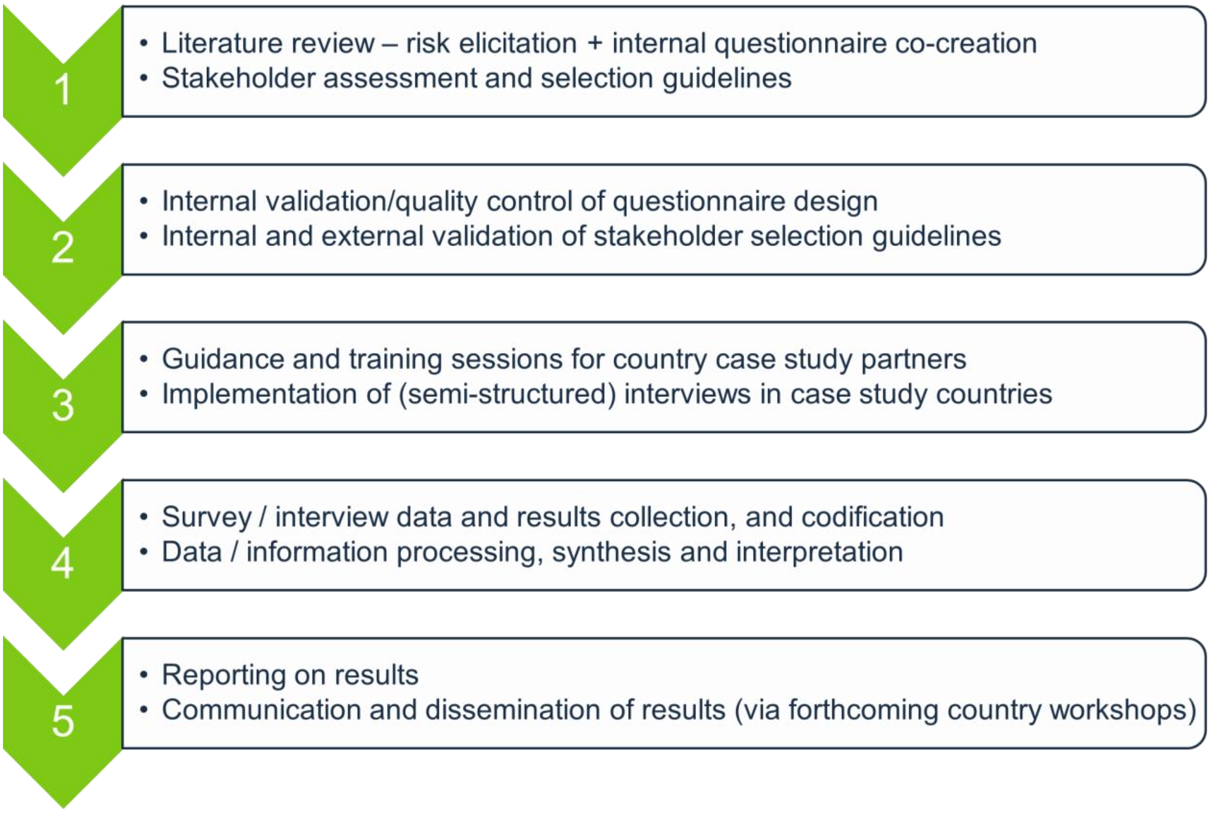

Figure 1 Overview of the risk assessment methodology within LANDMARC

Phase 1: Leaders of the involved tasks co-created a qualitative risk and opportunity assessment questionnaire based on a literature review. This will result in a unique elicitation of task-specific risks that could potentially apply to every case study and LMT. Due to the radical conceptual base difference of the potential risks, a distinction in the risk elicitation for each task will be kept. Because of the unequal representation of stakeholder profiles in LANDMARC's stakeholder repository, it was decided

[1] Relevant tasks include:
Task 4.1: Qualitative climate risk assessment
Task 4.2: Better understanding and modelling of the sensitivity of LMT to climate variations
Task 5.2: Assessment of risks, co-benefits and trade-offs of LMTs

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to target certain profiles instead of launching a massive survey among all stakeholders, providing the chance of individually driving them through the questions and collecting insights that couldn't be recorded by a self-filled questionnaire. This approach implies that stakeholder selection guidelines must be given to the CS leads before launching the survey.

Phase 2: The task leaders hosted meetings with modellers and CS leads to cross-check the quality and adequateness of the survey. After all parties agreed that the survey fulfils their data collection necessities, the survey was piloted in a selection of CSs ensuring a good representation of all cultural backgrounds and environmental conditions. This exercise provided insights into the on-field effectiveness of the proposed method, allowing for survey and methodology modifications before launching the assessment to all CSs.

Phase 3: The country case study leaders reached out to a representative group of stakeholders, that include at least relevant candidates from different disciplines (policy, private sector, and research), different perspectives (farmer/forest manager, water board, municipality, industry, etc.) and represent the different technologies and practices included in the portfolio. The sample size is of 3 to 5 SHs per CS country and LMT, making a total of around 100 interviews. The stakeholder selection for the survey was based on the stakeholder and network mapping that has been performed within the framework of two other LANDMARC tasks[2]. In addition, we have also made use of contacts provided by other interviewed stakeholders, intending to capture all (potentially) relevant stakeholder perspectives and scales. The country case study leaders are responsible for sending carrying out the consultations and ensuring follow-up and reminders with their stakeholder base.

Phase 4: The collection, processing, synthesis, and feedback of the survey (in Annex 2; Implementation of the assessment) results was led by the task leaders. The way in which this synthesis will be performed will serve the following purposes:

a) An overall integrated risk and impact assessment. The assessment will also cover the dimension of risk and impact prioritization and the perspectives and scale dimensions.
b) A country level risk and impact synthesis will be provided for all case study countries.

More detailed information about the implementation of the assessment can be found in Annex 2; Implementation of the assessment.

2.2 Survey Results – Climate Risks

The results shown in this section are based on the responses by 97 interviewees to stakeholders in thirteen countries, including Spain, Portugal, Germany, Indonesia, Vietnam, Canada, Burkina Faso,

[2] These are:
Task 2.1: Stakeholder engagement and scenario construction
Task 2.3: Establish national LMT networks

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Nepal, The Netherlands, Switzerland, and Kenya. The number of interviews carries out by country is shown in Table 3 and Table 4.

Country	Number of interviews
Spain	11
Portugal	4
Germany	2
Switzerland	9
The Netherlands	5
Burkina Faso	18
Kenya	5
Sweden	12
Vietnam	5
Nepal	4
Indonesia	11
Canada	8
Venezuela	2

Table 3: Number of interviews per country

<table>
<tr><th>LMT</th><th>Subcategory</th><th colspan="2">Number of interviews</th></tr>
<tr><td rowspan="2">Agroforestry</td><td>Dehesas & Montados</td><td>9</td><td rowspan="2">32</td></tr>
<tr><td>Rest</td><td>23</td></tr>
<tr><td>Afforestation/Reforestation</td><td></td><td colspan="2">6</td></tr>
<tr><td rowspan="2">Wetland Management</td><td>Tropical</td><td>2</td><td rowspan="2">11</td></tr>
<tr><td>Peatlands</td><td>9</td></tr>
<tr><td>Forest Management</td><td></td><td colspan="2">8</td></tr>
<tr><td>Biochar</td><td></td><td colspan="2">5</td></tr>
<tr><td rowspan="3">Cropland Management</td><td>Organic Fertilizers</td><td>6</td><td rowspan="3">24</td></tr>
<tr><td>Reduced/No Tillage</td><td>4</td></tr>
<tr><td>Other</td><td>14</td></tr>
</table>

Table 4: Number of interviews per LMT

Despite having performed interviews with stakeholders in Sweden as well, it was decided to keep these results out of this deliverable. The reason for this is that the only LMT in Sweden is BECCS, which has limited climate risks and effects on the environment, thus the discussions were focused on socio-economic parameters and will be discussed in detail in Deliverable 5.2 (Jenny Lieu & David Ismangil, 2023).

2.2.1 Overview of general results

Considering the aggregated data from all case study countries without any further manipulation and interpretation (Figure 2), the answers sorted by climate risks and effects on the environment are shown in

Figure 2 represents an overview of the climate risks of all 97 assessed interviews. Despite needing further contextualization and filtering for a more appropriate interpretation, it can already be witnessed that droughts, heavy rainfalls, heatwaves, and erosion are mentioned as the main risks by a large share of our interviewees, regardless of the LMT or climate zone.

It is worth mentioning that out of the “other climate risks”, almost all of them correspond to pests due to parasite agents that did not use to be a threat, but now are due to climate change.

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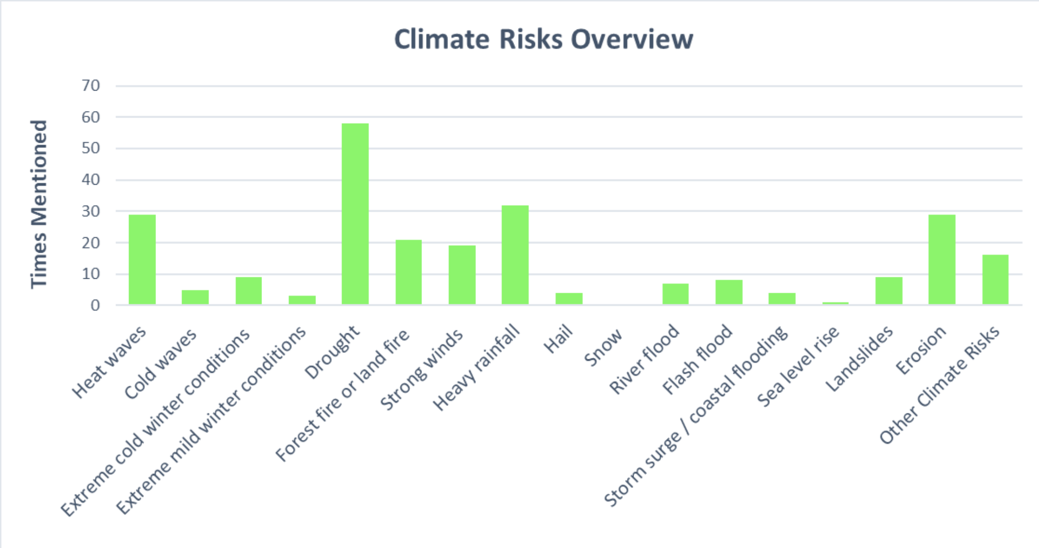

Figure 2: Overview of Climate Risks

2.2.2 Risks per region

Not only LMT and country data was used, but survey responses were also contextualized according to the approximate Köppen-Geiger (*Koppen-Geiger Climate Changes - 1901 - 2100 - Science On a Sphere*, 2013). This approximation is based on a characterization of the climate of the area in cases where the specific area is known, and a generalization assuming the dominant climate in the country when the specific area is unknown.

As for the distinction between dry and humid climates, Oceanic, Humid Tropical, Humid Subtropical, Humid Continental have been regarded as humid climates, whereas Hot Semi-Arid, Tropical Savannah and Hot-Summer Mediterranean have been considered dry climates, as shown in Table 5.

Dry Climates	Hot-Summer Mediterranean
	Hot Semi-Arid
	Tropical Savannah
Humid Climates	Oceanic
	Humid Continental
	Humid Tropical
	Humid Subtropical

Table 5: Classification of dry and humid climates

The distinction between warm and cold climates is harder to draft, given that some climates experience strong temperature differences between seasons, but for the purpose of this deliverable climates experiencing long summers with high temperatures or warm temperatures all year-round have been considered as warm climates. This way, Humid Tropical, Hot Semi-Arid, Humid Subtropical, Tropical Savannah and Hot-Summer Mediterranean are regarded as warm climates, whereas Oceanic and Humid Continental are considered cold climates, as shown in Table 6.

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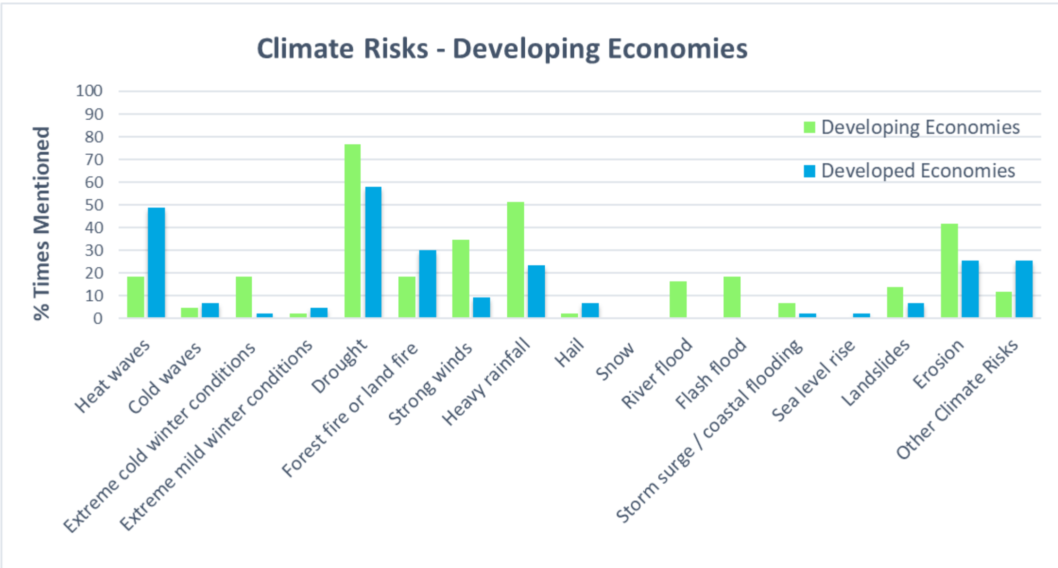
Cold Climates	Oceanic
	Humid Continental
Warm Climates	Hot-Summer Mediterranean
	Humid Tropical
	Hot Semi-Arid
	Humid Subtropical
	Tropical Savannah

Table 6: Classification of cold and warm climates

Developing vs Developed Economies

The reason to distinguish between risks in advanced and developing economies is the assumption that risks are weighed and perceived differently according to socio-economic circumstances. From the assessment of the interviews, it can be deduced that stakeholders in developing economies are more likely to refer to climate risks in terms of food security and availability of resources, whereas in more developed economies stakeholders tend to worry more about subsidies and enabling regulatory frameworks for LMT implementation and scaling.



Developing Economies	45
Developed Economies	52

Figure 3: Climate risks in developing and developed economies

However, from Figure 3 we cannot perceive in principle a dramatic difference in the key or prioritized climate risks. Nonetheless, through a more detailed analysis we can extract the following ideas:

- The **spectrum of relevant (and/or perceived) risks is larger in developing economies**, indicating an increased average vulnerability and exposure to climate change.
- The biggest differences **in climate risk perception refer to those risks related to erosion**; erosion itself, landslides, floods, and heavy rains. From the responses of our stakeholders, we learned that heavy rains and flood risks are closely linked to erosion, as when the soil degrades, it decreases its

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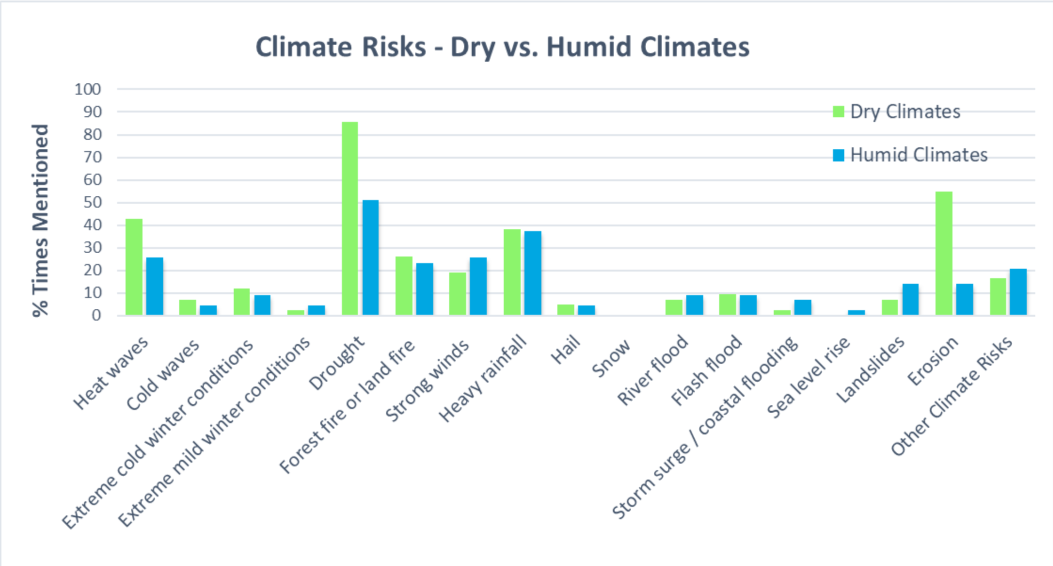
water absorption and retention capacities, which increases the risks of water runs, at the same time increasing erosion in a feedback loop.

- The other major learning that can be extracted from this comparison is **that developing countries are more affected by infrastructure-related climate risks**; river floods, flash floods and coastal surges. These are risks that can largely be mitigated with the appropriate infrastructure, perhaps not so widespread in developing economies.

Dry vs Humid climates

Figure 4 shows some significant differences between the climate risks LMTs are exposed to in dry and humid climates. As a general remark, the graph suggests that LMTs in dry climates tend to be more affected by risks linked to climate change than those in more humid climates.

Whereas it may seem that drought risks relate to a decrease in average annual rainfall, that is not exactly the case; most plant species and techniques in dry climates are perceived as well adapted to low precipitations, so **small** and even moderate **variations in average rainfall won't generally have dramatic effects.**



Dry Climates	45
Humid Climates	52

Figure 4: Climate risks in dry and humid climates

The most damaging effects are, however, according to our interviewees, **the increased unpredictability of rain seasons and the increased irregularity of rainfall during these periods.** Seedlings can dry out if rain does not come when it is expected, ruining harvests and afforestation or reforestation efforts. Also, according to interviewees, an irregular rainy season can trigger the sprouting of seeds on the ground, which will then die if rain events are followed by a long period without rain, leaving soil seed reservoirs depleted for later rains. This results in low ground coverage in grasslands even when the average rainfall has been adequate. These conditions also favour the proliferation of grasses to the detriment of legumes, which are more beneficial for the soil. **In addition,**

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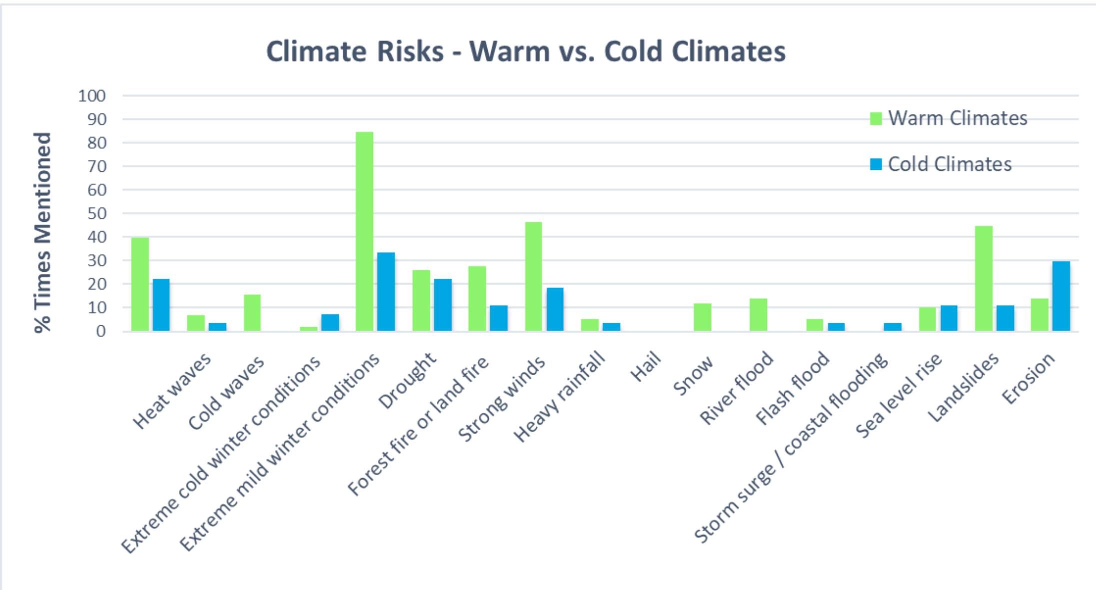
most stakeholders report that rains are increasingly concentrated in shorter periods, resulting in heavier rainfalls during shorter time frames.

- These **variations in rain distribution are connected with** the other major risk in dry climates; **erosion**. The lower ground coverage in grasslands leaves the soil exposed to erosion, with ground coverages over 60% minimizing erosion, and under 30% representing a disaster in terms of erosion, according to an interviewee. Also, heavier rainfalls increase the risk of water run-offs, which erode soils. This is a **feedback loop**, as **more eroded soils** pose a lower water retention capacity, decreasing absorption **and increasing the risks of run-offs, further worsening erosion**. **It is crucial to tackling erosion in dry climates to decrease a wider range of climate risks.**
- Although not exclusive to dry climates, abnormally high temperatures also represent a higher risk in dryer climates. Once again, according to the interviews, **it is not the increase in the average temperature which needs more careful consideration, but the distribution of these abnormalities.** Whereas plant species and methods in dry warm climates are well adapted to heatwaves during the summer, abnormally high temperatures in other periods pose a much higher risk. This is **especially relevant for periods of higher plant respiration, such as spring or during the night**. Abnormally high temperatures in these periods will compromise plant growth, resulting in lower carbon sequestration and lower ground coverage, increasing the risk of erosion.

Warm vs Cold climates



Warm Climates	61
Cold Climates	36

Figure 5: Climate risks in warm and cold climates

From Figure 5 it can be deduced that climate **risks in warm and dry climates largely overlap**, with a higher prominence of heavy rainfalls as the warm category also includes wet tropical climates, with a strong differentiation between the rainy and the dry seasons.

- Again, the qualitative results (based on the stakeholder interviews) suggest that **LMTs in warm** (similar to dry) **climates are (perceived to be) more exposed to climate change-related extreme**

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events than cooler climates, with droughts being mentioned as **one of the main risks** by most of the interviewed stakeholders. Most stakeholders mentioned that **drought periods and heatwaves often happen simultaneously**, but it is drought that causes the most damaging effects.[3] We did **not find a big difference in the (perceived) risk of forest fires between dry-humid and warm-cold climates**, which may appear to be **more linked to land and human factors (e.g., natural forest/land, managed forests/land) than to climate extremes** according to the interviews.

- When it comes to climate risks **in colder climates**, it stands out that "other risks" is the only field where cool environments stand out. This is almost exclusively due **to an increased risk of pests** that did not use to pose a threat to local plant species, but **due to climate change are finding more favourable conditions and affecting areas at higher latitudes than they did in the past.**

2.2.3 Risks per LMT category

In this section, individual LMT categories will be assessed to determine the specific characteristics of the climate risks linked to their implementation.

The categorization of individual LMTs is sometimes not straightforward as different subcategorizations can be developed, as different LMTs within the same category can have different characteristics that make them vulnerable to different climate risks. Therefore, whenever it proceeds, a distinction between different techniques framed as the same LMT will be drawn. Also, different LMTs will be compared whenever this comparison is thought to provide with useful insights.

Within this section we discuss the following LMT categories:

- Agroforestry
- Wetland management
- Afforestation/reforestation
- Agricultural practices
- Other LMTs

Agroforestry

Characterisation and categorization of agroforestry systems is particularly complex. They can range from simple hedgerows alongside roads to mixed farming systems with or without livestock, or complex food forest systems. There are several different formal/legal definitions or informal interpretations of the concept of agroforestry. However, there is not yet one single, uniform (internationally) agreed definition. The lack of a good legal definition can be problematic, in relation to obtaining farm support as several crops, and farming activities may be carried out on the same parcel (e.g., when farm support is dependent on specific crop codes). Given its inherent diversity we anticipate that some form of a subclassification scheme will be needed to be able to (legally) differentiate between various agroforestry systems (Boki Luske et al., 2020). Within this report, we have grouped the results of all agroforestry systems, but also have isolated the **dehesas and montados**

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[3] Once again, the higher risk of drought is not the amount of rain but the increasingly irregular distribution of rains and increasingly long drought periods (linked to longer heatwaves).

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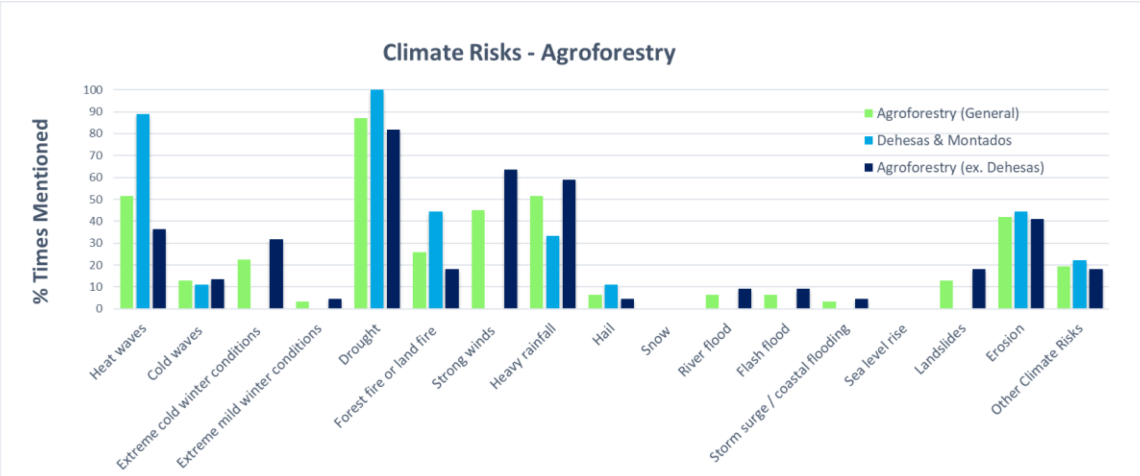
agroforestry systems (see Figure 6), as these systems tend to be more complex because of involving the exploitation of tree resources, grasslands and different species of livestock (making it an agrosilvopastoral system, a specific type of agroforestry). There are also 2 results coming from agrosilvopastoral systems under the category of agroforestry, but it was decided to keep them under this category because they come from different ecosystems and are therefore not representative of the dehesas and montados categories.

In Figure 6 we see that the interviewed stakeholder identify heatwaves, droughts and heavy rainfalls and erosion as the main risks faced by agroforestry systems.



Agroforestry	32
Dehesas & Montados	9
Agroforestry (ex. Dehesas)	23

Figure 6: Climate risk of agroforestry

- Depending on the type of agroforestry system, **heatwaves can be damaging even if they are not accompanied by extended drought periods**. This is **especially relevant for fruit trees** (including nut trees), **as too much sun can burn the fruits** and ruin the harvests, according to an interviewee. Along with heatwaves, **droughts pose a risk**, particularly **to younger trees**, and summer droughts can also have a negative effect on fruit harvests. Heavy rainfalls can also pose a climate risk to agroforestry systems, although this risk can be largely mitigated by a careful selection of species. The risk of fire is closely linked to heatwaves, droughts and strong winds, but is considered (by the respondents) even more related to the use and design of the agroforestry system rather than climate events. **An actively maintained system, with** enough spacing between trees, high canopies to avoid the fire reaching leaves and branches, and **a correct tree species selection** (avoiding, for example, trees rich in flammable resin such as pines) **will largely diminish the risk of forest fires.**
- Specifically for the dehesas and montados agroforestry systems, as has been highlighted before in this report, **heatwaves and droughts pose a risk** not so much **depending** on the specific severity (or extreme), but more **on the distribution and timing of the events**. Dehesas and montados systems are generally well adapted to hot and dry summers, so heatwaves or droughts during this period do not suppose a threat to the system. However, low, or **irregular precipitations** during the spring season can result **in low pasture growth** and low ground coverage, limiting the protection

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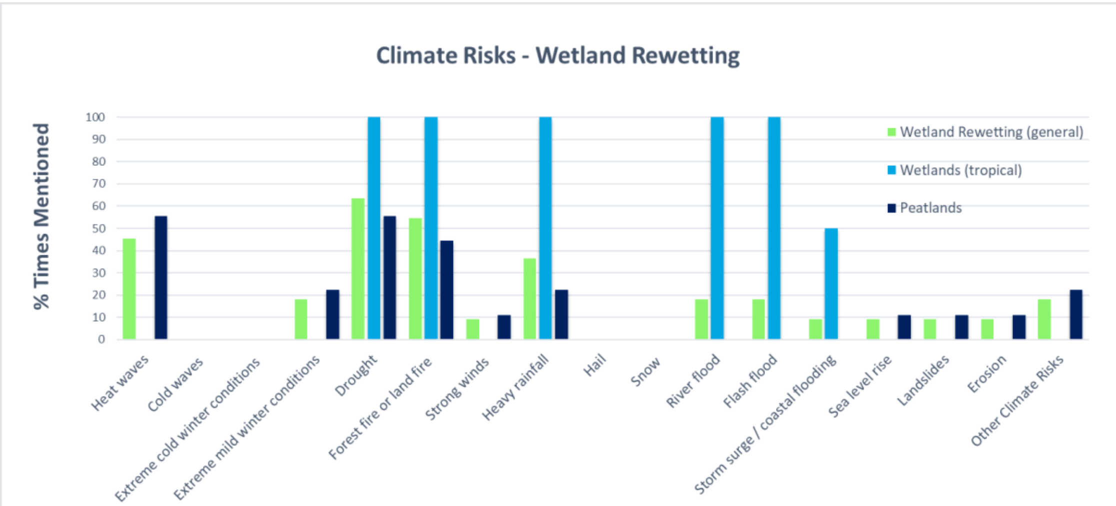
against **erosion, decreasing carbon sequestration, and meaning less food for livestock,** which would need more external input, also translating into more CO_2 emissions (i.e., cascading risks). Also, long dry periods in the rainy season favour the growth of grasses instead of legumes, the second being more beneficial for soil health. Also, cork oaks suffer more from droughts than holm oaks, but also produce a higher economic revenue due to the exploitation of cork, so are often prioritized when conditions allow for it.

Abnormally high temperatures during periods of high plant transpiration (as spring or at night) also have a detrimental effect on plant growth.

A concerning climate risk for dehesas and montados is reported to be a **fungal parasite known as "La seca"** (*Phytophthora cinnamomi)*, which is affecting large areas of holm oaks with devastating effects, killing centuries-old trees. The increased occurrence of this parasite is closely related to the effects of climate change and the abandonment of the land (el Español, 2017).

Wetland rewetting

Similar to the categorization and classification of different agroforestry systems wetland management has several subcategories. Within the LANDMARC project, so far, we have generally referred to "peatland rewetting", however, here we deem "wetland management" as more appropriate. This category involves techniques that re-humidify or restore different types of wetlands, but not necessarily all of them are peatlands, as is the case for tropical wetlands. Within this report, we differentiate between peatlands and tropical wetlands to better discern between the climate risks they are exposed to.



Wetland Rewetting	11
Wetlands (tropical)	2
Peatlands	9

Figure 7: Climate risks of wetland rewetting

- As can be observed in Figure 7, tropical wetlands are reported to be more affected by river floods (because of the assessed LMTs being located next to river mouths), and also by droughts in case the rainy season is not rainy enough.
- However, in the case of peatlands, a man-made intervention is usually necessary to maintain a consistent or higher water table year-round. **In case not enough water is available, the water**

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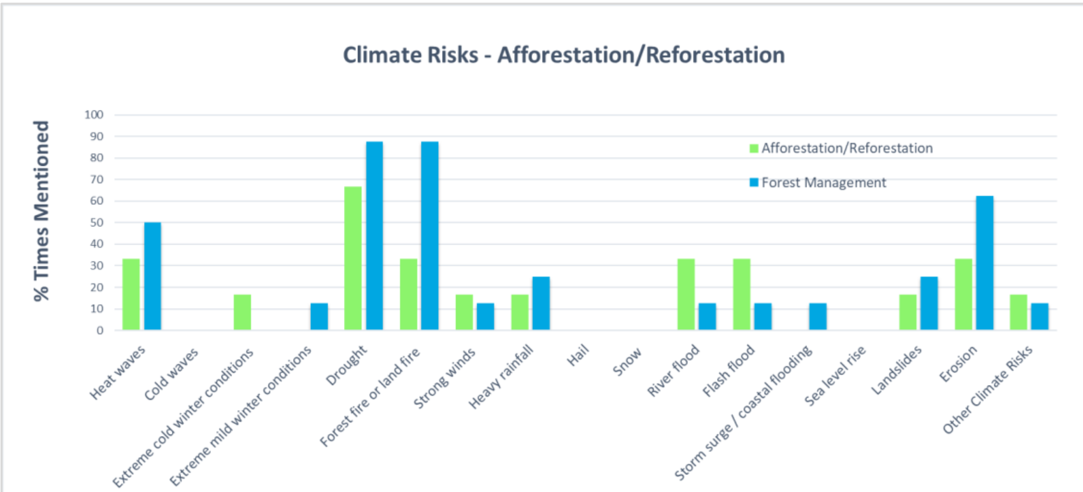
table drops, leaving the peaty soils exposed to oxidation**. Drought events are usually linked to heatwaves, although heat itself should not pose a big threat to this LMT. The interviewees also highlighted **heavy rains** as a risk factor; when the (managed) wetlands get saturated with water, it is **very difficult to work in them with machinery**, and it is necessary to wait until they drain to be able to work in them. In case of **sea level rise, salty water could eventually diffuse** through the terrain in coastal areas as the phreatic level rises**, leaving the land virtually unusable for decades**. Some types of peatlands need to get frozen during the winter for the proper functioning of the system, therefore too mild winters can compromise the health of the LMT.

- One interviewee mentioned an increased risk of parasitic infections in livestock linked to the rewetting of peatlands and warmer temperatures; rewetted peatlands create better conditions for the proliferation of mosquitoes and other similar parasites, that spread diseases in the cattle.

Afforestation and reforestation

Afforestation and reforestation have been grouped, as they share many characteristics (the principal difference is the previous land use of the terrain), although there can be differences respecting previous reconditioning of the terrain. Also, forest management has been included in Figure 8 to compare their characteristics, as reforestation can be part of forest management practices.



Afforestation/Reforestation	6
Forest Management	8

Figure 8: Climate risks of afforestation and reforestation (including forest management)

We find that, despite the variety of countries that were assessed for forest management (Venezuela, Nepal, Spain, Germany, and Burkina Faso), the key climate risks identified by the interviewees are quite consistent.

