SCALING LAND-BASED MITIGATION SOLUTIONS IN SPAIN

LAND-BASED MITIGATION NARRATIVES

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2. Introduction

This report includes a description of a generic nation-wide transition scenario for the implementation of land-based mitigation technologies and practices for the AFOLU sector (agriculture, forestry, and other land use sectors) in Spain. The report shows the outcomes of a series of research steps that have been conducted in this country since the start of the project in June 2020 until the end of 2022:

First, we performed an initial scoping of key LMTs in the case study country. The scoping assessment resulted in a long list of broad portfolios of different LMTs that could be viable within the various case study countries.

Second, following this long list, we developed a short-list LMT portfolio containing key LMTs that would be the most relevant for a given country context. All case study country partners were asked to propose and validate their LMT portfolio through complementary (policy) literature review and with the help of stakeholder interviews (i.e. external validation by relevant country experts and stakeholders). Ex-ante no specific guidance of criteria for LMT portfolio short-listing was provided to allow for a free and open co-design process with stakeholders. The scoping process and results are presented in section 3 of this report (step 1 & 2).

For the case study of Spain, the methodologies of specialised literature review and interviews with experts in the fields of science, public administration, and the professional agricultural and forestry sectors were mainly used.

Third, after the short-listed LMT portfolios were validated, the LANDMARC case study country partners were asked to develop national scaling narratives or storylines for each LMT included in their portfolio. The assessments focusses on climate risks, vulnerabilities as well as socio-economic co-benefits and trade-offs associated with upscaling LMTs in the case study countries. The analysis is based on a broad range of information/literature sources, and stakeholder consultations conducted. This process is supported through a risk and impact assessment (i.e. an online survey and workshops/seminar/webinars) conducted through the LANDMARC tasks 4.1, 4.2 and 5.2. The results of this analysis are a set of LMT narratives which are presented in section 4 of this report.

The stakeholder interviews were conducted in a structured way, so that the responses could be used in the final report in an easily recognisable place in terms of policy aspects, economic performance, or impacts on climate risks.

The research steps are designed to enable both an **analysis of the risks and (climate) impacts of scaling up land-based mitigation and negative emission solutions**. As such this report mainly contributes to objectives 2, 3 and 4 of the six LANDMARC key objectives (see Table 1).

Table 1: LANDMARC project objectives.

	Project key objectives
1	Determine the potential and effectiveness of LMTs in GHGs mitigation using Earth Observation (EO)
2	Improve climate resilience of LMT solutions at the local level for large-scale implementation
3	Assess the risks, co-benefits, and trade-offs of scaling up local LMTs nationally
4	Scaling up LMT solutions to the continental and global level to assess effectiveness
5	Improve current methodologies to estimate emissions and removals for LMTs
6	LMT capacity building and develop new tools and services for decision making

While the results shown in this report represent a mostly qualitative storyline describing the context and impact of scaling up LMTs in a country context, they also enables project partners to proceed with the translation of the outcomes in a manner so that they can serve as direct model input.

Furthermore, these national level assessments provide a testing ground and empirical basis for the continental, and global assessment of the realistic scaling potential of land-based mitigation and negative emission solutions implemented in Work Packages 6 and 7 of the LANDMARC project (***Objective 4***).This report has been produced as part of the LANDMARC project.

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3. Scoping of land-based mitigation and negative emission solutions in Spain

LANDMARC focusses on a particular set of NETPs: carbon capture and geological storage, linked to bioenergy production (BECCS), biochar, and land management practices in the Agriculture, Forestry and Other Land Use (AFOLU) sector. These are marked by a red line in Fig.1. Sometimes land users employ technologies like biochar in their land management practices. The more industrial negative emission solutions, like direct air capture (DAC) or different carbon capture and utilization options are thereby excluded for further assessment. NEGEM and OCEANNETs are related EU projects that also research the potential of NETPs, where the latter focuses on ocean based NETPs.[1]

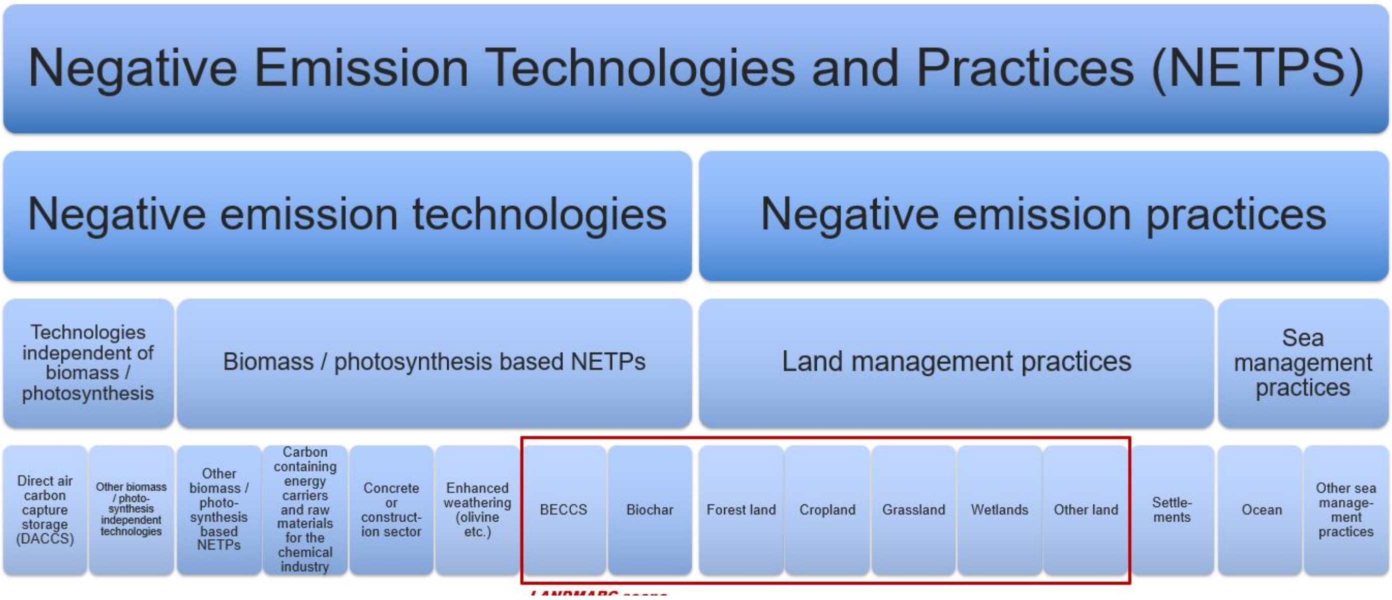

Figure 1: Scope of the LANDMARC project

3.1 Overview of potential of LMTs in Spain

3.1.1 Introduction

Spain, due to its geographical location and socio-economic characteristics, faces significant risks derived from climate change. Key sectors of the Spanish economy, such as agriculture, forestry, tourism, and transport; closely depend on the climate. Other essential factors for human well-being such as health, biodiversity, or housing also depend on climate.

Climate change is a reality in Spain, and numerous effects have been observed, including an average increase in temperatures of approximately 1.7 ºC since pre-industrial times (fig. 2), longer summer season, more extremely warm nights, longer heatwave events, a decrease in rainfall, disappearance of glaciers, a decrease in average river flows, an expansion of semi-arid climate, warming sea waters, sea-level rise, and acidification of marine waters. The existing models forecast an intensification of these trends in the future. Also, these models project an increase in extreme temperatures, an increase in evapotranspiration, a decrease in aquifer recharge, an increase in drought events, and an increase in torrential rains and floods (Government of Spain, 2020a).

Figure 2. Annual average temperatures for Spain for the period 1901-2018. The gradation from blue to red indicates the increase in temperature. Figure extracted from the Spanish National Plan for Climate Change Adaptation 2021-2030 (Government of Spain, 2020a).

Adaptation and mitigation are two complementary strategies against climate change. The PNACC (Spanish National Plan for Climate Change Adaptation 2021-2030) (Government of Spain, 2020a) aims to coordinate action towards avoiding and lessening the impacts of climate change. This plan emphasizes adaptation to climate change without giving up on climate mitigation, as it can reduce the need and cost of adaptation. **It defines 18 areas of work and specifies objectives and action plans for each. These areas are climate, human health, water, biodiversity, forestry, farming, coasts, urbanism, cultural heritage, energy, transport, industry, tourism, financial system, disaster risk management, research and innovation, education, and security.** The most relevant of these areas for **LANDMARC** are **water, biodiversity, forestry, and farming**. These are reviewed and analyzed in the following sections to assess current and potential LMT use.

3.1.2 Land management practices for wetlands

The PNACC establishes that climate change should be specifically considered in the management of water and water resources. Particularly, the plan aims to lessen the impacts and reduce the risk of extreme events such as droughts and floods. This will be achieved by maintaining a 'good state' of the water bodies and their associated ecosystems according to the Water Framework Directive through sustainable practices. In this sense, management plans are expected to be designed with a holistic and integrative perspective, including climate change adaptation, flow management, and pollution control.

From all the planned actions, the most relevant for LANDMARC are those aimed at the recovery of the morphology and dynamics of the water channels. These intend to help regulating the hydrological regime through restoration of meanders, reconnection of flood plains, naturalization of channels, preservation of wetlands, improvement of fluvial continuity, and recovery of floodplain forests. These actions offer multiple co-benefits aside from water regulation that are directly relevant to land mitigation, including biodiversity enhancement, wetland ecosystem restoration, erosion reduction and soil structure improvement. Thus, although not specifically considered in the PNACC, the projected land management practices for water management have the potential of acting as negative emission practices too, as wetlands generally act as carbon sinks (Taillardat et al., 2020). Also, naturalized forests, in this case floodplain forests, can capture carbon continuously for decades (Lewis et al., 2019).

Finally, it is important to highlight that the management of hydrological resources cannot be separated from the management of forest resources. Soil, forests, and water form a triangle of integral management in the territory, which means that hydrology can be considered as a LMT in the strict sense of the term.

3.1.3 Land management practices for forest and biodiversity

Forestry, desertification, hunting, and inland fishing are considered jointly in the PNACC. Forest management is particularly relevant in Spain due to its high forest diversity and its increasing vulnerability to risks enhanced by climate change. These risks include extreme climatic events, drought, desertification, fires, and climatic stress on tree species. The PNACC report acknowledges that climate change should be considered in forest planning and management to guarantee the provision of ecosystem services. There is an emphasis on land degradation and forest fire prevention using adaptive and nature-based solutions, all of which contribute directly or indirectly to land mitigation.

Desertification and land degradation control measures can generate co-benefits for climate change mitigation, biodiversity conservation, and food security. Specific measures to address desertification and land degradation include nature-based solutions for erosion control and restoration of degraded and abandoned areas such as quarries, mining areas, landfills, abandoned agricultural plots, etc. These include afforestation and reforestation projects in degraded areas using native species and general recovery of the native vegetation cover.

The planning instruments for forests and the Spanish forest sector such as the Spanish Forest Strategy, the Spanish Forest Plan, the Forest Resources Management Plans, or the Spanish Strategy for the Conservation and Sustainable Use of Forest Resources, among others, coordinate the forest policies and allow synergies with other sectors that influence forest management while creating conditions for the multifunctional potential of Spanish forests to be sustainably managed. Climate considerations must be incorporated into the available forest policy instruments to ensure efficient and sustainable management.

The available climatic projections for Spain indicate an increase in extreme climatic events, especially during summer, leading to extended heat waves dominated by high temperatures and low relative humidity. These conditions generate a greater tendency for the forest fuel to burn, increasing the risk of large forest fires. Thus, it is important to consider climate change in forest fire prevention and extinction plans, and in restoration projects for burnt areas. The knowledge of forest ecology allows us to address the expected impact of climate change and manage landscapes to increase their resilience to fires. The integration of regional policies and the involvement of different stakeholders, together with the promotion of agroforestry systems and traditional uses such as pastoralism, are a good mechanism to implement adaptive measures in the face of the increase in the danger of fires. This is highly relevant for LANDMARC, as a successful forest fire prevention can be considered a land management mitigation practice. As mentioned earlier, naturalized forests capture and store carbon over decades (Lewis et al., 2019). Hence, forest fires lead to large carbon release events. These events can make up to 50% of the global emissions of CO y NOx (Galanter et al., 2000). In certain forest ecosystems, the contribution by forest fires to carbon release is similar to that of deforestation (Aragão et al., 2018). Post-fire carbon dynamics and fluxes are not completely understood and depend on the specific forest ecosystem. While some forest ecosystems tend to keep releasing carbon over several years after a fire event, others immediately compensate for the release of carbon thanks to natural regeneration (Goetz et al., 2012; Houghton et al., 2012).

In addition to forest, the PNACC expects natural heritage, biodiversity, and protected areas to be affected by climate change and aims to improve ecosystem resilience. Issues such as increasing ecosystem disturbance, habitat fragmentation and the presence of invasive species are worsened by climate change. Consequently, climate change must be factored in for future conservation schemes and protected area management plans.

Some of the actions projected to enhance climate change adaptation for natural heritage, biodiversity, and protected areas can potentially act as negative emission land management practices and be directly relevant for LANDMARC. These include the creation of green corridors to increase habitat connectivity, interventions to increase the permeability of the territory to species movement, interventions aimed at improving the provision of regulating ecosystem services, changes in practices to reduce the pressure on ecosystems, and ecological restoration projects. Interestingly, the PNACC also states that areas that are highly relevant to mitigate the impacts of climate change will be identified, restored, and protected. The report does not provide more detail on this topic, but this hints that, even though the primary focus of the PNACC is climate change adaptation, mitigation is also considered in this national plan.

3.1.4 Land management practices and negative emission technologies for croplands and grasslands

Agriculture, livestock, fishing, aquaculture, and food are considered under the same title in the PNACC document. The plan aims to adapt these sectors to the climate change projections to ensure food security through increased ecosystem resiliency and promotion of sustainability in the food system. Agriculture, livestock, fishing, and aquaculture are strategic sectors in Spain, with great economic, social, territorial, and environmental importance. The food sector is also one of the most important in the Spanish economy and the food industry is the leading industrial sector. The area devoted to agricultural and livestock activities in Spain, farmland, and area of main use for pastures, is around 25 million hectares, which is half of the total area of the country. Also, the agricultural sector can act as a net emitter or net carbon sink depending on the agricultural practices applied. Carbon emissions by the agricultural sector are derived from the use of fossil fuels, the use of fertilizers, the burning of agricultural residues, livestock, rice fields, liming of soils and the use of urea. Almost half of the emissions from this sector are generated by the use of fertilizers and soil management, while the other half is caused by livestock (enteric fermentation and manure management).

As in previous sections, management actions to increase resilience also help in climate change mitigation. Essential pillars of the strategy include preservation of soil and water resources and biodiversity conservation. Organic farming, conservation agriculture, reduced tillage, precision agriculture, extensive livestock (low density), appropriate manure and slurry management, cattle diet modifications, use of renewable energy sources, and use of anaerobic biodigesters are favoured practices. Other proposed adaptive measures are floodplain forest restoration to protect soils in agricultural areas, crop rotations, crop diversification, avoidance of bare soil, incorporation of pruning waste to the soil. These are resource-saving measures that can potentially be climate change mitigating as well, and thus directly relevant to LANDMARC. Particularly, grassland management for livestock can be a very effective and resilient land mitigation practice (Dass et al., 2018). Increasing pasture species diversity and applying compost soil amendments can constitute carbon sinks (DeLonge et al., 2013; Hewins et al., 2018; Hungate et al., 2017).

3.2 Determining the LMT scope for Spanish national level simulation modelling

In this section, we discuss which set of LMTs we will study in detail in Spain. From the perspective of the National Plan for Adaptation to Climate Change 2021-2030 (Government of Spain, 2020a), forest and agricultural uses represent the LMTs with the greatest impact. Table 1 summarises the main LMTs and indicates which ones are included in the short-list of the LANDMARC LMT portfolio. The main rationales for including the various LMTs in the national level scaling simulation assessment are presented below.

Table 1. Long-listing of relevant land based LMTs in Spain.

LMTs	Specification	Included in national LANDMARC LMT portfolio
Grasslands	Dehesas (Spain) and montados (Portugal) management (agroforestry)	YES
	Grasslands for soil regeneration and carbon sequestration	YES
Agriculture	Reduced tillage	NO
	Harvest residues, crop rotation	NO
	AD residue based on organic fertilizers/digestates	NO
	Soil conservation and regeneration	NO
	Landscape management in agricultural lands (hedgerows etc.)	NO
Forest land	Forest planning and management	YES
	Afforestation/reforestation of degraded lands	YES
	Forest fire prevention	NO
	Watershed and forest management	NO
Wetlands	Wetland conservation	NO
	Floodplain forest recovery	NO

Forests

Land use and forest planning in the medium- and long-term faces, in the climate change scenario, important challenges in Spain. Monitoring and inventory of forest resources need to reflect the continuous change in environmental variables spatially and over time. It must also consider the ecological and economic value of the mitigation potential of the forest and make this value compatible with other traditional uses.

The CO_2 capture and emission processes in a forest constitute a complex system with four groups of carbon storage agents: aboveground biomass, root biomass, decomposing organic matter and forest products stored outside the forest (that is, wood, paper, etc.). Each of these reservoirs has different average lifetimes, after which they end up being incorporated back into the atmosphere. Therefore, it can be affirmed that forests act as sinks since they store large amounts of carbon for long periods (wood) and by increasing their biomass annually due to growth. On the other hand, they are also sources of emission due to natural mortality, fires, deforestation, and decomposition of forest products, plants and plant organs (Montero et al., 2005).

Despite these sources of emission, managing forests for carbon sequestration is a cost-effective way of mitigating climate change. This can be achieved by regulating tree density, rotation periods, and thinning regimes to achieve mitigation, without increasing forest management cost and increasing carbon capture by Spanish forests from 35 to 42 $MtCO_2e$ (Albiac et al., 2017).

One of the main initiatives of the Government in Spain is to convert plots from various land uses to forest land and promote sustainable forest management (Government of Spain, 2020b). Specifically, converting unproductive and degraded agricultural lands to grasslands or forests can increase soil carbon sequestration, although more studies are needed on this topic (Rodríguez Martín et al., 2016). In Spain, the Agricultural Land Afforestation Program started more than 25 years ago thanks to the Common Agricultural Policy (Vadell et al., 2019). This program has successfully improved ecosystem service provision including soil conservation, regulation of the hydrological regime, biodiversity indicators, carbon sequestration in vegetation and soil through trees.

Afforestation/reforestation of degraded lands

One of the main initiatives of the Government in Spain is to convert plots from various land uses to forest land and promote sustainable forest management (Government of Spain, 2020b). Specifically, converting unproductive and degraded agricultural lands to grasslands or forests can increase soil carbon sequestration, although more studies are needed on this topic (Rodríguez Martín et al., 2016). In Spain, the Agricultural Land Afforestation Program started more than 25 years ago thanks to the Common Agricultural Policy (Vadell et al., 2019). This program has successfully improved ecosystem service provision including soil conservation, regulation of the hydrological regime, biodiversity indicators, carbon sequestration in vegetation and soil through trees.

Agroforestry (dehesas)

A great proportion of the extensive livestock management (low-density cattle) takes place within dehesas. These agroforestry systems derive from the Mediterranean oak (holm oaks, cork oaks and oaks) forest by continuous human intervention over centuries. The result is a low tree density forest that is adapted to the productive needs of the nearby human populations.

The Agroforestry system Montado, in Portugal, and Dehesa, in Spain, is a High Nature Value system characterized by a high complexity as a result of the interactions between climate, soil, pasture (natural pastures, fertilized natural pastures, and sown biodiverse permanent pastures rich in legumes), trees (e.g., pure or mix stands of cork oak, holm oak, stone pine), and animals (e.g., sheep, pigs, cows, goats). Montado/Dehesa is one of the most prominent and best preserved low-intensity farming systems in Europe. The integration of traditional land-use and biodiversity conservation that is characteristic of this system is an exemplar for the wise management of the countryside. As well as the Montado regeneration is the last frontier to the desertification process. Moreover, with a good management plan, these systems can be strong carbon sinks with low GEE emissions.

The aforementioned different structural layers of dehesas (tree, shrub, and pasture) can be managed separately as intrinsically sustainable managed forest or grassland systems, as both benefit from the ecological interactions among the different biotic elements of the dehesa. Besides, one of the main objectives of the Government of Spain to increase carbon sequestration is to promote agroforestry systems such as dehesas for livestock production (Government of Spain, 2020b).

Grasslands (grassland management in dehesas agro-ecosystem)

Grassland management in Spain and Portugal is closely linked to the multifunctional agroforestry systems known as dehesas or montados. There is grassland and sometimes also a shrub layer under the tree canopy. In the dehesas, acorns, pasture and twigs are used for free-range livestock feeding. This livestock use is compatibilized with other uses such as agriculture, forestry, hunting, or recreation in this multifunctional landscape. These agroforestry systems are exclusive of the Mediterranean region and have great cultural relevance, especially in rural areas. Besides, their inherent landscape complexity and biodiversity enhance overall landscape connectivity, strengthen biodiversity indicators, and have great potential for climate change mitigation. There are several examples of successful and sustainable dehesa management, which have enormous potential for scaling up and can be an example to follow for territories facing sustainability challenges.

Also, there are 1,420,000 hectares of dehesa grasslands in the Extremadura region, equivalent to 57% of the useful agricultural area. This is why in this assessment of negative emission land management practices in Spain, agroforestry management and grassland management are considered described jointly in this section.

Currently, the potential value of the dehesa systems and grasslands as carbon fixers is not fully known, and the relationship between biodiversity and carbon sequestration in these pastures is understudied. Dehesas are highly resilient and multifunctional systems that can ensure food security and biodiversity conservation in a climate change scenario, and contribute consistently to mitigation (Pateiro et al., 2020). A study in central-western Spain found that an increase in forest cover in dehesas could benefit long term carbon capture in the soil (Howlett et al., 2011). Also, particularly for the grassland portion of dehesa systems, managing for livestock, increasing pasture species diversity, and applying compost soil amendments can act as resilient net carbon sinks (Dass et al., 2018; DeLonge et al., 2013; Hewins et al., 2018; Hungate et al., 2017). In the case of dehesas, these compost amendments can come from waste generated during pruning and clearing of the tree and shrub layers of the system, decreasing the need for external inputs.

3.3 Discussion on short-listing LMTs

3.3.1 Land management dynamics in Spanish agriculture

In general, agriculture plays a double role in the face of climate change, placing itself, on the one hand, as a victim of disturbances derived from meteorological phenomena, and on the other, acting as a source of greenhouse gases that causes climate change itself. The agricultural area shows a decreasing trend (figure 4). This evolution of agricultural land area results in the estimated greenhouse gas emissions shown in table 3.

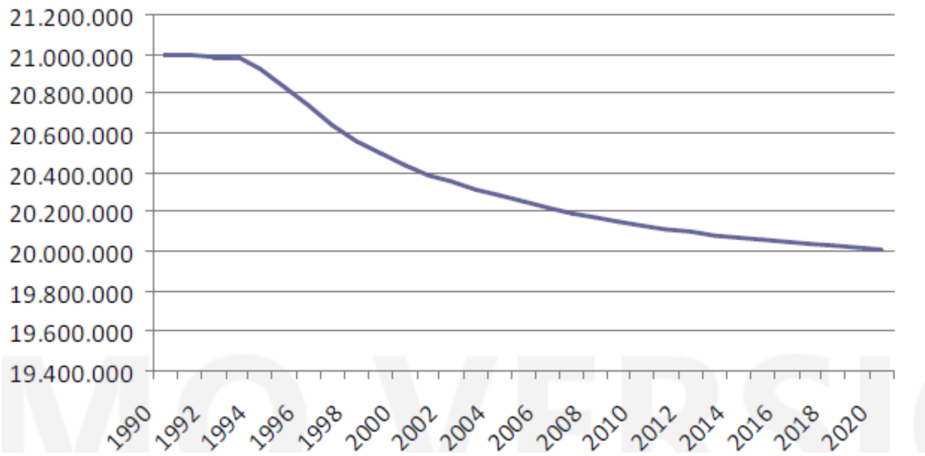

Figure 4. Evolution and projections of the agriculture land area, in hectares, between 1990 and 2020 (ha) (Government of Spain, 2015).

Table 3. Projection of net CO2 emissions in agricultural lands in 2015 and 2020 (Gg CO2-eq) (Government of Spain, 2015).

	2015	2020
Agriculture land use	- 2421	- 2726

3.3.2 Land use change dynamics. Grasslands.

The grasslands land use in Spain shows a decreasing trend, as shown in figure 3. This is likely a result of increasing stabling and feed use in livestock production. This intensive livestock production contributes to climate change, while the agroforestry system described in earlier sections (grasslands within dehesa systems) are likely a carbon sink. As a result of the evolution of grasslands area, the estimated CO2 absorptions are presented in table 2.

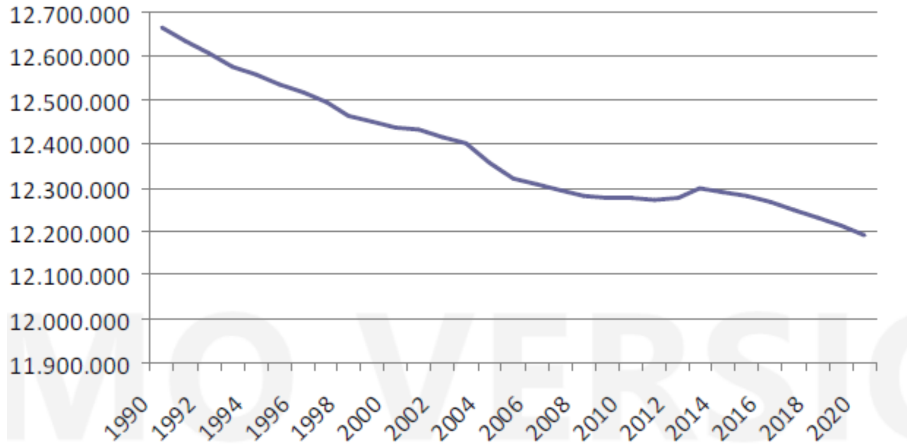

Figure 3. Evolution and projections of grasslands area, in hectares, between 1990 and 2020 (Government of Spain, 2015).

Table 2. Projection of net CO2 emissions in grasslands in 2015 and 2020 (Gg CO2-eq) (Government of Spain, 2015)

	2015	2020
Grasslands land use	1276	1832

3.3.3 Forest management

Forests are the main stable carbon sink and reservoir of biodiversity on the Iberian Peninsula. Its sustainable and profitable management, conservation and restoration are considered priorities and are part of the Spanish strategy for adaptation and mitigation of climate change. Forest area shows a stable trend over the last years, after a surge between 1992 and 2005, when the majority of the afforestation projects from the Agricultural Land Afforestation Program took place (Vadell et al., 2019) (figure 5). This evolution of forest land area results in the estimated greenhouse gas emissions shown in table 4.

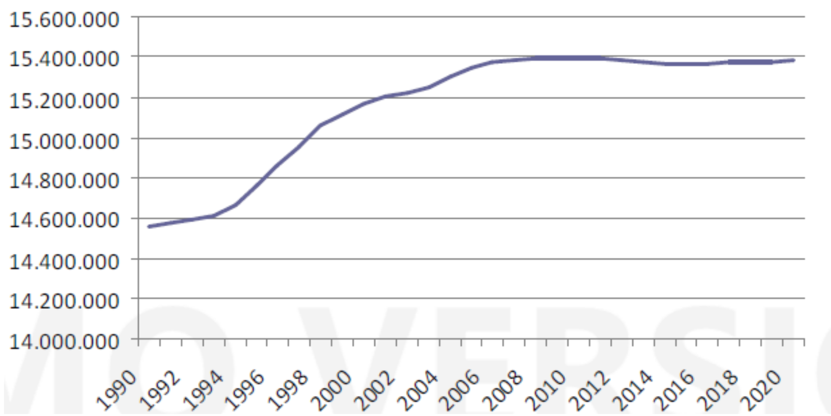

Figure 5. Evolution and projections of the forest land area, in hectares, between 1990 and 2020. (Government of Spain, 2015).

Table 4. Projection of net CO2 emissions in forest lands in 2015 and 2020 (Gg CO2-eq) (Government of Spain, 2015)

	2015	**2020**
Forestry land use	- 34119	- 34157

4. Co-design of LMT narratives

4.1 Introduction

The list of LMTs has been narrowed down to four for further analysis within the LANDMARC project. These include:

- dehesas (Spain) and montados (Portugal) management (agroforestry),
- grasslands for soil regeneration and carbon sequestration,
- forest planning and management, and
- afforestation/reforestation of degraded lands.

These LMTs are expected to have high carbon sequestration potential in Spain and could provide an additional source of income for farmers in a hypothetical carbon market. The qualitative narratives of the four LMTs for Spain are presented in the following sections.

4.2 Dehesas (Spain) and montados (Portugal) management (agroforestry)

4.2.1 Introduction

Agroforestry systems such as dehesas and montados could be key to achieve climate targets (Kay et al., 2019b). Dehesas and montados are heterogeneous “savannah” agroforestry ecosystems that include a grass layer, a tree layer and sometimes also a shrub layer. All these elements contribute to carbon sequestration within the system. This traditional multifunctional landscape and land use holds great potential for carbon sequestration, as resources are used very efficiently (VVAA, 2013). Carbon sequestration in dehesas could be achieved through a combination of pasture, tree and shrub growth.

Figure 5. Dehesa agroecosystem in Montehermoso (Extremadura, Spain). C16.

4.2.2 Policy context

Agroforestry systems are recognized in the EU Strategy of Adaptation to Climate Change, the European Forestry Strategy and the Intergovernmental Panel on Climate Change as relevant adaptation and mitigation mechanisms (in+dehesa, 2020).

The Long Term Decarbonization Strategy 2050 for the Spanish economy aims to reach climate neutrality by 2050. This strategy identifies the promotion of agroforestry systems such as dehesas and montados and their regeneration as one of its main lines of work (Government of Spain, 2020c). The traditional management of dehesas is inherently sustainable, as it is a multifunctional use of the land that takes advantage of the ecological interactions between the different elements of the ecosystem (trees, pastures, shrubs, livestock).

Which national policies exist that address the LMT?

Considering the ambitions demonstrated by the European institutions in terms of relaunching the economy, protecting the environment and increasing biodiversity, namely through the recently approved European Recovery Plan and the European Ecological Pact - "Green Deal" – the Confederation of Portuguese Farmers (CAP) is promoting activities related to agriculture in a context of sustainable exploitation of resources, in line with modern concepts of environmental protection, mitigation of climate change and combating desertification.

However, as far as political aspects are concerned, the lack of support from the institutions for the countryside should be highlighted, as the importance of the countryside in society and the economy is not really valued.

In addition, there is a very long and heavy bureaucracy, which makes it difficult for landowners to improve their farms. The policies are geared towards extreme ecological conservation, not allowing the owner to carry out the uses that have traditionally been made on the farm for decades and that have given rise to what we see today. Everything is seen from a regulatory point of view and not from the reality of the countryside.

Which actors are currently applying the LMT (e.g. land users, forest owners farmers)?