Many of the risks of afforestation and reforestation overlap with the ones mentioned previously for **agroforestry**, with a few notable observations. Afforestation/reforestation efforts need to be carefully planned to **avoid using the same species of trees and of the same ages** (avoid monocultures), **as this could drastically reduce the climate resilience of the system**; interviewees mentioned that pests that attack trees of certain species or ages would have devastating effects on a forest in which all trees are the same species and age. Also, the benefits in biodiversity, soil health and resilience in general largely

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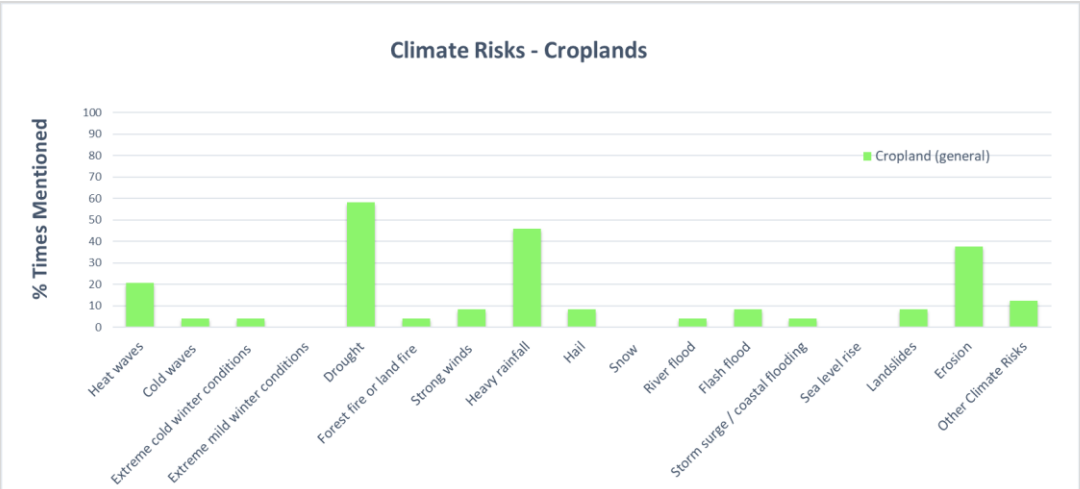
stem from using a variety of species. Tree species must be carefully selected to prime local species that are well adapted to the local environment (with a view to future effects of climate change) and that provide the most benefits to the ecosystem.

Climate extremes affect young trees to a much greater extent than mature trees, the major threats being droughts, heatwaves, and strong winds. According to the interviews, **mature forests are** indicated as more **resilient to climate events**, with most (perceived) major losses in forests being due to pests and forest fires rather than direct climate events. However, the effects of prolonged periods with occurring climate extremes can decrease the health of trees, making them more vulnerable to parasites or more prone to forest fires.

Interestingly, despite not being mentioned as one of the main risks, recent studies suggest that the most damaging climate disturbance in European forests is strong winds, being responsible for almost half of all forest biomass lost due to climate extremes, more than through forest fires (Patacca et al., 2022). However, the interviewed stakeholders do not perceive strong winds as one of the main risks. Further analysis of this observation would allow for a better analysis of the climate risks on forest masses.

Agricultural practices

24 stakeholders in 5 countries were asked about the climate risk of a wide range of LMTs in relation to sustainable agricultural practices. Also here we find a diverse set of specific types of agricultural practices. In Figure 9, we provide an overview of the climate risk of all of them can be observed. Despite targeting different LMTs, the **main climate risks remain constant; droughts, heavy rainfalls and (soil) erosion are considered the most damaging parameters**, followed by heatwaves (linked to a great extent to droughts) and other risks, referring exclusively to pests.



Cropland	24

Figure 9: Overview climate risks agricultural practices

In Figure 10, a more detailed analysis of the risk depending on the techniques can be observed.

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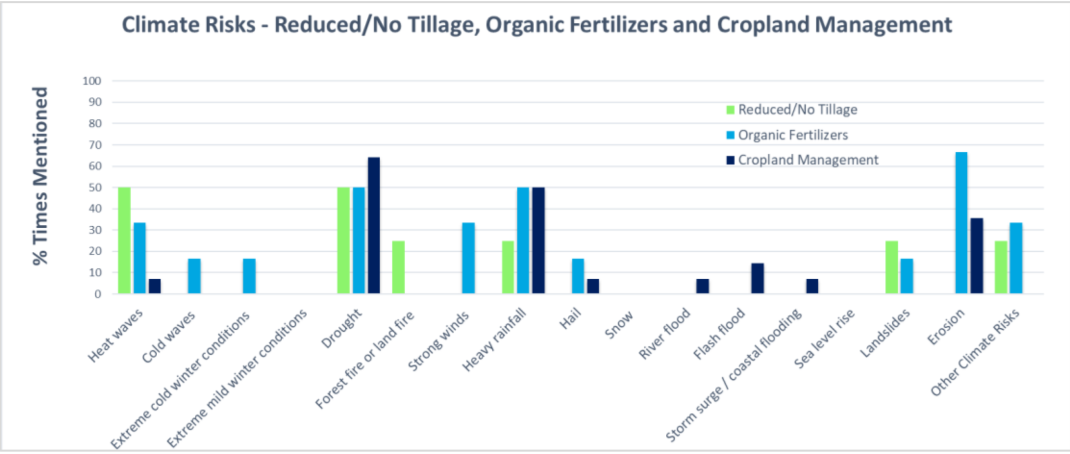
All the techniques assessed are cropland management techniques, but there is a large variety of techniques, with only "reduced/no tillage" and "organic fertilizers" counting on a significant representation, so all the other techniques were included under "cropland management".

It can be concluded that the risks remain largely similar to all the techniques. As mentioned before for other techniques, the main risk of droughts is not the decrease in average rainfall, but the increased



Reduced/No Tillage	4
Organic Fertilizers	6
Cropland Management	14

Figure 10: Climate risks of different agricultural practices

unpredictability of the rains, and the tendency of precipitation to be concentrated in shorter periods with heavy rainfall. This makes it more difficult for land users to plan their harvest, implying a heavier workload for them (as they will start taking action to mitigate the effects of droughts based on last years' experience, which can be even counter-productive for the present year's conditions). Heavy rains in short periods also contribute to soil erosion by removing the most fertile topsoil, the same as strong winds.

The distribution of rains is also very important when manure is applied to the soil, as a sudden and fast rewetting of the soil can result in strong pulses of N_2O. Also, heatwaves can lead to high emissions in manure heaps in farms.

In the case of dry-seeded rice (Nepal), the main benefits are achieved in spring rice. However, yields of dry-seeded rice are lower, but this can be a consequence of the misuse of herbicides. However, **dry-seeded rice cultivation is more exposed to the unpredictability of rains**. Not flooding the fields also means a **higher risk of pests and more difficult weed control**.

Other LMTs

In Figure 11 the climate risks linked to biochar and avoided grassland conversion can be observed. Dehesas and Montados have also been included in the comparison to provide context, although are not directly related to any of these practices.

Biochar has several climate risks associated with its application; risks affecting biomass supply could potentially affect its availability, and the **excessive or incorrect application of biochar could lead to**

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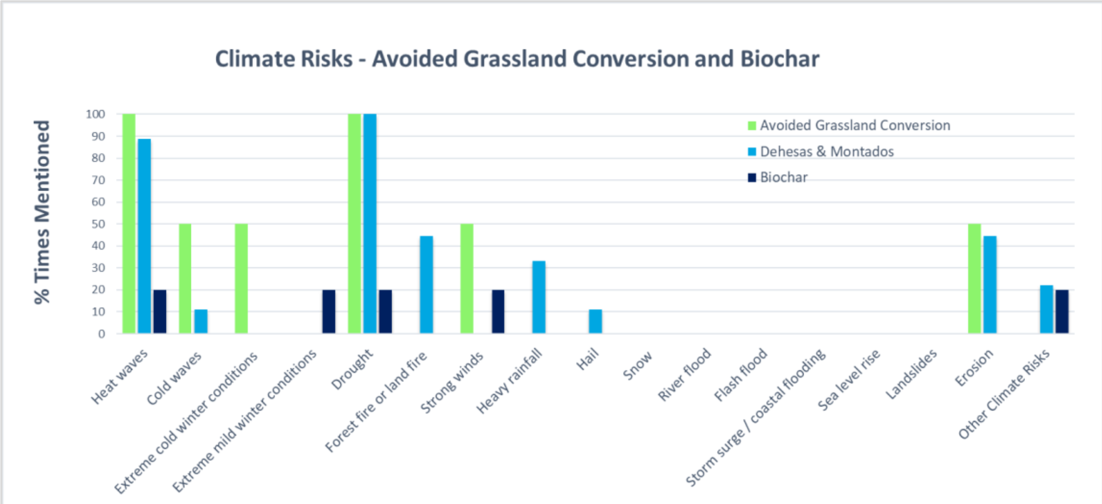
negative effects on soil health. However, in practice, this is generally not directly associated with climate risks.

On the other side, **avoided grassland conversion has a similar (perceived) climate risk profile relative to dehesas and montados**, with droughts, and particularly irregularity of rainfall, threatening the development of grasses, and indirectly producing losses in soil health and increasing erosion due to poor plant coverage. Also, frost conditions combined with grazing can severely damage the grasses during winter months.



Avoided Grassland Conversion	2
Dehesas & Montados	9
Biochar	5

Figure 11: Climate risks of biochar and avoided grassland conversion, compared to dehesas & montados

2.2.4 Overview Risks

Despite a large number of techniques and regions considered, a few climate risks have been consistently referred to as the main threats by most interviewees from most countries and most techniques.

Heatwaves and droughts are closely linked and mentioned largely interchangeably by most interviewees, but the greatest risk is posed by droughts (heatwaves when not linked to drought episodes, despite also being damaging in most cases, suppose a far less dangerous risk).

In most cases, droughts do not necessarily refer to a decrease in annual precipitation, but to an increasingly irregular distribution (through time and space) of rains, with a higher prevalence of long periods without rain followed by episodes of heavy rain, and increasingly unpredictable rain seasons. This interferes greatly with plant growth and land use planning and produces a chain of events involving other risks.

Soil erosion seems to be both the consequence and cause of a large number of other risks enumerated in this deliverable. According to the analysis, soil erosion is a consequence of both the effects of climate change (mostly droughts) and poor land management. Soil erosion increases the risk of floods,

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droughts (as it decreases the soil's water retention) loss of nutrients, and debilitates plants, making them more vulnerable to pests. It is both difficult and crucial to stop the erosion cycle, as it is a self-fulfilling process that results in the impossibility to grow life on it, so LMTs that can stop the erosion cycle should be prioritized. Also, pests were not included as a climate risk in the questionnaire, but from the interviews, it can be extracted that pests pose an increasingly significant threat to LMTs as a consequence of climate change.

Climate extremes are more prevalent in warm (and even more in warm and dry) climates (Figure 4 and Figure 5), which prevail in the global south. Infrastructure was found to be a relevant factor when facing climate extremes, so climate extremes of the same magnitude suppose a higher risk when infrastructure is not available. However, some techniques can be applied by smallholders to significantly reduce their exposure to climate extremes that do not need a lot of infrastructures. Some of these techniques are traditional to the area (e.g., indigenous practices), developed over millennia to deal with local conditions, and should be preserved instead of replaced with modern industrial agricultural techniques without careful prior consideration.

From the analysis, it can also be concluded the role of (mature and carefully selected) trees in mitigating the effects of climate change in many ways and improving resilience. Mature trees can partially decrease these risks while being remarkably resilient themselves, so they are an extraordinary agent not only for climate change mitigation but also for adaptation.

2.3 Survey Results – Effects on the environment

2.3.1 Overview effects on the environment

When it comes to the effects of LMT implementation on the environment, the intention was to record both positive and negative effects on the environment. However, from the interview results, we observe that **almost no negative effects on the environment are associated with the implementation of LMTs**. This section thus mainly reports on positive effects. Where appropriate specific negative effects are discussed. Thus, Figure 12 shows positive effects linked to LMTs.

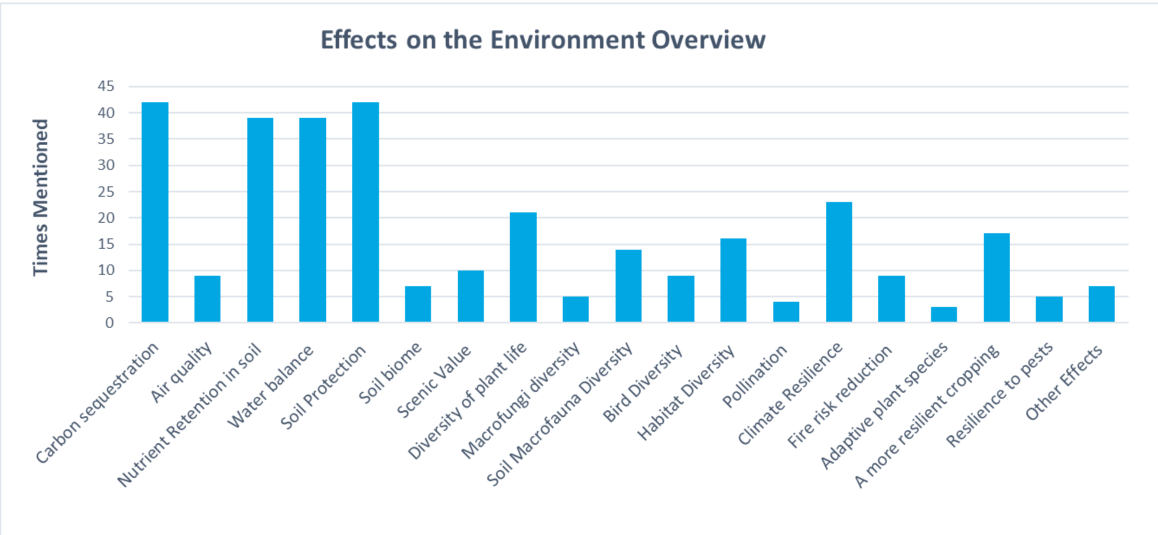

Figure 12: Overview of effects on the environment

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In Figure 12 we can see that **almost all addressed effects on the environment are considered significant**. However, aside from the intended carbon sequestration impact of LMTs, **soil health-related** effects (water balance, soil protection, nutrient retention) **and climate resilience are most often mentioned.**

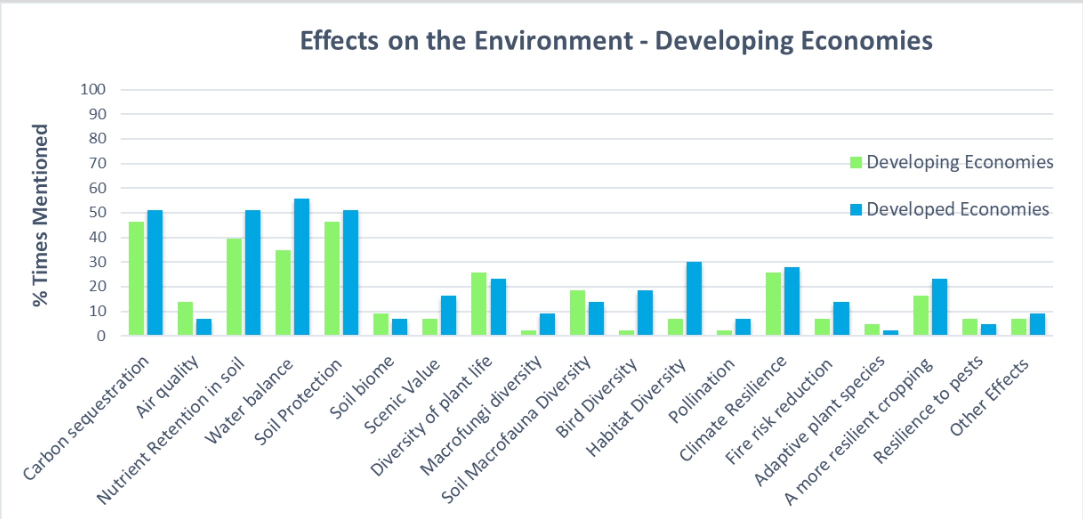
Based on the results on climate risks presented in the previous section, we should pay special attention to effects related to erosion reduction and soil health as they could also help mitigate risks not only directly related to the soil but also against floods, heavy rains, erosion and more.

Although being a core aspect of LMT implementation, carbon sequestration is 'only' mentioned as a relevant positive effect in less than half of all the interviews (41 mentions from a total of 97 interviews). This could suggest that there are other (stronger) drivers for promoting sustainable land management practices, relative to climate change mitigation (retaining and/or absorbing CO_2). Hence **maximizing or optimizing an LMT purely for its climate change mitigation benefits may not be the preferred strategy for scaling up**.

2.3.2 Effects on the environment per region

Developed vs Developing economies

The distinction between the effects on the environment on developed and developing economies is based on the idea that the perception of the effects on the environment could highlight underlying issues that are specific to developing or developed economies.



Developing Economies	45
Developed Economies	52

Figure 13: Effects on the environment in developing and developed economies

From Figure 13 it can be extracted that **there are no major differences between the effects on the environment linked to the implementation of LMTs in developing and developed economies**. The most noticeable difference can be observed in those effects related to diversity (plant, macrofauna…), perhaps as an indication that biodiversity is generally more diminished in developed economies.

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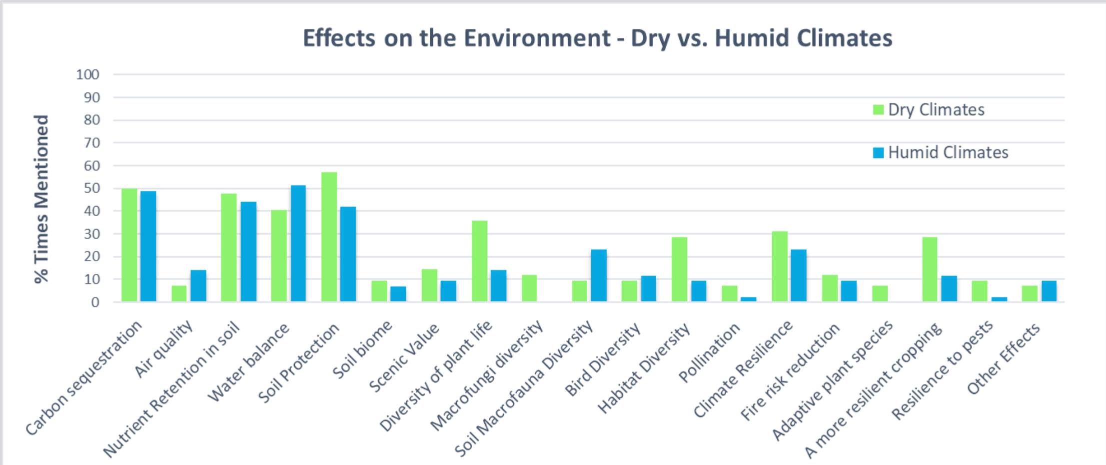
Dry vs Humid climates

There is a wide range of beneficial effects on the environment derived from the implementation of LMTs in both dry and humid climates (see Figure 14). We observe that dry climates may benefit (slightly) more from these LMT practices, particularly due to increased climate resilience. This could also suggest a difference between the stakeholder perceptions (from dry vs. humid climates) of the general state of their ecosystems.



Dry Climates	45
Humid Climates	52

Figure 14: Effects on the environment in dry and humid climates

Apart from what is shown in Figure 14 the results from the stakeholders consultations suggest that LMT **actions improving water and nutrient retention are considered particularly beneficial for dry climates**, resulting both in increasing carbon sequestration and mitigating (soil) erosion. **This is the case for agroforestry**, were trees decrease water evaporation from the soil by providing shade, and nutrient retention is increased due to decreased leaching. **Also, agricultural practices** such grass walls in Burkina Faso, biopores in Indonesia or half-moons in Kenya were techniques mentioned by the interviewiwees that **substantially increase water retention**, contributing to decrease erosion. These techniques will be discussed later in Agricultural practices.

Warm vs Cold climates

Most benefits derived from the implementation of LMTs, in warm and cold environments, **are connected to soil health, with slightly higher benefits for warm climates** (see Figure 15). Also, whereas carbon sequestration is one of the most commonly mentioned benefits of the implementation of LMTs, it does not clearly stand out as the main for none of the categories.

- A positive conclusion can be extracted from Figure 15: Effects on the environment on warm and cold climates; as mentioned before, **erosion and desertification are among the hardest and most urgent climate risks to address**, particularly in dry-warm climates, as erosion feeds back into decreased water balance and nutrient retention, which creates more erosion. **The implementation of LMTs seems to have a great potential to stop this process, resulting in higher carbon sequestration, soil health and overall climate resilience.**

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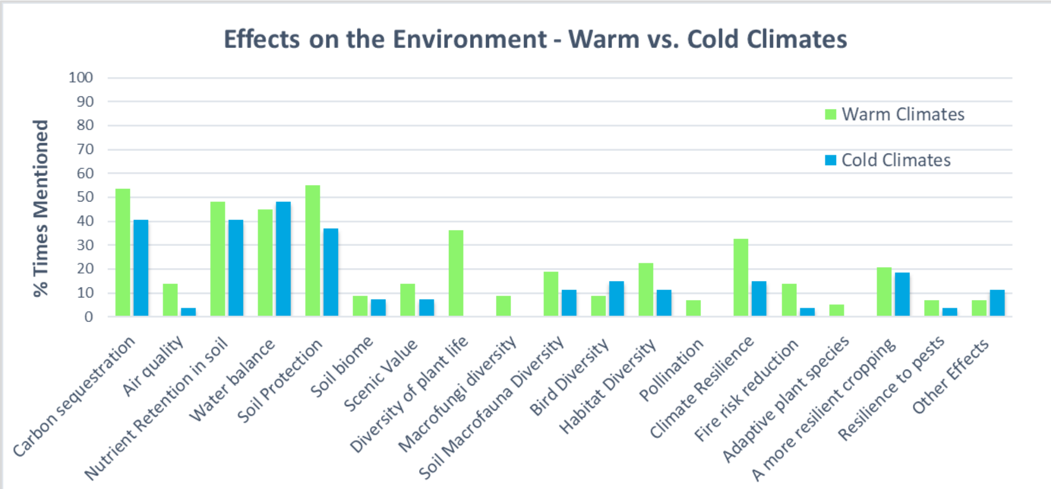
- Closely linked to this observation, it can be noted that many interviewees highlighted increased plant diversity as one of the main effects of the implementation of LMTs in warm climates. Similarly



Warm Climates	61
Cold Climates	36

Figure 15: Effects on the environment on warm and cold climates

to dry climates, it can be deducted from the interviews that warm climates suffer more from erosion, and the **soil restoration effect caused by the implementation of LMTs fosters plant diversity**. Also, certain land uses such as dehesas and montados also increase plant diversity due to the characteristics of the land management (explained in more detail in Agroforestry).

2.3.3 Effects on the environment per LMT

Agroforestry systems

Many positive effects on the environment are linked to the implementation of agroforestry and dehesas and montados (Figure 16). Despite large differences in their beneficial effects consequence of the wide range of practices that can be framed under the umbrella of agroforestry, **agroforestry contributes to better water retention, better nutrient retention, erosion reduction, increase in biodiversity and resilience in many ways:**

- The incorporation of trees in agricultural systems increases resilience at many different levels; they help retain water, increasing resilience against droughts. Despite drought being one of the major climate risks, it also contributes to mitigating it, creating a self-fulfilling loop of resilience. Stakeholders also report an **increase in nutrient retention**, although this effect **is limited to the immediate proximities of the tree**, so to take full advantage of this effect, a high density of trees would be necessary.
- Another far-reaching positive effect of the implementation of trees in agricultural systems is that they **avoid nutrient leaching, particularly nitrates**. The reduction in nitrates leaching into water bodies can reduce water purification costs to a greater extent and significantly reduce the incidence of cancer in nearby populations.

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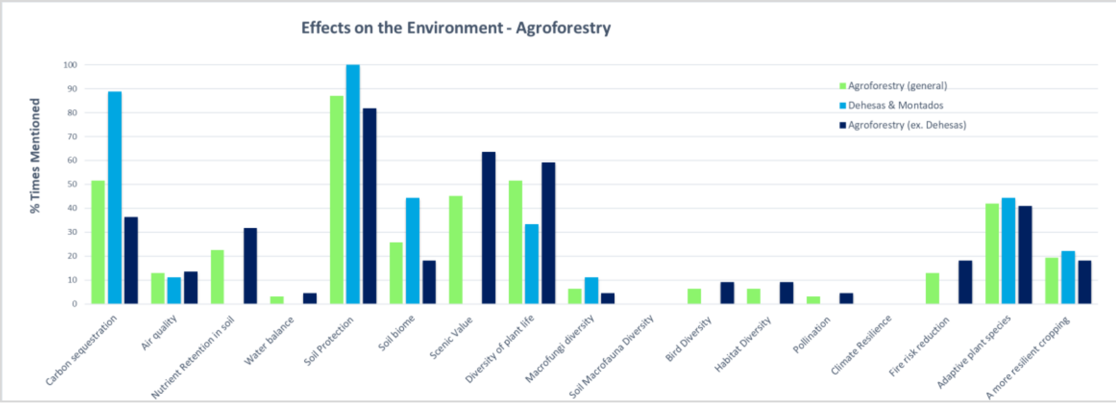
- Another effect mentioned by stakeholders is **an increased resilience to pests** and a potential reduction in the use of pesticides, as trees can host predators or parasites (such as birds or other insects).
- **Trees can** also be incorporated to effectively **protect agricultural systems from strong winds and excessive sunlight**, as well as to avoid landslides in mountainous regions during episodes of heavy



Agroforestry	32
Dehesas & Montados	9
Agroforestry (ex. Dehesas)	23

Figure 16: Effects on the environment of agroforestry

rains. Even if trees are not incorporated directly into the agricultural system, the plantation of trees in buffer areas around the fields significantly brings some advantages.
- However, the conditions of the terrain must be assessed before implementing agroforestry, as it is impossible to implement in heavily degraded lands.
- The case of dehesas and montados is even interesting given the complexity of the system. Apart from the above-mentioned advantages for agroforestry systems, **dehesas and montados are characterized by a very fast carbon cycle** by incorporating grazing animals. Low-density extensive farming livestock constantly eat the grasses and supply the soil with different nutrients. Different species graze on different plants, which **promotes plant diversity** by allowing for the proliferation of more species than would happen without farming, where only the best-adapted species would dominate. This diversity also **attracts a large number of pollinating agents** and allows for the proliferation of a great macrofungi diversity. They also play an important role in **avoiding erosion and desertification in regions in Spain and Portugal that are vulnerable to this phenomenon.**
- **Carbon sequestration in dehesas and montados is mostly driven by its pastures**, although trees also play a significant role.
- This increased diversity makes **the dehesas-montados system remarkably resilient**, also due to the diversified source of income for the landowners and users.

Wetland management

As can be observed in Figure 17, **wetlands play a significant role in carbon sequestration, soil health** (water balance, nutrient retention, and soil protection), **diversity and climate resilience as a whole**. The **highest mitigation potential** from wetlands does not actually **come from** its carbon sequestration potential but from **the emission reductions linked to the rewetting and non-disturbance of wetlands**. While covering only about 3% of the global land surface, they are estimated to sequester the same

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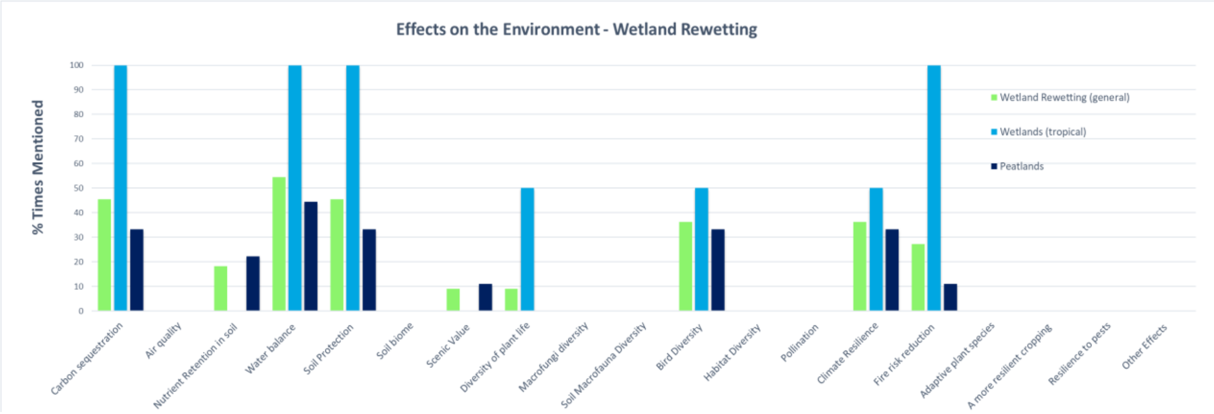
amount of carbon as all the forests combined, making wetlands 10 times more carbon dense than forests. Although only 0.3% of all wetlands have been drained, its associated emissions are estimated **to account for 6% of man-made human emissions** (Dixon et al., 1994) (Bridgham et al., 2006).

The carbon sequestration potential of the rewetting of peatlands comes from avoiding the oxidation of the peat layers of the soil. Wetlands are therefore one of the LMTs with the highest carbon sequestration potential, and a often overlooked one.



Wetland Rewetting	11
Wetlands (tropical)	2
Peatlands	9

Figure 17: Effects on the environment of wetland rewetting

- **One of the main effects of the draining of peatlands is soil subsidence;** when the water table is lowered to drain the peatlands for agricultural use and achieve higher yields, the ground level drops in the mid-long term. When this practice extends to whole regions, as in some areas of the Netherlands, soil subsidence can affect whole regions, **damaging buildings and infrastructures to a great extent with subsequent damage costs**. Besides, **the drop in ground level in areas that already are at sea level or even below it largely rises the exposure of these regions to sea level rise and saline water intrusion**, potentially making the lands unproductive. As with erosion, this is a self-fulfilling feedback loop, in which the water table is artificially lowered to favour higher yields, but the ground level also drops over time, making it necessary to further lower the water table.
- **The rewetting of wetlands** (rising the water table), according to the interviewees, **could minimize or even completely stop the process of soil subsidence**, aside from largely avoiding the CO_2 emissions derived from the oxidation of peaty soils. It would be necessary to conduct a large-scale assessment of avoided cost in infrastructure repair linked to the rewetting of peatlands vs the drop in productivity of the lands, but it could be possible that it would pay off even without considering any environmental parameters.
- The most effective way of rewetting peatlands is to rise the water level to up to 5 cm below the surface line; a higher water table could result in increased CH_4 emissions.
- **The rewetting of wetlands has positive effects on soil water balance and wildlife, particularly on bird diversity, as well as largely avoiding peat fires**.
- The case of tropical **wetlands is slightly different; they are more exposed to floods and to fires**. The rewetting of these wetlands increases the climate resilience of the areas by improving water

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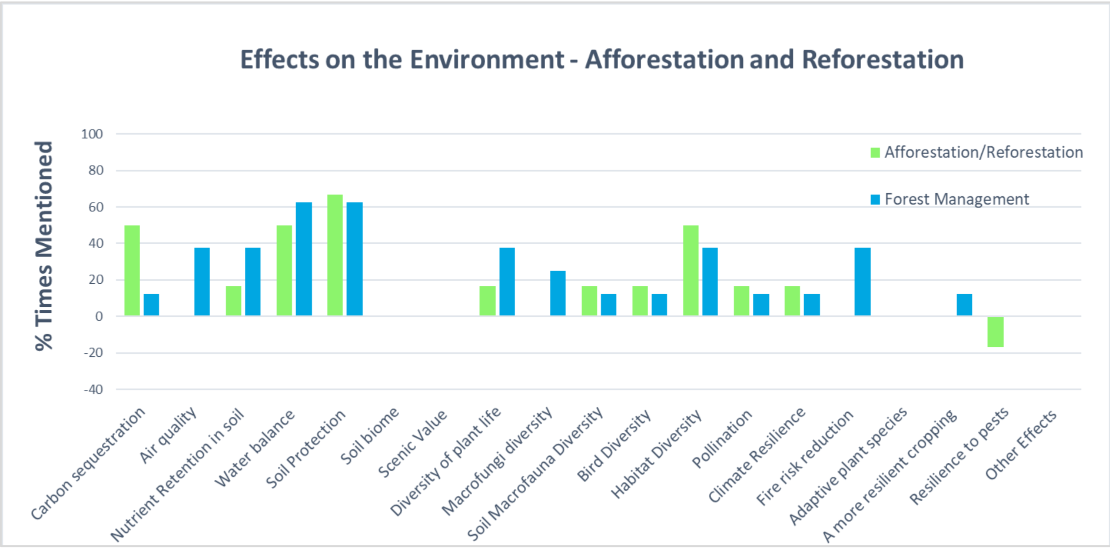
balance (drained peatlands have a very low water retention capacity) and decreasing the risk of fires. Rewetting actions also include revegetation, and increasing bird and plant diversity.

Afforestation and Reforestation

In Figure 18, the effects on the environment of the implementation of afforestation/reforestation and forest management practices can be observed. They have been merged in the same graph because reforestation can be a part of forest management practices, and therefore it is relevant to compare their similarities. As in the case of risks, **they share many similarities with agroforestry**. **Afforestation/reforestation** is reported to be an LMT with a very **high resilience improvement potential, avoided erosion and carbon sequestration potential**, not only because of the carbon sequestered in the trees but also in the increased biodiversity that forests bring along. Keeping the residue of crops in the soil will increase soil organic matter and water infiltration.



Afforestation/Reforestation	6
Forest Management	8

Figure 18: Effects on the environment of afforestation and reforestation compared to forest

As already pointed out in the climate risks section, **poorly planned and designed reforestation actions can bring negative effects on the environment by decreasing the pest resilience of the systems** in case monocultures of the same tree species from the same age are introduced.

The effects on the environment of forest management depend largely on the type of management performed, as a higher harvesting frequency will be more damaging to the soil health, as well as using industrial methods for wood harvesting. Some tree species, such as coniferous, can also decrease the soil water status.

The controlled and well-planned use of forest fires can have a beneficial impact on carbon sequestration and forest resilience by decreasing the risk of major, uncontrolled forest fires. **However, forest fires negatively affect the soil even if controlled, especially when followed by heavy rain episodes**, so good planning of this technique is vital to obtain the most benefits.