In Spain and Portugal, there are highly qualified farmers ("front runners") who use PA techniques (state-of-the-art technology), conservation farming, biological farming and the use of composting, which will allow a reduction in emissions from synthetic fertilizers and their replacement with organic fertilizers, a reduction in emissions from livestock systems by increasing the quality of the diet and installing biodiverse pastures. Farmers and many producer associations improved their products and processes, such as fruits and vegetables, as well as olive oil, wine or cork, thus enabling them to compete with the best producers in the world. In the agricultural sector, there is professional training that is mandatory, by national or community imposition, in which CAP develops a considerable activity, and training to develop specific technical skills. However, there are still a significant number of companies that do not have specific training. Moreover, in recent years, there has been a growing market interest in organic products that will force greater promotion of national production and exports, a better organization of production and marketing and a reduction in the external food deficit.

It should be highlighted that the Spanish dehesas provide high quality foodstuffs, among which Iberian pork products, such as Iberian ham, stand out.

Politicians and administrations need to have a better knowledge of the countryside in order to reach agreements that facilitate the sustainable management of the land and at the same time are profitable for the landowners. The amount of exploitation generated by the dehesa and all that surrounds it has been forgotten.

In addition, there is a lack of political support for the regeneration of the dehesas, as well as for cultural work such as pruning, clearing, planting, etc.

Which funds are available for the LMT?

Currently, the economic situation is unfavourable for carrying out improvements in the dehesas due to the high cost of materials and new techniques and technologies, as well as the weather conditions, which make it difficult for improvements related to pastures, trees or livestock to be successful.

With regard to business risks, the dehesas face major challenges such as high initial investment, due to the high cost of the land and the long period necessary for its amortisation.

In terms of social aspects, it is important to say that there is a lack of specialised labour, with knowledge about the proper management of these fields. The new generations are not motivated to work in the fields; they see it as a very demanding and unprofitable job.

As far as environmental aspects are concerned, we have already mentioned that there are many benefits generated by the dehesas related to the soil, plants, animals and birds. For all these reasons, they should not be abandoned when it comes to carrying out actions such as cork harvesting, tree pruning, pest treatment, grazing or tree regeneration.

In general terms, the overall amount of additional investments in some of the technologies identified, which can lead to reductions in fertiliser emissions and increases in carbon sequestration on agricultural land, pastures and forests, amounts to around EUR 570 million over the period 2021-2050, equivalent to an annual amount of around 19 million euros.

4.2.3 Current land use and potential land-use competition

Dehesas are traditional land use systems that have been occurring in the Iberian Peninsula for centuries. In Spain, dehesas cover an approximate area of 3.5 million ha. Most of them are privately owned and dedicated to livestock. Expansion of dehesa management as a LMT would not necessarily mean the geographical expansion of dehesa system themselves. Instead, carbon capture could be included as one of the objectives of the multifunctional management plan of the dehesa system. Consequently, dehesa management as an LMT would not compete with other land uses.

What is the national (1) historic and (2) current land use of the LMT and how is this projected to develop over the coming decades (2030 & 2050)?

The management of the agricultural sector aims to a more effective climate action and better protection of the environment and biodiversity. To reduce emissions and increase sequestration, the agricultural sector must focus on a green scheme in which there are more equitable payments to farmers when they consider the environment, climate change and the country in their practices. In the case of the livestock sector, emission reductions can occur through improvements in food digestibility and in livestock effluent management systems. The use of biodiverse pastures has a very important contribution to the net sequestration associated with the use of agricultural land in 2050 (e.g., biodiverse pastures covering the soil in between lines of oliveyards and vineyards, sequestering carbon, reducing nutrients leaching and soil erosion).

In addition, the expansion of organic and conservation agriculture, and PA will allow a reduction in emissions associated with animal effluents and the use of fertilizers. Therefore, the emissions reduction in agriculture is occurring at a slower rate than in other sectors, inherent to the characteristics of the associated biophysical systems, which means that its weight in national emissions will be between 29% and 34% by 2050, depending on whether one considers or not the contribution of land uses.

The main effects of dehesas on the local environment are several:

- Dehesas as carbon sinks, through both the woodland and pasture present.
- In terms of soil protection, adequate vegetation cover, through trees and grasses, controls erosion processes and in turn contributes to the balance of the water balance.
- In terms of diversity, the high biodiversity present in a pasture system is evident, both in terms of plant life, macro-fungi, macro-fauna and birds.
- The scenic value of the landscape is important in that it prevents fragmentation of the landscape, due to the diversity of habitats present.
- Nowadays there is a high demand from society for this biodiversity present in the dehesa, which is reflected in ornithological tourism or the increasingly demanded orchid tourism, both of which nowadays move large amounts of money.
- As a cleared Mediterranean ecosystem, the risk of fire is lower in the dehesa than in a forest with closed undergrowth where, in the event of a fire, the area would be completely destroyed.

It is very necessary to include pastureland systems in national policy, because they are suffering a great decline, and in less than 50 years many dehesas will have disappeared as we know them today.

Furthermore, society is unaware of the existence of aid or subsidies related to the regeneration of woodland. The dehesas are very close to society, but they are not valued. In the past, dehesas were used in a more sustainable way, but nowadays there is no respect for the environment (rubbish, excess of vehicles) which contributes to the degradation of the vegetation cover and the biodiversity of the environment. In short, there is a lack of environmental awareness.

The positive impact of the dehesa on the daily life of rural communities due to its diversified uses has been forgotten, as well as the lack of awareness of the benefits it can generate. All this leads to a deterioration of the traditional pasture system and a loss of biodiversity.

With regard to business risks, dehesas face major challenges such as a high initial investment with a long payback period. Currently it is difficult to invest in dehesa, due to climate change, because if it is affecting 70-100 year old holm oaks, which are drying out, the new trees that are put in place for tree regeneration may not survive these episodes of extreme conditions. Therefore, in addition to the high economic costs for investment, there are also climate-related risks.

In terms of environmental aspects, changes in land use have a major negative impact on the dehesa.

The opportunities are many: it provides a great increase in biodiversity in the environment. Water and soil management is essential for the conservation of pastures and to avoid soil degradation.

Are there other land use developments that compete with the expansion of the LMT, and if so, how do those affect the scaling-up of the LMTs?

The evolution of the Spanish economy and society in the last 50 years, although positive, has not stopped the population exodus to large urban centers and the progressive aging of the rural population, leading to the abandonment of territories and traditional activities in agriculture. Consequently, it gave rise to the progressive extension of forest use, often spontaneous and not managed with great concentration of fuel loads and strong exposure to rural fire hazard, which are added to the destruction of the forest and the goods and services it produces, further promoting the abandonment and masculinization of these territories.

However, at this stage and considering cropland optimization the only way to go is to consider the usage of sustainable agriculture practices, namely PA techniques and others that for sure will start to exist in the fields to solve the labor deficit in agriculture (e.g., robotics).

In some areas, species increasingly adapted to extreme conditions such as drought are appearing, for example *Crataegus monogyna* or *Cistus ladanifer*, which appear on degraded land and are capable of adapting to more extreme conditions. In turn, these species of low ecological value contribute to reducing erosion on degraded land and therefore favour the establishment of other less resilient species.

Dehesa is a system heavily affected by pests, which is being aggravated by drought conditions. It may be that in 50 years there will be very few trees left in the dehesas, it should be borne in mind that these are ancient trees. With the right planning, there would be no major difficulties in the maintenance of dehesas, nor do they involve a high economic cost for the landowner. There are new technologies available on the market that can be applied in pasture systems and whose economic cost is not so high. It is observed that the application of these new technologies in the future will be the main tools for detecting problems in the pastures, such as dry trees or the state of the pastures. Another aspect to be highlighted is the over-exploitation of livestock due to high stocking rates.

In terms of political barriers or opportunities, there is a lack of support for pasture systems, and the necessary measures for tree regeneration are not applied. There is also excessive bureaucracy in the processing of permits for actions and exploitation in pastureland systems, which hinders the maintenance of the ecosystem.

4.2.4 Climate risks & sensitivities

Extreme temperatures could trigger mortality events in trees and higher incidence of forest fires. In addition, a shifting pattern of temperatures and rainfall could gradually eliminate trees from dehesas due to stress and vulnerability to diseases. Previous studies have found that forest species composition is changing as a result of climate change (Batllori et al., 2020). This could mean that the current locations of dehesas might not have the ideal environmental conditions for the typical dehesa trees (*Quercus* spp.) to thrive in the future. Climate projections for Spain include the worsening of drought periods. Dehesa ecosystems are resilient to drought disturbances (Martínez-Valderrama et al., 2021).

The main risk factors related to climate and the management and conservation of the dehesas considered bin Spain are drought as the main problem, together with heat waves, which are increasingly present and prolonged over time. Forest fires are also increasingly present due to the drought we are currently experiencing in our fields and especially in nearby areas. The most relevant periods of drought in living memory are those of the early 1980s and 1990s. As for heat waves, the last few summers have been more frequent and longer in summer.

Furthermore, the main visible effects of the dehesa on the local environment are several. On the one hand, environmental, affecting both soil structure and water balance and soil protection. When there is rainfall and a good autumn and spring, the vegetation cover is excellent and everything is in balance. In terms of diversity, the high biodiversity present in a dehesa is evident, both in terms of plants, animals and birds. The scenic value of the landscape is important, we all like to see a green and flowery dehesa in autumn and spring. The risk of fire is lower compared to a forest that is more enclosed and with more tree vegetation, but in the event of fire the losses are greater because the trees are centuries old.

It is also important to mention that it is an ecosystem with a high capacity to adapt to extreme conditions such as the current drought, and this may be due to the diversity of products it generates, as well as its agrarian, forestry and grassland use. The progressive increase in temperatures, the absence of rainfall and the distribution of the latter are becoming more and more common. More concentrated and torrential rainfall combined with higher temperatures affects both fauna and flora in the dehesa as they are not used to it and can lead to alterations in their cycles, such as flowering or acorn production. For example, the torrential rains in November 1997 in Badajoz led to episodes of soil loss that were very significant in comparison with the average values for the area. This soil loss was due both to the torrential rains and to tillage practices, which showed that good agricultural practices are very important in agroforestry systems.

4.2.5 Economic implications

The lack of generational replacement and the age of the managers of agroforestry systems is an obstacle to the implementation of new technologies in the dehesas. In addition to the current difficulty in finding labour to carry out field work and the lack of training of this labour force in specific tasks. The economic situation also hinders the management and application of technologies, due to the high costs, which leads the owner to depend on subsidies for such implementation.

In terms of political risks, despite the fact that the dehesa is highly regarded at national level, there is little support for this agroforestry system. This is often due to a lack of knowledge on the part of the institutions, which is reflected in the inadequacy of aid. For example, the European Union does not fully understand dehesa because it cannot be classified as either a forest or a crop.

In Spain, although much importance is given to the dehesa and it is well considered, only in Andalusia is there a more up-to-date law on the Dehesa. In Extremadura, for example, the legislation regulating this agro-forest-grass system is outdated and out of date.

This political situation means that the European Union often allocates large amounts of money to rural development, and therefore also to the dehesa, and yet it is lost due to a lack of knowledge or inefficiency in the management of the funds earmarked for this agroforestry system. In addition, the lengthy bureaucracy is a major obstacle to the proper management of the agroforestry system. The aids available take a long time to be resolved, the owner has to anticipate a high investment and then assume a great uncertainty for the collection of these aids.

On the social side, the lack of generational replacement, the lack of interest on the part of young people in agricultural work and the lack of training in specific jobs have already been mentioned. Furthermore, there is a certain reluctance to change the mentality that involves the application of new management tools or the inclusion of women in farm work.

Socially, it can be said that the dehesas are very well regarded by society in general, especially by the rural population, due to the fact that most families in rural environments depend on agricultural and livestock activity and in many cases on the dehesa.

The main business risks are reflected in the high costs of agroforestry land, which makes these lands inaccessible to young people, and the fact that most of the land is inherited, which is leading to land division. In addition, high investments are required for machinery and livestock. All this means that in addition to the high investment, there is a high uncertainty of payback.

The existing risks and benefits generated in the dehesa are directly related to the good agricultural practices developed in these systems. It is also worth highlighting the opportunities that exist in terms of R&D related to the dehesa, as many related R&D projects are currently being developed, as well as various calls for proposals in which these agroforestry systems are being considered.

Most dehesas are already actively managed for livestock raising. Adjustments to the multifunctional management could make livestock compatible with mitigation and open a new source of income for farmers under a potential carbon capture market. A life cycle assessment of dehesas under organic management found that carbon sequestration values were extremely high. Up to 89% of the carbon emissions were compensated for meat producing ruminants, and 100% for dairy goats and Iberian pigs fed in montanera (making use of the grass and acorns within the dehesa) (Horrillo et al., 2020). Agroforestry systems such as dehesas tend to have slightly lower revenues than agriculture. However, the inclusion of monetize positive externalities such as carbon capture and storage payments could increase the profitability of agroforestry (Kay et al., 2019a). It is estimated that 0.93 tC/ha/year is sequestered in aerial biomass in dehesas (in+dehesa, 2020). More general estimates for agroforestry systems suggest a range between 0.09 and 7.29 tC/ha/year (Kay et al., 2019b).

4.2.6 Co-benefits and trade-offs

Conversion from conventional farming activities to agroforestry approaches could capture between 1.4 and 43.4% of the agricultural carbon emissions in the European Union and Switzerland (Kay et al., 2019b). Also, agroforestry systems such as dehesas and montados optimize the use of resources and have very low pollution externalities from soil and nutrient losses (Kay et al., 2019a). Dehesa systems are traditional landscapes with great aesthetic, historical and ethnographic value, and are frequently visited by eco-tourists. In addition, they are inherently biodiverse, hosting endangered flora and fauna (amphibians, birds) in many cases. Studies have found that agroforestry both increases biodiversity (mean species abundance) and carbon sequestration opportunities (Nunez et al., 2020). The pasture management carried out in dehesa ecosystems for livestock helps preventing erosion and floods (Fuentes Pazos et al., 2018).

The main visible effects of the dehesa on the local environment are several. Well-managed agroforestry systems, i.e., with good agricultural practices for their management, contribute on the one hand to increasing their carbon sequestration capacity and on the other hand to the reduction of emissions into the atmosphere.

In addition, a well-managed agroforestry system contributes to increasing the system's capacity for soil nutrient retention, improved water balance, soil protection and soil macrofauna.

On the other hand, the fact that the dehesa is characterised by a diversity of habitats, areas with more or less density of scrub or woodland, pastures or aquifers, contributes or generates an added value to the landscape. Biodiversity in the dehesa is favoured by the implementation of good practices in agroforestry systems for both flora and fauna.

In terms of resilience, well-managed dehesas through the implementation of good agricultural practices contribute to better adaptation to climatic conditions, as well as being species adapted to the environment. The resilience or capacity of an agroforestry system to adapt to changing conditions is directly related to the climate and the implementation of good agricultural practices.

On the other hand, being an agroforestry system with scattered trees and grazing livestock, the probability of a major forest fire is considerably reduced.

4.2.7 Risks associated with scaling up

The main risk to scaling up would be relating to climate change, as dehesa ecosystems could be dramatically altered by shifts in temperature and rainfall patterns. It must be understood that the dehesas are vulnerable to increased periods and intensity of drought, and this in the Iberian Peninsula has effects, among them, a greater risk of advancing desertification. Careful planning is required to ensure that specific dehesa locations will still be environmentally adequate for *Quercus* spp. trees in the future. This is highly relevant, as these trees grow slowly, are hard to replace and are a key element of dehesa and montado systems. In addition, climate change could limit water availability, hindering the productivity of dehesas (in+dehesa, 2020).

4.2.8 Research gaps

More information on the carbon sequestration potential of dehesas and montados ecosystems is required. Also, life cycle assessments of meat and dairy products of dehesas and montados are needed for accurate estimations of the dehesa carbon sink.