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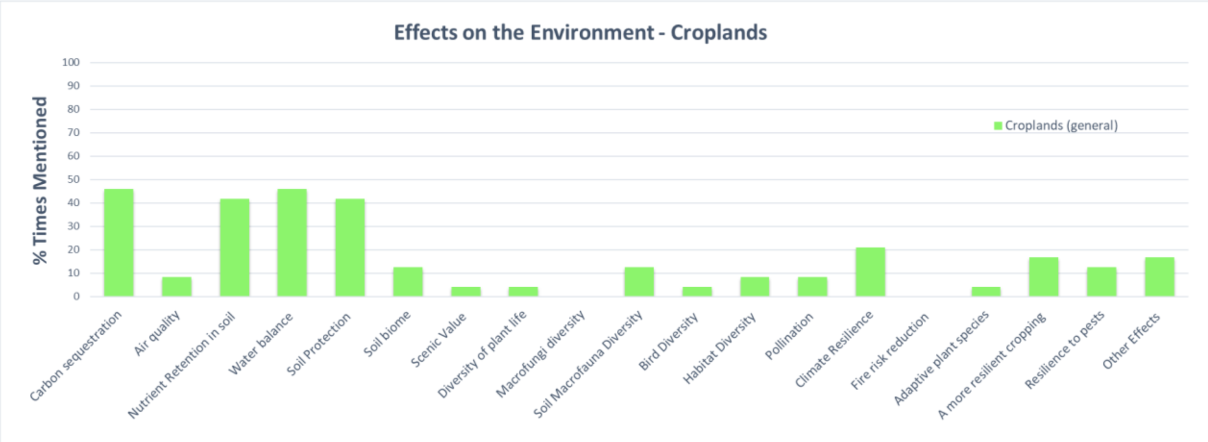
In Figure 19, an overview of the effects on the environment of different sustainable agricultural techniques can be observed. It can be highlighted that, despite the differences in the techniques**, there is a very clear enhancement in soil health parameters reported, and related to improved climate resilience**. Whereas carbon sequestration is an effect linked to sustainable agriculture techniques, it is not as significant as in other LMTs such as wetland management or afforestation. However, **their overall effects on sustainability are remarkable.**



Cropland	24

Figure 19: Overview effects on the environment of agricultural practices

In Figure 20 we can observe in more detail the effects on the environment of these LMTs. **No tilling involved not only stopping the tilling process, but leaving the soil as undisturbed as possible, and covered in mulch at all times**, resulting in an increased organic input. The continuous cover of the soil increases C input and can sequester soil carbon. Also, the **soil is less prone to erosion** as a consequence. The main advantage of no-till is the **improved soil structure due to minimal disturbance.** The soils can have an almost grassland-like natural structure with a lot of soil life, such as earthworms. **This improves water infiltration and reduces run-off a**nd the constantly present mulch reduces the impact of raindrops, effectively **reducing soil erosion**. Reduced tillage in that sense was said to be much less efficient as keeping a cover is the most important principle of no-till. Despite its advantages, 2 interviewees reported no tilling faces resistance due to the “dirty” appearance of the fields where it is applied, often leading to “shaming” from other land users.

Integrated Soil Fertility Management (ISFM), or **organic agriculture**, uses natural inputs such as manure (either “raw” or processed) to enrich the soil. Through increased humus contents, **the system becomes more resilient and heat waves are less severe**. Higher soil carbon stocks improve almost all soil functions, from **better water infiltration and holding capacity, to better nutrient retention and a more resilient soil microbiome**. Also, nutrient cycles are tightened, and the soil provides sufficient nutrients to the plants, **leading to a local circularity of nutrients**. All these factors add up to **a higher**

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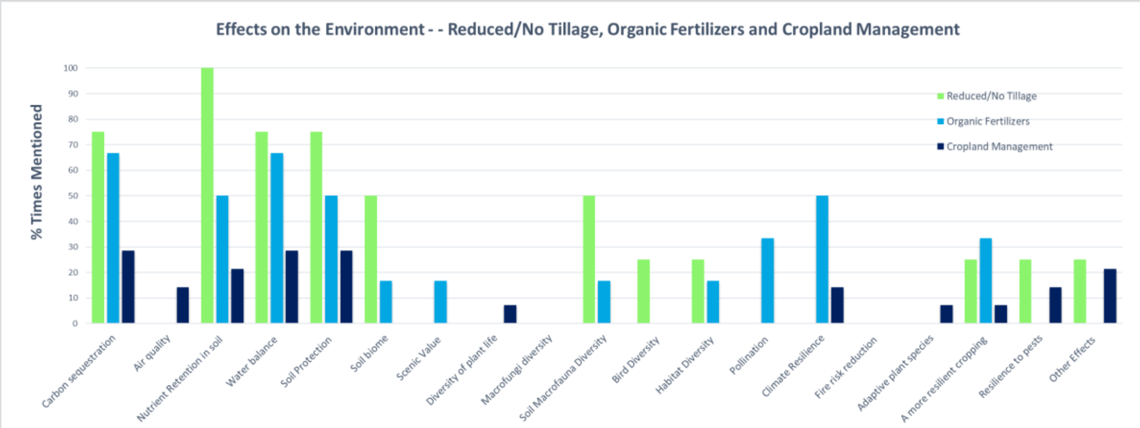
climate resilience of agriculture in general, especially toward extreme events, such as severe rainfall or drought.



Reduced/No Tillage	4
Organic Fertilizers	6
Cropland Management	14

Figure 20: Effects on the environment of different agricultural practices

Cropland management involves a wide spectrum of practices, but the one analysed more in detail is the inclusion of **grass walls between crops**. This technique is not widespread but is getting more relevant given its capacity to **avoid erosion due to strong winds and increased water infiltration and nutrient retention.** These grasses must be displayed in a compact layer to avoid the wind penetrating them and should be spaced between 30 and 47 meters to achieve better resilience without sacrificing harvests due to the effects of shadow. These grasses are then also used for mulching and feeding livestock.

Another technique interviewees in Burkina Faso report as agricultural techniques used to fight pests is mixing water with neem (a plant that produces an oil with anti-infestation properties) leaves and spraying the filtered product on the plants. Ashes and chilli pepper are also used to fight pests, particularly in eggplants and okra.

In the case **of dry-seeded rice, the most relevant effect on the environment is reduced methane emissions due to not flooding the fields**. However, the increase in dry conditions means that there could be more nitrous oxide emissions.

Carbon sequestration is mostly perceived or labelled as a side goal of these practices. However, the implementation of these practices will help preserve the environment in many ways. In terms of biodiversity, introducing these practices will increase tree and macrofauna diversity. Keeping the residue of crops in the soil will increase soil organic matter and water infiltration, although some farmers in Burkina Faso don't like to keep the crop residuals on their land as they use it for feeding the animals.

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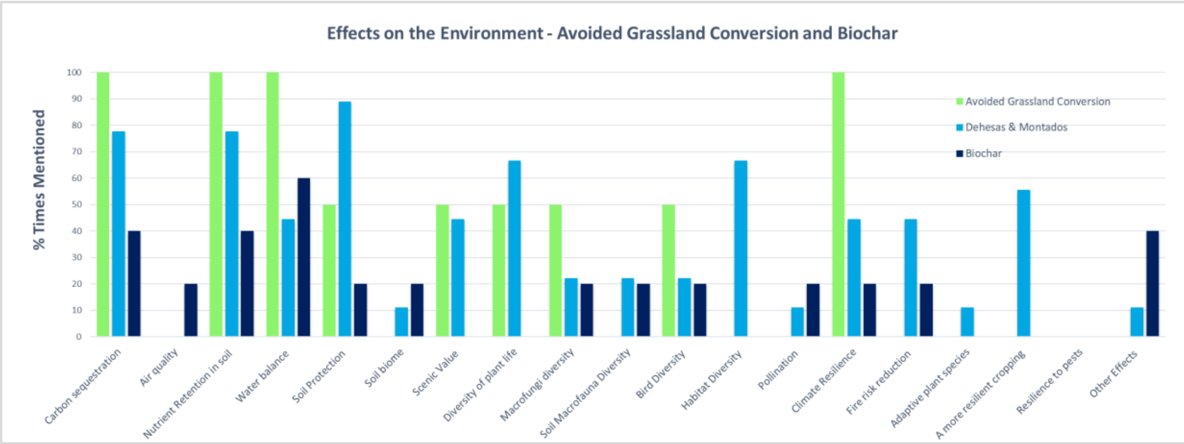
The avoided conversion of grasslands and biochar have been included in the same chapter because they cannot be so easily compared to other LMTs, and the samples for these techniques are rather small, so comparisons are not easy. However, dehesas and montados have been included in the graph to see contextualize avoided the effects of avoided grassland conversion, as some dehesas and montados practices could share some similarities with the technique.



Avoided Grassland Conversion	2
Dehesas & Montados	9
Biochar	5

Figure 21: Effects on the environment of the avoided conversion of grasslands and biochar

In Figure 21 it can be noted that **biochar** is considered to provide several benefits to the soil, such as **increasing water-holding capacity** and it may also be beneficial in **capturing and binding soil pollutants**, due to its high surface area. **Biochar also has great potential for soil restoration and features one of the longest-proven soil carbon permanence**.

A potential negative effect could be the increase in soil temperature due to a change in the albedo (darker soils).

Avoided grassland conversion brings great benefits to soil health, such as water and nutrient retention, erosion reduction, which results in a higher biodiversity and enhanced climate resilience. Also, unconverted grasslands favour the development of macro fungi, which store phosphorous and nitrates, decreasing the external supply of nutrients (e.g., from organic or chemical fertilizers). Most of the carbon in grasslands is stored in the roots of the plants, so combining it with livestock grazing (when done properly) does not necessarily affect carbon sequestration.

2.3.4 Overview effects on the environment

Despite being the core objective of LMTs, the analysis of the stakeholder interviews show that carbon sequestration is one of the many effects of LMT implementation. We observe that the interviewees often indicate that other positive effects often outweigh carbon sequestration. Increased climate resilience towards the effects of climate change, erosion reduction and long-term sustainability are the main effects derived from the implementation of LMTs.

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In those LMTs involving the introduction or maintenance of plant species in the lands, such as agroforestry, afforestation/reforestation, avoided grassland conversion, as well as some agricultural techniques such as grass barriers or no tilling, the most beneficial effects are seen in soil water retention, nutrient retention, soil health and resistance against strong winds. This is very relevant, because it means that these techniques greatly enhance the system's resilience towards the most climate change-related risks such as droughts and erosion. This last parameter is particularly interesting because, as it has been described previously in this report, erosion is a self-fulfilling process that can be difficult to stop.

Another important observation is that several interviewees suggest that monocultures of any kind in relation to LMT implementation should be avoided. Natural, unmanaged land-based ecosystems tend to adapt by gravitating to a new equilibrium. This is facilitated through the diversity of the ecosystem, e.g., closed nutrient cycles, symbiotic relationships between species and pest controlled through the presence of predators. Monocultures break this cycle, and this is why external inputs such as chemical fertilizers and pesticides are needed to keep the land productive in the short term, thereby often compromising the long-term sustainability, productivity and soil health, leading to erosion and loss of ecosystem services.

Carefully planned agricultural systems, with consideration of nutrient cycles, diversity, and choice of the most appropriate techniques and species adapted to the local environment can dramatically reduce these negative impacts, even achieving higher yields in some cases. Generally, the more diverse and complex the system (as in the case of agrosilvopastoral systems such as dehesas and montados), the higher the system resilience and long-term productivity and sustainability. In addition, these effects are easily observed by the land users and are generally considered more important relative to carbon sequestration, which is often an unknown or more difficult-to-understand concept outside the research community. Therefore, the emphasis when promoting these techniques among land users should be put on the resilience and long-term sustainability effects rather than on climate change mitigation.

Another general finding is that trees play a major role in resilience, and their introduction into the ecosystem, either as forest in agroforestry or afforestation or in agricultural systems as agroforestry, greatly increases the balance and climate change resilience by improving water and nutrient retention, stabilising the soil, acting as a barrier for excessive sunlight and wind and hosting biodiversity, therefore increasing pollination and pest control. Most mature tree species are remarkably resilient to many climate extremes, so they can act as system protectors to other species. In addition, carefully selected species can also diversify income sources for land users.

Another major finding is the role of wetlands and peatlands in carbon sequestration. As a difference from other LMTs considered in this assessment, wetlands have a large mitigation potential (in the form of emissions reductions due to their rewetting and non-conversion. However, carbon sequestration is slow, and there are CH_4 emissions associated with the rewetting process, particularly in the beginning). It is not only negative emissions, but the rewetting of peatlands brings other major benefits such as the reduction (or complete) avoidance of soil subsidence, which affects entire regions all over the

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world, with dramatic ecological and economic consequences. This leads to the necessity of carrying out further environmental and economic studies prior to any actions involving the disturbance of peatlands and wetlands, as the costs associated with these actions could largely outweigh the direct benefits, even when only considering economic parameters. The rewetting and non-conversion of peatlands and wetlands is one of the higher-impact and lower-cost LMT actions.

2.4 Further considerations and discussion

The method used for these consultations (1-to-1 interviews with selected stakeholders), allowing the interviewees to elaborate further on those topics they found more relevant, yielded a lot of very relevant insights that would have been difficult to achieve through a mass survey without the intervention of case study leads. We consider the extent of the sample (97 interviews) and results of this qualitative risk assessment highly relevant but not sufficiently representative of all countries, and all LMTs. Despite the additional efforts to have a sufficiently diverse stakeholder representation (e.g., attributes, profiles, perspectives, gender, inclusive) our resources and survey method provided certain limitations. As a consequence, our sample may not reflect the full scope of perspectives and profiles.

However, despite the involvement of the interviewer ensuring a high stakeholder involvement, there are some limitations in this process:

- Given the broad range of profiles addressed, not all stakeholders are equally familiar with the terms and concepts asked in the interview, so the quantity and quality of the responses vary depending on the interview.
- As no remuneration was given to the stakeholders because of their participation in the interview, engagement levels are highly variable, and getting stakeholders to dedicate around one hour of their time for unpaid consultations is challenging, even with highly supportive stakeholders.
- Because of the variations in ongoing stakeholder consultation processes (e.g., in a workshop format for example, or as part of larger consultations), the format of the questionnaire was not always the most suitable. In some countries, the LANDMARC partners had to be flexible and adapt their approach to also fit the availability of the stakeholders and the requirements of the event. It was noted that when stakeholders were not given a defined set of parameters to address, they tend to elaborate further on the socio-economic parameters linked to the LMTs than on climate risks and effects on the environment. This is particularly true for stakeholders in developed countries, who seem to perceive the most limiting factors in access to funding and financing and the regulatory framework, rather than in climate risks.
- Similarly, the format also had to be adapted to address some specific profiles of stakeholders, such as members of indigenous communities in Canada. Their language and perception of the techniques and environment differ largely from the ones normally used in the techno-scientific context, so their responses had to be interpreted to make them fit into this deliverable’s framing.
- The risk assessment is performed at a local level, without consideration of inter-regional risk allocation. As a hypothetical example, BECCS could have great climate change mitigation potential at a global level, and conditions for the implementation of BECCS are best in the global south. However, BECCS is a very land-intensive technique, and the implementation of this technique

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leaves less land for food cultivation, leaving the region more exposed to famines in case of bad harvests due to climate change. Therefore, the risks derived from the mitigation of climate change, mainly caused by the global north, are assumed by those whose contribution to climate change is much lower. These ethical risk allocation concepts were not addressed in this consultation but would need further consideration.

- Another limitation is that when stakeholders evaluate risks, they do it from their individual perceptions of risk. Risk perceptions can vary widely depending on the person, background, and cultural framework. As an example, in the interviewees, it became evident that the concerns and risks perceived by land users and the research community differ moderately, with the first giving more importance to funding schemes, regulatory framework and economical revenue of the practices, and the research community perceiving as a higher priority carbon sequestration and ecosystem sustainability. Also, risks regarding, for example, droughts, are perceived as a higher threat when irrigation systems are not available.

Taking these limitations into consideration, the following conclusions can be drafted:

First, despite the main climate risks being similar in all countries and for most techniques (droughts and heatwaves, heavy rains, heavy winds, erosion, and pests), they need to be further contextualized. Most damaging droughts do not necessarily refer to a decrease in average rainfall, but to a change of the rainfall distribution, with prolonged periods without rain, shorter periods with heavier rains and increased unpredictability of the rainy seasons. A slight or even moderate decrease in average rainfall, with a regular distribution, does not pose a great threat to most systems. Also, the risk associated with heatwaves does not necessarily refer to higher spikes of temperatures, but to increasingly long periods of sustained high temperatures, and high-temperature events in areas or periods where they traditionally did not occur, such as in spring or during the night. Erosion, heavy rains, and droughts are closely linked (cascading) climate risks, as (increasingly common) heavy rains remove nutrients from the soil, triggering erosion. Eroded soils suffer from decreased plant density, which decreases soil water retention and increases run-offs when heavy rains happen, worsening the soil condition. Stopping this cascading process should be regarded as a high priority in the fight against climate change. Pests, despite being naturally occurring, are fuelled by many current land management practices, as the loss of diversity due to monocultures creates the perfect environment for the mass proliferation of parasites. The other main component of pests is the spread of the damaging agents to latitudes where the ecosystems do not have predators to keep them under control due to the rise in temperatures. Also, the availability of infrastructure plays a significant role in the damaging potential of risks, as river floods, storm surges or even droughts can be more easily overcome when the right infrastructure is already available (e.g., similar risk exposure, but different expected risk severity). Generally, due to underdeveloped or lower-quality infrastructures, the global south appears to be more exposed and vulnerable to climate and weather extremes. However, it is also in the global South where LMTs can yield higher climate, environmental and other socio-economic benefits.

Second, despite being the main focus of LMTs, carbon sequestration is only one of the many (perceived) environmental advantages of the LMT solutions considered in this report. Moreover, the climate change mitigation benefit is often considered to be a less relevant driver for LMT

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implementation. Most LMTs provide major (perceived) advantages in terms of climate resilience, soil health/quality/biodiversity and long-term sustainability of the assessed systems. Another major finding is that (soil) erosion is one of the main consequences of climate change and the misuse of land (often linked to monocultures and industrial agriculture). Soil erosion can become part of a destructive self-fulfilling cycle leading to, for example, desertification. Most LMTs assessed in this consultation have the potential to limit or stop the erosion process. LMTs generally improve overall system resilience to climate extremes and long-term sustainability when compared to mainstream practices.

Such co-benefits and eco-system benefits are generally difficult to monetise in the short term. As a result, we find that many land users are sceptical to change their current practices as the LMT practice may affect yields and income. This is because LMT-related innovations often come with increased uncertainties and barriers (e.g., farm-level income, regulatory barriers, etc.),.

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3. Climate Risk Management

3.1 Introduction

In the previous sections we discussed the results of a qualitative assessment of climate risks and environmental impacts related to LMTs. We find that climate change related risks are becoming an increasing concern for land-based mitigation activities (or other forms of sustainable land management practices and that climate risk management should be mainstreamed with existing risk management practices (see Box 1).

Box 1: The need to mainstream climate risk management

Climate change poses a (relatively) new category of risks for countries, companies, communities, and citizens across the globe. Leading international institutions, such as the United Nations (UN, 2022) have labelled climate change as a threat or risk multiplier. Adequately addressing climate change related risks is essential for a global society that aims to achieve multiple sustainable development goals. Several international bodies, like the Food and Agricultural Organisation (FAO, 2021) or the Asian Development Bank (ADB, 2017) already acted to "mainstream climate risk management" not only as a required element of the risk management processes, but also in view of broader food security, disaster risk reduction and (rural) development programs.

For the vast majority of LMTs, which are typically implemented in open and nature-based systems, climate change related risks need to be considered by LMT managers and practitioners, policy makers, investors, and other relevant societal stakeholders. Risk management process linked to LMTs that do not proactively assess and manage climate change related risks may fall short in ensuring the effectiveness of their emission reduction or carbon removal effort.

Risk assessments such as we have performed within Chapters 1 and 2 are generally part of an iterative risk management process that aims to proactively reduce the exposure and vulnerability to a specific (set of) risk(s).

Within this section we first discuss the basic steps of existing risk management processes (Section 3.2). Secondly, we discuss the existence of overlapping / interacting risk management processes and introduce the concept of a 'risk management ecosystem' (Section 3.3). Thirdly we briefly discuss the crucial role stakeholders, and stakeholder engagement has in risk management processes (Section 3.3). After that we describe and discuss risk management and the rism management ecosystem in relation to LMTs (Section 3.5) and illustrate it with the help of a mock-example (Section 3.6). We finalise this Chapter by presenting the basic design features and some preliminary results of the design and field testing of an IT enabled tool for executing climate risk assessment for LMTs (Section 3.7).

With this Chapter we aim to provide stakeholders and communities involved in LMT implementation with additional information and guidance on how to start with managing climate change risks.

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3.2 Existing risk management processes

There are many different standards, and protocols focussing on risk management. Several commercial/voluntary risk management standards/protocols/tools exist. For example, the ISO 31000 (*ISO - ISO 31000 — Risk Management*, n.d.), or Corporate Social Responsibility (CSR) risk check (*Home | CSR Risk Check*, n.d.) refer to enterprises that are aiming to manage risks. This so-called Enterprise Risk Management (ERM) (Green, 2015) can be targeting companies that have or are assuming a leading role and responsibility within the relevant supply chain (e.g., for raw materials, or manufacturing). Other ERM approaches specifically target financial institutions, like banks, and pension funds (PwC, 2021)Aside from this risk management also can be spatially more explicit. This is the case, for example, with disaster risk management practices. Disaster risk management generally is initiated and/or led by national, local (public) authorities and/or communities. Their actions generally take the form of national risk assessment and management strategies (EC, 2019) and/or community-based disaster risk management(ADPC, 2006)(UNDP, 2012).

Whatever the type of risk management protocol or standard chosen, each process follows several general steps, which typically includes an iterative, and participatory cycle comprising the following four basic steps, namely, Risk 1) Identification, 2) Assessment, 3) Management, and 4) Monitoring (see Figure 22).

Figure 22: Typical steps in a risk management cycle
Source: Authors' own illustration.

Such risk management processes, protocols or standards provide very useful reference and general guidance on how to set up and organise a risk management process. I.e. the basics organisational steps

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apply irrespective of the types of risks to be managed. However, such standards and protocols generally lack specific data, information and guidance on sector, activity or LMT specific risk management actions to be taken. Hence, the sector or activity specific application largely and quality of the risk management process largely depends on the relevant stakeholders that are involved in the process. Within the LANDMARC project we performed a risk assessment targeting specific stakeholders, within a specific context (country-context and specific LMT portfolio). Proactive risk management in relation to LMTs is vital to ensure their mid- to long-term climate effectiveness in sequestering carbon in soils and trees (e.g., to reduce their expose to climate extremes, forest fires, droughts, etc.) and to safeguard the provision of other ecosystem services (e.g., preventing soil erosion, water retention, etc.). This specific information can be used to inform expand the scope of existing risk management practices, to also include climate change risk management.

The identification of risks is a crucial first step, where the team or stakeholders engaged within the risk management process convene and assess to which risks the project, company or community is exposed to. The risk assessment can both be fed with both qualitative and quantitative information and data. The main results from the *identification* (Step 1) and *assessment* (Step 2) of climate risks in relation to the LANDMARC LMT portfolios in the 13 countries are presented and discussed in Chapter 1 and Chapter 2 above. This information generally serves to get a better understanding of the magnitude, severity of, and exposure to identified risks. These two steps are relevant information for the risk managers and ***relevant stakeholders*** (*we discuss the selection and role of stakeholders in more detail in Section 3.3*) to start managing these risks (*Step 3*). Part of this step can be to determine which risks to address first (risk prioritization),[4] and to decide collectively which risks cannot (yet) be addressed by themselves, for example due to limited resources (time, capacities, funding).

After the risk identification (Step 1), risk assessment (Step 2), and risk prioritization a more detailed risk management plan needs to be developed. Such risk management plans generally entails the formulation, planning of tasks. The scope of the tasks can vary greatly, depending on the specific prioritized risk that is to be mitigated. The risk management plan is the prelude for the implementation of specific risk management actions, for which some framework for monitoring and evaluation (Step 4) will be needed.

[4] There are different (qualitative) methods and tools to aid with risk prioritization. For example, several criteria can be used to score and rank different risks in an effort to prioritize risk management actions in a resource constrained context (e.g., available human and financial resources limit the capacity to manage all relevant risks). Such risk prioritization should always be done within a participatory setting, with the involvement of relevant stakeholder groups. For risks that cannot (yet) be addressed (e.g., limited time, funding, capacities), risk management strategies can still be formulated. Such a strategy can, for example, also include transference of the management of a particular risk (e.g., escalating or delegating the risk management) to a more competent or relevant authority. This can be the case for example, when the risk management actions of a single farmer (e.g. to prevent soil erosion or forest fires) will likely be ineffective and that collective action at the regional level would be more effective. In such circumstance the individual farmer could escalate the risk management to a regional authority.

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To illustrate, we assume the example of an climate risk management for peatland management as an LMT. The objective of the LMT is to retain carbon in peat soils by rewetting the area. To this end the regional water board has decided, together with local stakeholders (e.g., such as livestock farmers, and village councils) to increase the groundwater levels to prevent any further oxidation of peat soil carbon. However, this region is increasingly exposed to climate change (risk identification and assessment), which manifests in more extreme weather patterns with more extreme rainfall and prolonged drought periods. To manage these climate change related risk the region requires more infrastructure to control both the in- and outflow of water in the region (water management basin). In prolonged drought periods water levels need to be replenished from outside the region, while in periods of extreme rainfall, sufficient pumping capacity will be needed to discharge excess water (i.e. to prevent flooding). Similarly, to improve the climate resilience for agroforestry systems tree species selection will be of vital importance. However, the local context will largely determine which tree species would be more suitable and fitting with the specific ecosystem or habitat to not only become climate resilient, but also contribute to biodiversity. The same applies to forest fire prevention strategies, where in unmanaged and remote forest areas indigenous fire management practices may be favoured, while in other regions other with a higher share of managed forests other risk management actions fit better (See Section 3.7 for a more detailed example of a climate risk management plan for LMTs within Portugal and Spain).

Knowing that the climate risk management actions are not only specific to a single LMT, but also highly context specific (e.g., risk exposure, country-context, etc.), the involvement of local stakeholders, and utilization of local knowledge is needed to co-develop meaningful climate risk management actions (See Section 3.3).

3.3 The role of stakeholders and stakeholder management in risk management

Any effective risk management strategy, relies on the active engagement with stakeholders. All existing risk management standards and protocols refer specifically to stakeholder engagement and participatory processes for the co-creation and co-design or risk management strategies.

On this the ISO 31000:2018 Risk management guidelines (ISO, 2018) state that:
“Appropriate and timely involvement of stakeholders enables their knowledge, views and perceptions to be considered. This results in improved awareness and informed risk management.”

(Mojtahedi & Oo, 2017; Ndlela, 2019; van Vliet et al., 2020) acknowledge the importance of proactive and meaningful stakeholder engagement within the different stages of the risk management process. For effective risk management, professionalised stakeholder engagement and management is needed. Stakeholder engagement refers to the identification, analysis, planned engagement of relevant stakeholders, as well as analysing the stakeholder environment or context. Additionally the stakeholder engagement process should be inclusive, representing different groups that may not be very powerful but heavily impacted by the LMT implementation or climatic risks.

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While most risk management protocols and standards agree on the main steps of the risk management cycle (see Section 3.1), few of them provide detailed guidance on how to select and engage with relevant stakeholders effectively and meaningfully. Detailed ex-ante guidance on which stakeholder to involve (stakeholder selection) is hard to provide as it largely depends on a broad range of context-specific factors. The relevant stakeholder base is likely to be dynamic and dependent on the specific context. On (Ndlela, 2019) states that:

"Behind every risk are individuals, groups or social actors who are (or who perceive themselves to be) affected by a risk (or decisions, strategies and/or processes in its management). These stakeholders are dynamic and likely to change during the course of the process. Some are constant, while others come and go, and others may join in at different stages of the process."

To safeguard the involvement of the affected stakeholders throughout the different steps of the risk management process, proactive stakeholder mapping, selection, planning and engagement is a key condition. It will also require a regular 'recalibration' of the risk management process design, by re-evaluating if all relevant stakeholders are included. Within this report in Section 2.1 and Annex 2 we provide some methodological explanation on efforts that have been taken within LANDMARC to safeguard adequate stakeholder selection and engagement for the purpose of this climate risk assessment. Similar methods can be used to initiate stakeholder management for a full risk management process. The stakeholder selection and engagement method developed for this qualitative climate risk assessment built upon more extensive stakeholder mapping and analysis work conducted within the LANDMARC project.[5] This work supports the engagement with stakeholders for all country-specific assessment work to be conducted, thus including for this climate risk assessment.

Due to the dynamic and fluid nature of such a social-organisational processes it will be good to recognise also what specific attributes a stakeholder has (e.g., capacities, resources, perspectives, and interests), and what their expected/perceived role could be within the risk management process. Particularly within more localised (micro-level), and/or community-based risk management processes there are often significant gaps in the time, resources, capacities of the relevant (local)stakeholders to be able to meaningfully engage. These gaps can be the source of frustrations in case mutual expectations are not met and/or roles and responsibilities are not clearly defined. To illustrate, there can be cases where the local risk management process is initiated and hosted by paid, and trained professionals (e.g., representatives from companies, or local governments); while the active involvement of relevant community stakeholders is assumed to occur on a voluntary (non-paid) basis. This dichotomy between paid professionals and non-paid volunteers can be a source of frustration and inertia. For example, the paid professionals may blame the (non-paid, volunteer) local community for

[5] Here we refer to Task 2.1 'Stakeholder engagement and scenario construction' and Task 2.3 'Establish national LMT networks'. Within the framework of these tasks, for each LANDMARC case study country stakeholder repositories were developed (Milestone 5), as well as the results from the local stakeholder engagement actions will be published (forthcoming publication of a LANDMARC report app. April 2024).

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their low interest in addressing key risks, while the local community is frustrated by the slow progress in risk management action planning after repeatedly dedicating their limited spare or free time to this process. The unequal power dynamic and resources allocated are often not sufficiently documented in academic research nor discussed in methodological approaches.

Aside from any inertia, such conditions may also result in an (unintended) bias in terms of local stakeholder representation, may not be sufficiently inclusive and run a higher risk of proposing measures that are not accepted by affected stakeholders.

For many risk management processes it may be too costly and time consuming to train and/or compensate each and every relevant volunteer/stakeholder for their active engagement. Yet, at the same time an insufficient recognition of such potential stakeholder engagement biases can result in risk blindness and misrepresentation or exclusion of specific stakeholder perspectives. A very simple example of this is can be a risk management coordinator that structurally organises stakeholder meetings during normal office hours. This could – by default - limit the presence of relevant (volunteer) stakeholders with daytime jobs or stakeholders with a parenting or caretaking role. More subtle, and difficult to address stakeholder representation biases can arise in relation to capacities, skills, knowledge, network, generation, gender, race, and culture.

Too effectively manage stakeholders within a full risk management process, it will be useful to also better understand the dynamics of other similar risk management processes that run in parallel. Many different companies, from different branches/sectors (e.g., agriculture, financial institutions, local/national governments) are currently revising and updating their risk management strategies and procedures to also include climate change related risks. For example, financial institutions like banks want to have better knowledge of the exposure and vulnerability of their investment portfolios to climate change related risks, and farmer cooperatives are seeking better solutions and strategies to improve the climate resilience of their farming activities. Those ongoing risk management processes which overlap in terms of i) time, ii) space, iii) the type of risks managed, or iv) the type of risk management actions proposed provide some scope for collaboration and resource efficiency.

Finding relevant synergies, and aligning these processes has value. However, at the same time such separate risk management processes can also result in inefficiencies and conflicts which in turn can slow down the implementation of risk management actions. Below (Section 3.4) we discuss in more detail the notion of a 'risk management ecosystem'. This refer to as a number of separated (in)formal social-organisational processes (stakeholder networks) that aim to address climate change related risks. We argue that a basic mapping of the relevant risk management ecosystem is relevant for improving the efficiency of individual risk management processes. This can result in better alignment of risk management strategies, sharing of data/resources between separate risk management processes, etc.

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3.4 The risk management ecosystem

Section 3.2 describes the general steps of a risk management process. Risk management standards and protocols generally are structured and designed to support different target groups (e.g., enterprise risk management for commercial enterprises, disaster risk management for local communities, and/or local/regional governments). Despite the commonalities in general process steps, risk management standards and protocols show significant diversity in terms of the relevant scope and stakeholder selection and management. Risk management processes can run at the level of individual households, commercial projects, entire companies, full supply chains or even an entire country. Such risk existing management processes that operate at a different scale or level can potentially be synergetic/conflicting.

In this section we discuss the notion of a 'risk management ecosystem' within which there is scope to align different risk management processes.

3.4.1 Risk management at what level?

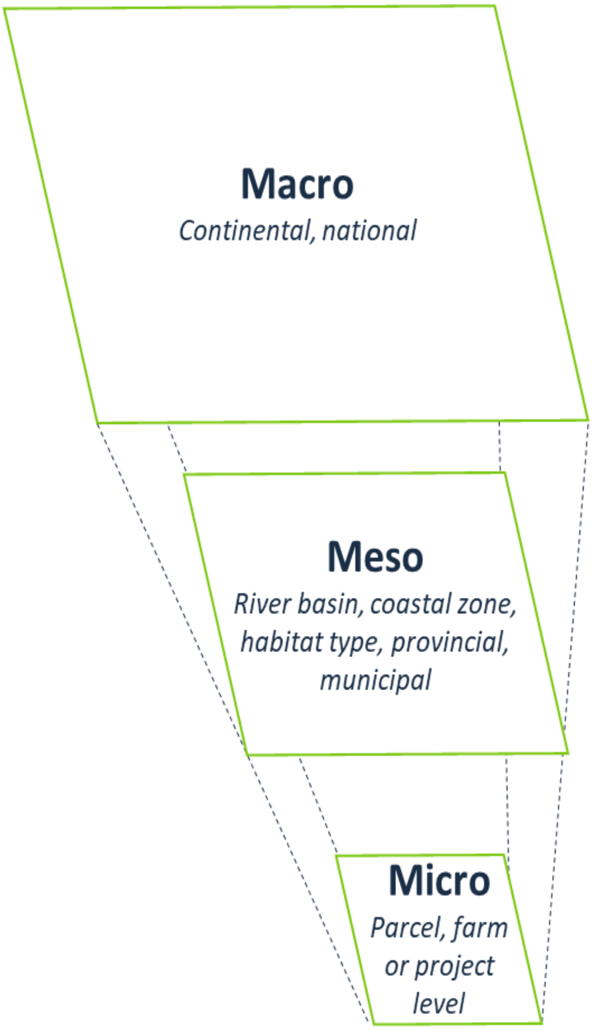

Figure 23: Risk management at different scales

For individual or stand-alone risk management processes, it will be useful to determine the scale or level at which the risk management will be conducted. This can range from the micro-level to the macro-level (see Figure 23). The ***micro-level*** can involve risk management practices at a small scale, for example at parcel, project, or farm level. This can take the form of a project risk management plan, which is co-developed by a small group of relevant stakeholders (e.g., the farmer, the investor/bank, local government). At the ***macro-level*** you can find risk management being initiated at the national, EU or even continental level. This type of risk management process can take the form of a national climate change adaptation strategy. In between - at the ***meso-level*** - risk management may be conducted, at the (sub)regional level for example for entire river basins, specific habitat types, coastal zones, soil regions or cross-border supply chains. Such risk management processes can take the form of a river basin climate risk management plan, or a agro-food conglomerate aiming to manage supply chain related risks.