4.3 Grasslands for soil regeneration and carbon sequestration

4.3.1 Introduction

Grasslands and pastures are the most common land cover in the planet, covering about 25% of the Earth. Even though many of these grasslands are degraded, they still store large amounts of carbon and hold great mitigation potential, especially in underground biomass. Grassland and pasture soil amendments for increased organic matter and productivity using compost constitutes a net carbon sink (DeLonge et al., 2013; Hewins et al., 2018). Increasing pasture diversity also captures carbon (Hungate et al., 2017). Moderate livestock loads could also increase the amount of carbon stored in the soil, although this depends on the particular environmental characteristics of the site (Hewins et al., 2018; Rolinski et al., 2018).

Grasslands have the availability of capturing carbon and also emit GHG. Grasslands are generally expected to have high biomass turnover, productivity and nutrient cycle, and only moderate capacity for carbon sequestration in biomass when compared to woody communities. Therefore, not all area available for sown biodiverse grassland is available for sequestering carbon and neutralize emissions.

A particular activity, taking place in grazed lands is reported and accounted for under "grassland remaining grassland": Sown Biodiverse Permanent Pastures Rich in Legumes (SBPPRL) sown biodiverse permanent grassland rich in legumes. Sown biodiverse grasslands are based on a diverse mixture of about twenty different species, many of which (approximately 30-50%) are legumes. These grasslands are more productive than the baseline land use system – spontaneous natural grasslands. Productivity is accompanied by an increase in soil organic matter (SOM) and correspondent carbon sequestration. Teixeira et al. (2011) analyzed the effect from a shift from natural to sown biodiverse grasslands, and calculations based on this work estimated a carbon sequestration factor of 6.48 tCO_2.ha-1.yr-1 for a period of 10 years. Most of the time, these grasslands are grazed directly by cattle, sheep or goats and result from the seeding with improved and selected seeds. Thus, grazing intensity and opportunity can influence pasture growth and thus affect soil carbon storage. Both undergrazing and overgrazing can decrease soil carbon build-up. In addition, pastures that favor the intercropping of different species should be used. It increases grassland productivity by increasing soil carbon sequestration.

A grassland study showed that the composition of the species community is sensitive to CO_2 increase, which has implications for its stability and resilience. For example, in an annual Mediterranean grassland after three years of trials, species diversity decreased with increasing CO_2, increased with increasing precipitation and showed no effect with increasing temperature. In sown grassland, the increase in CO_2 favored legumes.

The increase in climate variability, with more frequent occurrence of extreme events will also have a negative effect on agricultural activity as it will increase the uncertainty associated with different agricultural systems. On the other hand, the increase in extreme events can lower crop productivity more than the effect of increasing average values. This results from the fact that the impact of extreme events largely depends on the phenological state of the crop at that time. The more frequent occurrence of more intense rainfall will have a negative impact on productivity as it increases the occurrence of periods of saturated soil and, consequently, of stress for crops. Those events will also have impacts at the level of soil erosion.

4.3.2 Policy context

The Spanish Long Term Decarbonization Strategy 2050, which aims to reach climate neutrality by 2050, identifies the increase of carbon content in soils as one of its main lines of work (Government of Spain, 2020c). The Common Agricultural Policy, in its first pillar, promotes *greening*. This implies the application of sustainable practices that would have an indirect positive effect on carbon sequestration (EIP-AGRI, 2018).

Which national policies exist that address the LMT?

According to the trajectories for carbon neutrality of the Spanish economy by 2050, it is necessary to ensure the capacity for carbon sequestration by increasing the organic matter content in grasslands, especially in areas with sown, improved, permanent and biodiverse grasslands. The use of biodiverse grassland has a very important contribution to the net sequestration associated with the use of agricultural land in 2050.

In terms of environmental risks, a pasture plot, with optimal vegetation cover, considerably reduces soil erosion, as well as reducing emissions compared to bare soil. The opportunities generated by a pasture cover increase biodiversity and improve water and soil management.

There is a lack of political support for grassland, due to lack of awareness and knowledge, which leads to a lack of funding for grassland. Lack of knowledge and awareness of the benefits of grassland such as reduced erosion, increased biodiversity, increased organic matter and therefore increased carbon assimilation and storage capacity.

With regard to the CAP, there is a lack of coordination between the different administrations, which means that the new CAP (2023-2027) in Spain is not updated for the most widespread crops currently grown.

Bureaucracy is also long and tedious in Spain, which hinders the development of new techniques and knowledge in general.

There is a lot of uncertainty in the income regime, there is a popular saying: "Any business that depends on the sky, is not a business", it reflects the reality of the Extremadura countryside.

Which actors are currently applying the LMT (e.g. land users, forest owners farmers)?

In a similar way to croplands, the expansion of biological and conservation farming and PA, as well as permanent grasslands, will reduce emissions associated with fertilizer use and animal effluents, and increase carbon sequestration resulting from increases in organic matter content in the soil. These approaches are highly being used by highly qualified farmers who use state-of-the-art technology, including sowing biodiverse grasslands which induce other environmental benefits, such as the preservation of natural and ecological resources, promotion of biodiversity and/or improvements in animal welfare.

The high costs of the technology right now make it difficult to access and implement. As well as the lack of knowledge and lack of training on the part of farmers and landowners, which makes it necessary to hire specialised labour and therefore increases costs. The failure of the application of new technologies is based on the high costs of both equipment and specialised labour for their application, which is necessary due to the lack of knowledge on the part of landowners about the use of such equipment.

With regard to social risks, there is a lack of generational change, the new generations do not want to work in the countryside. There is also a lack of knowledge about pasture cultivation, as society does not consider pasture as a crop that needs management and agronomy.

Which funds are available for the LMT?

Markets in grassland are regulated by the CAP and the future lies in achieving a circular economy.

From a financial point of view, it currently takes between 300-400 €/ha to establish one hectare of grassland. High capital costs are needed due to very high land prices, as well as a long payback period.

In the new CAP there are three new lines related to pasture: low carbon agriculture, which is achieved with spontaneous or sown biodiverse plant cover, agroecology, favouring the biodiversity of agroecosystems, and crop rotation. Payments in the new CAP for pastures are 60-70€/Ha, i.e. they are very little valued in Spain.

4.3.3 Current land use and potential land-use competition

Permanent pasture area has been reduced over the last decade (National Statistics Institute, 2020). Agricultural areas have decreased as well. This is probably a result of the ongoing rural abandonment taking place in Spain over the last decades. Population is migrating towards large cities looking for jobs. Using grasslands and pastures for carbon sequestration would not encounter any conflict with other land uses, especially in isolated areas of the country. In fact, new uses of the land such as carbon sequestration management could create new job opportunities in rural areas, contributing to their revitalization.

Contrary to cropland, the areas of grassland have seen an increase since 1990, with most of the area coming from cropland (rain-fed annual crops). The conversion from agriculture to grasslands usually results in an increased sequestration, while the conversions from forest land and other land result in increased emissions. The net-balance has favoured emissions, although these have been heavily reduced since 1990. More recently the introduction of incentives for biodiverse grasslands has allowed an increase in sequestration rates due to an increase in the areas of grasslands and extensive livestock, the greater use of more sustainable practices in environmental terms (e.g., organic production, integrated production, direct sowing and minimal mobilization) and the reduction in the use of fertilizers.

The main effect of grasses on the local environment is primarily related to soil, water and air. In particular, they contribute mainly to the water balance, due to their water retention capacity, which is linked to a higher retention of nutrients and therefore to a better soil quality and a reduction of erosion. Currently, due to the lack of water, extensive livestock farms, whose main food is grass, are going through very hard times due to the lack of feed and drinking water.

In terms of their contribution to carbon sequestration, it is the roots that accumulate carbon, so in pasture land under livestock management it is the soil that is the largest store of carbon. Grasses do not store large amounts of carbon, but the roots of these species do, which is stored in the soil.

The diversity of macro-fungi is very important for their nitrogen and phosphorus storage capacity, therefore, soils with good soil quality reduce the amount of external inputs of inorganic fertiliser to the pasture.

Pasture management as a tool for increasing carbon sequestration and vegetation cover of the systems. With these tools we will not be able to avoid climate change, but we will try to mitigate it and adapt to new climatic conditions. For example, a fire in an area of pasture burns the pastures and trees. The following year the grasses return with a little rain, but it will take at least 20 years for the holm oaks to return to their carbon sequestration function. Therefore, in a forest fire situation, grasses adapt better and perform a higher long-term CO_2 storage function than oaks, because during the first 20 years the trees accumulate low amounts of CO_2.

Adaptable plant species need to be genetically improved in order to achieve species that are able to adapt to the new climatic conditions.

4.3.4 Climate risks & sensitivities

Extreme temperatures and extended drought periods would have a very detrimental impact on grassland productivity and thus, carbon capture. This is especially relevant in Spain, where aridity is increasing as a result of climate change. A simulation study carried out in France found that less protein content and water drainage, and more interannual and interseasonal variation are likely to happen by the year 2100 (Graux et al., 2013). Community compositions are also expected to shift as a result of a change in climate patterns (Ghahramani et al., 2019).

How sensitive is the LMT to climate related changes regarding:

Climatic conditions drastically affect grassland productivity in the same way affect the productivity of crops. The geographic distribution of grasslands is a function of climate and photoperiod, total amount of precipitation and effect of temperature on phenological development. The occurrence of extreme weather events ,such as, heat waves, hailstorms or dry spells can compromise part or all the production of a campaign. In a climate change scenario, the probability of occurrence of these events is greater, so it is possible to predict greater production losses in this way.

The main risk factors related to climate and pasture management in Spain considered are drought as the most important, followed by heat waves, cold waves, frost and erosion. Regarding these, it was commented that pastures develop in optimal temperatures between 25-35ºC, anything below 20ºC and above 50ºC for a long period of time causes lack of growth and senescence.

In the past, it was colder than now, when the minimum temperatures reached -5ºC and 5ºC, the grasses showed a stop of growth, because with Tª<0ºC the grasses burned. Nowadays, it is not as cold and these temperatures are not as frequent as in the past.

On the other hand, frost stops the growth of grasses and others that are very sensitive to cold burn and die.

There have been several episodes of drought lasting 3-4 years, and since 2019 we are currently in a period of drought. In Extremadura for example pp<200mm is a disaster, a period of drought in winter is not the same as in spring, because evapotranspiration in spring is higher and if it does not rain it is a disaster for the emergence of grasses. The false autumn or inadequate distribution of rainfall is a very important situation, because the worst thing is that it rains at the beginning of autumn, for example, but it does not rain again until January, which means that the grasses are born in autumn but due to the lack of rain they die and the seed bank is lost. However, if the rain falls at another time, the seed bank remains in the soil available for another season with better conditions.

In terms of erosion, if a drought occurs, the soil is not covered with vegetation cover and this leads to runoff processes, gullying and loss of nutrients. Therefore, a soil cover <30% total disaster of 30-60% can prevent erosion, above 60% is an optimal cover where no or minimal erosion would occur.

4.3.5 Economic implications

Grazing management in grasslands and pastures would need to be regulated to achieve optimal carbon sequestration (EIP-AGRI, 2018). In many cases, this will mean lowering the livestock loads, which will have an impact on productivity. However, this could be compensated by the income generated for farmers in a potential carbon market. In addition, management practices that promote carbon sequestration are often advantageous for farmers in the long run. Soils with high carbon content have better structure, are more nutritious for plants and can hold water more efficiently, improving their fertility in the long run (EIP-AGRI, 2018). Also, sustainable grazing management will usually lead to higher quality meat products and higher income for farmers (EIP-AGRI, 2018).

As for the barriers to the application of good pasture management, we find that the management of Mediterranean pastures in large areas is complex due to the need to divide the land into fences and to rotate grazing over them, something that in many cases is not done due to the increased costs and limitations that this entails.

However, the investment in improving pastures by sowing improved species pays for itself in the first year, i.e. the benefit of the grassland is immediate and pays for itself in terms of increased quality and biomass production.

In terms of political and institutional aspects, pastures are abandoned, they do not have sufficient support because the benefits they bring are not contemplated. The new CAP will favour pastures, so that the owner is required to carry out certain actions, which he is already doing, but they will be better remunerated. For example, greater administrative control will be required by means of a field notebook in which the different actions carried out, such as sowing, fertilising, grazing, mowing, etc., are recorded.

The high cost of acquiring land for Mediterranean pastures must be emphasised, which means that a very long period is needed to amortise this investment. This disadvantage means that pasture land is being used for the implementation of photovoltaic plants or the planting of woody species in intensive systems.

The social opportunities generated by proper pasture management are directly related to livestock farming, in such a way that good pasture management contributes to an increase in profitability, generating greater economic value, employment and therefore fixing the population in rural areas.

The main constraint to the implementation of the grasslands management could be lack of knowledge about pasture improvement, its correct management. The costs of improvement and therefore the benefits generated. For example, pasture improvement represents 0.1% of the total costs of a farm and this percentage is amortised per year and the benefits can last up to 10 years.

It is necessary that work in the countryside is better remunerated and socially recognised, for which it is necessary to provide products with added value. For example, the dehesa with livestock, in the case of cattle, which in itself provides little labour, if we improve the landscape and its conservation we will provide it with greater added value, which also involves selling the fact that pastures are CO2 sinks and their importance.

In terms of environmental opportunities, knowledge plays an important role in terms of the choice of species to achieve a balance of species that provides an increase in biodiversity and therefore carbon storage capacity.

4.3.6 Co-benefits and trade-offs

In a context of climate change, with increased frequency and intensity of wildfires, grasslands and pastures could be a more resilient mechanism than forests for climate change mitigation (Dass et al., 2018). Grazed grasslands and pastures are essential for the economic sustainability of many urban communities. In addition, they provide various ecosystem services, including erosion prevention, water regulation and biodiversity support (EIP-AGRI, 2018). Grassland management for carbon would also have a positive impact on biodiversity, as an increase in plant biodiversity leads to an increase in carbon storage (EIP-AGRI, 2018).

The most important effects of grasslands on the local environment are carbon sequestration, water balance directly related to soil protection, as well as biodiversity and fire risk reduction. In terms of carbon sequestration, grasslands are key, if we manage grasslands well, we will have a good vegetation cover that will act as a carbon sink, as well as reducing the amount of emissions, because the dependence on external inputs (animal supplementation) would be lower. So that a well-managed grassland cover contributes to a higher retention of nutrients in the soil and therefore to an improvement of soil quality and a better regulation of the water balance.

In terms of biodiversity, a land with a good grassland vegetation cover, the more balanced it is, the more it affects the scenic landscape value, due to the high biodiversity in terms of plant and bird species, although the contribution of grassland to these factors will depend on the stocking rate of livestock using the land. Grasslands have an important role as carbon sinks as well as buffers for the overall system.

The main risk factor related to climate and pasture management in Spain considered by farmers is drought, both lack of water and inadequate rainfall distribution. Linked to drought are the increasingly frequent and longer heat waves in the summer season. Past droughts of note were those of 1982-1983 and 1993-1994 due to their severity.

Furthermore, the pastures are affected by continuous frosts and strong winds, the latter of which, when they occur, reduce the intensity of the rainfall.

There is a lack of definition of national strategies to encourage the use of more productive, more resilient and persistent species and mixtures, and improvement in the management of installed pastures (e.g., sowing, fertilization, mineral correction, animal management, etc.) is lacking.

Direct aids (i.e., integrated production, organic production, greening, etc.) are neither sufficient nor adequate to promote the improvement of production and the impact of forage and grass crops. More research and experimentation are needed, on species, varieties, mixtures, cultural techniques and the management of grasslands and animals to increase the efficiency of the use of these foods, their quality, reduce costs, improve animal performance and, above all, increase the effective animal load to better value natural meadows and grasslands.

It is clear that proper grassland management and adequate vegetation cover contributes to the regulation of water flows, soil protection and more even and efficient distribution of rainwater.