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3.4.2 Overlapping risk management processes

Ongoing risk management processes - operating at different levels or scales - can overlap (see Figure 24). This can be the case when an enterprise e.g., a local farming cooperative aims to manage flood risks in their region, while at the same time the national authorities are working on a national adaptation strategy to manage climate change related risks at the national level.

Figure 24: Illustration of overlapping risk management processes (mock example for The Netherlands)
Source: Authors' own illustration

Overlaps can be complementary when properly aligned, but can also result in counter-productive outcomes, for example when contradicting risk management actions are taken or when both processes are not aware of each other's risk management actions. This can occur, for example, when the risk management processes operate across different companies, sectors, and countries. Within these circumstances it is useful to align both processes by establishing clear lines of communication and information/knowledge exchange. The alignment could also imply that two (or more) risk management processes are merged or integrated into one operational process. At this point questions regarding the (legal) mandate and status of the risk management process and associated stakeholder group will surface. In addition, questions regarding subsidiarity (EU, 2022) may also arise, i.e., which risk(s) are best managed at what level and by whom? At some point, there can be a need to either upscale (escalate) from bottom-up, or downscale (delegate) from top-down the management of specific risks by transferring the risk management responsibility to another risk management initiator/operator.

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Within a risk management eco-system there can also be parallel processes that fit within a top-down hierarchy with a more strategic, tactical, or operational focus.

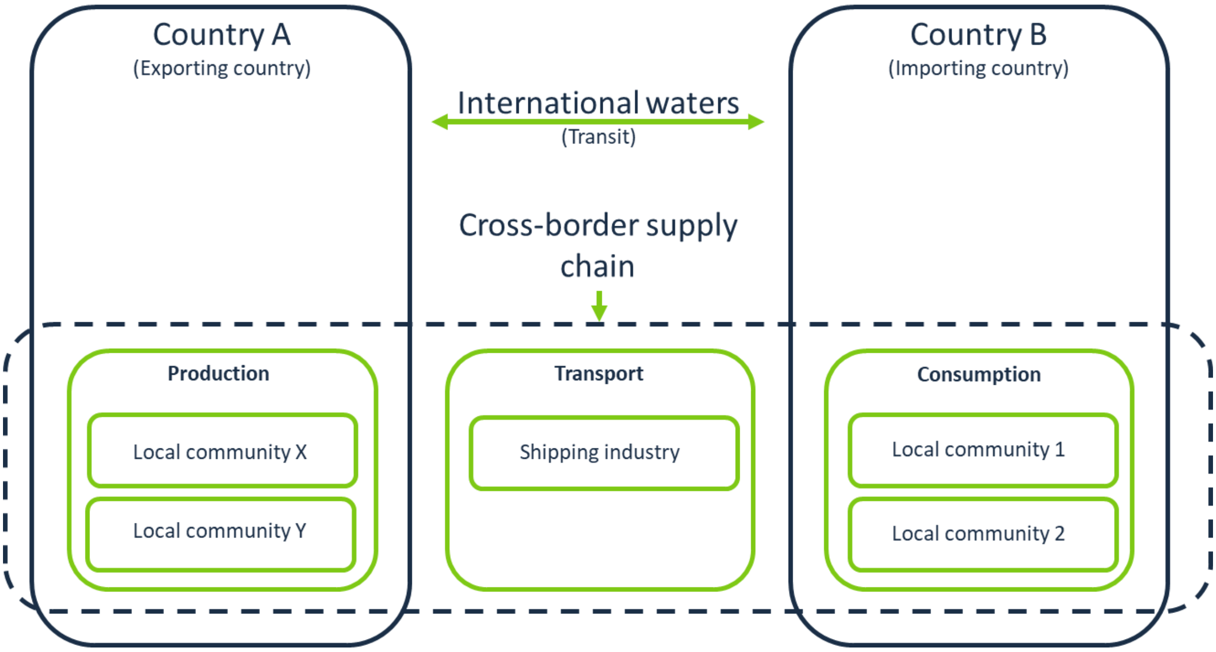

Figure 25: Potentially overlapping or interacting risk management processes operating at different levels (e.g., Macro-level; country, meso-level; supply chain, micro-level; community)
Source: Authors' own illustration.

In Figure 25 we provide a diagram where several risk management processes hosted by different stakeholder groups can overlap. There are different systems or units that can be selected for risk management. For example, both country A and B can engage in national level climate change risk management through their national adaptation strategies. Similarly, the private sector stakeholders that are operating in an international cross-border supply chain (e.g., food commodity) could also aim to address climate change related risks within their value chain to effectively manage security of supply, and food security. Aside from that the international shipping industry may also collectively seek to manage climate change risks specific to the shipping industry (e.g., accessibility to ports on low lying deltas, alternative shipping routing due to increased hurricane occurrence or wave heights); or a local community in country A may decide to address the risks of landslides and soil erosion in the semi-mountainous region where their coffee plantations are.

Particularly, in cross-border, or cross-sectoral systems there will be a question of responsibility and liability with respect to risk management. For example, we can assume a single farming community that manages land located within two countries. Addressing droughts or exteme precipitation for these farming communities can only be effective if both countries' are clear about each others responsibilities and liabilities. Will the importing country / company assume some level of responsibility with addressing specific climate risks in the exporting country / company? And if so, does the country / company also assume some level of accountability and liability for the implementation of the risk management plan for a given LMT (e.g., by funding the risk management process, or providing capacity building and training programs, in the exporting country, etc.)?

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3.4.3 Unit of analysis

At each 'level' the stakeholders engaging within the risk management process will also have to determine what the relevant 'system'[6] or 'unit of analysis' will be. Will the risk management be focussing on a single new LMT project (e.g., afforestation at a 50-ha plot in Southern Spain?), an entire supply chain (e.g., international supply chain for wood-based materials for green buildings in Europe?), a full asset or project portfolio (e.g., portfolio of 10 large-scale agro-forestry initiatives in Latin America), a specific community or geographic region (e.g., flood risks in Belgium river-side communities or coastal erosion in Indonesia)?

The unit of analysis that is chosen is indicative for the level of ambition a risk management stakeholder group may have. At the same time it may also reflect some of the limitations the stakeholder group may face in terms of their ability to effectively manage climate risks themselves. Properly defining the unit of analysis helps with determining what type of responsibility the stakeholder group may be willing to take. It can also be an expression of the ambition level of the risk management stakeholder group. For instance, a group of local farmers may decide to implement several carbon farming practices (e.g., no till) and smart forest management practices on their own land (unit of analysis) to improve the climate resilience of their farms. For the decision making and implementation of their actions these farmers would have a relatively high level of control. However, the same group of farmers, may only have limited influence in controlling the water management in the regional river basin (limited span of control).

A robust definition and discussion about the relevant 'unit of analysis' for the risk management process will also help to determine potential shortcomings of the risk management process which could fall short of managing other broader environmental or societal risks. This again refers to the question of subsidiarity and escalating or delegating the management of certain climate risks, for example for a single LMT or LMT portfolio within a country, supply chain or local community.

3.4.4 Societal perspectives

We observe that some ongoing climate change mitigation policies may have 'risk blindness' or gaps, where, for example, the interests and perspectives of local (indigenous) communities are not sufficiently safeguarded (Virla et al., 2021) implementing low carbon or mitigation actions. Such blindness can result in a risk management strategy which may be good for the incumbent companies or a country, but not for the local community (or vice versa). For example, an agro-food conglomerate may choose to increase the number of crop production locations to spread the risk of crop failure due to increasing droughts. While this diversification strategy would solve the supply-side risks of the conglomerate, the drought risk for the local farming communities at the individual production locations would not be addressed.

[6] Including system boundaries.

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3.5 LMTs and the Risk Management ecosystem

In the previous sections we the role of stakeholders (Section 3.3) and the risk management ecosystem (Section 3.4). In this section we more closely link this to risk management related to land-based mitigation technologies and practices (LMTs). Within the LANDMARC project there are 13 case study countries in which a broad spectrum of assessment work in relation to LMT portfolios of is being conducted (see Table 7).

Sub-category	LMT	National Portfolios (short-lists)												
		NL	DE	CH	VE	BF	KE	CA	SE	ID	ES	VN	NP	PT
Wetlands	Peat soil rewetting, Paludiculture, wetland restoration and conservation	x	x					X		x				
Cropland	Reduced/no-tillage			x			x							
	Cropland management		x			x	x						x	x
	Organic farming	x								x		x	x	
	BECCS	x		x				X	x					
	Biochar			x				X	x			x		
	Agroforestry			x			x						x	
Grassland	Avoided grassland conversion													
	Grassland management for carbon sequestration		x					X			x			x
	Agroforestry	x									x		x	
Forest land	Avoided deforestation					x	x							
	Afforestation/Reforestation	x	x			x	x	X		x	x	x	x	
	Forest management (incl. fire management)		x		x	x		X	x	x	x		x	x
	Agroforestry				x	x				x		x	x	

Table 7: Overview of portfolios in LANDMARC case study countries

The social science research activities involving stakeholder consultation and engagement within LANDMARC also includes the climate and environmental risk assessment performed for this report.

The results of the risk assessment survey provided a good indication of which climate and environmental risks could be prioritized for active risk management. However, one aspect that we did not survey is how a risk management process should be organised and implemented within the specific country/region for the respective individual LMTs.

We recommend that the management of climate change related risks should not be seen as a separate process; rather should be integrated or mainstreamed with traditional environmental, social, and economic risk management processes and practices. Following this logic and referring to the discussion in Sections 3.1 and 3.4, we recommend that the management of climate change related risks in relation to LMTs should also be integrated within existing risk management processes and within the broader risk management ecosystem.

In the following section we briefly present and discuss a potential the risk management ecosystem for a subset of LMTs in forestry systems.

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3.6 The risk management ecosystem in forestry systems: An example

Within forestry-based systems various LMTs can be applied, ranging from forest conservation / preservation (e.g., avoided deforestation, restoration, revitalization, indigenous forest fire management practices), to afforestation and reforestation. Aside from that there are several (inter)national supply chains relying on the supply and utilization of wood or woody biomass, for application in the building sector (e.g., carbon stored in wood-based materials) or in bioenergy (e.g., BECCS or biochar), as depicted in Figure 26.

From our survey we find that the four main (perceived) climate risks associated with forestry systems (see Section 2.3.3) include: **i)** droughts, **ii)** forest fires, **iii)** erosion, and **iv)** heatwaves. These pose a direct risk to the stakeholders based in country A (e.g., logging industry and forest conservation agency in the exporting country), and indirectly affect the stakeholders within the importing country B (e.g., building sector and bioenergy sector).

For illustration purposes we can assume that an enterprise is already running a risk management process for their supply chain. Meaning that as part of the corporate social responsibility (CSR) strategy the enterprise importing the wood to produce wood-based materials and bioenergy already has started a process for managing the company's risks alongside its supply chain ERM or enterprise risk management). It will do so by also engaging with key stakeholders in the exporting country. The importing company has decided to align its ERM process with the existing process for certification of sustainable forest management, such as FSC (FSC, 2022), or PEFC (PEFC, 2022). In addition to that, the exporting country – as part of their national climate strategy – will also be launching a risk management process to manage climatic and environmental risks for their domestic forests to preserve it as a carbon sink, and biodiversity to promote biodiversity (see Figure 26).

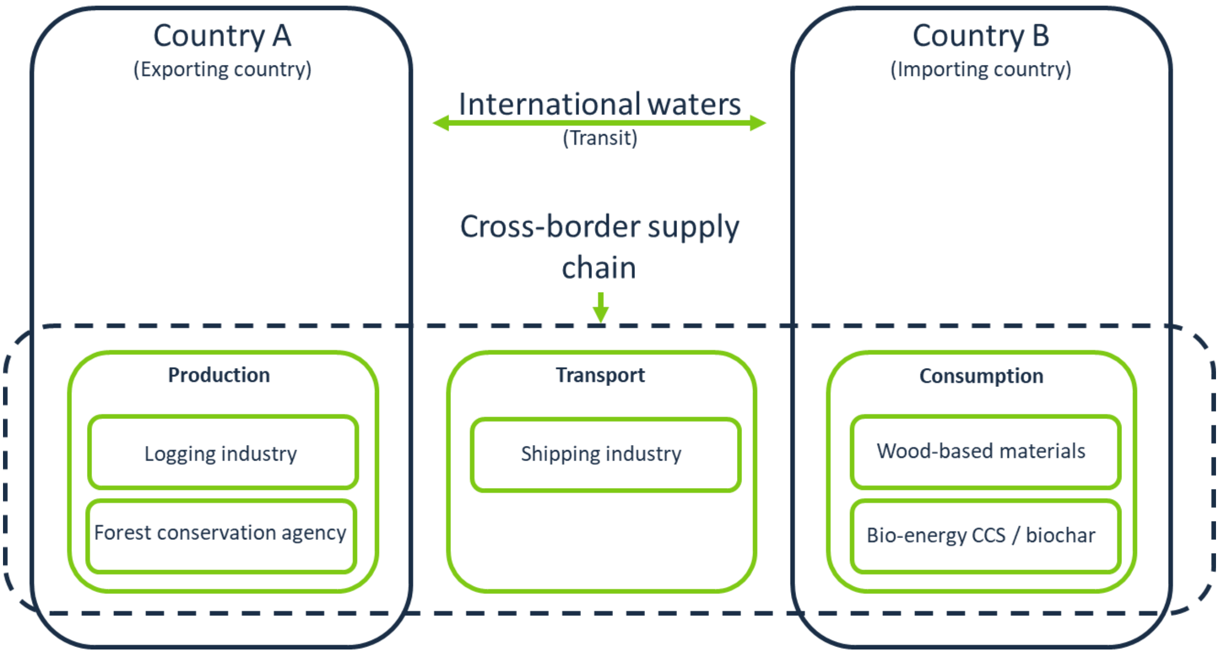

Figure 26: Risk management ecosystem for forest systems / supply chains (mock-example)
Source: Authors' own illustration

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From Figure 26 we can see that both risk management (enterprise level and national level) processes operate at a **different level**. The risk management process hosted, coordinated by the foreign enterprise importing wood biomass operates at the supply chain level, while the national government coordinates a country-wide risk management process. Both risk management processes partially **overlap**, where the foreign enterprise may target only a limited area of the country's forests (e.g., only those managed by their preferred suppliers), the national risk management process could target all forest areas in Country A.

The two separate risk management processes cover a fundamentally different **unit of analysis**. Where the national risk management process in Country A does not cover the risks related to international supply chains, the enterprise led risk management process may also assumes management of risks related to their international supply chain (e.g., international shipping), as well as any domestic risks (in Country B). Such domestic risks (in Country B) could relate to the policy conditions and financial-economic conditions for investing in renewable bioenergy and/or Carbon Dioxide Removal options, such as carbon storage in durable wood-based materials, BECCS and/or biochar.

By design, both of the aforementioned ongoing risk management processes are fundamentally different. These differences can translate into e.g.,:

- a different selection and engagement of stakeholders: only with (voluntary) involvement of contracted external stakeholders vs. participation and involvement of local communities,
- a different prioritization of risks to be mitigated: where the enterprise led risk management prioritizes mitigating policy and financial risks for the companies' investments, while at the national level the risk management process prioritizes climate change risk management and climate resilience of local forest communities
- a different risk management strategy and actions: with supply source diversification vs. local investments to mitigate illegal logging, improve forest fire prevention and promote water conservation.

Both risk management processes will have their own biases, shortcomings and blind spots which may result in over- or underrepresentation of certain societal perspectives. Identifying synergies and establishing linkages between different risk management processes could foster knowledge sharing, capacity building as well as data exchange. This can help with further professionalising risk management at different levels.[7]

[7] A similar logic can also be applied for understanding the RM ecosystem, and RM process in relation to other LMT categories, including LMTs in agroforestry systems, crop-/grassland systems, wetland systems, and engineered LMT solutions, such as BECCS or biochar. However, for these systems, other stakeholders, different climate risks, different risk prioritization, and different risk mitigation action will be proposed.

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3.7 A climate risk assessment tool for LMTs

3.7.1 Introduction

Within the framework of the LANDMARC project, a group of master's students as part of their course titled *"Design of Climate Change Mitigation and Adaptation Strategies"* from Wageningen University in The Netherlands were invited to develop an initial (beta) version of a tool for assessing climate risks specifically for LMTs.

The work conducted by the group of master students built upon information collected and knowledge created within the LANDMARC project. The objective of the assignment was to create a IT-enabled tool that could aid different LMT practitioners with planning and performing climate risk management within their own country, community or supply chain. This tool development goes beyond the scope of the specific objective of LANDMARC Task 4.1 (Qualitative climate risk assessment) and the specific objective of this report. Within LANDMARC this tasks aims to provide the LANDMARC "case study leaders with guidance on how to perform a climate risk assessment in a participatory fashion". While the results of this task will feed back to the case study country stakeholders with whom LANDMARC partners are already engaging, LANDMARC did not foresee the development of a interactive tool for performing climate risk assessment. Such a tool could may trigger and enable LMT practitioners to start their own climate risk management processes, and can be complementary to a more static (background) guidance document for performing risk management.

The group comprising out of, A. Cemin, B. Wear, C. Ciscato, F. Dossi, I. Sonak, L. Gontscharoff (with course supervisor Dr. B. Kruijt from Wageningen University) have developed a climate risk assessment tool which is documented in a comprehensive report that was commissioned by JIN (LANDMARC partner) under supervision of E. Spijker. The basic aim was to develop and test a novel climate risk assessment and management tool. The report is Annexed to this Deliverable and can be read as a stand-alone or complementary report.

The student group was encouraged to think 'outside of the box' and include new (IT) tools and practices that could facilitate / support both online and offline participatory processes.

The overall aim of the collaboration between LANDMARC and the WUR students was:

1) to identify and assess the risks posed by climate change for effective functioning of chosen LMTs.
2) to develop an engaging, user-friendly guidance tool for climate-related risk management of LMTs.

The intended tool should guide stakeholders in identifying, assessing, prioritizing, and managing climate risks. In the following section the general process for tool development and the tool are briefly summarized.

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3.7.2 About the tool and tool development

Focus area and LMT selection

The tool was developed and tested in parallel with two ongoing LANDMARC LMT case studies within Portugal and Spain, executed by LANDMARC partners Ambienta and Agroinsider. The ambition is that this tool could be reproduced and adapted (open source) to fit different geographical and socio-economic contexts.

Both agroforestry and afforestation were chosen as the key LMTs to focus on for Portugal and Spain. The specific LMT areas targeted include:

1) Agroforestry in Dehesas and Montados in Spain and Portugal, and
2) Afforestation in Extremadura (an autonomous region of Western Spain)

Climate risk assessment process

Four main steps within the climate risk assessment and management process were identified (see Table 8).

Step	Guidance
1 Risk identification	For both LMTs a flowchart was developed that helps to identify the (main) climate risk(s). Literature review was conducted to analyse and determine the climate risks as well as their interconnections
2 Risk characterisation	A short video (by means of augmented reality) was developed to help stakeholders to characterise the identified risks and explain their implications and possible risk management options.
3 Risk prioritization	No specific guidance for this was developed as part of the tool development as for this pilot study this would require further in-depth stakeholder engagement to prioritize action planning for specific risks. There are a broad range of (qualitative) tools available that can help to rank, score, and weigh specific risks relative to each other (e.g., multi criteria decision analysis).
4 Action planning	A worked example of a risk management and action planning table was developed for the purpose of the tool development.

Table 8: Climate risk assessment process steps and activities implemented for tool development

In collaboration with Agroinsider and Ambienta, and their local Portuguese and Spanish stakeholders the following key climate change related risks for both LMTs were identified:

1. Drought
2. Desertification
3. Heat wave
4. Heavy storm
5. Soil erosion
6. Shrub expansion
7. Soil and plant disease
8. Wildfire

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Requirements for using the tool

1. Two electronic devices such as a laptop, smartphone, or a tablet. Alternatively, the flowchart can be printed out and you need only a single electronic device to scan the risk(s),
2. An active internet connection,
3. Latest version of phone software,
4. Free Artivive App, downloaded on your smartphone or tablet (available at the App Store or Google Play).

Steps

- **Step 1:** Open the document and go through the manual "how to use the tool?" before you start using the tool.
- **Step 2:** Begin from the START point of the flowchart. You are asked to answer different questions with either YES or NO and identify your path to a specific risk or group of risks. To support and verify your answer, each question is referenced to a threshold and definition. Find the thresholds and risk definitions at the end of this manual.
- In case the result from going through the flowchart is low risk, there is a reduced chance that you will face any of these climate-related risks. There is no video that follows the low-risk result.
- **Step 3:** When you have identified a risk or group of risks, open the Artivive App and point your smartphone at the risk image and a video with voiceover will appear. This video will explain the implications of the risk(s) identified.
- **Step 4:** In the same video with voiceover, a guide table will help you develop an action plan for risk management. Scan the QR code on the flowchart (Figure 7 or Figure 8) to find an example action plan for inspiration.

Note: All steps can be followed by navigating through the following Prezi slideshow!
https://prezi.com/view/aBZ3X08hUbp1DhvrGfOm/

The flowchart is the starting point of the climate risk assessment and management process. By navigating through this chart, the stakeholder(s) will be able to identify the key climate risk(s) for the respective LMT, be able to get information (through AR and video) on possible climate risk management options and will be instructed to develop a climate risk management or action plan. A suggested simplified template for a risk management / action plan is provided in Table 9.

Components	Details
1. LMT	● What is your LMT?
2. Risk scope (which climate risk(s) are targeted?)	● Which risk would you like to target?
3. Is the risk currently managed?	● Is the risk currently managed?
4. Proposed scale of the action(s)?	● Scale-level of action: Individual farm-level/ Group of collaborating farms/ All mixed in terms of sectors and locations? ● How big is your farm/plot? ● What are the vegetation types? For example, which trees or shrubs are grown (or do you plan to grow)? Which crops are grown?

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	● How many trees do you have on your plot in trees per hectare? ● Do you already have irrigation options? If so, what type?
5. Proposed management strategies/ actions	● Choose relevant management options and design your own management strategy: How many actions/ measures are you proposing?
6. Description of action(s)	● Describe your risk management action(s) in details
7. Timing of actions (start date, end date and if needed, intermediate milestones)	● In which season can the management strategies be implemented? Consider, for example, seasonal variations in temperature and precipitation. ● Consider specific timings: for example, is there a time when fertilisers should be applied, or seeds sown?
8. Monitoring of risk(s) and action(s)	● Keep a check on the implementation of the strategy and keep updating the strategy with good practices. Improve efficiency and maintain the continuation of carbon storage via implementation of the LMT. ● Continuously look into the following: monitoring, evaluation, updating and implementing.
9. Cost of action(s)	Make an estimate of the costs involved such as: ● Operational and maintenance cost: seedlings, fertilisers, treatments, organic fertiliser, fuel, irrigation, labour, fencing, machinery cost, depreciation ● Labour costs ● Marketing costs ● Monitoring cost: e.g., soil testing
10. Possible fundings and institutions support	● Get acquainted with the framework of policies that are in place in your region ● Is there funding available at an intergovernmental level? ● Is there funding available at a national level? ● Is there funding available at a local level? ● Is there private / corporate funding available? ● Are there possibilities to link multiple funding opportunities? ● Seek support through institutions/networks/associations: reach out to other farmers, get in contact with agricultural advisory services, consider contacting a consultancy firm, get informed about the insurance policy schemes available in your region.
11. Person/ organisation(s) responsible for monitoring and implementing action(s)	● How can your LMT be monitored? For example, is there a possibility to monitor biodiversity, tree/soil health? ● Who can do this monitoring?

Table 9: Draft template for climate risk management / action plan

Limitations and possible next steps

The current version of tool was developed within a relatively short time frame and has not been extensively (field)tested. Preliminary testing showed good potential, but further refinements, improvements, extensions will be needed. Key next steps should involve:

- Expansion of the tool to cover more regions, more LMTs, and a wider set of (climate) risks,
- Conversion / translation of the tool in multiple languages

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The further development of the tool can be supported by knowledge, data, and information on LMT collected and created within LANDMARC, and other relevant research projects.

The current tool does not include a procedure or guidance on how to arrange the risk prioritization, neither is there a tool (excel or software-based) that enables the management and monitoring of specific priority risks. However, such supporting tools can also be sourced from other existing (traditional) risk management guidance and support resources.

The tool does also not provide final solutions for risk management; however, we recommend that final solutions and decision-making for implementation of actions should be taken by the relevant stakeholders and be informed with the (latest) scientific information and data.

We consider that an IT enabled, and interactive tool provides a good basis for hosting both online and offline participatory processes to collect (or crowdsource) data, information from different perspectives. This provides an additional or complementary route – relative to traditional, analogue engagement processes - to engage and include more relevant stakeholders. While there may be stakeholders and communities that would not have the tools and resources to meet the technical minimum requirements to make use of the IT-based tool, the information and guidance provided can also be adapted for usage within traditional offline, participatory processes.

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ANNEXES

Annex 1; LMTs and climate risk management in NDCs

An extensive review of the NDC documents of the CS countries has been performed to assess to which degree nature-based mitigation techniques are included within the latest submissions of the countries' plans to achieve climate neutrality (*NDC Content | NDC Partnership*, n.d.). A brief summary can be found below:

Venezuela

The NDC contains mentions to carbon capture in almost every project involving the plantation of trees or reforestation. The NDC cites that the accountancy technique to be used is the one defined by the IPCC. The document also cites the capture of CH_4 in waste treatment plants. However, there are no specific mentions or projects directly aimed to foster negative emissions.

Canada

The NDC mentions carbon capture and provides specific budgets for negative emissions project. The NDC is structured in actions per region, and we found mentions to negative emissions in 3 regions. However, most of the mentions to carbon capture in Canada's NDC are related to technological solutions. Only the chapter for Prince Edward Island mentions biological approaches to carbon capture. Climate Risk mitigation for disasters is only mentioned for the Métis nation.

Kenya

Kenya's NDC mentions the Climate Risk Management framework as one of their key policies for their 2030 vision. Kenya does mention the scaling up of Nature Based Solutions for mitigation in their 2030 vision, but the document does not provide further details.

Nepal

There are no mentions about negative emissions. The country is to develop a Disaster Risk Management plan for its 2030 agenda.

Switzerland

There are no mentions to negative emissions or carbon capture in Switzerland's NDC.

Indonesia

The NDC contains very brief mentions to negative emission; it mentions the capture of methane in industrial liquid waste treatment, and carbon sequestration as a desirable side effect of reforestation activities.

Vietnam

The NDC contains mentions to carbon sequestration in the LULUCF sector and includes this reductions on its scenarios, but there are not mentions to specific techniques or plans to implement national carbon markets. Regarding risk management, it mentions that it plans to improve risk management at the community level.

Burkina Faso

The NDC from Burkina Faso includes carbon sequestration in the LULUCF, Energy, Transportation and Waste. However, when looking at the specific projects, there is not a distinction between sequestration and reduction (for example, none of the projects in the transportation sector seem to be related with carbon sequestration).

European Union

Negative emissions in the EU are regulated by the ETS. Land-use related emissions and removals addressed by the regulation on emissions and removals from land use, land use change and forestry (LULUCF).

The above illustrates that the inclusion of LMTs in most assessed NDCs is still modest and can be improved. Carbon sequestration is often mentioned as a side goal of other actions (such as the conservation and restoration of natural areas) rather than projects aimed to decrease atmospheric greenhouse gases. Besides, we could find very little information about the exposure to the effects of climate change of these techniques, or about the climate sensitivities derived from its implementation. It is therefore necessary to fill this gap so countries can design a solid roadmap for their mitigation strategies based on the use of land.

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Annex 2; Implementation of the assessment

A quality-over-quantity approach was chosen for the implementation of this survey. A limited number of key stakeholders (3-5 per LMT and case study country) were guided through the survey in an open interview by LANDMARC partners to get insights on the impacts of the LMT, providing free space for further elaboration. Due to constrictions from the Covid-19 outbreack, most of these interviews were held online. Specific stakeholder profiles were targeted during this exercise to ensure a good depiction of all perspectives and avoid a potential bias of the assessment due to eventual unbalances in stakeholder representation in the stakeholder repository

We define two main stages for this assessment: Survey Design and Data Collection

Survey design

Literature review

Prior to the elaboration of the survey, the WOCAT questionnaire on Sustainable Land Management approaches was thoroughly reviewed as it contains many relevant questions about the vulnerability and effects of the implementation of LMTs. Aside from this, literature concerning the assessment of socio-economic parameters and stakeholder engagement was revised (CARE Climate Vulnerability and Capacity Analysis Handbook, facilitation guides from previous similar exercises and several risk assessment matrixes).

Survey elaboration

A series of meetings were held among task leaders to decide on the relevant parameters to be assessed and to shape the survey, ensuring that the format is both adequate for the stakeholders and that it meets the information collection requirements. The interviewing process is intended to take 45-60 mins per stakeholder.

A special emphasis was put in using an integrative language that is understandable and perceive as adequate by stakeholders with all cultural backgrounds, and to include several layers of specificity in the description of the parameters to ensure that they are easily understandable by people with different levels of expertise in the matter, while still benefiting from the knowledge of the experts.

To increase the understandability of the survey, there is a different survey for each LMT. When the term "survey" or "questionnaire" is used in this guide, it refers to the generic version of the document (that is, not applied to any specific LMT). This questionnaire can be found in

Survey structure

(A general version of the survey can be found in Annex 3; Generic Survey)

The survey consists of 4 main sections:

1. The first section asks for stakeholder profiling question information.
2. The second section evaluates the climate-related risks to which this LMT is exposed.

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3. The third section addresses the effects the implementation of the LMT has on the local environment.
4. The fourth section evaluates a variety of socio-economic related risk the implementation of the LMT could face.

Aside from the sections in the survey, short (one to two pages) written reports about the interview were written by the interviewers to document those ideas that couldn't be properly recorded by the questionnaire.

A pre-selection form was sent to the stakeholders shortly before the interview asking them the select up to 5 of the most relevant parameters from sections 2 and 3. The goal is to assess in detail those parameters that are the most relevant for the stakeholders, instead of spending time assessing lower relevance parameters, which could result in stakeholder fatigue and low-quality data.

1) The questions in section 1 are meant to picture the profile of the stakeholder by depicting their occupation, gender (reported), age group (perceived) and main interest in the implementation of the LMT (e.g., environmental awareness, business opportunity, cultural reasons…). This will allow to contextualize the data.
2) Questions in section 2 (linked to task 4.1) are aimed to assess the vulnerability of the LMT to climate extremes, determining when a climate extreme becomes a hazard for the LMT under local circumstances.
3) Section 3 (linked to task 4.2) evaluates the effect the implementation of the LMT would have on the local environment. For that, several potential effects the LMT could have on the environment (sorted by "soil, water and air", "diversity" and "resilience" categories) are enumerated and depicted with short explanations, asking the stakeholder to elaborate further on the pre-selected most relevant effects.
4) Section 4 assesses social, economic, governance and policy related issues linked to the implementation of the LMT. Section 4 has a more open format than sections 2 and 3, and instead of asking the stakeholder to elaborate about specific parameters, a contextual factor topic will be brought up by the interviewer, and the interviewee will be asked to comment about the impacts (both positive and negative) the current framework has in relation to the LMT. A table with the contextual factors and some examples will be shown in the screen to the stakeholder to help triggering ideas. A data collection matrix including impacts and time scale is provided to the interviewer (or note taker), with pre-defined impacts and free space in case the stakeholder elaborates about different topics. Results from section 4 will be used in the upcoming Deliverable 5.2.

   After section 4, there are 5 short closing up questions asking the stakeholder about some final thoughts about the LMT after the reflection brought up by the interview.
5. After finishing the interview with the stakeholder, a short (1 to 2 pages) report with the main findings of the interview will be written, with the goal of documenting the information that couldn't be properly recorded by the questionnaire in a storyline style.

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Survey validation

After task leaders agreed on the pre-final survey design, the survey was tested through real interviews for validation. To ensure a good representativity cultural backgrounds within piloting partners, the survey was tested among highly supportive stakeholders in The Netherlands, Indonesia, and Canada (with representation of native-American communities). Feedback from piloting stakeholders was later discussed and incorporated to the survey by task leaders to create the final version.

Data collection

Stakeholder selection

Stakeholder selection is key to this task, as highly detailed, time-consuming consultations with a limited number of stakeholders instead are going to be carried out. Therefore, stakeholders with specific

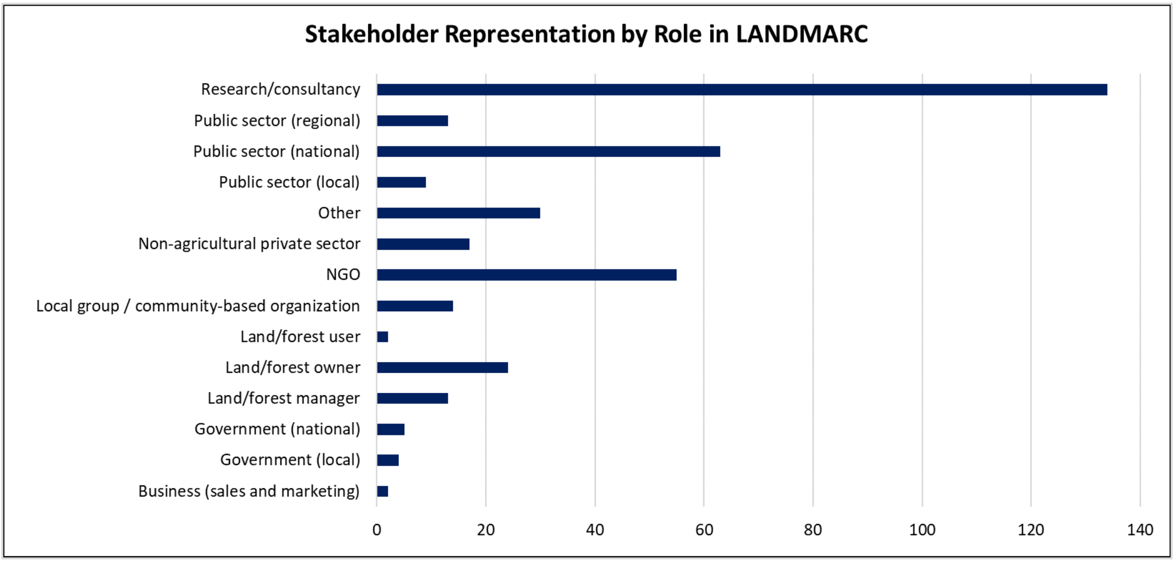

Figure 27: Stakeholder representation by sector in LANDMARC

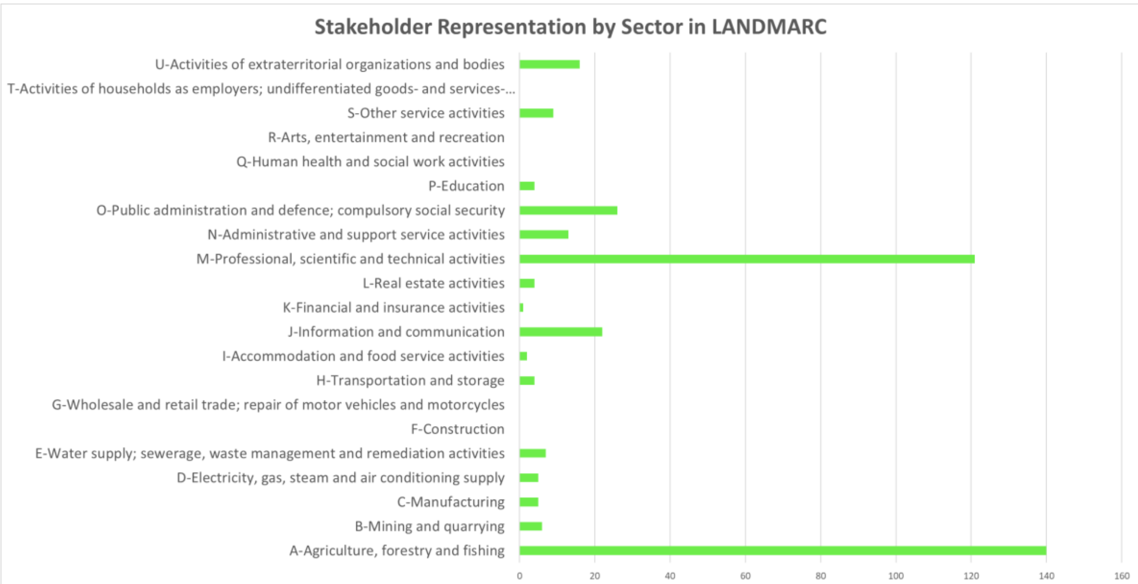

Figure 28: Stakeholder representation by sector in the LANDMARC repository

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attributes and perspectives (e.g., inclusive) must be carefully selected to ensure the collection of all relevant information and viewpoints.

After our first round of stakeholder mapping we found that various stakeholder roles and (sub)sectors were not equally represented within LANDMARC's national stakeholder repositories (see Figure 28 and Figure 27). These 'biases' or 'gaps' were even more profound for individual countries. Due to this a set of criteria were set to guide the stakeholder selection process for conducting the interviews.

In order to cover all perspectives, the profiles of these stakeholders will desirably include:

- Stakeholders from **government** (local, regional, or national)
- Stakeholders from the **public sector** (local, regional, or national)
- Stakeholders from a **local group/community**
- **Land/forest user**
- Stakeholders from **research/consultancy/NGO**

This selection should ideally include the representation of stakeholders from the local, regional, and national sectors. Also, a balanced ratio of men and women will be surveyed (the sample should include 2 to 3 male and female).

Age is another parameter to consider, as perspectives in climate-related issues proved to differ significantly between age groups (Tyson et al., 2021). However, LANDMARC's stakeholder repository does not include information about the age of the stakeholders (and cannot be easily guessed as the gender), so the perceived age group will be recorded in the survey to later contextualize the data.

As there is a limited number of stakeholders in LANDMARC's stakeholder's repository, there were cases when it was not possible to find participants fitting all the characteristics in a country's repository (also, in quite a few cases stakeholders could not be directly linked to a specific LMTs which required further interviewer research). We therefore encouraged the interviewees to ask for further contacts ('snowballing') to the participants that fit into the targeted profiles of this survey. In addition, this method proved to be effective in increasing the stakeholder's response rate.

LMT Prioritization

During the implementation phase of the stakeholder interviews, it was found (based on preliminary feedback and results) that for certain LMTs the climate change related risks were rather minimal. This particularly related to more engineered solutions such as BECCS or biochar, while other more nature-based solutions, often relying on natural processes (e.g., photosynthesis, oxidation) showed higher levels of exposure to climate change related and environmental risks. Within this report we focus more on the latter category of nature based LMTs, while the more engineered options will be discussed in more detail in D5.2.

Surveying/Interviewing process

1) **Contacting the stakeholder**
    a) After selecting a stakeholder from the database, a first standard email is sent to the stakeholder, briefly describing the LANDMARC project, the goal of the survey and asking them

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to participate in the consultation. If no response has been received in a two weeks period, the case study lead will send a reminder.

b) In case the stakeholder confirms their interest about the interview, a second standard email including a meeting invitation, the pre-selection form and the GDPR consent will be sent.

2) Interview

It is strongly recommended that 2 people from the LANDMARC project join the online interview: one assuming the role of the chair, and the other one mainly as a notetaker. This has been proven to increase the quality of the collected data and to decrease the bias introduced by the interviewer taking notes.

Once in the call, the interviewer shares the screen and show the questionnaire to the interviewee in sections 1, 2 and 3 (these guidelines can also be found in the questionnaire).

In sections 2 and 3, the interviewer asks the stakeholder to elaborate on the pre-selected topics, taking notes in the comments section of the parameters and writing any complementary information in the threshold and past events fields in section 2 if possible. Questions to be asked can include which variables are critical, how often do the events take place, when did the last event happen, what is the aftermath of the event.

In section 4, the interviewer shares Table 3 of the questionnaire to the interviewee, while bringing up the topics included in it, with help of the examples to help the stakeholder triggering ideas. In the meantime, the notetaker writes the insights of the stakeholder in the questionnaire tables dedicate to each of the topics.

3) Report

1 to 2 pages reports with the most relevant outcomes of the interview were written after the videocall. The main goal of these reports is not to sum up what it is already written in the questionnaire, but to document those ideas that couldn't be easily recorded by the questionnaire in a storyline format, increasing the contextualization of the findings and contributing to a better understanding of the interactions between issues.

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Annex 3; Generic Survey

Introduction to the questionnaire and interview guidelines

The goal of this questionnaire is to evaluate the resilience of Land Mitigation Techniques towards Climate Change and natural catastrophes. Land Mitigation Techniques are practices on the use of land that allow to either capture CO2 or decrease the CO2 emissions compared to current practices, with the goal of mitigating climate change. In this survey, we evaluate the effect large-scale implementation of LMT would have on the social and economic wellbeing of the hosting societies.

The survey consists of 5 sections:

Section 1: General questions	**Stakeholder profiling questions**
Section 2: Climate-related risk factors	Climate extremes that could affect LMT
Section 3: Effect on the local environment	How does LMT shape the environment
Section 4: Interview	Impacts for upscaling LMT
Section 5: Closing-up questions	Short questions to record SH's subjective opinion on LMT after reflecting during the interview

This questionnaire is to be filled by Case Study (CS) leaders during and after the interview session with the stakeholders. A list with the parameters addressed in sections 3 (effect of LMT on the local environment- WP3) and section 2 (climate-related risk factors- WP4) and the General Data Protection Regulation (GDPR) consent will be sent to the stakeholders before the interview for pre-selection. Once in the interview, the Case Study leaders will ask the stakeholder to provide details on the pre-selected parameters according to the questionnaire.

In section 4 (upscaling risks of individual LMT-WP5), CS leaders and regional leaders can use this document as a guideline for interviewing stakeholders. The topics are meant as a first direction, to be customized based upon the knowledge of the stakeholder and supplementary sources, such as literature reviews.

The central questions regarding risk are on the relevance of an event or risk type for/to a stakeholder, the effect from/to an LMT, and the stakeholder interpretation of the associated time and spatial scales. In section 2, Climate-related risk factors, we look at the climate events that could compromise the success of LMT. The nature of these events is often more seasonal/cyclical/recurring. In section 4, suggested interview guidelines…, events can be interpreted as both seasonal / cyclical / recurring and singular. Example: 1. Land use challenges might occur every year due to environmental conditions (cyclical). 2. There might be a development in the (distant) future that significantly challenges land use, such as an ecosystem shift (singular).

These temporal and spatial scales, and their interpretation, are likely to differ between stakeholders.

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Interview guideline step overview:

1. Send the GDPR consent form. **The consent form must be sent out no less than 48 hours before the interview.**
2. Send the **pre-selection form** at least **48 hours** before the interview. The stakeholder will be asked to select **up to 5 parameters in sections 2 and 3.**
3. Fill in the already known information in section 1 with the goal of saving time.
4. In sections 2 and 3, ask the stakeholder to elaborate on the selected parameters and write notes in Table 10 and Table 11.
5. In section 4, **show Table 12** to the stakeholder and bring up the topics of discussion (in bold), with the help of examples of parameters within the topic (in bold, black letters). **Write the notes in each topic's tables (Table 13 to Table 21) and come back to Table 12 after the topic has been discussed to continue the discussion**.
6. Ask the stakeholder the **closing-up questions** at the end of the questionnaire.
7. **After the interview, write a 1-2 page summary with the main outcomes of the interview**. The goal is to document all the ideas that couldn't be recorded by the survey.

More detailed information about the process can be found in each section.

(Our data gathering and practices are fully compliant with GDPR, and your privacy will be fully assured. For more information on our data management policy, see the GDPR consent form with contacts listed. Your name will only be used to contact you for further information. Your gender and organization will help inform the different perspectives on the issues at hand)

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1. General Information

LMT and site

Assessed Land Mitigation Technique:

Locally used name of LMT:

Country:

Location:

Contact details of the resource person

Name*:

Gender**: Male/Female/Other (specify)

Organisation*:

Perceived age group: <25/25-35/35-45/45-55/>55

Other information

☐ land user ☐ SLM (Sustainable Land Management) specialist/ technical adviser

☐ other (specify): ………….

Occupation:

Please ask the stakeholder: What is your main interest in relation to the implementation and further upscaling of LMT in your country? (eg. Economical, protection of the environment, cultural values...)

Date:

*Your name and organisation will not be disclosed

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2. Climate-related risk factors of LMT

In this section, you will ask the stakeholder about the exposure of LMT to climate-related extreme events, the probability (likelihood) that a specific event can occur, as well as the magnitude of the potential damage/harm (severity) of that climate-related extreme event **for the pre-selected event types.** The risk elicitation and information collection grid can be found in Table 10. Effects on the environment can be found in Table 11.

Also briefly describe how the extreme event(s) can affect LMT (*e.g. excessive heat limiting growth*). If the stakeholder is aware of specific critical event related thresholds values relevant to LMT, or past extreme events, please note them (*e.g. daily maximum temperatures above 30°C for 7 consecutive days, the cold wave of February 2020…*). Also, list any relevant sources of information if known, and past events that fit into the category.

Climate-related extreme events or disasters	Mark the 5 most relevant events	Critical event threshold values for LMT	Past events	Comments
2.1 Heat waves				
2.2 Cold waves (unusually cold conditions at any time of the year)				
2.3 Extreme cold winter conditions (e.g. frost)				
2.4 Extreme mild winter conditions				
2.5 Drought				
2.6 Forest fire or land fire (grass, shrub, bush)				
2.7 Strong winds				

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Climate-related extreme events or disasters	Mark the 5 most relevant events	Critical event threshold values for LMT	Past events	Comments
(e.g. related to storm systems; if known please specify the types of weather systems that play a role, e.g. tropical cyclones, thunderstorms, etc.)				
2.8 Heavy rainfall				
2.9 Hail				
2.10 Snow				
2.11 River flood				
2.12 Flash flood				
2.13 Storm surge / coastal flooding				
2.14 Sea level rise				
2.15 Landslides				
2.16 Erosion				
2.17 Other relevant climate events not listed above				

Table 10: Elicitation of climate risks for the interview

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3. Effect of LMT in the local environment

In your opinion, how does LMT contribute to:

Parameter		Mark the 5 most relevant events	Comments
Soil, Water and Air	**3.1 Carbon sequestration**		
	3.2 Air quality (impact on reduction / increase of air pollutants like NOx, Sox, PM, NH3, etc.)		
	3.3 Nutrient Retention in soil: the capacity of a system, contributing to the reduction of nitrogen and phosphorus leaching and consequent improvement in the quality of infiltrated water		
	3.4 Water balance or "Hydric balance": Regulation of water flows due to the specific plant characteristics, under specific conditions, contributing to the management of water availability		

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Parameter		Mark the 5 most relevant events	Comments
	3.5 Soil Protection: Control soil erosion, water infiltration, nutrient retention, atmospheric gas regulation, soil acidity and salinity		
	3.6 Soil biome e.g. microorganisms contributing to soil fertility		
Diversity	**3.7 Scenic Value of the Landscape:** prevention of landscape fragmentation, ensuring ecological sustainability and maintenance or preservation of the scenic and cultural value of the national landscape.		
	3.8 Diversity of plant life or "Phytodiversity": Flora diversity in terms of abundance, species richness and rarity. Maintenance or preservation of mosaic and non-productive and heterogeneous structures		
	3.9 Macrofungi diversity: Fungi species that contribute to nitrogen and phosphorus fixation and soil quality (e.g. mushrooms)		
	3.10 Soil Macrofauna Diversity: species of arthropods and other invertebrates that regulate habitat and soil quality (e.g. earthworms)		
	3.11 Bird Diversity:		

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Parameter		Mark the 5 most relevant events	Comments
	management of any mosaics or plots in the landscape to ensure bird diversity		
	3.12 Habitat Diversity: increasing ecosystem diversity changes environment's patterns (e.g. increased resilience to plagues)		
	3.13 Pollination: Ensuring the existence and distribution of pollinating agents that contribute to the pollination of neighbouring agricultural fields and ensure productivity (e.g. bees)		
Resilience	**3.14 Climate Resilience:** regulation of the concentration of GHG in the atmosphere soil carbon sequestration and systems' vegetation cover Increased CO2 sequestration…		
	3.15 Fire risk reduction: Reduction of incidence, intensity or propagation capacity of fire episodes due to social, biophysical characteristics and system's landscape		
	3.16 Adaptive plant species (short life, drought resistance, high nutrient efficiency, high production, pest and disease resistance)		

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Parameter		Mark the 5 most relevant events	Comments
	3.17 A more resilient cropping system (organic agriculture, agroforestry, multi-species and multi-product)		
	3.18 Resilience to pests Pest attack patterns on plants		

Table 11: Elicitation of effects on the environment linked to the implementation of LMTs.

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4. Interview guidelines for risks & opportunities in upscaling of LMT

Overview:

1. Read introduction
2. Show Table 12 to the stakeholder and start a dialogue with the stakeholder about the topics (in bold), with help of the examples (in bold back) to help trigger ideas.
3. Write any relevant observations from the stakeholder in the tables referring to each topic (tables 13 to 21). If the discussed topic does not fit with any of the categories described on the tables, use the provided blank space.
4. When you've finished taking the notes, come back to Table 12 to continue discussing the next topic, and continue this process until all relevant parameters have been addressed.

Estimated time needed: ~45 mins.

Introduction guidelines for CS lead:

The following questions are meant as a (semi-structured) interview guideline. The outputs of these efforts will be used to inform a survey focused on a greater reach of stakeholders based on the breadth of information collected in the interviews. The following categories are meant as a starting point for the dialogues and customization of the (structured) interviews. CS/Regional lead can make changes as they see fit based on their literature review, expertise, and interactions with the consortium such as modelling teams.

In this part, we ask you to evaluate the risks in the implementation LMT could face from different stakeholder perspectives across 9 risk contextual categories (see Table 12).

To complete this part, it is important to define the concept of "risk". **Risks** refer to a specific possible outcome that is perceived to be negative, varies across scales: time scale, governance scale (national provincial/local-national government), area of location and size of land are highly dependent on your perspective. Therefore, we aim to gather your perception of risks in LMT you have experience with.

By **risks**, we mean the **barriers** to implementing land-use based mitigation options or potential **negative outcomes** of implementing the land-use based mitigation option.

On the opposite side of risks we have **opportunities** that can ***enable*** the implementation or scaling up of an LMT and have ***positive impacts***. Thus opportunities are also based on contextual factors as listed in Table 12 below) including technology, politics, policy, institutions, society, economy/market, businesses and the environment.

We refer to 9 main contextual categories of risk in Table 12:

Contextual factors for impact: barriers and enablers to implementing LMT
1. **Technology/practice** parameters: Land-use based technology/practices risks refer to the negative impact the technology may have on people or the environment or challenges to implementing and/or scaling up the technology **(e.g. technical challenges, scalability challenges, accidents, failure of the technique to reach its targets…)**
2. **Political parameters** refer to policy choices that cause dissent and disputes among political actors and groups within the same or different jurisdictions **(e.g. lack of political support, political instability, corruption…)**
3. **Institutional parameters** refer to implementation challenges and opportunities, lack of coordination or conflict within or across institutions, or a lack of institutional legitimacy **(e.g. institutional misalignment, long/tedious bureaucracy, exceptional institutional support, lack of institutional legitimacy, inclusion of LMT in national NDC…)** *Note:* Institutions are defined as "formal and informal rules and norms that organise social, political and economic relations"[8] (North, 1990). They may include policy, education, market, religious, and cultural institutions
4. **Policy parameters** refer to challenges and opportunities with implementing policies such as policy instruments, regulations, strategies, programmes and initiatives **(e.g. poor policy design, challenges with policy implementation, strong policy support, lack of adequate monitoring…)**

[8] North, D. (1990). Institutions, institutional change, and economic performance. New York: Cambridge University Press See in GSDRC: https://gsdrc.org/topic-guides/inclusive-institutions/concepts-and-debates/defining-institutions/

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Contextual factors for impact: barriers and enablers to implementing LMT
5. **Societal parameters** refer to the social support towards implementing a technology such as threatening societal groups and/or creating inequalities among them **(e.g. proximity of the technology to communities, social changes, local culture, lack of knowledge, resistance to behavioural change, preference for the new scape, negative health impacts, impact in daily life of locals…)**
6. **Economy-wide factors** refer to the influence of policies on national economic indicators, which might affect specific stakeholders such as public or private organizations, local SHs **(e.g. trade imbalances, energy security, market regulation, lack of subsidies, market domination…)**
7. **Business factors** refer to specific challenges and opportunities related to running a business including investment challenges, payback periods and revenue stream **(e.g. investment challenges, more diversified sources of income, high capital costs, long payback period…)**
8. **Environmental factors** refer to changes in the nature/environment including human, flora and fauna ecosystems **(e.g. biodiversity loss, waste issues, increase in biodiversity…)**
9. Avoided costs derived from the implementation of LMT **(e.g. avoided infrastructure expenses due to avoided soil subsidence, avoided costs in water purification because of avoided chemical substances leaching…)**

Table 12: Elicitation of (some) socio-economic risks

Thus both risks and opportunities could take place at different temporal and spatial scales. Increased risk could be an immediate effect of a technology or practice being implemented, or it could only be relevant decades from now. The risks could also be different at different spatial scales: for example, at a local scale, there could be more immediate environmental effects that might not be relevant at a national scale. Finally, the time dimension of risks could be different at different scales: countrywide risks might not be apparent for decades, while local risks are felt more immediately.

The temporal scale is interpretable as seasonal/cyclical/recurring and singular events. In some cases, stakeholders will understand events to be part of a cycle: for example, a political season of 1-4 years, re-occurring environmental events, or implementation delays. In other cases, stakeholders will put forth singular events: while risks due to worsening climate change could be cyclical (drought every 1-4 years, heatwaves in summer, hail in winter), the risk of an overall loss of land due to a climate shift and its change in land use (and associated cultural/institutional/economic consequences) might be a singular event risk – in the near or distant future. In these guidelines, we aim to capture both interpretations that stakeholders might have for these risks – both the cyclical, and likely more near term, worries, and the singular events.

Please rate the risk & opportunity relevance following parameters for their importance to LMT, NA if the risk does not apply. Some specific fields are included and explained for each of the categories – the applicable time scale and spatial scales. For all fields, we have included space for explaining the answer and added a comment section for any additional remarks.

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In the tables below we will refrain from using the terms risks and opportunities to avoid confusion. Instead, we will talk about risks as barriers and/or negative outcomes and opportunities as enablers and positive outcomes. We will simply refer to them as negative or positive impacts. Stakeholders intuitively can talk about negative and positive aspects without having to refer to our risk and opportunity framing.

4.1. Land-use based mitigation technology/practices risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Applicable spatial scale:
    - Technology implementation scale (individual, household, community, municipality, sub-national, national, supranational, global)
    - Technology spatial impact scale: at which technology scale does this risk take place? (Individual, household, community, municipality, sub-national, national, supranational, global)

LMT/Technological negative or positive impacts	Applicable time scale	Applicable spatial scale	Comments
Technical challenges: (high cost, unavailability of materials…)			
Infrastructure integration challenges			
Technological lock-in			
Scalability challenges			
Technical accidents			

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LMT/Technological negative or positive impacts	Applicable time scale	Applicable spatial scale	Comments
Failure of LMT to reach mitigation targets and/or future reversal			
Failure of technology to reach adaptation targets			
Other technology impacts (free text)			

Table 13: Technology/practices risks

4.2. Political risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Governance scale: at which governance scale does this impact take place? (community, city, province/state/national/Supernational/Continental/global)

Political negative or positive impacts	Applicable time scale	Applicable governance scale	Comments
Lack of political support (existence of higher priorities…)			
Political instability			

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Political negative or positive impacts	Applicable time scale	Applicable governance scale	Comments
Corruption			
Other political risks (free text)			

Table 14: political risks

4.3. Institutional risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Governance scale: at which governance scale does this impact take place? (community, city, province/state/national/Supernational/Continental/global)

Institutional negative or positive impacts	Applicable time scale	Applicable governance scale	Comments
Institutional misalignment			
Exceptionally strong institutional support			
Lack of institutional legitimacy			
Inclusion of LMT within national NDC			
Other institutional impacts (free text)			

Table 15: institutional risks

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4.4. Policy risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Governance scale: at which governance scale does this impact take place? (community, city, province/state/national/Supernational/Continental/global)

Policy negative or positive impacts	Applicable time scale	Applicable governance scale	Comments
Poor policy design			
Challenges with policy implementation			
Strong policy support			
Lack or inadequate monitoring and evaluation			
Long/tedious bureaucracy			
Other policy impacts (free text)			

Table 16: policy risks

4.5. Societal risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Societal scale: at which governance scale does this impact take place? (individual, household, community, municipality, sub-national, national, supranational, global)

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Societal negative or positive impacts	Applicable time scale	Applicable societal scale	Comments
Proximity of the technology to local communities			
Social changes			
Social injustice			
Resistance to behavioural change			
Societal resistance			
Preference for the new scape			
Local culture (social class, social rules…)			
Capacity gap (lack of knowledge…)			
Impact daily lives and practices of local communities			
Negative health impacts			
Other societal impacts (free text)			

Table 17: societal impacts

4.6. Economy-wide (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Spatial impact scale: at which technology scale does this impact take place? (Individual, household, community, municipality, sub-national, national, supranational, global)

Economy-wide risks negative or positive impacts		Applicable time scale	Applicable spatial scale	Comments
Trade imbalances				
Energy security challenges				
Market domination				
Market regulations				
Lack of subsidies				
Other economic factors (free text)				

Table 18: economic risks

4.7 Business risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this impact most relevant (months, years, decades…)
- Spatial impact scale: at which technology scale does this impact take place? (Individual, household, community, municipality, sub-national, national, supranational, global)

Business negative or positive impacts	Applicable time scale	Applicable spatial scale	Comments
Investment challenges			

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Business negative or positive impacts	Applicable time scale	Applicable spatial scale	Comments
High(er) capital costs			
Long payback period			
More diversified sources of income			
Uncertain/revenue stream			
Other business factors (free text)			

Table 19: business risks

4.8. Environmental risks (barriers/negative outcomes) & opportunities (enablers/ positive outcomes)

- Applicable time scale: for which time scale is this risk most relevant (months, years, decades…)
- Environmental scale: at which environmental scale does this impact take place? (individual, household, community, municipality, sub-national, national, supranational, global)

Environmental negative or positive impacts	Applicable time scale	Applicable environmental scale	Comments
Land-use change			
Low emissions reductions potential			
Biodiversity loss			
Increase in biodiversity			
Water and soil management			

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Environmental negative or positive impacts	Applicable time scale	Applicable environmental scale	Comments
Other environmental factors (free text)			

Table 20: environmental impatcs

4.9. Possibilities for avoided costs

- Applicable time scale: for which time scale is this risk most relevant (months, years, decades…)
- Spatial impact scale: at which technology scale does this impact take place? (Individual, household, community, municipality, sub-national, national, supranational, global)

Possibilities for avoided cost	Applicable time scale	Applicable spatial scale	Comments
Avoided soil subsidence			
Avoided chemical substances leaching			
Other environmental factors (free text)			

Table 21: avoided costs

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Annex 4; Aggregated results of the consultation

Stakeholder Profile			Location				Climate Risks T4.1																
Gender	**Age Group**	**Sector**	**Case Study Country**	**Assessed LMT**	**Developing Country**	**Climate**	**Heat waves**	**Cold waves**	**Extreme cold winter conditions**	**Extreme mild winter conditions**	**Drought**	**Forest fire or land fire**	**Strong winds**	**Heavy rainfall**	**Hail**	**Snow**	**River flood**	**Flash flood**	**Storm surge / coastal flooding**	**Sea level rise**	**Landslides**	**Erosion**	**Other relevant climate events not listed**
male	45-55	research/consultar	Netherlands	Peat soil rewetting and paludiculture	No	oceanic climate	1				1	1											
female	25-35	research/consultar	Netherlands	Agroforestry	No	oceanic climate	1	1				1		1	1								
male	25-35	Land/forest user	Netherlands	Peat soil rewetting and paludiculture	No	oceanic climate					1			1									
male	45-55	research/consultar	Netherlands	Domestic biomass based BECCS	No	oceanic climate																	
female	>55	research/consultar	Netherlands	Peat soil rewetting and paludiculture	No	oceanic climate					1		1	1						1	1		1
female	>55	Government	Indonesia	Agroforestry	Yes	humid tropical climate					1	1		1			1		1				
male	>55	research/consultar	Indonesia	Peat soil rewetting and paludiculture	Yes	humid tropical climate					1	1		1			1	1	1				
male	25-35	research/consultar	Indonesia	Agroforestry	Yes	humid tropical climate					1		1				1	1					
female	35-45	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1		1		1	1									
male	45-55	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1		1		1	1									
male	35-45	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1		1		1	1									
male	>55	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1		1		1	1									
female		Local Group/Comn	Indonesia	Agroforestry	Yes	humid tropical climate		1			1		1	1				1					
female	25-35	research/consultar	Indonesia	Agroforestry	Yes	humid tropical climate					1		1	1							1	1	
male	35-45	research/consultar	Indonesia	Agroforestry	Yes	humid tropical climate					1		1	1							1	1	
male	35-45	research/consultar	Indonesia	Peat soil rewetting and paludiculture	Yes	humid tropical climate					1	1		1			1	1					
male	>55	Land/forest user	Kenya	Afforestation/Reforestation	Yes	Hot semi-arid					1						1	1				1	1
female	45-55	research/consultar	Kenya	Agroforestry	Yes	Hot semi-arid					1			1							1	1	
male	35-45	Local Group/Comn	Kenya	Agroforestry	Yes	Hot semi-arid															1	1	1
female	25-35	research/consultar	Kenya	Cropland management	Yes	Hot semi-arid	1							1									
male	35-45	Land/forest user	Kenya	Cropland management	Yes	Hot semi-arid					1			1			1	1				1	
other/ur	>55	research/consultar	Nepal	Cropland management	Yes	humid subtropical climate					1												
other/ur	unknov	research/consultar	Nepal	Cropland management	Yes	humid subtropical climate																	
female	unknov	research/consultar	Nepal	Forest management (incl. fire management)	Yes	humid subtropical climate						1									1		
other/ur	unknov	research/consultar	Nepal	Agroforestry	Yes	humid subtropical climate																	
male	unknov	research/consultar	Burkina Faso	Forest management (incl. fire management)	Yes	Hot semi-arid					1	1										1	
female	unknov	research/consultar	Burkina Faso	Agroforestry	Yes	Hot semi-arid					1		1	1								1	
male	unknov	research/consultar	Burkina Faso	Cropland management	Yes	Hot semi-arid					1							1					
male	unknov	research/consultar	Burkina Faso	Agroforestry	Yes	Hot semi-arid					1	1	1									1	
male	unknov	research/consultar	Burkina Faso	Cropland management	Yes	Hot semi-arid					1			1								1	
other/ur	25-35	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																	1
other/ur	25-36	research/consultar	Sweden	Biochar	No	humid continental climate																	
other/ur	unknov	Public Sector	Sweden	Domestic biomass based BECCS	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate					1	1							1				1
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Biochar	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Biochar	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																	
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																	1
other/ur	unknov	Land/forest user	Sweden	Afforestation/Reforestation	No	humid continental climate																	
male	45-55	research/consultar	Vietnam	Afforestation/Reforestation	Yes	Tropical savanna climate			1		1	1	1				1	1			1	1	
female	25-35		Vietnam	Agroforestry	Yes	Tropical savanna climate	1		1		1	1	1	1								1	
male	35-45	research/consultar	Vietnam	Agroforestry	Yes	Tropical savanna climate	1	1	1		1		1									1	
male	45-55	research/consultar	Vietnam	Agroforestry	Yes	Tropical savanna climate					1												
male	45-56	research/consultar	Vietnam	Agroforestry	Yes	Tropical savanna climate	1		1	1	1		1	1									
other/ur	unknov	research/consultar	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate						1									1		
other/ur	unknov	Local Group/Comn	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate				1			1									1	
other/ur	other/(	research/consultar	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate																	

Stakeholder Profile			Location				Climate Risks T4.1																
Gender	Age Group	Sector	Case Study Country	Assessed LMT	Developing Country	Climate	Heat waves	Cold waves	Extreme cold winter conditions	Extreme mild winter conditions	Drought	Forest fire or land fire	Strong winds	Heavy rainfall	Hail	Snow	River flood	Flash flood	Storm surge / coastal flooding	Sea level rise	Landslides	Erosion	Other relevant climate events not listed
other/ur	unknov	Local Group/Comm	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate	1				1			1	1							1	1
other/ur	unknov	Local Group/Comm	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate															1	1	
other/ur	unknov	research/consultar	Switzerland	Biochar	No	humid continental climate																	1
other/ur	unknov	Local Group/Comm	Switzerland	Reduced/no-tillage	No	humid continental climate	1				1			1									1
other/ur	unknov	Local Group/Comm	Switzerland	Reduced/no-tillage	No	humid continental climate																	
other/ur	unknov	Local Group/Comm	Switzerland	Reduced/no-tillage	No	humid continental climate	1				1	1									1		
male	>55	Land/forest user	Spain	Afforestation/Reforestation	No	Hot-summer Mediterranean	1				1			1									
male	35-45	Government	Spain	Forest management (incl. fire management)	No	Hot-summer Mediterranean	1				1	1										1	
male	>55	Land/forest user	Spain	Avoided grassland conversion	No	Hot-summer Mediterranean	1		1		1		1										
male	>55	research/consultar	Spain	Avoided grassland conversion	No	Hot-summer Mediterranean	1	1			1											1	
male	>55	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean					1												
male	35-45	Local Group/Comm	Spain	Forest management (incl. fire management)	No	Hot-summer Mediterranean	1				1	1										1	
male	>55	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean	1				1	1										1	1
female	35-45	Public Sector	Spain	Afforestation/Reforestation	No	Hot-summer Mediterranean	1				1	1											
female	35-45	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean	1				1			1									
female	>55	Land/forest user	Spain	Agroforestry	No	Hot-summer Mediterranean	1				1	1											
male	35-45	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean	1	1			1	1											
male	45-55	unknown	Burkina Faso	Cropland management	Yes	Hot semi-arid					1			1	1				1				
male	unknov	Government	Burkina Faso	Agroforestry	Yes	Hot semi-arid					1												1
male	unknov	research/consultar	Burkina Faso	Agroforestry	Yes	Hot semi-arid							1									1	1
male	unknov	Government	Burkina Faso	Agroforestry	Yes	Hot semi-arid					1												1
male	unknov	Government	Burkina Faso	Cropland management	Yes	Hot semi-arid																1	
male	unknov	research/consultar	Burkina Faso	Reduced/no-tillage	Yes	Hot semi-arid																	
male	unknov	research/consultar	Burkina Faso	Cropland management	Yes	Hot semi-arid																	
male	unknov	research/consultar	Burkina Faso	Crop rotation	Yes	Hot semi-arid																	
male	unknov	Local Group/Comm	Burkina Faso	Forest management (incl. fire management)	Yes	Hot semi-arid					1			1								1	
male	unknov	Government	Burkina Faso	Cropland management	Yes	Hot semi-arid					1			1								1	
male	unknov	Local Group/Comm	Burkina Faso	Cropland management	Yes	Hot semi-arid					1			1									
female	unknov	Local Group/Comm	Burkina Faso	Cropland management	Yes	Hot semi-arid					1												
female	unknov	Local Group/Comm	Burkina Faso	Cropland management	Yes	Hot semi-arid					1			1								1	
male	35-45	research/consultar	Germany	Forest management (incl. fire management)	No	humid continental climate	1			1	1	1	1										1
male	>55	research/consultar	Germany	Peat soil rewetting and paludiculture	No	humid continental climate	1			1	1	1										1	
female	25-35	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1				1			1								1	
male	>55	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1				1				1							1	
female	35-45	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1				1			1								1	
male	45-55	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1				1	1											1
male		Land/forest user	Canada	Biochar	No	humid continental climate	1			1	1		1										
female		research/consultar	Canada	Afforestation/Reforestation	No	humid continental climate																	
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate	1			1		1											
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate																	
male		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate																	
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate	1				1												
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate	1					1											1
male	25-35	research/consultar	Canada	Organic fertilizers and AD-based digestates	No	humid continental climate	1	1	1		1		1	1								1	
male	>55	Public Sector	Venezuela	Forest management (incl. fire management)		Tropical savanna climate	1				1	1						1			1		
female	>55	Government	Venezuela	Forest management (incl. fire management)	Yes	Tropical savanna climate					1	1		1			1		1			1	
female	45-55	Land/forest user	Venezuela	Agroforestry	Yes	Tropical savanna climate					1	1										1	