Grazing management has a direct impact on biodiversity, as the management itself can influence the botanical composition or the phytodiversity of the plot. Continuous grazing encourages the emergence of less productive species and biomass less exposed to consumption by livestock. However, if grazing rotations are carried out, you will see a greater diversity of species and therefore a more resilient pasture that is better adapted to adverse conditions. In Mediterranean pastures, if we don't protect the pasture in early autumn, when the legumes emerge, that fence is going to have worse grass than if we let it rest. Likewise, this happens during the flowering season, logically the grasses that thrive have a smaller size, producing seeds that livestock cannot access and producing an imbalance in the diversity of species.

Pasture management in the Mediterranean context has a direct effect on the probability of fires due to the presence of trees. It is a risk to have these areas without any management, as the probability increases.

4.3.7 Risks associated with scaling up

Livestock farms are highly polluting if managed unsustainably. Scaling up grasslands for carbon sequestration would require a careful assessment of the sequestration potential of an area, and comprehensive management plan including circular economy and elements such as the use of compost for soil amendments.

The parameter that has the greatest impact is drought, but not only in terms of a decrease in the amount of precipitation collected, but also in terms of the irregular distribution of rainfall. An example is: it does not have the same effect if 500 mm/m2 falls over a hydrological year if it falls in 4 episodes of rainfall as if this amount is distributed in an irregular way which allows the pastures to have moisture for as long as possible. This reduction in litres or inadequate distribution of rainfall affects both the amount of biomass and the quality or botanical composition of the grassland. Thus, adequate rainfall in the right way favours the production of legumes, whereas when rain falls too early, and then falls too little or too late, it enhances the emergence of grasses.

Other important factors related to grasses are heat waves, frost and ground fires. So heat waves also depend on when they occur, they will affect more or less, so if they occur when the pastures are already dry or parched, the effects are of little importance. However, when they occur during the reproductive period of these species, such as at the end of spring, the impact is much greater, because the natural cycle is altered and natural seed production is affected. This last climatic episode occurred in the spring of 2022 and its effects will be visible this autumn.

As for frosts, they limit the development of species. If they last longer, they can kill many plants, which penalises both the quantity and the quality of the grass. It is also important to consider the grazing that is carried out in cold periods, as this is grazing that greatly penalises the pastures, and the trampling of these plants during the frost period ends up killing them.

In Mediterranean pastures, where there are fences that are not used until the end of the summer, the probability of a forest fire is greater, so it is very important in the management of pastures to take into account the risk of fire, because the pastures resurface the following year but the trees that accompany them take decades to recover.

In terms of policy parameters, there are no policies aimed at sustainable pasture management. Although the new CAP is now promoting greener agriculture and livestock farming, in terms of pasture use, the techniques required of owners are practically the same as in the previous period, with the difference that they must be registered.

The problem is that there are pastures that should be used by livestock, because of the benefits and opportunities they generate. However, there is a lack of political support that values this type of production. It makes no sense to call for the sustainable use of pastureland and, on the other hand, not to value the products generated by such use. At the present time, the politicians are misjudging livestock farmers, they are being persecuted and the current tools for measuring emissions are inadequate because they are generalist, and no distinction is made between the emissions produced, for example, by a stall animal and those produced by an animal grazing in the field.

There is no legislation to support or promote the management of pastures and their use. There is no legislation to protect these ecosystems. The Mediterranean pastures have never received support from the CAP; on the contrary, they have been heavily penalised, for example, by deducting money for the presence of trees.

With regard to social parameters, it should be pointed out that there is a clear lack of labour to carry out tasks in the fields, problems of depopulation, and a lack of knowledge and training to carry out these tasks. The availability of manpower is essential for proper pasture management or valuation. Nowadays, due to this lack, farms are opting to give up good management, livestock graze freely on large areas of land, but they are not managed, there are no rotations, for example. This is due to various causes such as:

- nowadays it is not well seen or valued to work in the countryside,
- young people do not want to work in the countryside, they are not motivated because they see it as a sacrifice and old-fashioned, as well as the amount of aid that people receive from the government, which means that there is no interest in working in the countryside because they prefer to live on subsidies.

4.3.8 Research gaps

Accurate monitoring and measuring methods for carbon uptake by grassland species are required. In addition, life cycle assessments for meat and dairy products are essential no calculate the carbon effectively removed from the atmosphere by grassland systems. More information on the appropriate grazing management for specific locations and combination of species is required (EIP-AGRI, 2018).

Research and experimentation work is needed to determine the best varieties and mixtures for each edaphoclimatic combination. There is also a lack of studies on the response to production factors (e.g., fertilization, irrigation, etc.) and on management, to be able to advise livestock producers and prepare manuals on good practices, which can serve as guides for the good use of these productions by the animals.

As far as pasture management technologies are concerned, there are quite a few advances such as different types of fencing, genetic improvement, specific harvesters for pasture species, etc. The obstacle is not the lack of technologies in grassland management, but the lack of knowledge for the application of new techniques or new technologies that have been developed in recent years.The technological blockage comes from a lack of knowledge both of the existence of these technologies and of the people who can access them for their correct application.

There is a lack of promotion of the ecosystemic benefits generated by the exploitation of pastures and extensive livestock farming, as well as a valuation by consumers, and institutional support to promote and value these products. The risk is not high, because to implement sustainable management you do not need to make a large investment, but no matter how small it is, if the income does not increase, managers stop implementing sustainable management because in the end they see it as a reduction in their costs. In terms of environmental aspects, it is clear that proper pasture management generates a number of ecosystem services that would not otherwise be generated. Sustainable management leads to reduced inputs and increased carbon sequestration.

4.4 Forests planning and management

4.4.1 Introduction

Forests capture carbon from the atmosphere as the trees grow, and then store it long-term in their biomass. The carbon emission-capture in forests is a complex system comprising four main carbon pools: aerial biomass, underground biomass, soil organic matter and forest products outside of the forest (wooden furniture, paper, pulp, wooden buildings, etc.). It is estimated that Spanish forests capture up to 19% of the carbon dioxide emitted in the country. Also, these forests store more than 2858 tonnes of carbon dioxide. Consequently, forests play a major role in carbon mitigation in Spain, and carbon sequestration should be explicitly taken into account in sustainable forestry management. Sustainable forestry could improve carbon capture by forests due to the rejuvenation process that wood extraction instigates in the forest mass, and wooden products could have long lives outside the forest (Montero et al., 2005).

Specifically, *carbon silviculture* should speed up natural forest regeneration using an adequate forest cutting plan. It should also make use of biomass waste generated during cuttings or prunings, clear the shrub layer when necessary to increase tree regeneration. Also, the forestry management should optimise que quality of the wood extracted, as higher quality wood is usually turned into long lasting wooden products. Lastly, forest fire prevention should also be a cornerstone of the forestry management, avoiding large carbon release events as a result of forest fires (Montero et al., 2005).

What is the general context of the LMT and how does it address climate change mitigation?

Forests and associated woodlands occupy 54% of Spain's surface area (27 million ha). This area has been increasing at a rate of more than 180,000 ha/year in the last 25 years (the highest rate in the EU) both by action (afforestation, afforestation of agricultural land) and by spontaneous expansion of forests as a result of rural abandonment. (https://juntosporlosbosques.ingenierosdemontes.org/)

Spanish forests produce goods, some of which are traded via the market, and environmental services. The former includes timber and firewood with a harvested volume of almost 20 million m3/year (1,000 M € in primary value), cork with 70,000 t/year (cork stoppers alone account for 350 M €/year), natural resin with 12,000 t (14 M €/year), as well as hunting and fishing, chestnuts, asparagus, forest fruits, pastures, pine nuts and mushrooms, etc.

Spanish forestry use less than 40% of the wood from the growth of the forests and 80% of this is generated in 20% of the surface area (Galicia and the Cantabrian coast). Wood is the basis of a complex industrial fabric that includes: wood industry (sawn timber, boards, wood packaging), pulp and paper industry, and furniture industry. Together with the remaining forestry products, it generates 1.7% of GDP, 300,000 direct jobs (1.7% of total employment - INE Input-Output Tables 2015), covering 5% of the primary energy consumed in Spain, with a consumed in Spain, with 40% of total renewable energy as a target (IDAE 2015).

In many of the non-wood products, harvesting is not regulated, producing a free appropriation that does not contribute to defraying the costs of forest management. Nor are the environmental services generated by forests, such as environmental services generated by forests, such as water regulation, improvement of water quality, the effect of water regulation, water quality improvement, atmospheric carbon sink effect, erosion and desertification processes, and preservation of biodiversity, as well as others of a social nature, such as landscape - key in coastal areas for their coast, mountains and islands - due to their relevance for tourism, recreation and leisure.

Spanish forests are crucial in the fight against climate change as they are the only manageable sink. Beyond reducing its own emissions, it is the only sector that can offset the emissions of others. Today, the growth of the forest stock of Spain's total CO2 emissions, as well as significant additional climatic benefits from temporary storage thanks to the use of long-lasting forest products, especially wood in construction, and by the substitution of non-renewable raw materials and energies.

Wood and cork are the most widely available materials for the transition to bio-economy, capable of replacing non-renewable raw materials in construction, chemical industry or energy for non-renewable raw materials. The use of forest-based biomass is a unique opportunity for fire risk reduction, job creation, mitigation, energy of fires, job creation, climate change mitigation and reduction of external energy dependence.

4.4.2 Policy context

Both the PNACC and the Climate Change and Ecological Transition Bill consider the necessity of incentivising private and public stakeholders to increase carbon sequestration in the available terrestrial and marine carbon sinks. Among these sinks, the agricultural and forestry sector are expected to play a major role (Government of Spain, 2021a, 2020a). Specifically, the Long Term Decarbonization Strategy 2050 for the Spanish economy, which aims to reach climate neutrality by 2050, identifies the promotion of sustainable forest management as one of its main lines of work (Government of Spain, 2020c). Also, the Spanish Forestry Law promotes incentivising positive externalities of forests such as carbon capture, biodiversity conservation, soil preservation and hydrological regime maintenance (Government of Spain, 2003). Since 2014, forest lands can be listed in the voluntary register of forest carbon dioxide removal projects. The aim of this register is to enable carbon compensation for Spanish companies. Since the creation of the register, the number of listed projects has been increasing steadily. Registered mitigation projects may be eligible for funding depending on their local administration (Government of Spain, 2021b).

The Spanish Forest Plan was created to structure the specific actions required by the National Forest Strategy, which aims to manage forest sustainably, increase their multifunctionality, and contribute to social cohesion in rural areas. This plan was designed in 2002 and will remain in effect until 2032. The plan projects various forest restoration projects mainly for hydrological regulation, but considers carbon sequestration as a positive externality of these actions. Also, the plan promotes silvicultural management of forests, optimising biomass production and increasing carbon sequestration up to 20% (Government of Spain, 2002).

Which national policies exist that address the LMT?

In Spain, forestry management competences are delegated by the Government to the 17 Spanish Autonomous Communities, so that forestry policy is managed in a fragmented manner in each of the 17 Autonomous Communities plus the cities of Ceuta and Melilla.

However, there are general criteria, set by the Spanish Forestry Strategy and the Spanish Forestry Plan, directed by the Spanish Government, which in turn follow the guidelines of the European Commission.

The Spanish Forestry Plan (https://www.miteco.gob.es/es/biodiversidad/temas/politica-forestal/planificacion-forestal/politica-forestal-en-espana/pfe_plan_forestal_esp.aspx), the application in time and space of the Spanish Forestry Strategy, aims to structure the necessary actions for the development of a Spanish forestry policy based on the principles of sustainable development, multifunctionality of forests, contribution to territorial and ecological cohesion and public and social participation in the formulation of policies, strategies and programmes, proposing the co-responsibility of society in the conservation and management of forests. It was approved by the Council of Ministers in July 2002.

The Spanish Forestry Plan is projected for 30 years (2002-2032). During this period, two in-depth revisions of the document are planned, which may affect the diagnosis, structure, development and interpretation of the measures proposed in the Plan. At the same time, and to the extent that the financial scenario may be altered, a second cycle of revisions will be carried out which will exclusively affect the financial programming of the Plan.

Inspiring principles:

- Sustainable development.
- Multifunctionality of forests.
- Contribution to territorial cohesion through rural development, fixing population and employment.
- Contribution to ecological cohesion, integrating the conservation of biological diversity in forest management and preserving the genetic heritage of forests.
- Public and social participation in the formulation of policies, strategies and programmes.

The Spanish Forestry Plan proposes a total of 150 measures, including the following:

- Permanently updated statistics: National Forest Inventory, Spanish Forest Map, National Soil Erosion Inventory, Forest Fires Statistics, European forest damage monitoring networks, as well as other statistics of interest to the forestry sector.
- Hydrological-forest restoration actions framed in a Priority Actions Programme.
- Drawing up Basic Instructions for the Management and Use of Forestry.

- Establishment of Forest Resource Management Plans as forestry planning instruments on a regional scale and promotion of sustainable forest management through forest management.
- Elaboration of a Spanish Plan for Dehesas.
- Support for forest certification.
- Promotion of forestry.
- Support for the monitoring, prevention and extinction of forest fires.
- Updating of regulations for the use and marketing of forest reproductive material.
- Integration of biodiversity conservation in forest management. Guidelines and management models in Natura 2000 Network forest areas.
- Elaboration, by the competent administrations, of a Forest Industry Plan.
- Promotion of forestry associations.
- Establishment of the Forestry Committee in the National Commission for the Protection of Nature.

Which actors are currently applying the LMT (e.g. land users, forest owners farmers)?

Two thirds of Spanish forests are owned by more than 2 million private citizens or groups, while the other third is public, located in mountain areas and mainly owned by municipalities. Although progress has been made in recent decades in the implementation of sustainable forest management in a large number of forests, there are still certain areas with forest land abandoned for various reasons: lack of income to maintain them or collective properties whose owners cannot be identified due to loss of inheritance, as well as a very pronounced smallholding in the northern half, which makes management extremely difficult.

Which funds are available for the LMT?

Beyond the funding received in the forestry sector from the European Commission (ERDF funds, CAP, EAFRD, Horizon2020, EIP AGRI...), the General State Budgets in Spain, or the benefits that the economic activities of the private forestry sector reinvest in the forests themselves, it is necessary to advance in new forms of funding for the maintenance and sustainability of a sector that can effectively be a real and stable carbon sink over time. For that, there are some interesting proposals from Spanish foresters stakeholders (Plataforma Juntos por los Bosques):

- ensure an adequate allocation for the forestry sector in the General State Budget, which, beyond the fires, will enable actions to be undertaken and the objectives of the Spanish Forestry Plan 2002 to be achieved,
- Convene the representatives of the Monitoring Committee of the Socio-Economic Activation Plan for the Forestry Sector.
- Present to the Council of Ministers a proposal for measures in Spanish taxes, to stimulate Sustainable Forest Management and mobilise existing resources.
- Define and reach a consensus with the sector and interested agents on an ambitious forestry political agenda that includes at least the following actions:

- Implement a Programme for the promotion of forest products, to increase their responsible consumption, which will activate forest management in Spain.
- Recover a Hydrological-Forestry Restoration Plan to help alleviate soil loss due to erosion and reduce the risk of desertification. This could be implemented by means of an Agreement with the Autonomous Regions and the Hydrographic Confederations, with sufficient funds to apply the European Water Framework Directive.
- Strengthen forest health, updating and speeding up the registration of phytosanitary products and improving forest damage networks, as a tool for forest planning and pest monitoring.
- Ensure the unity of the internal market for forestry service companies.
- Retake and prioritise the National Forest Inventory and its cartography, the Spanish Forest Map, as key tools for sustainable forest management and included in the National Statistical Plan.
- Promote forestry research, establishing a legal and financial institutional framework to define the sector's research priorities, support its development and guarantee its application, as well as the dissemination of results.
- Address the reporting obligations of the Greenhouse Gas Emissions Inventory, improving methodologies for compliance with both EU regulations, the agreements of the Climate Change Convention (LULUCF) including the recent Paris Agreement in relation to changes in land use, forestry and the sink effect of forest products, as well as incentivising domestic forest sinks.