Stakeholder Profile			Location				Climate Sensitivities T4.2																		
Gender	Age Group	Sector	Case Study Country	Assessed LMT	Developing Country	Climate	Carbon sequestration	Air quality	Nutrient Retention in soil	Water balance or "Hydric balance"	Soil Protection	Soil biome	Scenic Value of the Landscape	Diversity of plant life or "Phytodiversity	Macrofungi diversity	Soil Macrofauna Diversity	Bird Diversity	Habitat Diversity	Pollination	Climate Resilience	Fire risk reduction	Adaptive plant species	A more resilient cropping	Resilience to pests	Other Climate sensitivities
male	45-55	research/consultar	Netherlands	Peat soil rewetting and paludiculture	No	oceanic climate	1			1	1		1							1					
female	25-35	research/consultar	Netherlands	Agroforestry	No	oceanic climate	1		1	1								1					1		
male	25-35	Land/forest user	Netherlands	Peat soil rewetting and paludiculture	No	oceanic climate	1		1	1	1						1								
male	45-55	research/consultar	Netherlands	Domestic biomass based BECCS	No	oceanic climate	1	1	1		1		1										1		
female	>55	research/consultar	Netherlands	Peat soil rewetting and paludiculture	No	oceanic climate			**1**	1							1								
female	>55	Government	Indonesia	Agroforestry	Yes	humid tropical climate	1	1		1	1										1				
male	>55	research/consultar	Indonesia	Peat soil rewetting and paludiculture	Yes	humid tropical climate	1			1	1						1			1	1				
male	25-35	research/consultar	Indonesia	Agroforestry	Yes	humid tropical climate			1		1	1						1		1					
female	35-45	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1	1				1		1				1					
male	45-55	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1	1				1		1				1					
male	35-45	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1	1				1		1				1					
male	>55	Public Sector	Indonesia	Agroforestry	Yes	humid tropical climate	1		1	1				1		1				1					
female		Local Group/Comm	Indonesia	Agroforestry	Yes	humid tropical climate	1	1		1	1					1									
female	25-35	research/consultar	Indonesia	Agroforestry	Yes	humid tropical climate	1	1	1		1		1			1									
male	35-45	research/consultar	Indonesia	Agroforestry	Yes	humid tropical climate	1	1	2		1		1			1									
male	35-45	research/consultar	Indonesia	Peat soil rewetting and paludiculture	Yes	humid tropical climate	1			1	1			1							1				
male	>55	Land/forest user	Kenya	Afforestation/Reforestation	Yes	Hot semi-arid					1														
female	45-55	research/consultar	Kenya	Agroforestry	Yes	Hot semi-arid			1		1								1	1			1		
male	35-45	Local Group/Comm	Kenya	Agroforestry	Yes	Hot semi-arid	1					1	1	1	1										
female	25-35	research/consultar	Kenya	Cropland management	Yes	Hot semi-arid	1	1	1	1															
male	35-45	Land/forest user	Kenya	Cropland management	Yes	Hot semi-arid			1		1			1								1			
other/ur	>55	research/consultar	Nepal	Cropland management	Yes	humid subtropical climate		1																	1
other/ur	unknov	research/consultar	Nepal	Cropland management	Yes	humid subtropical climate																			
female	unknov	research/consultar	Nepal	Forest management (incl. fire management)	Yes	humid subtropical climate					1														
other/ur	unknov	research/consultar	Nepal	Agroforestry	Yes	humid subtropical climate								1											
male	unknov	research/consultar	Burkina Faso	Forest management (incl. fire management)	Yes	Hot semi-arid																			
female	unknov	research/consultar	Burkina Faso	Agroforestry	Yes	Hot semi-arid			1																
male	unknov	research/consultar	Burkina Faso	Cropland management	Yes	Hot semi-arid	1																		
male	unknov	research/consultar	Burkina Faso	Agroforestry	Yes	Hot semi-arid	1		1		1			1								1	1		
male	unknov	research/consultar	Burkina Faso	Cropland management	Yes	Hot semi-arid	1																		
other/ur	25-35	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	25-36	research/consultar	Sweden	Biochar	No	humid continental climate				1															1
other/ur	unknov	Public Sector	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Biochar	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Biochar	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	research/consultar	Sweden	Domestic biomass based BECCS	No	humid continental climate																			
other/ur	unknov	Land/forest user	Sweden	Afforestation/Reforestation	No	humid continental climate																			
male	45-55	research/consultar	Vietnam	Afforestation/Reforestation	Yes	Tropical savanna climate	1			1	1							1							
female	25-35		Vietnam	Agroforestry	Yes	Tropical savanna climate					1			1				1		1			1		
male	35-45	research/consultar	Vietnam	Agroforestry	Yes	Tropical savanna climate	1				1							1		1			1	1	
male	45-55	research/consultar	Vietnam	Agroforestry	Yes	Tropical savanna climate	1		1	1		1		1									1		
male	45-56	research/consultar	Vietnam	Agroforestry	Yes	Tropical savanna climate			1	1	1	1				1							1		
other/ur	unknov	research/consultar	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate	1																1		
other/ur	unknov	Local Group/Comm	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate	1		1	1	1					1		1		1					
other/ur	other/u	research/consultar	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate																			
other/ur	unknov	Local Group/Comm	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate				1									1						
other/ur	unknov	Local Group/Comm	Switzerland	Organic fertilizers and AD-based digestates	No	humid continental climate	1		1	1	1									1			1		
other/ur	unknov	research/consultar	Switzerland	Biochar	No	humid continental climate	1		1	1	1														1

Stakeholder Profile			Location				Climate Sensitivities T4.2																		
Gender	Age Group	Sector	Case Study Country	Assessed LMT	Developing Country	Climate	Carbon sequestration	Air quality	Nutrient Retention in soil	Water balance or "Hydric balance"	Soil Protection	Soil biome	Scenic Value of the Landscape	Diversity of plant life or "Phytodiversity	Macrofungi diversity	Soil Macrofauna Diversity	Bird Diversity	Habitat Diversity	Pollination	Climate Resilience	Fire risk reduction	Adaptive plant species	A more resilient cropping	Resilience to pests	Other Climate sensitivities
other/ur	unknov	Local Group/Comm	Switzerland	Reduced/no-tillage	No	humid continental climate	1		1	1	1												1		
other/ur	unknov	Local Group/Comm	Switzerland	Reduced/no-tillage	No	humid continental climate	1		1	1	1	1				1									1
other/ur	unknov	Local Group/Comm	Switzerland	Reduced/no-tillage	No	humid continental climate			1	1		1				1	1	1						1	
male	>55	Land/forest user	Spain	Afforestation/Reforestation	No	Hot-summer Mediterranean	1			1	1			1				1		1					
male	35-45	Government	Spain	Forest management (incl. fire management)	No	Hot-summer Mediterranean		1	1	1				1				1			1				
male	>55	Land/forest user	Spain	Avoided grassland conversion	No	Hot-summer Mediterranean	1		1	1			1	1			1			1					
male	>55	research/consultar	Spain	Avoided grassland conversion	No	Hot-summer Mediterranean	1		1	1	1				1					1					
male	>55	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean			1	1	1		1	1					1	1					
male	35-45	Local Group/Comm	Spain	Forest management (incl. fire management)	No	Hot-summer Mediterranean		1		1	1			1	1			1		1					
male	>55	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean	1		1	1	1		1	1	1		1	1			1				1
female	35-45	Public Sector	Spain	Afforestation/Reforestation	No	Hot-summer Mediterranean	1		1	1	1					1	1	1	1					1	
female	35-45	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean	1		1	1	1	1	1			1		1		1	1				
female	>55	Land/forest user	Spain	Agroforestry	No	Hot-summer Mediterranean							1	1	1	1	1	1		1	1	1	1		
male	35-45	research/consultar	Spain	Agroforestry	No	Hot-summer Mediterranean	1			1	1			1				1		1	1				
male	45-55	unknown	Burkina Faso	Cropland management	Yes	Hot semi-arid																			
male	unknov	Government	Burkina Faso	Agroforestry	Yes	Hot semi-arid																			
male	unknov	research/consultar	Burkina Faso	Agroforestry	Yes	Hot semi-arid																			
male	unknov	Government	Burkina Faso	Agroforestry	Yes	Hot semi-arid																			
male	unknov	Government	Burkina Faso	Cropland management	Yes	Hot semi-arid																			
male	unknov	research/consultar	Burkina Faso	Reduced/no-tillage	Yes	Hot semi-arid	1		1		1														
male	unknov	research/consultar	Burkina Faso	Cropland management	Yes	Hot semi-arid	1			1	1														1
male	unknov	research/consultar	Burkina Faso	Crop rotation	Yes	Hot semi-arid														1			1	1	
male	unknov	Local Group/Comm	Burkina Faso	Forest management (incl. fire management)	Yes	Hot semi-arid																			
male	unknov	Government	Burkina Faso	Cropland management	Yes	Hot semi-arid																			
male	unknov	Local Group/Comm	Burkina Faso	Cropland management	Yes	Hot semi-arid				1	1														
female	unknov	Local Group/Comm	Burkina Faso	Cropland management	Yes	Hot semi-arid																			
female	unknov	Local Group/Comm	Burkina Faso	Cropland management	Yes	Hot semi-arid			1	1	1									1				1	1
male	35-45	research/consultar	Germany	Forest management (incl. fire management)	No	humid continental climate	1		1	1	1														
male	>55	research/consultar	Germany	Peat soil rewetting and paludiculture	No	humid continental climate				1	1						1			1	1				
female	25-35	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1		1		1							1					1		
male	>55	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1		1		1			1									1		
female	35-45	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1		1		1							1					1		
male	45-55	Land/forest user	Portugal	Agroforestry	No	Hot-summer Mediterranean	1		1		1			1									1		
male		Land/forest user	Canada	Biochar	No	humid continental climate	1	1	1	1		1			1	1	1		1	1	1				
female		research/consultar	Canada	Afforestation/Reforestation	No	humid continental climate							1												
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate																			
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate																			
male		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate																			
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate	1						1												
female		research/consultar	Canada	Peat soil rewetting and paludiculture	No	humid continental climate														1					
male	25-35	research/consultar	Canada	Organic fertilizers and AD-based digestates	No	humid continental climate	1		1	1	1	1	1						1	1					
male	>55	Public Sector	Venezuela	Forest management (incl. fire management)		Tropical savanna climate		1		1	1			1	1	1	1	1	1		1				
female	>55	Government	Venezuela	Forest management (incl. fire management)	Yes	Tropical savanna climate			1	1	1										1		1		
female	45-55	Land/forest user	Venezuela	Agroforestry	Yes	Tropical savanna climate				1							1			1	1		1	1	

LANDMARC

A CLIMATE RISK ASSESSMENT TOOL FOR LMTS

CLIMATE RISK ASSESSMENT TOOL FOR LAND-BASED MITIGATION TECHNOLOGIES AND PRACTICES

A. CEMIN, B. WEAR, C. CISCATO, F. DOSSI, I. SONAK, L. GONTSCHAROFF

WUR #

STATUS: PUBLIC

This project has received funding from the European Unions' Horizon2020 Grant Agreement No 869367

LANDMARC

Land-use based Mitigation for Resilient Climate Pathways

GA No. 869367 [RIA]

Deliverable number	*Annex I to D4.1: Climate risk assessment and initial risk management plan*
Deliverable name	*Climate risk assessment tool for land-based mitigation technologies and practices*
WP / WP number	*4*
Delivery due date	*Date [31/12/2022] – M30*
Actual date of submission	*03/06/2022*
Dissemination level	*[public]*
Lead beneficiary	*JIN*
Responsible scientist / administrator	*E. Spijker (JIN – commissioner and supervisor)*
Contributor(s)	*Arianna Cemin, Brigitte Wear, Chiara Ciscato, Federica Dossi, Ishani Sonak, Loulou Gontscharoff (WUR)*
Reviewer(s)	*P. Lourencio (AgroInsider), F. Julian (Ambienta), E. Spijker (JIN), C. Picon (JIN) Student supervisor B. Kruijt (WUR)*
Changes with respect to the DoA	*N.A.*
Dissemination and uptake	*Risk managers in AFOLU sectors and supply chains linked to AFOLU sectors aiming to implement LMTs and actively engage with relevant stakeholders can use and build upon the ideas, concepts, information and tool developed and presented within this report.*

Preface

Negative emission solutions are expected to play a pivotal role in future climate actions and net zero emissions policy scenarios. To date most climate actions have focussed on phasing out fossil fuels and reducing greenhouse gas emissions in, for example, industry, electricity, and transport. While zero emission trajectories in these sectors will remain a priority for decades to come, it is expected that residual GHG emissions will remain. To be able to fulfil the Paris Agreement and meet the world's climate goals research, policy and markets are increasingly looking at negative emission solutions.

This is why the nineteen LANDMARC consortium partners work together in order to:

- Estimate the climate impact of land-based negative emission solutions, in agriculture, forestry, and other land-use sectors
- Assess the potential for regional and global upscaling of negative emission solutions
- Map their potential environmental, economic, and social co-benefits and trade-offs

LANDMARC is an interdisciplinary consortium with expertise from ecology, engineering, climate sciences, global carbon cycle, soil sciences, satellite earth observation sciences, agronomy, economics, social sciences, and business. There is a balanced representation of partners from academia, SMEs, and NGOs from the EU, Africa, Asia and the Americas, which ensures a wide coverage of LMTs operating in different contexts (e.g. climates, land-use practices, socio-economic etc.) and spatial scales.

The LANDMARC project consortium:

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Acknowledgements

This report has been produced within the framework of the LANDMARC project.

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Disclaimer 2:

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Abstract

To mitigate the impact of climate change, carbon concentrations in the atmosphere must decrease. One way to achieve this is by implementing land-based mitigation technologies (LMTs). LMTs are nature-based solutions that sequester carbon, such as afforestation. However, the capacity of the LMTs to do so is threatened by climatic risks. For example, more wildfires due to increased temperatures will lead to the loss of vegetation and, consequently, a large part of the stored carbon.

To ensure the permanence of carbon in these LMTs, climatic risks need to be addressed. However, in traditional risk management, climatic risks are often not included. Therefore, climate risk assessment (CRA) is essential in identifying and prioritising climate action. This project aims to identify and assess the climatic risks that impact the functioning of the chosen LMTs and to create a user-friendly guidance tool for the stakeholders implementing these LMTs. The tool is developed keeping in mind four steps of a CRA framework: risk identification, characterization, prioritisation, and action planning.

The LMTs we focus on are afforestation and agroforestry in Spain and Portugal. In total, eight climatic risks for the two LMTs were identified:

I. Drought
II. Desertification
III. Heat wave
IV. Heavy storm
V. Soil erosion
VI. Shrub expansion
VII. Soil and plant disease
VIII. Wildfire

Stakeholders can identify one or multiple risks through a flowchart with yes/no questions, as the first step in the tool. Afterwards, a video by means of augmented reality will help characterise the risk(s). For each of the identified risks, potential risk management actions were identified. A guiding table is developed to help the stakeholders design their own action plan.

The project entails a bottom-up approach which will help stakeholders identify and manage the risks climate change poses to their project, as the endeavour of the project is to create a shift away from the top-down approach of CRA. This has been achieved through a participatory tool which guides the stakeholder(s) in understanding the qualitative and quantitative aspects of climate risks. The idea is not to tell them what to do but to provide inspiration on how to manage the risks they face. In combination with their traditional knowledge, the tool provides guidance to enable stakeholders to design their own action plan to manage climate risks faced in their LMTs.

1. Introduction

1.1 Background

The concentration of greenhouse gases in the atmosphere has increased in the last decades, largely due to anthropogenic activities such as the burning of fossil fuels. This has led to climate change, which among other effects, is resulting in changes in temperature and precipitation patterns and increasing the frequency and intensity of extreme weather events. This is an existential threat to humanity and ecological systems. To mitigate this threat, climate action is imperative.

One of the main climate action strategies is the use of land-based mitigation technologies (LMTs). LMTs include, among others, agroforestry, afforestation, rewetting peatland, grassland management and reforestation. These aim to sequester carbon from the atmosphere and/or keep carbon stored in the terrestrial ecosystem. LMTs have been shown to mitigate around 10–15 Gt CO_2eq yr^{-1} globally by 2050 (Roe et al., 2021). Therefore, trust from the climate action community has been put into the effectiveness of these LMTs.

1.2 Rationale

In the wake of climate change and its adverse consequences on humanity and ecological systems, it becomes imperative to assess the risks climate change poses on the permanence of carbon through LMTs as the carbon stored through these LMTs can be re-emitted due to sudden climatic risks. To be climate relevant, the impact of such LMTs needs to be permanent. Therefore, Climate Risk Assessment (CRA) becomes crucial to help identify the likelihood of climatic risks (for example a heatwave) and their potential impacts on the continuation of LMTs. CRA is fundamental in characterising and prioritising climate action and provides support for further investment in climate adaptation and resilience strategies. Furthermore, when accompanied with a management plan, it supports the development of adaptation and climate proofing activities. Hence, the CRA framework can be pivotal for different stakeholders at local, national, and international level.

1.3 Aims of the project

The project entails developing a participatory CRA for a range of LMTs. The main aims of this project are, firstly, to identify and assess the risks posed by climate change for effective functioning of chosen LMTs. The second aim is to develop an engaging, user-friendly guidance tool for climate-related risk management of the two LMTs selected above. This tool will guide a variety of stakeholders in understanding their climate risks and how to manage these. The tool may also be reproduced and adapted to different geographical and socio- economic contexts.

Overall, the idea is to bridge the gap between research and practice in the context of climate change mitigation. By achieving these goals, we will address the needs of different stakeholders and contribute towards creating a climate-resilient future.

1.4 Regional context

This project focuses on LMTs in Spain and Portugal as the two countries have a high level of exposure to climate change and a low adaptive capacity. They are some of the most vulnerable countries to climate change within the European Union (Vargas-Amelin & Pindado, 2014).

In Spain, the principal threats faced under climate change include an increase in temperatures and a decline in precipitation. This could result in a significant reduction in water availability, exacerbating aridity and desertification (Vargas-Amelin & Pindado, 2014). It is also predicted that climatic shifts could lead to increased soil erosion and an increment in the frequency and intensity of extreme events, such as floods, wildfires, and heat waves (Ibid).

In Portugal, climate change is exacerbating extreme events associated with lack and excess of rainfall, causing droughts and floods. In the last decade, mean and extreme temperatures have been increasing whereas precipitations have substantially reduced. Storms, heat waves and wildfires have become more frequent, threatening biodiversity (Schleussner et al., 2019). Moreover, sea level rise is a risk to populations along the coast and surrounding areas (Ibid).

Land management in both countries offers new approaches to mitigation. In particular, silvo-pasture and forested ecosystems substantially contribute to carbon sequestration from the atmosphere (Howlett et al., 2011). Landscape systems such as dehesa in Western Spain and montado in Southern Portugal (such as in Alentejo) represent fundamental economic and cultural heritage. Economically, the harvest of cork, a non-timber forest product, is the main source of income. In addition, other than being exported, the Iberian pig that is bred there is a typical gastronomic component of the Iberian cuisine, alongside aromatic plants, and acorn-based products (Bugalho et al, 2018). Additionally, the cultural ecosystem services offered by these landscapes include recreational spaces and touristic destinations (Ibid). Therefore, these landscapes in these two countries have been chosen for the purpose of this project.

2. Methodology

2.1 Literature review

Extensive literature review conducted during this project provides information for this report and the tool. Specifically, we used the review to understand traditional risk assessment strategies, the climate risks and management strategies for the selected LMTs, policies on afforestation and agroforestry in Spain and Portugal, and risk definitions and thresholds. The review was carried out through searching keywords (such as "agroforestry", "afforestation", and "climate risks") using Google Scholar (https://scholar.google.com/) and the WUR online library (https://www.wur.nl/en/library.htm).

In addition to the literature review, we also received information from JIN on climate risk assessment methods, stakeholder repository for afforestation in Extremadura, and completed sample questionnaires on climate risk assessment for agroforestry and afforestation projects in Indonesia and Kenya. We also received responses from JIN's Spanish and Portuguese partners (Ambienta and Agroinsider) for specific questions we had on agroforestry and afforestation in Spain and Portugal. For detailed information, see Appendix I.

This tool has been designed to help different stakeholders navigate the field of CRA and climate-related risks through four main steps: identification, characterisation, prioritisation, and action planning. Identification is done through following the questions in the flowchart and characterisation is done through watching the video using augmented reality. Action planning can be achieved through following the guidance table with leading questions and examining the completed example tables.

2.2 Development of the tool

The tool was envisioned as an interactive and participatory instrument which will guide the stakeholder to minimise the impact of climate risks on the chosen LMTs. A holistic tool which considers the complexity of the interactions among multiple climate variables and how they cascade is yet to be achieved. Generally, climate risk assessment frameworks work from a top-down approach, but this tool was envisioned with a bottom-up approach. Keeping that into consideration, we designed a tool composed of two elements: a flowchart which leads to an image and an augmented reality which produces a video. The flowchart will walk the users through a set of questions to identify climate risks and is produced using Lucid (https://lucid.app). The images for the risks were found using the open-source database UnSplash (https://unsplash.com). These were then edited in Canva (www.canva.com) where the risks were superimposed onto the images. Slides with implications and management strategies for each risk were also produced in Canva. All these images and slides were converted into PowerPoint, where a recording of a voiceover and slides was made for each set of risks. This recording was then converted to an MP4 file.

Augmented reality was achieved using Artivive (https://artivive.com), where an image with a risk (from Canva) is added as a base image and the MP4 file from PowerPoint is used as the video. This video is shown when the user scans the base image using the Artivive App on their smartphone/tablet (see Tool Manual Section of this report to understand how it works). The tool was envisioned as an interactive and participatory instrument which will guide the stakeholder to minimise the impact of climate risks on the chosen LMTs. A holistic tool which considers the complexity of the interactions among multiple climate variables and how they cascade is yet to be achieved. Generally, climate risk assessment frameworks work from a top-down approach, but this tool was envisioned with a bottom-up approach. Keeping that into consideration, we designed a tool composed of two elements: a flowchart which leads to an image and an augmented reality which produces a video. The flowchart will walk the users through a set of questions to identify climate risks and is produced using Lucid (https://lucid.app).

The questions used in the flowchart are based on the literature review. During the literature review, we identified multiple causes of each risk and integrated the most important ones by converting them into questions. At the start point of the flowchart, we begin with the basic cause of a risk and progress towards more scientific ones which eventually land the stakeholder to a risk or a bundle of risks. However, we were faced with the dilemma of how to frame scientifically relevant yet user-friendly questions. At first, we planned on developing a flowchart based only on qualitative and perceived climatic risks but later we decided to integrate perceived risks to scientific thresholds. Moreover, throughout the development of the flowchart, we considered the most socio-economically relevant risk implications, so that the stakeholder could relate to them.

The idea behind integrating the action planning stage of the CRA in the tool was to develop a guiding table with relevant questions. This was conceptualised in a way where we did not give a set of directions to the stakeholders. It was rather to facilitate the problem-solving process for the stakeholder by helping them to design a tailor-made action plan. Two example action plans are attached to the tool to act as inspiration for the stakeholders.

3. Climate risk assessment

Risk assessment plays a fundamental role in decision-making processes for institutions, financial projects, supply chain management, health and safety, infrastructure, and engineering, and managing ecological and disaster risks. Traditionally, risk assessment aims to identify, conceptualise, and analyse potential events which may have negative consequences on a desired outcome. In addition to identifying and evaluating the nature and extent of the risk, risk assessment also includes selection of management strategies which can be applied to reduce and prevent the damage from potential events (Adger et al., 2018) (see Figure 1). However, due to the specificity of the factors analysed, risk assessment is highly context dependent.

Figure 1: Five steps of risk assessment

As the impacts of climate change become increasingly severe, climatic risks need to be urgently addressed and integrated into current risk assessment frameworks. Hence, the need to mainstream CRA in traditional risk assessment becomes imperative. This will help tackle the challenge of climate change at a local level.

CRA consists of 4 overarching phases (see Figure 2). The first phase is risk identification, which is where stakeholders make an initial assessment of the climate risks that they face in relation to the operationalisation and effectiveness of their projects. The second phase is risk characterisation, where risks identified in the first phase are categorised in terms of severity and likelihood of impact. Here, potential mitigation actions are also mentioned. The third phase is risk prioritisation, where risks are ranked in importance to enable most urgent risks to be tackled first. The fourth and final phase is action planning, which entails the planning and implementation of solutions towards climate risks. Action planning includes the costs, funding opportunities, timing, and responsibilities to achieve these solutions (JIN, 2016).

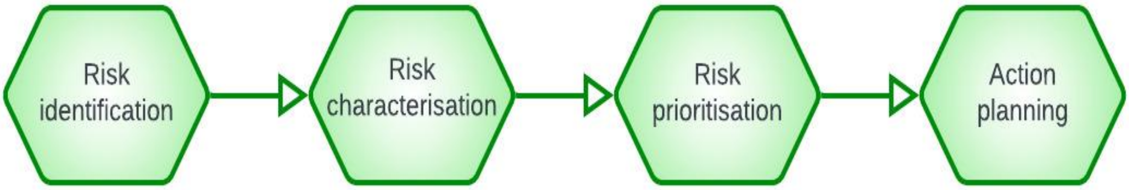

Figure 2: The four phases of CRA

To prepare for CRA, the first step is stakeholder mapping, which is carried out to visualise stakeholders involved in a project. It helps to identify relevant stakeholders, their interests, influence, responsibilities, and level of engagement in the project. It also helps to categorise stakeholders and their relationship with each other which makes it possible for the CRA tool to be tailor-made to different stakeholders and their specific contexts.

For this project, the CRA tool has been designed for the farmers/ landowners/ cooperatives, as they are the ones who implement the LMTs and potential risk management strategies. Moreover, other stakeholders such as governmental authorities and NGOs have been identified to have a high interest in the implementation of these LMTs and have the assets to do so (see Figure 3). Therefore, these stakeholders can play a vital role in assisting the farmers/ landowners in implementing these LMTs.

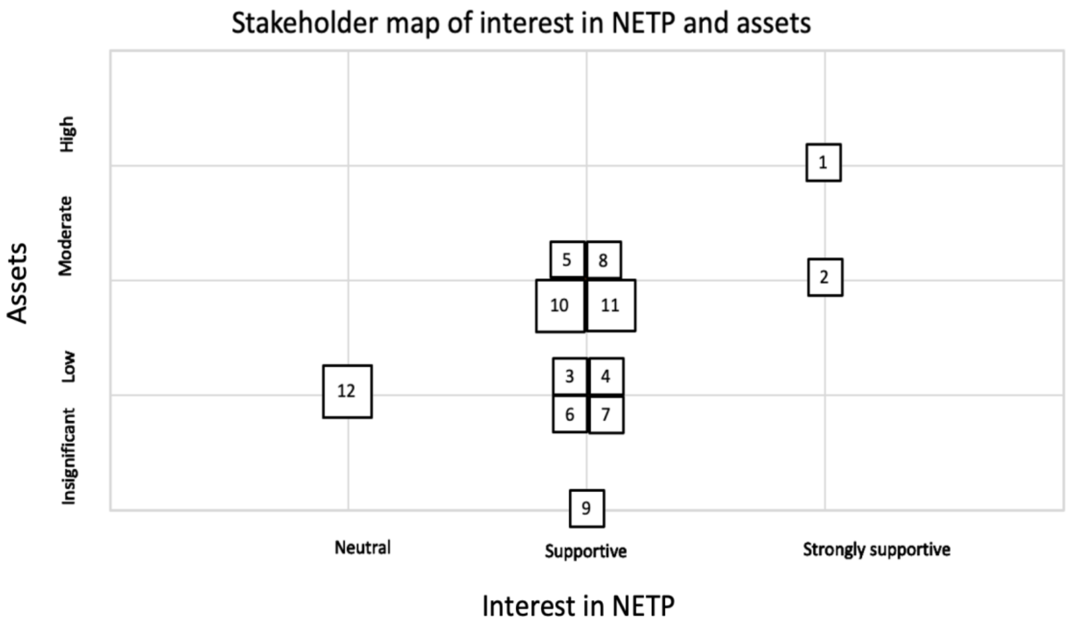

Figure 3: Stakeholder mapping

The following image shows the level of interest of stakeholder in Negative Emissions Technologies and Practices (NETPs) and the assets these stakeholders have. NETPs are technologies which sequester and store carbon from the atmosphere, these include LMTs as well as geoengineering and other carbon storage technologies (NASEM, et al. 2018). Assets are defined as equipment, products, construction, and infrastructure that stakeholders have for implementation of NETPs. The stakeholders in the map are those for reforestation programs on degraded agricultural land in Extremadura, Spain. The numbers refer to different stakeholders, see Appendix II for an overview of these stakeholders.

4. LMT selection and analysis

4.1 Selected LMTs

The two LMTs that we focus on in this project are afforestation in Extremadura (an autonomous region of Western Spain) and agroforestry in dehesa and montado in Spain and Portugal, respectively.

Agroforestry

Agroforestry is a land-use system where trees, crops and/or livestock are integrated on the same area of land. This concept is based on the premise that, compared to a monoculture, an integrated system improves the availability and utilisation of natural resources (Nair et al, 1993). Especially in the context of climate change, agroforestry practices help diversify the landscape and include a large variety of economic, environmental, and social benefits (Ibid). Agroforestry simultaneously captures carbon below- and above-ground, with a potential to create long-lasting reservoirs of CO_2 (Nair et al, 2010).

Among the different types of agroforestry practices, silvo-pastoral systems like dehesa and montado are characterised by the integration of trees and grazing animals on the same land (Rigueiro-Rodríguez et al., 2008).

Afforestation

Afforestation is the expansion of forest areas through either active tree planting or passive/natural regeneration (Doelman et al., 2019). Afforestation practices are LMTs as trees sequester carbon from the atmosphere. Some studies suggest that afforestation could play a major role in the mitigation of climate change. For example, Griscom et al. (2017) suggest that 10.3 $GtCO_2$ could be sequestered per year on 678 Mha of land by 2030.

4.2 Interconnection between risks

In total, eight climatic risks for the above mentioned two LMTs were identified[1]:

I. Drought;
II. Desertification;
III. Heat wave;
IV. Heavy storm;
V. Soil erosion;
VI. Shrub expansion;
VII. Soil and plant disease;
VIII. Wildfire

They are discussed in detail in this section. Figure 4 shows the correlation we may encounter between the risks identified through Climate Risk Assessment (CRA). This flowchart shows how the presence of a climate risk is inevitably linked to other risks that various stakeholders may encounter.

[1] See Tool Manual for Risk definitions

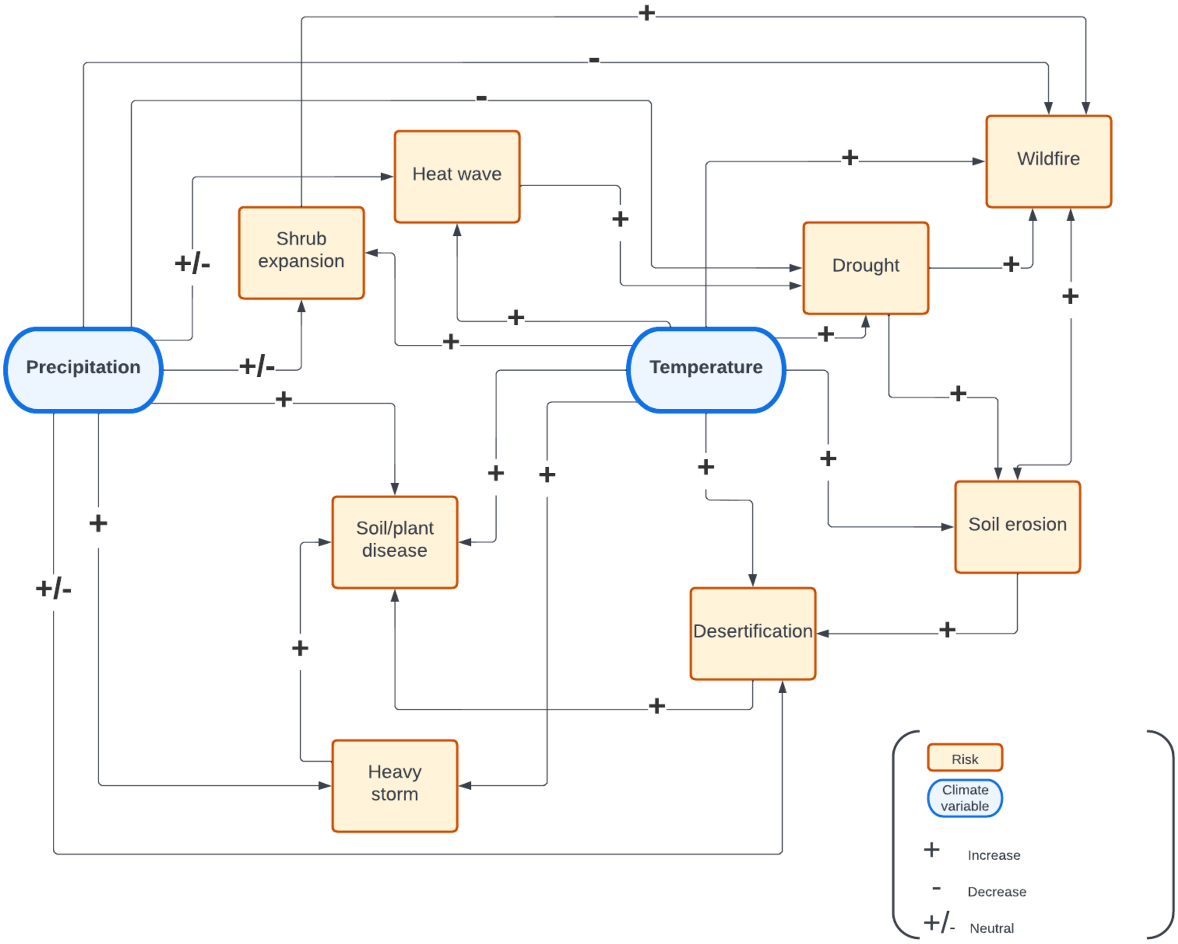

Figure 4: Interconnection between the risks

4.3 Dehesa and Montado

4.3.1 Introduction

The Dehesa is one of the most valued and widespread silvo-pastoral systems in the Iberian Peninsula. It occupies an estimated 4 million hectares in Spain and around 1 million hectares in Portugal, where it is called Montado (FEDEHESA, 2020) (Figure 5). Dehesa and Montado are considered among the most 'High Nature Value' (HNV) farming and forestry systems by the European Union. It involves a range of sustainable traditional management practices, with associated recognisable environmental values (Ibid). Dehesa and Montado are characterised by a Mediterranean climate and the extended biodiversity is explained by a variety of microhabitats: areas of sparse woodland, areas with dense bushes and trees, open areas intertwined with streams of trees and bushes, where we find a floral diversity that is almost unsurpassed on the planet (Ibid).

Figure 5: Map showing Dehesa and Montado in green, retrieved May 19, 2022 from https://www.alamy.com

Dehesa and montado involve two main oak tree species, *Quercus suber* and *Quercus rotundifolia* (Ferraz-de-Oliveira et al., 2016), intermixed with crops such as barley and oat. Moreover, livestock such as cattle, sheep, goats, and pigs boost the sustainability and economic viability of the system (Ibid).

4.3.2 Climate risks in dehesa and montado

Dehesa and montado are under severe threats from climate change. These risks are droughts, heavy storms, soil erosion, soil and plant diseases, wildfires, shrub expansion, and heat waves. Dehesa and montado face additional challenges, see Appendix III for more details.