4.4.3 Current land use and potential land-use competition

Forest ecosystems cover more than 27 million ha in Spain. Almost 15 million ha (29% of the country's area) of these are tree forest ecosystems, and almost 12 million ha (23% of the country's area) belong to shrubs or other treeless covers. There has been an increase in tree forest ecosystems and a decrease in treeless areas over the last years (Government of Spain, 2021c). As of 2019, there are 42 projects listed in the register of forest carbon dioxide removal projects, which covered a total area of 530.24 ha, and mitigated 4264 t CO_2 (Government of Spain, 2021b). However, there are probably other forested areas that are acting as carbon sinks and are not registered. Also, the high forest cover and the presence of treeless areas offer great potential for scaling up carbon silvicultural management without competing with other land uses.

Over the last years, trends in land use change in Spain have shown a decrease in agricultural and farming land uses, especially in the most isolated areas of the country. Forest has regenerated in these abandoned agricultural lands, or reforestations have been executed. Both productive (forestry) and unproductive forested areas have increased. Another, more localised land use change trend is the conversion to anthropic land covers as a result of the growth of cities and the rise in second home ownerships. However, these urbanisation processes are highly localised in certain areas of the country (Fernández Nogueira and Corbelle Rico, 2017).

What is the national (1) historic and (2) current land use of the LMT and how is this projected to develop over the coming decades (2030 & 2050)?

The Spanish Platform Together for Forests (juntos por los Bosques) provides a constructive critique of the plans for the forestry sector and the climate challenges framed in the Spanish government's foresight strategy for 2050. The following notes stand out:

- Activate the full potential of forests in the fight against climate change. In order to achieve the carbon neutrality in 2050 that this document and the EU guidelines foresee, forests are strategic in the fight against climate change.
- EU guidelines foresee, forests are strategic as the only manageable sink (mitigation) in all 3 dimensions:
  - increase of the sink in forest either by increased area or biomass/ha density
  - temporary sink for long-lasting forest products, especially in the construction sector
  - substitution of non-renewable raw materials whose processes are highly intensive in terms of energy and therefore CO2 emissions (cement, iron, aluminium, plastics, glass, synthetic textiles, etc.).
  - The weight of each of these depends on the time and place, with the greatest synergistic effect between the 3 dimensions while integrating adaptation.
- Green taxation. In practice it has not been used in Spain except when required by the EU. The tax on Hydrocarbon tax is merely a tax on revenue with a collateral environmental effect. It is following international recommendations, it is essential to reinforce and give coherence to environmental taxes, leaving aside their revenue-raising dimension and ensuring the neutrality of their effect. Another issue is the legitimate debate on the level of taxation as a whole. In any case, if one opts for the internalisation of environmental externalities it is not permissible to limit oneself only to negative externalities (pollution, waste, etc.), but also to recognise positive environmental services generated by the sustainable management of natural resources must also be recognised (payment for environmental services), which are so widely applied in international cooperation, especially in forests (REDD+), should also be recognised. In particular in relation to the fight against climate change, not transferring part of the taxation associated with reducing CO2 emissions to forestry, the only sector that acts as a mitigator of these emissions is grossly unfair as well as ineffective, as it misses out on the existing potential that can be activated through incentives is lost.
- Realigning water and forestry policies. Spanish Hydrographic Confederations must overcome their limitation to the Public Water Domain (DPH) and address the basin as a whole, which is where the water resource comes from.
- Recognise forestry and agricultural activity as a livelihood for less populated areas.
- Do not confuse risk with effective desertification. Thanks to the socio-economic changes that have taken place over the past 150 years and the reforestation of the past, the risk of desertification and erosion in Spain has slowed down considerably.

- Avoiding a focus on a single star measure: afforestation. Afforestation is one more instrument of forest management but it should not become an end in itself. It is true that it is more clearly recognised than other climate-positive forestry actions, but this fact, related to the greater simplicity of quantification, must not generate a dysfunctional land use dynamic that has already suffered in the past. In addition, it should be remembered that the carbon sequestration effect of reforestation on more than 90% of soils is very long term, whereas the effect of increased sequestration in the case of existing stagnant stands is short term and also avoids the emission of CO2 from fires.
- Environmental education that is more aware of the rural world. Environmental education, especially in the education system, needs to be reset in order to recognise primary activities and the rural world as a key asset, as a supplier of healthy and vital food, strategic bio-products and essential environmental services, not as something to be extinguished.

Are there other land use developments that compete with the expansion of the LMT, and if so, how do those affect the scaling-up of the LMTs?

The main effects of forests on the local environment are obvious. Forests clearly contribute to air quality, due to photosynthesis. Similarly, soils, with both tree and shrub cover, contribute to the soil's nutrient retention capacity and water balance. On the other hand, experts indicate that a diversity of ecosystems is better than a continuous mass of the same species in a given area, because biodiversity will be greater the greater the diversity of ecotones we find, and this biodiversity contributes to the ability to adapt to inclemency and recovery, i.e. greater resilience. Similarly, sustainable forest management, with regular and orderly silvicultural treatments, reduces the risk of forest fires.

4.4.4 Climate risks & sensitivities

Forests are highly threatened by climate change and the disturbances it provokes. Shifting temperatures and rainfall patterns are already increasing mortality in certain tree species, triggering a change in forest community composition (Batllori et al., 2020). The specific trajectories of species change are very case dependent and should be taken into account in long term forest planning for carbon sequestration. Climate also influences fire regime, which has changed in Spain (Moreno et al., 2014). Forest fires are the main cause of forest loss in the Mediterranean, and large fire events rates and burned areas are expected to increase under climate change conditions (Molina et al., 2019; Pérez-Sánchez et al., 2019).

The main risk factor related to climate and forest management and development is drought, not only because of the decrease in rainfall but also because of changes in the distribution of rainfall throughout the year. For example, the city of Cáceres has an average rainfall of 400 mm/year, experts speak of a 20% reduction due to climate change. This may seem like a slight variation, but it is also noticeable because these rains are not distributed as evenly as before. Recently, in the first autumn rains, we have seen how rainfall has been concentrated in a few torrential episodes, as rainfall that was previously distributed throughout the autumn and spring is increasingly concentrated in a shorter period.

Another factor related to drought is the increasingly frequent and prolonged heat waves. It should be noted that the negative effects of these heat waves are not due to the fact that the average maximum temperatures are exceeded at a specific time of the year, but rather the prolonged tendency of these maximum temperatures. An example of this was last 2022 summer, when we had three heat waves, the first at the beginning of June, another at the beginning of July and the last at the end of July/beginning of August. These climatic episodes have been prolonged in days, where the minimum temperature at night was between 22-28 degrees, something that affects both humans and plants.

Related to the above are the forest fires, which, due to the lack of precipitation and the prolonged tendency of high temperatures, make the probability of large fires high. Plants, as they have less humidity, accumulate a higher calorific value, temperatures at night do not decrease sufficiently and therefore make it difficult to extinguish fires.

Another of the most relevant factors is erosion, which is directly related to the factors mentioned above. The decrease in precipitation and the high temperatures lead to a critical situation of prolonged water stress in the soil, which reduces the water absorption capacity of the soil. We have been able to observe this in recent weeks, in which we have seen the formation of streams and soil dragging, due to both the concentration of torrential rains and the decrease in the soil's absorption capacity. In other words, the soil is so dry and compacted that it is not able to absorb water so quickly, as well as due to the speed with which the rain falls.

4.4.5 Economic implications

The rentability of carbon capture forestry as opposed to traditional timber silviculture or is hard to assess due to the long timescales of forest growth (Boyland, 2006), the spatial heterogeneity of forests (Campos et al., 2017), and the various carbon pools within a forest and in timber products (Eriksson et al., 2007). In addition, alternative uses like non timber products or carbon capture require specific studies developing natural growth and yield models for forests, which are uncommon (Campos et al., 2017). For these reasons, specific information adapted to Spanish forests is currently lacking. However, studies in other countries have found that carbon sequestration payment schemes have the potential to influence silvicultural management and increase profitability (Juutinen et al., 2018; Manley and Maclaren, 2012).

Carbon silviculture could be easily included in a multifunctional forestry management regime, which is already common in Mediterranean forests in Spain. However, this multifunctional forestry is not currently accurately quantified in terms of productivity or rentability (Campos et al., 2017). Instead, multifunctional forestry in Mediterranean forests remains a small-scale traditional management regime. Common guidelines for carbon forestry include the extension of rotation length and thinning to improve growth rates (Campos et al., 2017). These recommendations could easily be compatibilized with multifunctional forestry or cork forestry, two common forestry regimes in Spain.

Can the LMT be applied in a competitive way (i.e., returns exceed costs)?

With regard to the barriers to the application of forests as a tool for climate change mitigation, one of the main obstacles is the lack of demand for technologies aimed at the use of nearby natural resources. Thus, the main tool for mitigation and carbon capture in the environment in which we find ourselves in this part of Europe is the consumption of biomass from our forests. For example, there are many buildings belonging to regional administrations, which have heating systems that use fossil fuels. If this were to be replaced by biomass, we would be consuming biomass from our forests, which would contribute to better forest management and at the same time contribute to climate change mitigation, as forests are the main carbon sinks on the planet.

At the level of policies and administrations, the existing interlocking of policies set by the European legislative power, subsequently designed by the European executive power and finally implemented by regional administrations, fails. In other words, at the European level, the policies and objectives set by the European Union for the coming years are very ambitious and climate change is very present in these policies, however, regional administrations do not currently have sufficient capacity to address the proposed changes. This inability on the part of the administration is based on excessive bureaucracy and lack of qualified staff to carry out the measures.

Is there any information on the costs of the LMT implementation? E.g., what are the specific costs of the LMT to reduce GHG emissions (e.g. in EUR costs per ton CO2 equivalent per ha (EUR x ton CO2eq-1 x ha-1))

Another of the elements of this mechanism that we mentioned earlier are the forestry companies. In Spain they are small and medium-sized companies, whose contracts are required and governed by the public administration under the same conditions as those of large companies, which causes a great imbalance that in difficult times leads to the company's suffocation and its disappearance, or in good times the company's growth is not so great because it starts from low profit levels.

As far as social aspects are concerned, there is a notable lack of awareness in society of the need for a change in consumer habits. It is necessary to create a demand for natural resources, biomass in this case, which leads to a consumption of natural resources closer to home and therefore reduces dependence on fossil fuels. At the level of citizens, if we look around us, we see, for example, the increasing proliferation of photovoltaic parks and the ease with which solar panels can be installed in homes, which is the result of policies set by the legislature and implemented by the administration.

Furthermore, there is a way of thinking in which, for example, it is seen as a good thing by society to cut down trees in distant areas of our country for our own supply, but nevertheless in our forests the way of thinking that is being established is that of protection and extreme conservationism, without knowing that these forests need silvicultural treatments for their conservation.

Nature has demonstrated on many occasions its great capacity for resurgence when subjected to extreme conditions, as well as its ability to adapt to adversity.

The greatest opportunity lies in a change of consumption habits in society, so that we realise that we consume more than we need.

4.4.6 Co-benefits and trade-offs

The management actions required for carbon forestry, which include measures such as longer rotation periods and the promotion of forest regeneration can indirectly benefit biodiversity, erosion control, and water quality by improving the structural complexity of the forest. Landscape and recreation could also be positively impacted by more presence of large trees. In the unlikely scenario that carbon silviculture became a highly profitable activity, forestry could start competing with other land uses.

As carbon could also be stored in wooden products, the popularisation of carbon silviculture and wooden goods could diminish the demand for other less environmentally friendly materials such as plastics, steel or concrete.

What are the risks (negative side-effects) or co-benefits (positive side-effects) of the LMT?

The main risk factor related to climate and forest management and development is drought, followed by heatwave events. The effects can be seen for example in the reforestations of 10-15 years ago which were doing well, however, in addition to the effects of natural selection their situation has been aggravated by drought and extreme heat conditions, all of which have led to the death of many established stands. In the north there are many pines and strawberry trees that have suddenly dried up, which is unusual here given the climatic conditions.

Forest fires are also one of the factors that is having the greatest impact. This year 2022, together with 2003, we have suffered major fires, which in addition to the occasional loss of all the biodiversity of the area, we must take into account the erosion and loss of soil produced, which affects the resilience of the area, which, although we are used to the frequent occurrence of fires, this resilience or capacity for regeneration is diminishing.

Erosion has been reversed in some areas by forest management, but due to the occurrence of fires, droughts and heat waves this situation has worsened, contributing to the loss of regeneration capacity and soil fertility.

The main effect of forests on the local environment, local being understood as the environment involving human well-being, is mainly on water balance, air quality and soil protection, insofar as the environment and human development are improved.

Biodiversity would be included with habitat diversity as they are directly related and include diversity of plants, fauna, macrofungi, etc.

In terms of resilience, species that adapt to extreme conditions in the environment are fundamental for adaptation to climate change, to the environment or to disturbances that may arise.

Are there any other risks / co-benefits as part of the LMT implementation?

As regards the barriers to the application of good management, there are several obstacles, the main one being rural abandonment, the loss of local development capacity, which affects forests because there has been a devaluation of the products from these rural environments. Therefore, trying to develop sustainable management when there is no valuation of the products is difficult, insofar as we depend on subsidies and investments in the environment that vary greatly over time, depending on the economic situation at the time. We are all aware of the natural benefits of the environment, but we cannot forget that it is the traditional uses that have contributed to the environment's capacity to adapt to intrinsic conditions, so the main obstacle to the development of sustainable forest management that contributes to the mitigation of climate change, is the lack of valuation of the products and benefits produced by this rural or natural environment.

T*rade-offs of the LMT*

As for the political aspects, they are related to the abandonment of the rural environment. This fundamentally believes that this is not a political issue but rather economic interests, based on outsourcing production to other countries using raw materials other than those that have traditionally been used and that thanks to them the resilience and adaptive capacity of the forests has been maintained. Furthermore, subsidies and overly conservationist policies have contributed to the detriment of forests.

European forest management policy is very positive on paper, but in reality it does not deliver. There is a big contradiction, because the reality is a constant degradation of our forests. By really outsourcing everything, you cannot maintain our development because everything is interrelated, we cannot separate the development of society from the forests and nowadays they are separated because society does not look at forests as a source of profit, they have made us lose that perception. Therefore, we have to re-engage with forests, which is not necessary to do it in the same way as in the old days, 80 or 1000 years ago, because nowadays, there are many technologies and R&D that would make it easier to develop together with forests in a sustainable and self-sufficient way in our environment. It is all very well the, for example: "from farm to fork", the circular green economy, but the reality is that we are still dependent on the outside and they are not carried out because of political and economic interests.

4.4.7 Risks associated with scaling up

A forest with long rotation periods and a complex vertical structure could be prone to large forest fires due to the accumulation of fuels (biomass, which stores carbon) and the fuel continuity in the vertical axis (different vegetation strata). Careful fire prevention management and availability of extinction means are of utmost importance if carbon forestry is to be applied at a large scale. This is especially relevant in Spain, which has a climate characterised by a long, dry and warm summer season.

What are the risks of scaling up specific LMT solutions from the sub-national level to the national level?

In all sectors there is a problem with bureaucracy. However, in other sectors with higher profitability they can cope with these costs, however, in the forestry sector the lack of profitability does not allow to cushion these expenses.

With regard to economic risks, the main risks are market dominance and market regulation related to the above.

In terms of business risks, the investment challenges, the high costs and the lack of diversified income are generated by the aforementioned lack of revaluation of the products that could be obtained from the forest.

On the social side, the lack of knowledge is a determining factor that has led to the separation of society from forests, only looking towards them when there is some kind of ecological disaster such as the fires of last summer. Society does not see what forests contribute in a less tangible way, what they contribute and all that could be obtained, because society believes that management is like plundering, for example, when one sees the felling of trees for thinning, it is seen as plundering and not as a proper management of the stand. Lack of knowledge is a major obstacle to forest management.

4.4.8 Research gaps

As mentioned earlier, the main research gap hindering carbon sequestration forest management is the lack of accurate growth and yield models for certain tree species and management regimes different from timber silviculture.

What are the research gaps identified during this exercise?

As an opportunity, the main one today is the ability to be self-sufficient in terms of energy, food if we take into account extensive livestock farming and also the ecotourism benefits of revaluing natural habitats.

The greatest environmental risk is the lack of social and political support for forests, which leads to a neglect of forests and the environmental, cultural and social benefits they generate. They are only appreciated from an ecological and conservationist point of view of the city.

We must take advantage of this situation of economic crisis and absolute dependence on the outside world to look around us in order to take advantage of all the tools available today for forest management and to obtain self-sufficiency and take advantage of all the opportunities they generate.

4.5 Afforestation/reforestation of agriculture degraded areas

4.5.1 Introduction

Reforestation and afforestation projects are a cost-effective and simple way of capturing carbon, and are being used world-wide for that purpose (Nunes et al., 2020). In Spain, the Agricultural Lands

Afforestation program started more than 25 years ago as a result of the European Common Agricultural policy. Abandoned or low productivity agricultural lands were afforested, amounting to more than 730 000 ha. Even though it was not the intended primary objective of the program, the potential of this large scale afforestation scheme to help transitioning to a low emissions economy is widely acknowledged (Iglesias Ranz et al., 2021; Vadell et al., 2019).

What is the general context of the LMT and how does it address climate change mitigation?

Afforestation as a land use strategy to absorb carbon. As mentioned above, afforestation is considered a land management practice which can increase SOC stocks. Afforesting former croplands is agreed to be a valid and efficient opportunity to mitigate climate change (Bateni, Ventura et al., 2021; Cunningham, Mac Nally et al., 2015; Quinto et al., 2021). It was acknowledged in the Kyoto protocol (1997) as an effective method to sequester C into the soil (Lal, Negassa et al., 2015; Metz et al., 2001) and thus offset CO2 emissions (Black, Byrne et al., 2009). A recent publication shows that the practice of afforestation could sequester from 0 to 111 Mt CO2 yr-1 in the soil at the EU level (Bellassen, Angers et al., 2022).

Despite some divergency in the literature, both in magnitude and direction of change (Hoogmoed, Cunningham et al., 2012; Vesterdal, Rosenqvist et al., 2007), afforestation is generally considered as one of the best practices to increase SOC stock (Arrouays, Balesdent et al., 2002; Kim, Kirschbaum et al., 2016; Lorenz & Lal, 2014, 2018; Minasny, Malone et al., 2017). Indeed, this LUC (from cropland to forest) not only stores C as tree living biomass (both above- and belowground) and dead OM, but it also facilitates the transfer of OM to the soil, thus leading to an increase of the SOC stocks (Black, Byrne et al., 2009; Cardinael, Chevallier et al., 2017; Laganiere, Angers et al., 2010; D. Li, Niu et al., 2012; Liu, Yang et al., 2018; S. Shi, Zhang et al., 2013). This increase is mainly dictated by increased litter input above- and/or belowground (Bárcena, 2013; Rahman, Bàrcena et al., 2017). One the one hand, afforestation boosts primary production, which in turns increases the input of OM to the soil, thus enhancing soil C sequestration (Arrouays, Balesdent et al., 2002; Lorenz & Lal, 2018) (Figure 3). On the other hand trees, having extensive root systems, are able to enrich the soil via root-derived C inputs and thus increase the SOC stocks also in deep soil horizons (Lorenz & Lal, 2018). Trees also promote SOC sequestration by forcing a reduction or cessation of tillage, which leads to smaller decomposition rates of SOM (Lorenz & Lal, 2018). In an afforested landscape there are thus more C inputs to and less C losses from the soil in comparison to annual croplands, which are cyclically fallow.

4.5.2 Policy context

The Common Agricultural Policy reform of the year 1992 included the promotion of environmentally friendly agricultural practices as an objective. This included the afforestation of certain privately owned lands. This would contribute to reforest abandoned or unproductive lands, lessen the deficit in forestry products in Europe, promote sustainable environmental management and fight against the greenhouse effect. These objectives lead to the Agricultural Lands Afforestation program in Spain (Iglesias Ranz et al., 2021). In the early days, the program subsidized the establishment cost of the afforestation and established a system of payments to maintain the plantation during the first 5 years and compensate for the income lost due to the surrendering of agricultural activity. This last payment system has been reduced over the years (Vadell et al., 2019).

As mentioned earlier, both the PNACC and the Climate Change and Ecological Transition Bill consider the agricultural and forestry sector potential major carbon sinks (Government of Spain, 2021a, 2020a). Specifically, the Long Term Decarbonization Strategy 2050 for the Spanish economy, which aims to reach climate neutrality by 2050, identifies the creation of new forest areas as one of its main lines of work (Government of Spain, 2020c). This would continue the afforestation trend established by the Agricultural Lands Afforestation program.

Which national policies exist that address the LMT?

With regard to the CAP, the owners of reforested land request a change of use in order to be able to declare livestock. Previously they were pasture land and by requesting such a change, the rights increase, both for the land and for the head of livestock grazing on the land.

On the other hand, the implementation of reforestations on unproductive agricultural land represents a job opportunity for local society, as both the implementation and maintenance work requires local labour, as has been proven in recent years.

The environmental opportunities generated by reforestation are multiple, as mentioned in the previous section: carbon sinks, increased biodiversity, increased soil organic matter content and soil quality, and improved water quality.

Q1.2.2. Which actors are currently applying the LMT (e.g. land users, forest owners farmers)?

Most reforestations are implemented on private land, the main objective of which is to obtain profitability in addition to environmental aspects. Reforestations cannot be seen as a business because the income is not obtained directly and the initial investment required is high.

With regard to the economy, it should be noted that the implementation of reforestations represents an investment challenge for the owner, due to the high initial costs, the long period of recovery of the investment and the maintenance work in successive years. However, once the trees have reached adulthood, the sources of income are diversified: acorns, cork, firewood, livestock and improved pastures. With regard to subsidies, it has already been mentioned above that in recent years there have been several calls for proposals for the implementation of reforestations on agricultural land and for densification.

Which funds are available for the LMT?

Most of the reforestations in the last decades have been carried out thanks to the subsidies promoted by the regional administration for this purpose, otherwise many landowners would not have made these investments. The first reforestations with subsidies were carried out in 1993 and the last call for subsidies was in 2007. Therefore, the regional administration has managed this technique adequately, as it has been quick and in accordance with the needs of the ecosystem and the landowner.

4.5.3 Current land use and potential land use competition

Trends in land use change in Spain have shown a decrease in agricultural and farming uses, especially due to land abandonment in isolated areas. Forest has regenerated in these abandoned agricultural lands, or reforestations have been executed. The Agricultural Lands Afforestation program has been the most relevant program promoting the expansion of forested areas in Spain. Certain areas of the country have more area of forest now that what they have had over the last centuries. The program has contributed to the active use of lands that would otherwise be abandoned agricultural lands (Iglesias Ranz et al., 2021; Vadell et al., 2019). The progressive emptying of rural areas suggests that afforestation of abandoned lands could be an interesting option for carbon sequestration in Spain, as it is unlikely that other land uses would be in competition.

What is the national (1) historic and (2) current land use of the LMT and how is this projected to develop over the coming decades (2030 & 2050)?

In Spain, since 1993, different regulations have been applied to develop Community regulations. Currently, Royal Decree 6/2001, of 12 January, on the promotion of afforestation of agricultural land and Royal Decree 1203/2006, of 20 October, which amends the article relating to the justification of establishment and maintenance costs of RD6/2001, are still in force.

As regards the regulatory framework in the Autonomous Communities, for example in Andalusia, the most recent is the Order of 26 March 2009, which regulates the aid scheme for the promotion of the first afforestation of agricultural land in the framework of the Rural Development Programme of Andalusia 2007-2013 and the Order of 2 February 2010, which amends the Order of 26 March 2009.

At present, although these regulations are in force, there is no line of financing open in this respect in Andalusia. Only maintenance aid and compensatory aid from previous programmes continue. However, the new Andalusian Rural Development Plan is expected to include this type of aid for afforestation once again.

Are there other land use developments that compete with the expansion of the LMT, and if so, how do those affect the scaling-up of the LMTs?

Afforestation or reforestation is understood as the process of establishing a stand of trees on land that has never existed or has been absent for a certain period of time, for example, due to agricultural activities.

In this sense, afforestation of agricultural land offers interesting opportunities to restore forest landscapes in economically unprofitable, abandoned or degraded areas, as a result of the abandonment or rural exodus that has taken place in rural areas during the second half of the 20th century.

In this sense, we are talking about degraded and abandoned agricultural land. At present, the tendency is not to recover this land for agriculture, but there are locations where renewable energy projects can be considered, for example, photovoltaic solar energy plants that occupy these spaces. However, this alternative to the reforestation of degraded agricultural land, due to the amount of existing surface area, is limited in terms of the land it would occupy.

4.5.4 Climate risks & sensitivities

Various coniferous and broadleaved native species were used in the afforestation of agricultural lands. Both mixed and monoculture stands were established, with a dominance of broadleaved species such as *Quercus ilex* for the creation of permanent forests or harvesting or high value woods in long rotation periods (Vadell et al., 2019). Landowners chose the species using mainly economic criteria, such as the payment amounts, which varied depending on the species. Nowadays, it is acknowledged that forests are highly threatened by climate change and the disturbances it provokes. The changes in climate patterns are already increasing mortality in certain tree species, initiating a change in forest community composition (Batllori et al., 2020). The specific trajectories of species change are very case dependent and should be taken into account in long term forest planning for carbon sequestration. This shift in environmental conditions was not taken into account in 1992, when the Agricultural Lands Afforestation Program started.

How sensitive is the LMT to climate related changes regarding:

- ***a) heat waves (extreme temperatures)***
- ***b) drought and desertification***
- ***c) forest fires***
- ***d) heavy rain (extreme precipitation)***
- ***e) river floods and sea level rise***
- ***f) storms and tropical cyclones***
- ***g) increased or generally changed weather variability***
- ***h) erosion and land slides***
- ***i) ocean acidification***
- ***j) loss of biodiversity***

The main risk factor related to climate, forestations and their viability considered is drought. Most reforestations are of indigenous species, *Quercus* sp., which are adapted to the terrain. However, the increasingly frequent and prolonged drought conditions and heat waves in recent years have led to the appearance of a large number of dry stands. Moreover, these are small trees, with few sapwood, which means that if both planting and maintenance work is not carried out in good weather conditions, the plants do not develop properly and die. At present, the climatic conditions are not conducive to the good development or optimal establishment of reforestations and densifications, because the soil is not in a suitable condition for this due to the drought.

Forest fires affect reforestation directly, so in the first few years, until the plants are well developed, the scrub and grasses that appear between the lanes and create a permanent cover must be removed, thereby reducing the possibility of forest fires. As well as this maintenance work, the root system must not be affected, as this could damage it considerably.

On the other hand, the contribution of reforestation to the reduction of erosion processes in the areas where it is carried out is visible. Many of the reforestations carried out in recent decades have been carried out on agricultural land or land with poor soil conditions and therefore quite eroded, which has led to a slowing down of these processes. The establishment of a permanent vegetation cover on degraded soils, with few trees, e.g. less than 10 ft/ha or 20 bushes, slows down erosion considerably.

4.5.5 Economic implications

This LMT is highly competitive, as it implicates a change in land use from agricultural lands that are currently unproductive to forest lands that could be managed in various ways depending on the objectives of the land manager.

Can the LMT be applied in a competitive way (i.e., returns exceed costs)?

The implementation of most of the reforestation carried out in recent decades in Extremadura is thanks to the aid for the reforestation of agricultural land that the Regional Government of Extremadura promoted years ago. These calls for aid established the conditions for both implementation (planting framework, species, work, etc.) and for maintenance and grazing periods.

As far as business aspects are concerned, it is necessary to make a high initial investment with a long amortisation period. However, it is an activity that generates jobs, as a company specialised in this type of work was contracted to implement it, as well as to carry out pruning and maintenance work.

Moreover, reforestation is directly linked to livestock farming, as sheep grazing is carried out during two periods a year, which, among other things, provides organic matter to the soil and maintains the vegetation cover.

As far as the administrations are concerned, the bureaucratic procedures for obtaining permits to carry out work such as pruning and weeding are slow, which makes it difficult to carry out such work at the right time of year.

There are many benefits or opportunities generated by the implementation of reforestation in degraded areas, both environmental and economic, for example, many of the reforestations are in a high percentage of *Quercus suber*, which through the use of cork increases the margin of economic benefit compared to those of *Quercus ilex*.

Is there any information on the costs of the LMT implementation? E.g., what are the specific costs of the LMT to reduce GHG emissions (e.g. in EUR costs per ton CO2 equivalent per ha (EUR x ton CO2eq-1 x ha-1))

Afforestation costs range from roughly 1800 €/ha to 4000 €/ha for the initial establishment of the trees. The cost depends on the species chosen (Vadell et al., 2019). Subsequent costs of forest management depend on the strategy. In addition, maintenance costs need to be taken into account for the first 10 to 15 years after the initial planting, which may be soil tillage, scrub clearance, support irrigation or replacement of dead plants.

4.5.6 Co-benefits and trade-offs

As mentioned in earlier paragraphs, this LMT is unlikely to compete with agriculture for the most fertile and accessible lands. Instead, it uses abandoned or derelict lands in remote locations within the country, making positive impact on their value and productivity.

Throughout its years of implementation, the Agricultural Lands Afforestation program has also had a positive impact in other areas. First, the technology and techniques to execute the reforestations have advanced greatly. Survival rates of the trees have been maximized, keeping costs and losses to a minimum. They have also contributed to environmental awareness in society. Forestry related companies can thrive thanks to the abundance of forestry works. In addition, new streams of work and research have been developed, such as the ongoing developments in carbon quantification techniques. The revitalization of the country through the afforestation program has had a positive social impact in the rural communities. New forest products such as wood, honey, game, cork, mushrooms or truffles can be extracted. Lastly, the creation of new forested areas has increased biodiversity and diversified the landscape (Iglesias Ranz et al., 2021).

Objectives of the CAP afforestation programme for agricultural land:

- To contribute to the reduction of surplus products through set-aside and less extensive farming.
- To promote farming that is more environmentally friendly and at the same time provides higher quality products.
- To contribute to the rejuvenation of the agricultural workforce.
- To actively promote the education of farmers and the general public on the need to preserve the environment.
- To contribute to the generation of stable jobs, both in direct and indirect activities related to the above objectives.
- To increase in the long term the Community's forestry resources and the management of the natural area in a more appropriate way, seeking an alternative use of agricultural land through afforestation and the development of forestry activities on farms.

What are the risks (negative side-effects) or co-benefits (positive side-effects) of the LMT for:

a) agricultural production?
b) landscape?
c) biodiversity?

d) nitrogen emissions?
e) water quality?

The main effect of reforestations and their associated pastures on the local environment is primarily related to carbon sequestration, reforestations play an important role as carbon sinks. It can be seen how in soils that were previously bared with poor pasture quality, where, after the reforestation was implemented, the maintenance work carried out between subsequent lanes and the absence of grazing in the first 10 years or so, has led to an improvement in pasture, soil quality and water balance.

There has also been an increase in biodiversity, in terms of vertebrates, an increase in small and large game species, an increase in the diversity of birds present and nesting sites. All this is due to the fact that these are quiet areas that are used as a refuge, as well as ecosystems with a very high diversity of fungi as a result of the quality of the soil. Furthermore, some of the reforestations implemented in recent years have been carried out with mycorrhizal plants, although there are no major differences between the reforestations that did not use this type of plant, as these are the fewest.