Droughts

Risk: During the dry season, water scarcity is a significant limiting factor and droughts become more frequent. Under these conditions, the Gross Primary Production (GPP) and ecosystem respiration are reduced, reducing productivity and Net Primary Production (NPP), thus contributing to the inter-annual variation of soil carbon sequestration. This happens because plants lack the adequate water level to maintain the photosynthetic tissues alive, leading to stomatal closure. In addition, droughts increase resource competition between species, leading to local species extinction (Pereira et al., 2007). Intense drought events are the main limiting factors for tree recruitment, by reducing reproductive effort, enhancing abortion rates, and encouraging seed predation by insects (Diaz et al., 2021). Increase in temperature can also induce earlier senescence of the tree's tissues (Pereira et al., 2007; Pérez-Girón et al., 2022).

Risk management options: To minimise the impacts of droughts, it is necessary to plant drought-tolerance crop and tree varieties, such as *Quercus suber* (Pereira et al, 2007). To avoid tree weakening, practices such as tree over-pruning and frequent cork harvesting should be avoided (Pinto-Correia &

Mascarenhas, 1999b). In addition, better rainwater harvesting management will help increase the water available for irrigation (Velasco-Muñoz et al., 2019).

Heavy storm

Risk: Under extreme dry conditions brought about by climate change, high-intensity storms exceed the ability of soils to retain water, causing overflow (Ceballos and Schnabel, 1998). Moreover, heavy storms can lead to soil erosion and leaching of nutrients (Ramos & Martínez-Casasnovas, 2004). In old oak forests, heavy storms are generally not perceived as a high-level risk (Martínez et al., 2013). However, understorey crops are generally more sensitive to the impacts of heavy storms than trees in agroforestry systems. Heavy storms can cause significant damage to cereals such as wheat and lead to yield losses (Elahi et al., 2021; van der Velde et al., 2011).

Risk management options: Coping with heavy storms often requires technological infrastructure, such as better drainage systems which store water onsite and decrease surface water runoff (Keesstra et al., 2018). To minimise crop damage, a solution is to plant crop varieties which are more resistant to heavy rainfall and high wind speed. For example, planting varieties of thick-stem wheat (Elahi et al., 2021). Another management solution is planting shelterbelts around the crop field to protect crops from storm, wind, and soil erosion (Ibid). As for hail and windstorms, anti-hail nets can help minimise and sometimes even prevent damage to the area of interest (Iglesias and Alegre, 2006).

Soil erosion

Risk: Climate change is exacerbating extreme weather events, contributing to soil erosion. In dehesa and montado, it is mainly driven by heavy rainfall, with highest erosive events causing 25% of soil loss (González-Hidalgo et al., 2007). Soil erosion occurs in the upper soil layers, where water is lost mainly through accelerated evaporation due to increasing temperatures. Mediterranean soils are characterised by shallow soils with nutrients concentrated near the surface. Therefore, soil erosion poses a significant risk to the fertility of the soil as nutrients are easily leached (Shakesby, 2011). A further risk is the formation of gullies, created by the erosion of soil (Evelpidou et al., 2019).

Risk management option: To cope with soil degradation, crop rotation and replacement with legume-rich crops maintain high levels of soil nutrients, reinforcing the nitrogen-fixation process and at the same time feeding the animals (Napoli et al., 2017). Another good practice is reducing tillage to avoid CO_2 dispersion into the atmosphere. If tillage is an unavoidable management strategy, conservation tillage can be done, therefore preserving the soil organic carbon stock and enhancing nutrient infiltration and uptake (Evelpidou et al.,2019). Additionally, mulching can include vegetative materials or biological textile gravel spread on the soil surface to create a protective cover, to reduce. As a result, evapotranspiration and erosion are reduced, and increase infiltration is increased (Ibid). Soil erosion can also be prevented by avoiding the use of heavy machinery that would easily break roots (Pinto-Correia & Mascarenhas, 1999b).

Soil and plant disease

Risk: Under extreme precipitation and prolonged dry periods, several diseases can spread across dehesa and montado systems, directly affecting trees and soil. *Phytophthora cinnamomi* (Pc) is a soil-borne non-native pathogen that has significantly contributed to the decline of oak trees in these regions (Da Clara et al., 2013). Pc is the main cause of root rot in oak trees, constraining water uptake through the demolition of fine roots (Sánchez-Cuesta et al., 2021). The occurrence of *Phytophthora* species is enhanced by precipitation fluctuations ranging from flooding to water deficiency, favoured in periods of high temperatures (Pereira et al., 2007; Pérez-Girón et al., 2022). Moist soils, namely with higher water retention capacity, are the best hosts to Pc (Dunstan et al., 2020). In dehesa, pathogens and diseases occur due to the lack of daily management. Insufficient management causes the tree to become weaker and to age faster, the perfect host for Pc.

Risk management options: Regeneration and renewal of trees is crucial since the healthier the system is, the more resilient it is to climate risks. In the current and even more in the future climate conditions, regeneration of trees needs to be supported by human intervention (Caceres et al., 2017). Several techniques have been proposed for directly coping with Pc. Trees injected with potassium phosphate in the trunk can be optimal to eliminate the pathogen (Corcobado et al., 2013). In addition, fertilisers containing calcium can be added to enhance soil alkalinity, where Pc shows low virulence and incidence (Duque-Lazo et al., 2018). To help avoid the spread of this pathogen, the soil portion where the disease is directly visible can be removed and agricultural materials, such as machinery and equipment, can be disinfected (Sena et al.,2018). Moreover, good management of the site is recommended, with restricted entrance for humans and animals in the infected areas (Duque-Lazo et al., 2018). As shown by several studies, fallow is another agricultural practice that contributes significantly to Pc decline (Dunstan et al., 2020).

Wildfires

Risk: In Mediterranean regions like dehesa and montado, wildfires have historically been among the major risks. Now, due to climate change, wildfires are surging in these regions, mostly identified where ploughing and livestock grazing have decreased (Pereira et al., 2007). Wildfires are triggered under extreme climate conditions such as drought seasons, where soil erosion is high and drought-adapted deciduous and evergreen shrubs grow (Evelpidou et al.,2019). Wildfires usually target adult trees, especially after cork extraction, which usually takes place in summer (Acácio et al., 2009). However, oaks remain less inflammable due to their thick bark (Ibid). As a consequence, tree loss due to wildfires converts forests into shrublands, which regenerate more quickly (Ibid). There is also an increased risk of soil erosion after fires. This is because the combustion of vegetation and leaf litter reduces surface area for transpiration and evaporation and reduces the soil's water retention capacity. Overland flow increases due to the decrease in obstacles preventing runoff (Shakesby, 2011). In addition, the soil surface can become hydrophobic due to the change in chemical properties of burnt soil (Evelpidou et al., 2019).

Risk management options: To address wildfire prevention, shrub cutting is a suitable option, as it clears the land from inflammable shrub cover (Tárrega et al., 2009). One way to reduce shrub cover is through livestock grazing (Ibid). Another solution is to choose less flammable species (Pausas et al., 2004). For example, cork oak (*Quercus suber*) is relatively fire-resistant due to the presence of suberin in the cells of the bark. The cork insulates dormant buds, allowing cork oak to regenerate after fire. However, the removal of cork bark substantially increases the risk of cork oak damage and death from fire (Silva & Catry, F, 2006).

Shrub expansion

Risk: Due to the presence of shrubs *Cistus ladanifer* and *Retama sphaerocarpa*, Mediterranean silvo-pastures are more prone to droughts and water scarcity (Rolo et al., 2020). *Cistus ladanifer* is a shallow-rooted shrub that colonises degraded areas (Godinho et al., 2016). It is highly water-demanding and successfully competes with other species for surface-layered resources (Diaz et al., 2021). *Retama sphaerocarpa* is a leafless N-fixing, deep-rooted shrub, which has a lower impact on upper-layer soil moisture than *Cistus ladanifer*. However, when water is already scarce, the presence of *Retama sphaerocarpa* decreases the water available to trees (Rolo et al., 2020). The coexistence of trees and shrubs substantially decreases relative extractable water and increases competition between species. Moreover, the presence of shrubs can increase the risk of wildfires, as they replace oak trees and are more flammable (Godinho et al., 2016).

Risk management options: Shrub cutting is the most effective practice to cope with shrub encroachment, to clear the land from excessive shrub cover (Rolo & Moreno, 2019). Low to medium livestock grazing helps this process, as cattle usually sustains on bushes (Acácio et al., 2009). Another management intervention is the increase of nutrients in the soil, as this can rebalance belowground competition over resources (Henkin, 2021).

Heat wave

Risk: In the past years, the number of heat waves has been surging and is likely to quadruple by 2040 (Teskey et al., 2014). Heat waves have negative consequences on tree functions: photosynthesis is reduced, leaf growth is reduced, and tree mortality is exacerbated (Ibid). In a scenario of increased climatic variability, heat waves will have dramatic consequences on Mediterranean silvo-pastures. These phenomena are usually coupled with increase in drought and water scarcity, as well as the subsequent aridification of the land (Carpintero Garcia, 2021). In savannah-type regions, land productivity is negatively affected by heat events and vegetation may not adapt quickly enough to the new conditions (Flach et al., 2021).

Risk management options: Under extreme heat conditions, the main focus should be on reducing competition over water resources. To this end, adjusting tree density through pruning and shrub clearing is a potential management option (Pinheiro et al., 2022). However, if too intense, shrub clearing reduces carbon stocks and carbon sequestration of the LMT. Moreover, avoiding *Q. Suber* cork stripping would pose less stress on the ecosystem (Ibid). Another useful practice is irrigation, as oaks have both superficial and deep roots that can access water more easily (Morales et al., 2021).

4.4 Afforestation or marginal lands in Extremadura

4.4.1 Introduction

In the last 150 years, afforestation projects in Spain have covered more than 5 million hectares, equivalent to approximately 10% of the country's area (Herguido Sevillano et al., 2018) (Figure 6). As of 2003, it was estimated that 80,000 hectares of Extremadura had been afforested (European Forum on Nature Conservation and Pastoralism [EFNCP] , 2003). The two main species planted in afforestation in Extremadura are holm oak (*Quercus ilex,* subsp *ilex* and subsp. *rotundifolia*) and cork oak (*Quercus suber)*. Less commonly planted species include pines (*Pinus* spp.), olive (*Olea europaea*) and ash (*Fraxinus* spp.), among others (Herguido Sevillano et al., 2018).

Figure 6: Map of Spain showing location of Extremadura, taken from STEPMAP (https://www.stepmap.com/map/extremadura--cIqFh9elFm; created 07.06.2017)

4.4.2 Climate risks in afforestation in Extremadura

For afforestation projects in Extremadura, the climate risks include water scarcity and droughts, heat waves, wildfires, desertification and soil and plant disease. Afforestation faces additional challenges, see Appendix III for more details.

Reduced water availability and droughts

Risk: With climate change, Extremadura is experiencing reduced water availability (Moral et al., 2015), and prolonged periods of water scarcity could lead to drought conditions. In combination with high temperatures, droughts in the summer can be particularly damaging to trees. One of the physiological constraints that trees, such as oak trees (*Quercus* spp.), face is xylem cavitation with drought conditions, where the xylem collapses leading to the desiccation of plant tissue and death of trees (Urli et al., 2013).

Risk management options: To reduce the impact of droughts, more drought-resistant tree species or varieties can be planted. For example, studies show that cork oak (*Quercus suber*) is more drought resistant than holm oak (*Quercus ilex*) (Martín-Sánchez et al., 2022). Over-pruning and over-harvesting of cork reduce the overall health and resilience of trees and cause trees to be more susceptible to drought. Hence, these practices should be avoided to minimise the risk of tree mortality (Pinto-Correia & Mascarenhas, 1999b).

Heat waves

Risk: Heat waves are a climatic risk and could negatively impact the growth of trees. For example, it is generally assumed that the optimum temperature for photosynthesis ranges from 20ºC to 30ºC (Teskey et al., 2014). At temperatures higher than 30ºC, there is often a decline in photosynthesis rate (Ibid). In addition, there is a negative correlation between high temperatures in summer and radial growth, for example in cork oak and holm oak (*Quercus suber* and *Q. ilex*) (Costa et al., 2016).

Moreover, because heat waves often lead to increased soil evaporation, a common risk associated with heat waves is water scarcity for trees (Teskey et al., 2014).

Risk management options: One strategy would be to plant trees which are more tolerant to heat. As oaks have both superficial and deep roots, they can access water at lower levels and therefore maximise use of water resources in the soil (Morales et al., 2021). However, there has been relatively little research performed on the variations in heat stress tolerance in trees (Teskey et al., 2014). If combined with water shortage, a management strategy would be to reduce water stress of trees through irrigation, if possible (Ibid).

Wildfires

Risk: Although fires occur naturally in the Mediterranean, the drier weather and higher temperatures brought about by climate change are causing shifts in the fire regime leading to possible increase in the fire frequency and burnt areas (Dupuy et al., 2020). Forest fires can lead to tree mortality, reducing the climate change mitigation potential of afforestation projects. In addition, increasing frequency and intensity of forest fires can lead to a depletion in the soil seed bank for natural forest regeneration, reducing the genetic and species diversity of forest trees (Seddon et al., 2020). There is also an increased risk of soil erosion after fires. This is because the combustion of vegetation and leaf litter reduce surface area for transpiration and evaporation and soil water retention capacity. There is an increase in overland flow due to the decrease in obstacles preventing runoff (Shakesby, 2011). In addition, soil surfaces can become hydrophobic due to the change in chemical properties of burnt soil (Evelpidou et al., 2019).

Risk management options: One strategy is to plant species which are less flammable and hence more fire resistant. For example, oak trees are generally less flammable than pine trees (Pausas et al., 2004). Cork oak (*Quercus suber*) is particularly resilient to fires, due to the presence of suberin in the cells of the bark. The cork insulates dormant buds, allowing cork to regenerate after fire. However, the removal of cork bark substantially increases the risk of cork oak damage and death from fire (Silva & Catry 2006). As high-density forests have high fuel load and increase the risk of high intensity fires, another solution to mitigate the risk of wildfires is to reduce the density of these forests (Hermoso et al., 2021). Forest roads could act as important fuel breaks and decrease the spread of fires, and they provide easy access for firefighters to suppress forest fires once started (Bertomeu et al., 2022).

Desertification

Risk: One of the driest zones within the semi-arid, Mediterranean region is the province of Badajoz in Extremadura (Moral et al., 2015). As semi-arid regions are more sensitive to the availability of water resources, Extremadura, especially in the southwest, can be most seriously affected by desertification (Moral et al., 2017). Similar to soil erosion, a further risk of desertification is the formation of gullies, which are ditches created by the erosion of soil (Evelpidou et al., 2019).

Risk management options: The impacts of desertification can be partially reduced through maintaining a permanent soil cover, which can be achieved through mulching. Surface cover can play a critical role in reducing evapotranspiration, increasing infiltration, and reducing erosion (Evelpidou et al., 2019). Another management strategy is the construction of terraces, which would reduce soil erosion by runoff of large volumes of water (Ibid). In addition, gullies can be controlled by planting grass species, creating grassed waterways (Ibid).

Soil and plant diseases

Risk: Similar to dehesa and montado systems, plant diseases can occur after extreme precipitation and prolonged dry periods. Soil-borne pathogen *Phytophthora cinnamomi* has significantly contributed to the decline of oak trees in the region (Da Clara et al., 2013). By targeting fine roots, Pc quickly causes root rot and affects water uptake by the plant (Sánchez-Cuesta et al., 2021). The occurrence of *Phytophthora* species is enhanced by precipitation fluctuations ranging from flooding to water deficiency, favoured in periods of high temperatures (Pereira et al., 2007; Pérez-Girón et al., 2022). Pc survives well in moist soils, reproducing quickly and infecting neighbouring plants (Dunstan et al., 2020).

Risk management options: Similar to dehesa and montado, several techniques can be implemented to control the spread of Pc. Injection of potassium phosphate in the trunk can be optimal to eliminate the pathogen (Corcobado et al., 2013). In addition, fertilisers containing calcium can be added to enhance soil alkalinity, where Pc shows low virulence and incidence (Duque-Lazo et al., 2018). To help prevent the spread of this pathogen, the soil portion where the disease is directly visible can be removed and agricultural materials, such as machinery and equipment, can be disinfected (Sena et al.,2018). Moreover, restricted entrance for humans and animals in the infected areas is recommended (Duque-Lazo et al., 2018).

Drought	As precipitation regimes are altered and water decreases, trees reduce their stomatal conductance and photosynthetic rate, therefore taking in less carbon dioxide from the atmosphere and sequestering less carbon in biomass (Piayda et al., 2014).
Desertification	Desertification reduces carbon sequestration through the reduction of net primary productivity and through the direct loss of stored organic matter (Trumper et al., 2008).
Heat wave	Heat waves can inhibit photosynthesis and plant growth, therefore reducing the carbon sequestration capacity (Yuan et al., 2016)
Heavy storm	Storm events, especially ice-storms, reduce tree biomass, and reduce carbon sequestration. This may vary depending on intensity and frequency (Reichstein et al., 2013).
Soil and plant disease	*P. Cinnamomi*, localised in the roots, inhibits the functions of the plant, therefore limiting the uptake of carbon (Umami et al., 2021).
Soil erosion	Erosion results in the breakdown of soil microaggregates, therefore increasing the surface area of the soil, increasing soil respiration which leads to the loss of carbon to the atmosphere (Li et al., 2019).
Shrub expansion	Shrubs can expand throughout the landscape and create a flammable cover that will increase the risk for wildfire, leading to loss of carbon. Shrub expansion also reduces space for tree growth. As shrubs sequester less carbon than trees, an increased shrub cover reduces the overall potential for carbon sequestration (Bergmeier et al., 2021).
Wildfire	The effects of wildfires on soil organic carbon depend on the intensity and severity of the fire and soil characteristics. Due to the burning of litter, large quantities of carbon are lost from the soil and released to the atmosphere (Davies et al., 2013).

Table 1: Impact of risks on carbon sequestration

Not only do the climate risks mentioned above threaten tree health and ecosystem services provided by these LMTs, but these risks also pose a significant threat to their carbon sequestration capacity. In Table 1, we elaborate on the connections between these risks and carbon sequestration.

5. Policy framework

There are existing relevant policies for landowners regarding the selected LMTs on a European, national, and local level. These policies provide funding opportunities and institutional support with the aim to keep in place agroforestry and afforestation projects in Spain and Portugal. Institutional support for farmers is ensured through Article 51 in the EU Regulation 2021/2115 which sets the common guidelines for Member States. Farm advisory services tailored to the different production types should be guaranteed to maintain performance of agricultural holdings and rural businesses. They should also increase farmers' awareness of certain standards, requirements, and information, including environmental and climate ones.

Policy	Field of relevance	Key features
CAP	European level, draws agricultural legislation of the European Union	Contains the nine objectives to which Member States need to comply in their National Strategic plans. See Appendix IV for additional information.
CAP 2023-2027 Portugal, PEPAC (Planos Estratégicos da Política Agrícola Comum)	Portuguese national framework for afforestation and agroforestry funds	The PEPAC provides direct payments to farmers and landowners who meet the requirements. The received amount depends on the number of hectares. Aside from basic income support, six different risk management instruments are available which can support farmers and landowners when they are impacted by natural disasters or adverse climatic events. Additional information about these can be found in Appendix V.
CAP 2023-2027 Spain (Plan estratégico de la PAC de España)	Spanish national framework for afforestation and agroforestry funds	Proper maintenance of established afforestation and agroforestry systems can be supported through a compensation which consists of an annual premium per hectare or through a single payment to landowners. See Appendix VI for additional information.
Rural Development Programmes (RDPs) for Spain	Regional policies, mostly relevant for afforestation and funds for young farmers	More information on RDPs and especially in Extremadura can be found in Appendix VII.
New EU Forest strategy 2030	European afforestation projects and agroforestry	Provides financial incentives to the implementation of agroforestry and afforestation projects. For further information see Appendix VIII.
National Agricultural Insurance Plan for Spain	National level, insures crops, livestock, and aquaculture activities in Spain	Offers agriculture insurance policies through a mixed public/private scheme. Provides farmers with coverage for any extreme natural phenomenon.
Voluntary carbon markets	Relevant for any farmer managing an LMT	Provides private financing to climate-action projects. For further information on voluntary carbon markets functioning, see Appendix IX.

Table 2: Existing relevant policies for landowners on a European, national, and local level

Moreover, a crucial reference point for farmers is the European Network for Rural Development (ENRD) supports the implementation of EU Member States' Rural Development Programmes (RDPs) by sharing knowledge and facilitating exchange of information and cooperation across rural Europe. Table 2 provides a general overview of these policies. More information on these institutions and the potential support they can provide for farmers can be found in Appendices V-IX.

There are existing relevant policies for landowners regarding the selected LMTs on a European, national, and local level. These policies provide funding opportunities and institutional support with the aim to keep in place agroforestry and afforestation projects in Spain and Portugal. Table 2 provides a general overview of these policies. More information on these institutions and the potential support they can provide for farmers can be found in Appendices V-IX. There are existing relevant policies for landowners regarding the selected LMTs on a European, national, and local level. These policies provide funding opportunities and institutional support with the aim to keep in place agroforestry and afforestation projects in Spain and Portugal.

6. Tool

6.1 Introduction

The aim of this tool is to guide the user to identify the risks posed by climate change through a climate risk assessment. Thereafter, the tool will enable the user to develop an action plan to manage identified risks. This will help ensure effective and continuous functioning of the LMT. The tool may also be reproduced in different socio-economic and geographical contexts. Below, you will find the manual: **"How to Use the Tool?"**. This tool will help bridge the gap between research and practice in the context of climate mitigation. Through the tool, we address the needs of different stakeholders and enhance the prospects of a climate-resilient future.

6.2 Tool Manual

6.2.1 How to use the tool?

The tool is a user-friendly guide to help you through the 4 steps of climate risk assessment for the LMT in concern.

- The *first part* of the tool, i.e., the flowchart, helps you **identify** the climate risk(s).
- The *second part* is a video presented by means of augmented reality. It helps you **characterise** the risk and explains the implications each risk possesses on your LMT.
- *Thirdly*, you can prioritise your risk by designing your **action plan**. An example action plan is attached to the tool.

Prerequisites:

1. Two electronic devices such as a laptop, smartphone, or a tablet. Alternatively, the flowchart can be printed out and you need only a single electronic device to scan the risk(s).
2. An active internet connection
3. Latest version of phone software
4. Free Artivive App downloaded on your smartphone or tablet (available at the App Store or Google Play).

The following steps will help you complete a CRA for your LMT.

Step 1: Open the document and go through the manual "how to use the tool?" before you start using the tool.

Step 2: Begin from the **START** point of the flowchart. You are asked to answer different questions with either ***YES*** or ***NO*** and identify your path to a specific risk or group of risks. To support and verify your answer, each question is referenced to a threshold and definition. Find the thresholds and risk definitions at the end of this manual.
In case the result from going through the flowchart is *low risk*, there is a reduced chance that you will face any of these climate-related risks. There is no video that follows the *low-risk* result.

Step 3: When you have identified a risk or group of risks, open the Artivive App and point your smartphone at the risk image and a video with voiceover will appear. This video will explain the implications of the risk(s) identified.

Step 4: In the same video with voiceover, a guide table will help you develop an action plan for risk management. Scan the QR code on the flowchart (Figure 7 or Figure 8) to find an example action plan for inspiration.

Voila, you have a risk management plan which can help you minimise the impacts of climate risk on your LMT.

6.2.2 Thresholds

*1
Increase in average temperature:
An average increase of 0.5ºC over the year, compared to the baseline average from 1980-2020 of. (http://www.aemet.es)

*2
Hotter summer:
Summer (May-October) average temperatures higher than 23ºC (http://www.aemet.es).

*3
Decrease in precipitation:
Annual precipitation less than 500mm (http://www.aemet.es).

*4
Prolonged dry periods:
Consecutive dry days with precipitation thresholds set between 0.1 mm. (Serra *et al.*,2014).

*5
Precipitation extreme event:
Either rain >40mm/hour or monthly average rainfall higher than 1980-2010 average monthly rainfall (http://www.aemet.es).

*6
Runoff:
Significant runoff occurs when the vegetation and litter cover is below 30% and when the rainfall amount is higher than 20mm d^{-1} (Eshghizadeh et al., 2018)

*7
Shrub expansion:
Above 70% cover of *Cistus Ladanifer* or above 50% cover of *Retama sphaerocarpa* (López-Díaz, 2015).

*8
Increase in soil moisture:
Increase over 50% water holding capacity (https://vandersat.com).

6.2.3 Risk definitions

Drought "A prolonged dry period in the natural climate cycle that can occur anywhere in the world. It is a slow-onset disaster characterized by the lack of precipitation, resulting in a water shortage" (World Health Organization, 2022a).

- **Desertification** "Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (United Nations Convention to Combat Desertification, 1997).
- **Heat wave** "Two consecutive days with temperatures above the 95th percentile of the summer (June–August) maximum temperature" (Acero et al., 2017).
- **Heavy storm** "A disturbance of the atmosphere marked by wind and usually by rain, snow, hail, sleet, or thunder and lightning" (Merriam-Webster, 2022).
- **Shrub expansion** "The increase in density, cover and biomass of indigenous woody or shrubby plants" (van Auken, 2009).
- **Soil erosion** "The geological process in which earthen materials are worn away and transported by natural forces such as wind or water" (National Geographic Society, 2022).
- **Soil and plant disease** "A condition in a plant that impairs normal functioning and could reduce survival. Plant diseases often arise from pathogens such as viruses, bacteria, fungi and oomycetes" (Merriam-Webster, 2022).
- **Wildfire** "An unplanned fire that burns in a natural area such as a forest, grassland, or prairie" (World Health Organization, 2022b).

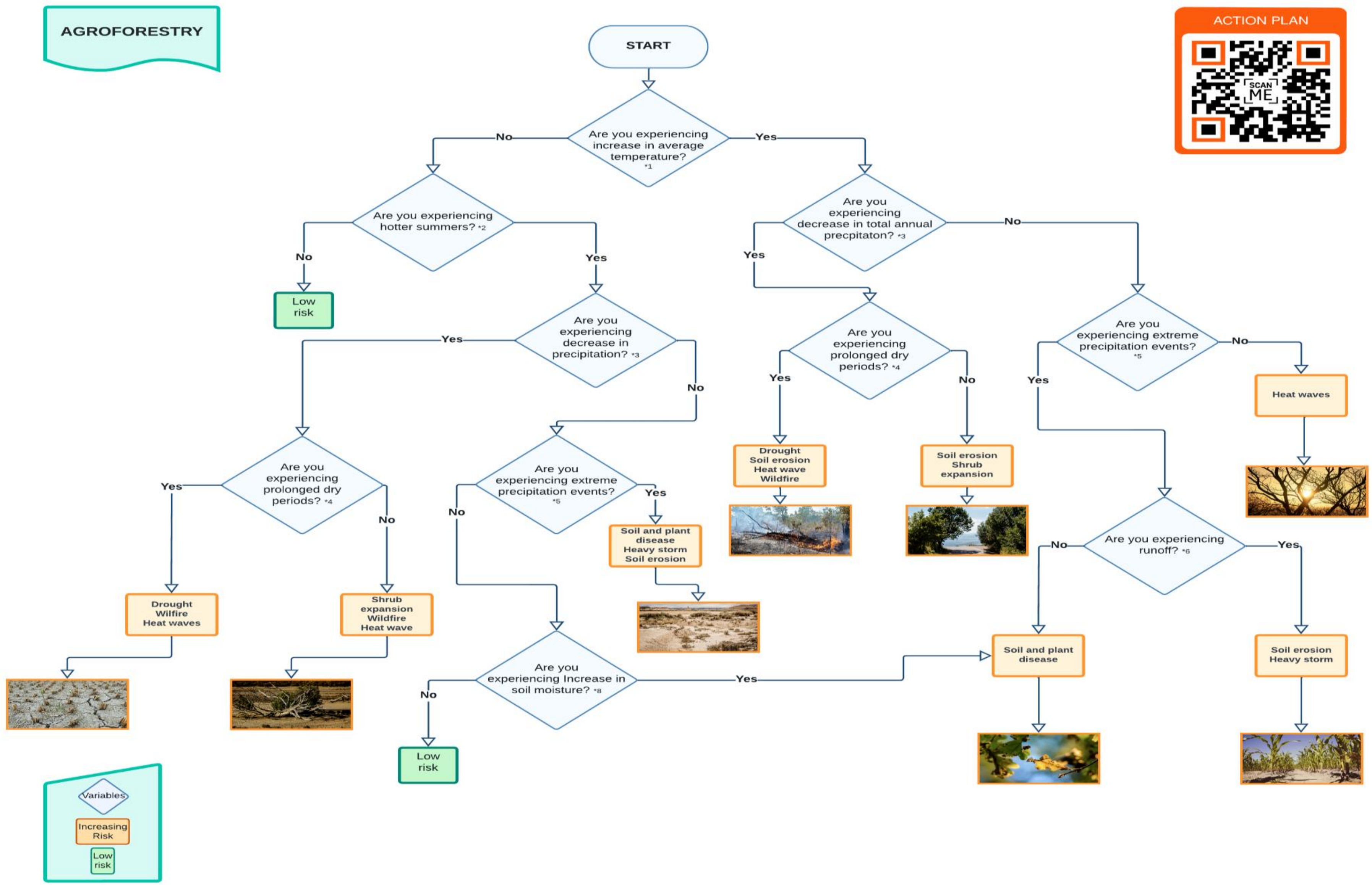

Figure 7: This flowchart shows the main climate-related risks associated with the agroforestry LMT

AFFORESTATION

ACTION PLAN

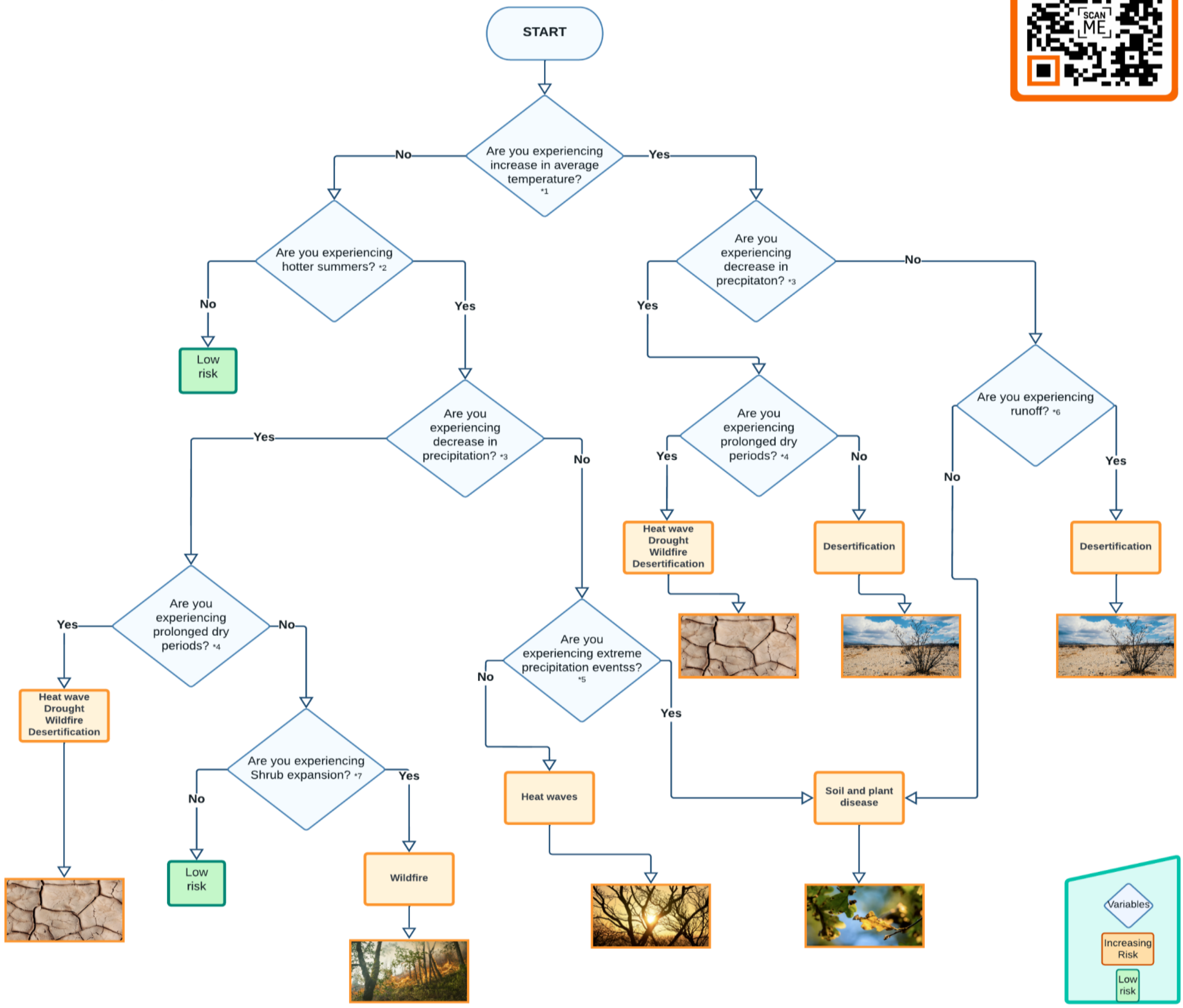

Figure 8: This flowchart shows the main climate-related risks associated with the afforestation LMT

6.3 Action planning tables

We developed three tables 3-5 to address the fourth phase of CRA. One contains guiding questions that can guide the stakeholders in coming up with an action plan for the identified risks (see Table 3). The second and third tables show completed (mock-)examples of how action plans could be filled in (see Table 4 and Table 5).

Table 3: Action plan guideline table

Components	Details
1. LMT	● What is your LMT?
2. Risk scope (which climate risk(s) are targeted?)	● Which risk would you like to target?
3. Is the risk currently managed?	● Is the risk currently managed?
4. Proposed scale of the action(s)?	● Scale-level of action: Individual farm-level/ Group of collaborating farms/ All mixed in terms of sectors and locations? ● How big is your farm/plot? ● What are the vegetation types? For example, which trees or shrubs are grown (or do you plan to grow)? Which crops are grown? ● How many trees do you have on your plot in trees per hectare? ● Do you already have irrigation options? If so, what type?
5. Proposed management strategies/ actions	● Choose relevant management options and design your own management strategy: How many actions/ measures are you proposing?
6. Description of action(s)	● Describe your risk management action(s) in details
7. Timing of actions (start date, end date and if needed, intermediate milestones)	● In which season can the management strategies be implemented? Consider, for example, seasonal variations in temperature and precipitation. ● Consider specific timings: for example, is there a time when fertilisers should be applied, or seeds sown?
8. Monitoring of risk(s) and action(s)	● Keep a check on the implementation of the strategy and keep updating the strategy with good practices. Improve efficiency and maintain the continuation of carbon storage via implementation of the LMT. ● Continuously look into the following: monitoring, evaluation, updating and implementing.

9. Cost of action(s)	Make an estimate of the costs involved such as: ● Operational and maintenance cost: seedlings, fertilisers, treatments, organic fertiliser, fuel, irrigation, labour, fencing, machinery cost, depreciation ● Labour costs ● Marketing costs ● Monitoring cost: e.g., soil testing
10. Possible fundings and institutions support	● Get acquainted with the framework of policies that are in place in your region ● Is there funding available at an intergovernmental level? ● Is there funding available at a national level? ● Is there funding available at a local level? ● Is there private / corporate funding available? ● Are there possibilities to link multiple funding opportunities? ● Seek support through institutions/networks/associations: reach out to other farmers, get in contact with agricultural advisory services, consider contacting a consultancy firm, get informed about the insurance policy schemes available in your region.
11. Person/ organisation(s) responsible for monitoring and implementing action(s)	● How can your LMT be monitored? For example, is there a possibility to monitor biodiversity, tree/soil health? ● Who can do this monitoring?

Table 4 shows an example of the action plan when the farmer faces the risk of soil and plant disease in an agroforestry project. Table 5 shows an example of when a farmer faces multiple risks (heat wave, drought, desertification, wildfire) in an afforestation project. These examples are provided to show landowners a possible complete action plan which they can come up with by answering the questions in Table 3. These action plans would be implemented after they have identified the climate risks of their LMT and decided on possible risk mitigation actions.

Table 4: Action plan example for the risk of soil and plant disease

Components	Details
LMT	Agroforestry in Extremadura region, Spain.
Risk scope (which climate risk(s) are targeted?)	Soil and plant disease e.g. *P. Cinnamomi,* a soil-borne pathogen that spreads in humid environments and attacks particularly weak or aged trees.
Is the risk currently managed?	No current active risk management.
Proposed scale of the action(s)?	There are different scale of action such as: ● Individual farm-level in North-West of Extremadura region

	● Group of collaborating farms that can be from different locations (or farmers' cooperative). ● Mixed in terms of sectors and locations (livestock-grass-forestry) farming systems in the entire Extremadura region <u>Individual farm-level in North-West of Extremadura region:</u> The farmer owns a 40-hectare farm with 45 trees per hectare. This farm is in Extremadura, with extremely dry conditions, especially in summer. Therefore, drought-tolerant holm oaks are the tree species used on this farm. The total cover corresponds to about 40% of the total land (AFTA, n.d.).	
Proposed management strategies/ actions	Action / measure 1	Action / measure 2
Description of action(s)	Fencing: it encloses the infected areas to avoid further contamination. The entrance to both humans and animals should be restricted (Duque-Lazo et al., 2018). For example, for 10 ha, 2200 m of fencing would be needed. For the described farm, this implies placement of approximately 5km of fencing.	Treatment with potassium phosphate: either with a foliar spray or by xylem injection. Approximately, the amount is 0.77 grams per cm stem diameter, at 4-5 cm above the soil (Gentile et al., 2009). Application of calcium fertiliser 14-30 ml in 4 litre of water and spray it on the plant. This should be added at the base of the plant to increase the pH of the soil and induce soil suppression of the pathogen. The fertiliser can be also mixed with topsoil and then applied around the plant (Duque-Lazo et al., 2018). For the described farm, this implies fertilisation of approximately 1200 trees.
Timing of actions (start date, end date and if needed, intermediate milestones)	There is not a specific starting date as the fencing needs to start when the disease is identified on your plot.	Potassium phosphate and calcium should be applied in the visible presence of the disease. It is highly recommended to apply both solutions also as prevention measures once in spring and once in autumn. The starting date for the implementation is either in spring or autumn. The application time is around 1 or 2 working days.

Monitoring of risk(s) and action(s)	To monitor the spread or recess of the disease, weekly checks should be applied through remote sensing technology (Zhang et al., 2019). Moreover, the level of infection can be checked through pH soil testing (Gentile et al., 2009). To monitor the progress of fencing and its state, a periodic review to check the status of fencing is needed. This can be filled in, in an excel document. Here can for example be written down where the fence is located, who made it, who should check it and if it is still intact.	Periodic review to check the spread of the disease and the application of calcium and phosphate (status of plant health). Moreover, the level of infection can be checked through pH soil testing (Gentile et al., 2009). To help monitor the application of potassium phosphate and calcium, create an excel file. This excel file can include information on aspects such as: ● When applied ● How much applied ● By whom applied ● Status of action ● Impact of action Through this the stakeholder can keep track of the status of the action. When the actions require more collective action, e.g. when the disease is located on the border of different plots, the excel file can be shared within a group of farmers or neighbours to help keep track of the actions performed by different people.
Cost of action(s)	Materials: ● Fence 75-112 euros / metre Labour: ● Hourly rate of 7 euros Other costs: ● 10 euros/ kit for soil pH testing ● 18 euro – 250 euro soil microbiology test.	Materials: ● Potassium phosphate between 15- 30 euros / kilogram ● Calcium fertiliser 30 euros / litre Labour: ● Hourly rate of 7 euros Other costs: ● 10 euros/ kit for soil pH testing ● 18 euro – 250 euro soil microbiology test.

Possible funding	Multiple funding opportunities are available for farmers/ landowners for the execution of this LMT. These funds operate at EU, National and local levels. The following funds are available: ● CAP ● RDPs (EAFRD) ● Modernization of Agricultural holdings ● Shared Ownership of Agricultural Holdings (for example gender mainstreaming policy, which is especially beneficial for female farmers) ● New EU Forest Strategy Check eligibility criteria for these policies and apply for such funding. Apart from these, apply for start-up funding, grants/financial aids. Also, look for investment opportunities willing to fund the LMT, reach out to companies which are looking to offset their carbon in the Spanish regional carbon registries and subscribe to the voluntary carbon offset markets in the region or in the country. In case of any confusion, reach out to financial experts, consultants, cooperatives, neighbours in and around the region. Seek institutional support from the existing networks: ● ENRD ● National Rural Networks (NRNs) ● RDP Managing Authorities and Paying Agencies ● Local Action Groups (LAGs) ● European NGOs ● Agricultural advisory services ● Agricultural and rural researchers ● Spanish agricultural insurance system (National Agricultural Insurance Agency (ENESA) + Consorcio de Compensación de Seguros + Agroseguro)
Person/ organisation(s) responsible for monitoring and implementing action(s)	● Landowners (farmers, groups and mixed organisations) ● Agroinsider association or regional carbon market associations ● Fedehesa/Asociación de Gestores de Dehesa de Extremadura –AGEDREX ● Ministry of Agriculture, Rural Development, Population and Territory - Junta de Extremadura The effectiveness of the agroforestry system for carbon sequestration should be maximised through maintaining tree health. In addition, the maintenance of tree and soil health will allow the farmer to benefit from harvesting products such as cork, resin, fodder, medicinal and aromatic plants, fruits and nuts, as well as honey and hunting wild game. The farmer needs to integrate the high economic value of the LMT respecting the tree regeneration processes that can offer additional benefits.

Table 5: Action plan example of heat wave, desertification, drought, wildfire

Components	Details
LMT	Afforestation in Extremadura, Spain.
Risk scope (which climate risk(s) are targeted?)	● Heat waves ● Droughts ● Desertification ● Wildfire

Is the risk currently managed?	No current active risk management.
Proposed scale of the action(s)?	There are different scale of action such as: ● Individual farm-level in North-West of Extremadura region ● Group of collaborating farms that can be from different locations (or farmers' cooperative). ● Mixed in terms of sectors and locations (livestock-grass-forestry) farming systems in the entire Extremadura region Individual farm-level in North-West of Extremadura region: The farmer owns a degraded farmland of 40ha (average size). They plan to continue with afforestation, with ~120-150 trees per hectare.
Proposed management strategies/ actions	Action / measure 1
Description of action(s)	To increase diversity, plant a mix of species of trees, herbs, and grass. To reduce competition, avoid planting trees of similar species next to each other. Plant a mix of species: cork oak and holm oak, together with other *Quercus* species (e.g. *Q. coccifera*, *Q. faginea* and *Q. canariensis*), *Pinus* species (*P. pinaster* and *P. pinea*), olive grove species. Prepare the soil for planting tree saplings. If required, add biomass to the soil. A protective layer of mulch can cover the soil to maintain the soil moisture, especially because cork grows best in moist soils. Add nutrients to the soil: fertilisers (organic), adding microbial biomass or compost (nature-based).
Timing of actions (start date, end date and if needed, intermediate milestones)	Ensure enough irrigation, such as drip irrigation, before the start of the dry season, especially when the risk of wildfire is high i.e., May to October (as per the Spanish Meteorological Department). This will also help reduce the risk of drought-like conditions.
Monitoring of risk(s) and action(s).	Monitor tree growth and soil water holding capacity/infiltration. Cork grows best in loamy but well-aerated soils. Measure the soil pH (4.7 - 6.5), and accordingly adjust the management practices such as fertiliser input etc. Monitor biodiversity, through mapping or through producing an inventory. After a few months, check the density of the trees, as highly dense forests can increase the risk of wildfires. Reduce density through felling, pruning, or shrub clearing. Build forest roads or stack rocks between forests to act as fuel breaks. Monitor the amount of carbon at the beginning of the implementation of the LMT through Normalised Difference Vegetation Index (NDVI)/ remote sensing (which can be done by hiring experts). Thereafter, take a periodical review for the carbon sequestered to check the functioning of the LMT and continuation of the flow of funds. Aim is to measure the carbon gain. The monitoring of these different actions can be done through the use of an excel file. In the excel sheet multiple aspects can be written down which provide an overview for each

	of the actions. Aspects that can be included are for example: status and impact of action, by whom the action is performed, who is responsible for it, and the location.
Cost of action(s)	Materials: ● Seeds and seedlings Estimate: 1400-2800 euros/ha for 80 trees/ha *Quercus ilex* seeds 6.95 euros per seed ● Wire mesh protector 30 euros/role of standard wire mesh protector (for keeping saplings from being eaten by herbivores) ● Microbial biomass / Compost 20 euros/ kilo of biomass or 5 euros/40 kilo of compost ● Irrigation 200-400 euros/ ha ● Fuel 2 euro/ litre for mulching, adding biomass, other ecosystem services ● Soil sample testing 10 euros/ kit for pH testing 18 euro – 250 euro for microbiology test 45 euro – 80 euro General Soil Health test Labour: Hourly rate of 7 euros
Possible funding	Multiple funding opportunities are available for farmers/ landowners for the execution of this LMT. These funds operate at EU, National and local levels. The following funds are available: • CAP • RDPs (EAFRD) • Modernization of Agricultural holdings • Shared Ownership of Agricultural Holdings (for example gender mainstreaming policy, which is especially beneficial for female farmers) • New EU Forest Strategy Check eligibility criteria for these policies and apply for such funding. Apart from these, apply for start-up funding, grants/financial aids. Also, look for investment opportunities willing to fund the LMT, reach out to companies which are looking to offset their carbon in the Spanish regional carbon registries and subscribe to the voluntary carbon offset markets in the region or in the country. In case of any confusion, reach out to financial experts, consultants, cooperatives, neighbours in and around the region. Seek institutional support from the existing networks: • ENRD • National Rural Networks (NRNs) • RDP Managing Authorities and Paying Agencies • Local Action Groups (LAGs) • European NGOs • Agricultural advisory services • Agricultural and rural researchers • Spanish agricultural insurance system (National Agricultural Insurance Agency (ENESA) + Consorcio de Compensación de Seguros + Agroseguro)

Person/ organisation(s) responsible for monitoring and implementing action(s)	• Landowners (farmers, groups, and mixed organisations) • Agroinsider association or regional carbon market associations • Fedehesa/Asociación de Gestores de Dehesa de Extremadura –AGEDREX • Ministry of Agriculture, Rural Development, Population and Territory - Junta de Extremadura Integrate economic benefits while implementing the LMT. For example, harvest highly valuable non-wood products, such as cork, resin, tannins, fodder, medicinal and aromatic plants, fruits, berries, nuts, roots, mushrooms, seeds, honey, ornamentals, and wild game. An ecosystem-based approach to forest management is to build eco-zones to avoid sharp edges between landscapes. Monitor tree health and periodical impact of invasive species. Keep a check with the government website for the risk warnings. Prepare in advance for the impending risk by measures mentioned above.

7. Discussion

Generally, climate risk assessment frameworks work from a top-down approach (Conway et al., 2019), but this tool facilitates a bottom-up approach to climate risk assessment in that landowners are guided in identifying the climate risks that they are facing and in building a robust action plan. Since LMTs will be increasingly impacted by climate risks, it will be crucial for policy makers to increase the level of support that can be provided to farmers. This tool constitutes an instrument through which the necessary dialogue between farmers and institutions can be started and bridges the current gap between stakeholders and institutions. Through this tool, farmers become more aware of the risks that they face, and they are guided in identifying the right level of aggregation that is needed to effectively manage climate risks. The tool refers farmers to the responsible institutions where they can seek support. The tool involves both the main implications of each risk as well as the main steps to take to receive institutional and financial support. For example, through the tool the user can understand what costs are involved in the implementation and management of their LMT. They can initiate their own action plan based on the guidance provided.

However, the tool has its own limitation which are discussed in detail in the next session.

7.1 Limitations

We carried out a comprehensive search of available literature, but our review is by no means exhaustive. One of the reasons for this is because we do not have a Spanish- or Portuguese-speaking member in our team, therefore papers written in these two languages were largely inaccessible to us. This was especially the case for papers on policy. Partly because of this language barrier, we found a shortage of literature on climate risks and management strategies for our selected LMTs. Another challenge to our literature review was the time constraint of the course. As a result, there is literature that we were unable to read and include in this report.

We aimed to represent the major risks and how they relate to climatic risks in our flowcharts. However, we omitted some climate risks which were not deemed highly relevant by JIN's Spanish and Portuguese partners, Ambienta and Agroinsider, respectively (see Appendix I). This is a limitation because, although less likely to occur, there is still a possibility that these risks are experienced under climate change.

Another limitation to our flowchart is regarding the output that could deviate from the reality the users face. We aimed to design the flowchart in a way which is user-friendly and helps guide the user to identify the climate risks they currently face. However, some of these climate-related risks could be difficult to identify. We address this by providing thresholds in the questions, but the perception of stakeholders on whether they have reached said thresholds may differ from reality. In the end this could potentially lead to a different output of the flowchart.

Our tool is not prescriptive and only acts as a guidance to help the user identify climate risks. This is because we recognise that the user is familiar with the climate conditions they face and already has a large amount of knowledge on management strategies to minimise loss and damage. Climate risks mentioned in this report and tool have been identified through extensive literature review. However, we did not pre-emptively diagnose the climate risks, the perceived climate conditions are a crucial input given by the user without which risk identification would not be possible. For the same reason a set of strategies is suggested to manage the risk, however, the user is responsible for designing an action plan that best suits their situation.

Additionally, prioritisation is not explicitly included in our tool because accurate information on stakeholders' profiles, their socio-economic conditions and their adaptive capacity is needed for the tool to provide guidance on prioritisation.

The tool created during this project is a beta-version. This means that it will function as a base upon which JIN will build before the tool can be finished and distributed to the different partners. Therefore, currently multiple limitations exist. One of the primary limitations to our tool is the language barrier, as it is presented in English. This could be a challenge to some users and could make the tool less accessible. Another language challenge is that the tool manual, flowchart, and action plans contain a large amount of scientific jargon, which could make the tool less accessible to users.

Furthermore, the lack of compatible electronic devices is a limitation. The tool requires an updated smartphone/tablet and requires that the user download the Artivive app. Moreover, the user must also have a relatively good quality camera, which is able to scan the image for the augmented reality video to be shown. Finally, some of the augmented reality videos are over one minute in length. This could pose a challenge to the user-friendliness of the tool, as users would have to hold up their devices for a relatively long time.

7.2 Way forward

The current version of the tool is an initial prototype and possible improvements are discussed in this section.

The tool provides a framework on how a stakeholder can be guided to complete a climate risk assessment using their experience-based knowledge. This basic structure could be easily applied to other contexts, to be used for different geographical areas and LMTs. Furthermore, this tool to be adapted to different countries and contexts, where technological resources are limited. This issue can be easily overcome by printing out all the relevant information from the tool.

The tool focuses on the environmental implications of the risks and suggests basic management options. To add to this, the socio-economic and political context of the region or countries where the tool is applied could be a valuable addition. This will help prioritise the risks depending on the adaptive capacity, resources, and funding available to the user(s). Risk prioritisation step can help confirm whether the risk identified by the stakeholders are real or perceived.

Furthermore, in the action plan it is addressed that one way to improve the monitoring of the actions could be done through data learning. The excel sheet could include a table where stakeholders can fill in when, how, where, which actions, who is responsible and which risks were addressed through this measure. By having such an excel sheet it is easier for the stakeholder to keep track of what has already been done and what has not. This is especially important when the actions require a more collective approach.

Finally, crowdsourcing may be a method for knowledge sharing and a way through which different stakeholders can contribute to future research on the topic. Crowdsourcing is a broad concept which focuses on retrieving knowledge, creativity, and skills from a large group of people through an online platform. For example, an online platform or document where stakeholders with the same LMT can share their experiences on the implementation and results of certain risk mitigation actions. Through this, stakeholders could learn from each other and adjust their action plan accordingly.

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Appendix I

Climate risks relevance provided by Ambienta and Agroinsider

Relevance of climate risks for the two LMTs determined by Ambienta and Agroinsider, where a rating of 5 is of highest relevance, 1 is of lowest relevance.

Table 6: Climate risk ranking perceived by Ambienta and Agroinsider partners

Event	Montado (Portugal)	Dehesa (Spain)	Afforestation (Extremadura)
Drought	5	5	5
Late Frost	3	2	2
Heavy hail	3	1	1
Desertification		4	4
Heavy Storms	4	1	1
Ice Storms	3	1	1
Heat Waves	4	4	4
Plant Diseases	3	5	5
Forest/rural fires	5		
Floods	2		

Appendix II

Overview of stakeholders

Table 7: Overview stakeholders chosen for stakeholders mapping

Reference number	Stakeholder	Economic Sector
1	Junta de Extremadura. CAP General Directorate. Sección ayudas a la Forestación.	Public administration and defence; compulsory social security
2	CICYTEX - Direction	Professional, scientific and technical activities
3	Universidad de Extremadura - Ingeniería Forestal	Education
4	CICYTEX - Grasslands Department	Professional, scientific and technical activities
5	Apag Asaja Extremadura	Agriculture, forestry and fishing
6	Innogestiona Ambiental S.L.	Professional, scientific and technical activities
7	Pensando Extremadura	Information and communication
8	Junta de Extremadura. Forestry Service.	Public administration and defence; compulsory social security
9	CAP Consultancy	Information and communication
10	CICYTEX - Dehesa Montado Project	Professional, scientific and technical activities
11	Junta de Extremadura. Forestry Service.	Public administration and defence; compulsory social security
12	Junta de Extremadura. Agrarian subsidies Service.	Public administration and defence; compulsory social security

Appendix III

Additional challenges to agroforestry and afforestation in Spain and Portugal

Dehesa and Montado

In addition to the climate-related risks mentioned above, silvo-pastures in Spain and Portugal are threatened by other pressures that mainly refer to human management of the land. Either management intensification or lack of land management are the main drivers (Plieninger et al., 2021). As for the former, intensification of livestock density puts pressure on the soil, leading to soil degradation. Additionally, rain-fed crops are usually abandoned to simplify the land system and the remaining cultivations are intensified (Ibid). As a result, single-commodity productions and monocultures like eucalyptus plantations are prioritised over diversification (Ibid). Associated to the intensification of management strategies, excessive pruning leads to unbalanced crowns, shoot overgrowing and large wounds in trees, often leading to infections (Moreno et al., 2009).

As for the latter, poor or lack of land management techniques can lead to land degradation and, eventually, abandonment. Poor management refers to insufficient clearing of shrub cover, which leads to shrub encroachment and increases the likelihood of wildfires (Plieninger et al., 2021). Moreover, land abandonment can result in soil erosion, lack of water availability and wildfires, with negative impacts on biodiversity (Quintas-Soriano et al., 2022).

To improve the resilience to climatic and non-climatic threats of dehesa and montado, transhumant pastoralism has been proposed as a possible strategy. It consists of a seasonal movement of livestock from summer to winter pastures, so that the presence of animals matches with the annual peak in productivity of the different areas (Carmona et al., 2013). Moreover, through seasonal rotation, the pressure on the soil is minimised and tree regeneration is enhanced (Ibid). In Spain, transhumance started to decline in the 20th century, with the intensification of agricultural practices and the construction of railroads. However, recent studies reported the multiple benefits of transhumant pastoralism and showed that farms in dehesa may gain from the reimplementation of this old practice.

Afforestation in Extremadura

Apart from the climate risks mentioned, there are additional challenges to carbon sequestration potential of afforestation projects in Extremadura. For example, labour costs can be preventatively expensive. Across Spain, costs of reforestation are on average 2500€ ha-1 (Vadell et al., 2016), and this cost can limit the feasibility of forest maintenance (Doelman et al., 2019). Forests in Extremadura are also threatened by pollution from agricultural, domestic, and industrial waste (Beaufoy et al., 2005). For example, from olive mills and from the washing out of pesticide containers (Ibid). The natural regeneration of trees is hindered by over-stocking of cattle (Beaufoy et al., 2005), as these graze on saplings and prevent tree growth. Another challenge is that landowners are typically only willing to plant trees on marginal lands so as to minimise profit loss from land not used for crops (Herguido Sevillano et al., 2018). This limits the area of land that is afforested.

Afforestation projects have received criticisms for overlooking environmental and social impacts. For example, forests in Extremadura are generally maintained for the purpose of production and do not have biodiversity conservation as a primary objective. This has led to intensive felling and creation of forest roads, which has contributed to the decline in Black vulture breeding sites (European Forum on

Nature Conservation and Pastoralism, 2003). In addition, afforestation can modify the hydrological cycle, altering rates of transpiration, rainfall interception, water holding capacity of soils, and water infiltration rates (Buechel et al., 2022). As a result, there can be an intense competition for water in afforested areas, especially in arid lands such as Extremadura. Another criticism by environmental groups, such as WWF, is that management of existing natural forests should take priority over new afforestation projects (Beaufoy, 2005).

Appendix IV

CAP general guidelines

Common Agricultural Policy (CAP) is agricultural legislation of the European Union, and each member state has their own national strategic plan in which they specify the interventions they want to use in order to comply with the nine objectives of CAP. For the past years the CAP 2015-2020 and the CAP transitional regulation have been in place but member states have been drafting up new national strategic CAP's as they are set to come into place over the time period 2023-2027. The funds of CAP are provided by two separate funds: European agricultural guarantee fund (EAGF) and the European agricultural fund for rural development (EAFRD). (The New Common Agricultural Policy: 2023–27, 2018)

Funding in CAP is divided into two pillars: Pillar I consists of direct payments, which farmers can receive based on the amount of hectares they manage. Not all land types are eligible for receiving direct payments, in total there are three different types allowed; permanent grassland or pasture, arable land and permanent crops (Augere-Granier, 2020). Definitions of these three land types can be found in every national strategic plan. For example, in the CAP 2015-2020 arable lands were not allowed to have more than 100 trees/ha. However, in the new CAP 2023-2027 this definition is expected to be changed. In the new CAP Member States can ensure that land under agroforestry will be fully eligible for direct Payments. As stated in the working paper from the Council of the European Union (WK 6333/2019 INIT) this will always be possible as long as it will be "justified based on the local specificities (e.g. density/species/size of the trees and pedoclimatic conditions) and the value added by the presence of trees, to ensure sustainable agricultural use of the land". The Pillar II of CAP regards rural development support, and because it is co-funded by EU countries they can decide on certain more specific measures to be funded in their own national rural development programmes (RDP's).

Appendix V

CAP Portugal 2023-2027

The information in this section is taken from the CAP report for Portugal (Ministério da Agricultura, Republic of Portugal, 2021). The name of Portugal 's strategic plan of CAP is PEPAC (Planos Estratégicos da Política Agrícola Comum). In PEPAC a distinction is made between three territories for Portugal:

- Mainland Portugal
- Azores (autonomous region – RAA)
- Madeira (autonomous region – RAM)

Table 8: Financial support based on Pillar I and Pillar II depending on the territory, stakeholders can make use of this support

	Pillar I		Pillar II
	Direct payments	Sectoral support	Support for Rural Development
Mainland Portugal	X	X	X
RAA		X	X
RAM		X	X

Direct payments are important for farmers as they provide a stable income throughout the year. Farmers can receive direct payments when they meet the requirements set in the regulations. For example, a minimum requirement is that the total amount due for payment is more than 100 euro and that the area of eligible land is more than 0.5 ha (p. 417). Aside from the basic income support, a different payment regulation exists for small farmers which is especially made in order to support smallholder farmers. This payment consists of three different payment levels depending on the amount of eligible hectares that are declared by the farmer and is a replacement of the basic income support (p.462). In Appendix II, further details on minimum level of agricultural activity, definitions and income support can be found.

Aside from the basic income, other funds exist that can be accessed which are more directly linked to climatic risks in agricultural land holdings. When the production losses are significant due to natural disasters or adverse climatic events, other (additional) policy measures can be activated. Furthermore, PEPAC highlights that the increased fire risk climate change poses to forestry affects agriculture as farms are often located near forests and farmers are often also forest landowners for additional income. For this reason, six different risk management instruments were identified in PEPAC, both for agroforestry and forestry:

- **Insurance (C.4.1.1):** This insurance is focused on crops and can be accessed when the production loss is more than 30% and a farmer is located in a risk zone.
- **Prevention of natural calamities and catastrophes (C.4.1.2):** The objective is to reduce the impact of natural catastrophes, adverse climatic events or catastrophic events, through preventive actions (construction & protection structures, other land improvements and equipment, preliminary studies, advertising campaigns about preventive measures) e.g. storms, tornadoes, heavy rains
- **Restoration of productive potential (C.4.1.3):** This public intervention starts after a governmental decision, in response to losses in agricultural holdings after a natural catastrophe or calamity in order to increase the resilience of the farm and minimise post-disaster negative effects on natural resources, water and soil
- **Rural emergency fund (C.4.1.4)**: Can be accessed after natural disasters, adverse climatic events or catastrophic events affect agricultural holdings. Easier to access than C.4.1.3 since it is more focused on smaller farms.

- **Forest prevention against biotic and abiotic agents (C.3.2.3):** Investment in preventive measures aimed at rural fires, natural disasters and catastrophic events that damage forests are supported through this measure.

- **Restoration of forestry potential following natural disasters, adverse weather events or catastrophic events (C3.2.4):** When forests are damaged due to rural fires, natural disasters or catastrophic events, investments in the repair measures are supported.

Appendix VI

CAP Spain 2023-2027

The information contained in the next paragraph is drawn from the Spanish Strategic plan for CAP 2023-2027 (Plan estratégico de la PAC de España). The most relevant section for LMTs can be found from page 1298 onwards in the official document and is titled "Compromisos de mantenimiento de forestaciones y sistemas agroforestales" (6502.2 SIGC). This section states the importance of proper maintenance of established afforestation and agroforestry systems, guaranteed through compensation by means of an annual premium per hectare or through a single payment in justified cases. These compensations are meant to cover loss of income or increase in costs for farmers who commit for a period of 5 to 7 years to implement voluntary actions that favour the development and conservation of afforestation and agroforestry systems. Eligible beneficiaries are public or private forest holders and their groupings, public administrations when they act by legal authorization on land that they do not own and other land managers that carry out the eligible actions. Actions will be carried out on land considered forest according to the definition of the Forest Law 43/2003, however actions that must necessarily be carried out outside forest land, such as the implementation of agroforestry systems will also be eligible. There are eligibility specificities for each region, these can be found on pages 1301-1305 of the document.

In Extremadura there are several conditions forestry and agroforestry have to adhere to in order to be eligible to receive financial support. For forestry on (agricultural) land, landowners need to be registered in the "Registro de Explotaciones Agrarias" and they need to have a formalised contract with the "Dirección General" in this area, which states the number of hectares where the commitments are fulfilled. The commitments which are considered eligible are the ones working to achieve the specific objectives 6.1 (d), (e) and (f) of the CAP. For agroforestry systems in order to receive the annual premium the entire area considered eligible must be in a good vegetative state and meet the requirements.

On an endnote, the adoption of the Spanish agricultural insurance system is not addressed by the Strategic Plan because Spain will continue to rely on the National Agricultural Insurance Plan as the main tool for managing the climate risk.

Appendix VII

Rural Development Programmes (RDP's) for Spain

The key to promoting sustainable agriculture and forestry lies in the regional rural development plans in the EU member states. Support for Rural Development is the second pillar of the Common Agricultural Policy (CAP), providing Member States with an envelope of EU funding to manage nationally or regionally under multi-annual, co-funded programmes.

Rural Development in Spain is managed on a decentralised basis by the main administrative regions of the country through 17 Rural Development Programmes (RDPs). The RDPs are funded under the European Agricultural Fund for Rural Development (EAFRD) and national contributions. It is a part of a broader framework of European Structural and Investment Funds (ESI Funds). The RDPs set out priority approaches and actions to meet the needs of the specific geographical area they cover. More significantly, RDP's in Spain are revised keeping in focus the adaptation to and mitigation of climate change.

The main objective of Extremadura's RDP (2023-2027) is to enhance the viability of farming and forestry in the region. In order to do this, support will be ensured to modernise and restructure farms in Extremadura. Young farmers will receive start-up aid to launch their business. Additionally, knowledge sharing and training courses for environmentally and economically sustainable farming and forestry will be made available. Irrigated farmlands will be provided with investment support for improving water use efficiency. Moreover, a management contract will be developed for fighting soil erosion and desertification. Local action groups (LAGs) under ENRD will play a key role in exchanging information across EU members and developing local initiatives.

Two key challenges in Extremadura are the competitiveness of farming and 'restoring, preserving and enhancing ecosystems related to agriculture and forestry.' For the latter, Measure 8 and Measure 15 of the EU Rural Development Programme are most important. This challenge is addressed by the measures provided in the RDPs, shown in Table 9.

Table 9:Overview of different measures in RDP for Extremadura.

Knowledge transfer and innovation in agriculture, forestry and rural areas	During the programming period Extremadura will support the development of innovative solutions through 42 European Innovation Partnership (EIP-AGRI) operational groups and it will create 7 000 places in training courses targeting the farm sector.
Competitiveness of the agricultural sector and sustainable forestry	Farm investments supported under this priority will aim at modernising and restructuring around 14% of all farms in the region, while 3% of farms will receive support for young farmers to launch their businesses.
Restoring, preserving and enhancing ecosystems related to agriculture and forestry	Most funds under this priority will be used for agro-environmental operations, including organic farming (92,680 ha), as well as support for environment/climate-friendly forest investments. 24.7% of the agricultural land will be under contract for biodiversity, 4.6% for water management and 5.2% for soil management. 310 operations will be implemented to improve the resilience and environmental value of forest ecosystems.
Resource efficiency and climate	This priority will mainly address investments related to water efficiency so that 15.6% of the region's irrigated area will switch to more efficient irrigation systems. 0.03 % of agricultural and forest land will come under management contracts related to carbon sequestration or conservation.

Social inclusion and local development in rural areas	Under this priority, the region will support actions to improve basic services and village renewal operations as well as LEADER Local Action Groups and their Local Development Strategies. These strategies will address small investments related to the diversification of non-agricultural activities in rural areas and the reinforcement of basic services and small-scale collective infrastructure.

Appendix VIII

New EU Forest strategy 2030

The EU Forest strategy is mainly focused on afforestation projects; however, agroforestry is also significantly mentioned in the new Forest Strategy and in the revised LULUCF Regulation. The new EU forest policy aims at contributing to the GHG emissions reduction set out in the EU climate law. Therefore, it provides incentives to continue implementing the LMTs in concern. The key points are the following:

1. Promoting Bioeconomy: The Commission will develop a 2050 roadmap for reducing whole life-cycle carbon emissions in buildings; the Innovation Fund, dedicated to the funding of innovative low-carbon technologies, offers support possibilities for innovative projects in construction, including wood construction. Institutional level: ecolabel related with carbon sequestration.
2. Ensuring sustainable use of wood-based resources for bioenergy: wood-based energy, increase wood biomass for energy without increasing the raw material and impacting biodiversity. This can be achieved by ensuring continuation of the two LMTs in concern.
3. Promoting non-wood-based services (such as ecotourism): EU forests provide highly valuable non-wood products, such as cork (80% of the worldwide production), resin, tannins, fodder, medicinal and aromatic plants, fruits, berries, nuts, roots, mushrooms, seeds, honey, ornamentals, and wild game, which often benefit the local community. This nature-based service can be maximised in the LMT.
4. Pushing the member states to start mapping and monitoring forests and ensuring no deterioration until they start to apply the protection regime.
5. Promoting ecosystem-based approaches to forest management which can enhance long-term adaptability and forests' capacity to recover and self-organise.
6. Monitoring the situation of tree health in the EU, including the impact of invasive alien species, diseases, and pests such as bark beetles, and encouraging the necessary preventive actions for early detection and eradication.
7. Financial incentives: Private forest owners and managers, especially of small holdings, often depend on forests directly for their livelihoods and their main income comes from the supply of wood. The other benefits, especially the provision of ecosystem services, are rarely or never rewarded. Forest owners and managers need drivers and financial incentives to be able to provide ecosystem services, in addition to wood and non-wood products. Ecosystem services ensure forest protection, restoration, and increase the resilience of their forests through the adoption of climate and biodiversity friendly forest management practices. There are several such incentives, for example:

a. In 2019, Portugal launched a pilot program to pay forest ecosystem services in two natural parks covering the re-naturalisation of eucalyptus plantations, planting autochthonous species and the development of non-wood products.
b. As part of the green heart of cork initiative developed by WWF Mediterranean, a private drinks company paid forest landowners to protect a water aquifer that was used for their production process.

Appendix IX

Voluntary carbon markets

Voluntary carbon credits direct private financing to climate-action projects that would not otherwise get off the ground (Blaufelder et al., 2021). By using carbon markets, entities can neutralise, or offset, their emissions by acquiring carbon credits generated by projects that are reducing GHG emissions elsewhere.

A voluntary carbon market is a virtual site where carbon has an established price and companies that want to reduce their emissions can access it to buy carbon credits. The money collected is invested in measures to offset these emissions. Entities responsible for diffuse greenhouse gas emissions will be able to compensate for their emissions in this market by investing in climate-resilient forest management with the aim of increasing carbon stocks in forests and wood products, as well as by reducing the risks of natural disturbances.

Spain's first voluntary carbon offset market was set up only in 2019. Moreover, there is a regional carbon registry in Spain where organisations put in their GHG emissions data annually, as well as their reduction measures. A yearly analysis is carried out with information about the type of organisations reporting, how many and what kind of measures they have put in place, as well as the global yearly variation in emissions.