As far as pollination is concerned, the presence of pollinating agents is evident due to the frequent installation of beehives between the lanes.

On the other hand, pest resistance is reduced, due to the homogeneity of age classes, so that pests have a more direct impact. In particular, the carbonaceous canker disease, *Biscogniauxia mediterranea*, in cork oak trees is notable for its high presence, caused by the disinfection of tools and implements used in maintenance forestry work.

Are there any other risks / co-benefits as part of the LMT implementation?

The effects of the reforestations on the local environment are various. In terms of soil, water and air parameters, it should be noted that the reforestations were carried out on agricultural land that was not very fertile.

T*rade-offs of the LMT*

After the installation of the reforestation, it can be observed how the soil structure, its water retention capacity and erosion have changed. There is an increase in organic matter in the soil, also due to the fact that pruning residues are shredded and left on the ground, which contributes to improving the soil as a carbon sink.

In terms of biodiversity, there has been a high increase, due to the fact that it was previously cereal land and now forms a compact mass of trees, which has led to the appearance of a greater diversity of plants and animals.

In addition, the *Quercus ilex* and *Quercus suber* are native species, adapted to the environment and climatic conditions of the area, which makes them more resilient.

4.5.7 Risks associated with scaling up

If afforestation projects were to be widely applied, they would need to be accompanied by a comprehensive fire prevention and extinction plan. Under no circumstances should forest plantations be left unmanaged, as even-aged trees constitute a continuous canopy layer that represents a danger of fire. Carbon capture would need to be compatibilized with controlling the accumulation of fuels (biomass), to prevent large forest fires that would release large amounts of carbon into the atmosphere. This is especially relevant in Spain, which has a climate characterised by a long, dry and warm summer season.

What are the risks of scaling up specific LMT solutions from the sub-national level to the national level?

The main climate-related risk factors affecting reforestation are drought, heat waves and heavy rainfall. During the years 1996-1998, for example, there was a period of drought that lasted several years. The effects of the drought were visible in the loss of many trees, which were replaced. This period of drought coincided with the first years of reforestation, in which seedlings of one or two saps were planted.

Over the last 20 years, the climate has been fairly stable in the area, so with the exception of the previous episodes, the weather has not played an important role in the development of reforestation.

It should also be noted that 2012 was a fairly rainy year, which resulted in more grass growing between the rows and the need for more frequent maintenance work.

In any case, the experiences serve as a reference for future interventions and scaling up. Most significantly, a budget should be set aside for the planning and execution of maintenance works for the reforestation of agricultural land for 20-30 years. Without maintenance the grading leads to risks of plant death or overgrowth of undergrowth and thus increased forest fuel, which increases the risks of forest fires.

Efficient planning and correct execution of the planning is essential for successful scaling.

4.5.8 Research gaps

More research is needed to accurately quantify the carbon sequestered by a growing forest. Accurate growth and yield models adapted for carbon capture silvicultural management are required.

What are the research gaps identified during this exercise?

To our knowledge there are very few studies carried out in Spain looking at the combined effect of afforestation on oaks biomass and SOC stocks changes. Studies were either conducted on Dehesas and compared these with tree-less pastures, or they were conducted following afforestation but with other afforested species (Perez-Cruzado, 2012). Also, the outcomes of the afforestation initiatives in Spain are generally poorly documented. A final issue worth mentioning is that, for the few studies which have been done on the effects of afforestation on SOC stocks, there are large inconsistencies regarding sampling methods, soil analysis techniques and experimental designs, which hinder the drawing of coherent conclusions.

5. Conclusion

The land mitigation technologies assessed in Spain in the framework of the LANDMARC project are land management activities that occupy large areas of land in the Iberian Peninsula. Forestry planning, forest restoration of degraded agricultural land, management of dehesa agroecosystems, or extensive grasslands, are traditional land uses in Spain, with decades and centuries of history, typical of the rural environment in Mediterranean climate environments.

Large areas of land, in rural areas, and in a Mediterranean climate. These three factors are very relevant when considering that these traditional land uses can also be considered as having an added value in terms of negative emissions and carbon sequestration and storage.

By occupying large areas, they can contribute quantitatively to the reduction of greenhouse gases.

The fact that they are traditional rural uses means that they are not immune to the implicit social and economic problems of rural areas in Spain, i.e. depopulation, masculinisation, emigration of young people and women to urban areas, abandonment of the land, increase in economic problems associated with agroforestry management, etc.

The Mediterranean climate also has its own particularities, and in the case of Spain, climate change affects aspects such as drought, desertification, forest fires and the increasingly irregular distribution of rainfall.

Therefore, considering these traditional land uses with new added values, related to ecosystem services, biodiversity, landscape, and the potential for carbon sequestration and storage, offers new perspectives and opportunities for the territories, stakeholders and people affected, in a rural environment that needs innovation, technology, talent and new sources of income, to face social, economic, environmental and climate challenges.

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ANNEX III

OVERVIEW OF INPUT TABLES FOR SIMULATION MODELLING PER COUNTRY

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4. Spain

4.1. Qualitative storylines by identifying measures and actions from interviews for each LMT scenario

Spain LMT 1: Dehesas management, Extremadura and Western Andalucía, Spain

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1 *(Go all Green)*: **"Increase of investments and improvement of the dehesa"** **Stakeholder representations:** Public administrations, scientific community, dehesa landowners, farming associations, nature conservation associations	• Recognition of dehesas as agro-ecosystems that provide ecosystem services (biodiversity, landscape, carbon sink, soil protection, public and recreational use...) and receive economic income for it (2040). • Improved management practices by landowners following investments in training and regeneration	• Ecosystem services are monetised. • The profitability of traditional uses (pasture, cork, firewood...) is improved. • Added value is invested in the regeneration of dehesas (tree planting and grassland improvement). • CAP • Fruitful investments in research to slow down the mortality rate of oak trees.	• Pilot projects from 2023 • Spanish legislation promotes investments in conservation and regeneration of the dehesa • Dehesa finds the right place and is recognised with its specific value in the CAP in 2030 • Promotion of carbon credits for best management practices • Job creation in rural areas
Scenario 2 *(Halfway is enough)*: **"Natural and social evolution of the current situation in the dehesa"** **Stakeholder representations**: Public administrations, scientific	• Dehesas are maintained with public support for regeneration and landowner investment from the direct	• Public aid for regeneration and drought control • Investments by landowners from traditional use benefits	• Pilot projects from 2030 • Progress in the legislation of the dehesa but this agro-ecosystem is still not

community, dehesa landowners, farming associations, nature conservation associations	benefits of agro-silvo-pastoral resources (2035).	• Technical and scientific advances against the dryness of kermes oak trees • CAP	recognised with its specific value in the CAP in 2030.
Scenario 3 *(The population crisis in rural areas worsens)*: ¨ Progress of desertification and the drying up of the Iberian quercine trees (oaks)" Stakeholder representations: Public administrations, scientific community, dehesa landowners, farming associations, nature conservation associations	• Dehesas are in progressive degradation, aggravated by drought and the advance of desertification (2050). • No solutions are found and the abandonment of dehesas is increasing due to lack of profitability (2040). • Public aid for regeneration and investments by landowners are insufficient to halt the degradation of the agro-ecosystems of the dehesa.	• Public support for regeneration and drought control is very low • Little investment by landowners due to the low profitability of the systems. • Quercus plantations and pasture improvements only in very specific areas. • Quercus mortality does not find solutions in agroforestry science.	• Pilot projects from 2030 • Progress in the legislation of the dehesa but this agro-ecosystem is still not recognised with its specific value in the CAP in 2040. • Administrative bureaucracy is not simplified

Spain LMT 2: Grasslands management for soil regeneration and carbon storage, Spain

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1 *(Go all Green)*: "Valorisation of grasslands with new uses such as carbon sequestration and storage,	• Livestock management of extensive pastures is carried out with greater sustainability criteria. It increases activity based on	• Ecosystem services are monetised and rents are obtained on carbon markets.	• Pilot projects from 2023 • EIP AGRI invests in operational groups related to good practices, grassland

improved agro-livestock practices, etc." **Stakeholder representations:** Public administrations, scientific community specialised in soils and grasslands, owners of large grasslands, agricultural and livestock associations, nature conservation associations.	organic fertilisation and good soil and grassland practices. • Extensive grazing increases its added value to the traditional use of livestock pastures, and provides ecosystem services (biodiversity, landscape, carbon sink, soil protection, hydrological regulation and green filter...) that are recognised and receive economic income for it (2040).	• Improved profitability of traditional uses (pastures, regulation of the hydrological cycle, organic agriculture, etc.). • Added value is invested in grassland regeneration, sowing of more biodiverse grassland species. • Fruitful research investments to curb grassland degradation • Better management practices by landowners who also invest in soil regeneration and holistic management.	management and carbon grazing • CAP distinguishes more types of grassland, including irrigated grassland, and recognises their agrarian and holistic value by 2030 • Job creation in rural areas
Scenario 2 *(Halfway is enough)*: "Maintenance of the current grassland situation, extensive livestock farming, best farming practices" **Stakeholder representations**: Public administrations, scientific community specialised in soils and grasslands, owners of large grasslands, agricultural and livestock associations, nature conservation associations.	• Livestock management of extensive pastures is carried out with greater sustainability criteria. • It increases activity based on organic fertilisation and good soil and pasture practices (2040).	• Improves the profitability of traditional uses (pastures, regulation of the hydrological cycle, organic farming, etc.). • Added value is invested in grassland regeneration, sowing of more biodiverse grassland species. • Fruitful research investments to curb grassland degradation	• Pilot projects from 2023 • EIP AGRI invests in operational groups related to good practice and grassland management • CAP distinguishes different types of grassland and recognises their agricultural value in 2030

		• Better management practices by landowners who also invest in soil regeneration	
Scenario 3 *(The population crisis in rural areas worsens)*: "Degradation of grasslands and gradual abandonment of traditional uses" **Stakeholder representations:** Public administrations, scientific community specialised in soils and grasslands, owners of large grasslands, agricultural and livestock associations, nature conservation associations.	• Grasslands are in progressive deterioration aggravated by drought and advancing desertification (2050). • No solutions are found and the abandonment and degradation of soils and grasslands increases due to lack of profitability (2040). • Public aid for regeneration and investments by landowners are insufficient to halt the degradation of livestock pastures.	• Public support for regeneration and drought control is very low • Little investment by landowners due to the low profitability of the systems. • Sowing of grass legumes and pasture improvements only in very specific areas. • Desertification is causing increasing problems and no solutions to soil erosion and degradation are being found.	• Pilot projects for pasture improvement and soil regeneration from 2030 onwards • Administrative bureaucracy is not simplified and aid for pasture improvement is becoming more complicated • The CAP does not make a clear commitment to extensive grazing land.

Spain LMT 3: Forest planning and management in Spain

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1 *(Go all Green)*: "Simplification of legal forest planning and management and increased forestry investments"	• Digitalisation, applied innovation, simplification of forest management and increased forestry	• Public administrations and forest owners.	• Pilot projects on forest management at different scales.

Stakeholder representations: Public administrations, technical and scientific forestry community, forest owners, forestry companies, forestry associations, nature conservation associations	investments from integrated and multi-scale perspectives. • The inventory of natural resources and forest management at different territorial scales is optimised and technical and administrative procedures are facilitated. 2035 • Commitment to innovation and forestry digitalisation. 2030 • Forests increase their added value to the traditional use of woody and non-woody forest uses, and provide ecosystem services (biodiversity, landscape, carbon sink, soil protection, hydrological regulation and green filter...) that are recognised and receive economic income for it (2040).	• Ecosystem services are monetised, rents are obtained in carbon markets. • Improved profitability of traditional uses (timber and non-timber, hunting and fishing, recreational use, regulation of the hydrological cycle, ...). • Added value is invested in forest restoration and preventive forestry to fight forest fires. • Successful research investments to curb desertification, biodiversity loss and forest fires • Better forestry practices by landowners who also invest in protection and defence of the forest system.	• Investments in forestry works increase in the general state budgets • Pilot projects on forests as a carbon sink. • EIP AGRI invests in operational groups related to more sustainable forestry practices and carbon sinks (2023). • The balance between timber and non-timber forest productivity and forest ecosystem services are the pillars of forest policy and management. • Decarbonisation strategy in Spain 2050. • Carbon sequestration and storage by forests is contemplated in the economic exploitation plan. • Job creation in rural areas
Scenario 2 *(Halfway is enough)*: "Simplification of legal forest planning and management and increased forestry investments" Stakeholder representations: Public administrations, technical and	• The inventory of natural resources and forest management at different territorial scales is optimised and technical and	• Public administrations and forest owners. • It improves the profitability of traditional uses (timber and non-timber, hunting and fishing, recreational	• Pilot projects on forest management at different scales. • Pilot projects on forests as a carbon sink.

scientific forestry community, forest owners, forestry companies, forestry associations, nature conservation associations	administrative procedures are facilitated. 2045 • Commitment to innovation and digitalisation of forestry. 2040 • Carbon sequestration and storage by forests is included in the economic exploitation plan.	use, regulation of the hydrological cycle, ...). • Added value is invested in forest restoration and preventive silviculture to fight forest fires. • Better forestry practices by landowners who also invest in protection and defence of the forest system.	• EIP AGRI invests in operational groups related to more sustainable forestry practices and carbon sinks. • The balance between timber and non-timber forest productivity and forest ecosystem services.
Scenario 3 *(The population crisis in rural areas worsens)*: "Abandonment of rural areas, increase in forest fires" **Stakeholder representations:** Public administrations, technical and scientific forestry community, forest owners, forestry companies, forestry associations, nature conservation associations	• Technical and administrative procedures are not facilitated. 2035 • Investment in forest innovation stagnates. • Traditional forestry is not profitable and there is a progressive abandonment of rural areas and forests (2040). • Large forest fires are devastating abandoned forests, biodiversity and carbon stocks in trees and soil. • Erosion is increasing and desertification is advancing on the Iberian Peninsula.	• Public administrations and forest owners. • Payments for ecosystem services are non-existent or very low. • Reduced profitability of traditional forest uses and increased operating costs. • Insufficient investment in forest restoration and preventive silviculture to fight forest fires. • Mediterranean forestry is practised only on forest land where it is profitable.	• Forest management does not overcome bureaucratic burdens and is maintained under complex conditions that make it difficult. • Forestry policy does not take fair account of the demography of rural areas. • The general state budgets do not provide for sufficient investment to make life and welfare attractive in rural areas.

Spain LMT 4: Afforestation/reforestation of agriculture degraded areas, Spain

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1 *(Go all Green)*: "Increased investment in afforestation of agricultural degraded land" **Stakeholder representations:** Public administrations, technical and scientific farming and forestry community, owners of degraded agricultural land, forestry companies, agricultural associations, nature conservation associations	• Degraded land condemned to desertification is transformed into new forests in 2050 with a promising horizon for 2075. • Agro-ecosystems providing ecosystem services (biodiversity, landscape, carbon sink, soil protection...) and receiving economic rent for it (2040) • Investments are made in reforestation and maintenance of reforestations. • Job creation in rural areas	• Public administrations and landowners. • Ecosystem services are monetised, rents are obtained in carbon markets. • Investments are made in reforestation and maintenance of reforestations. • Job creation in rural areas • Fruitful research investments to curb desertification and biodiversity loss. • Better management practices by landowners following investments in training and regeneration.	• Reforestation programmes for degraded agricultural land from the 1990s and early 2000s are being revived. • Reforestation pilot projects for carbon sinks. • EIP AGRI invests in operational groups related to reforestation of agricultural land and monitoring of results. • Decarbonisation strategy in Spain 2050.
Scenario 2 *(Halfway is enough)*: "Maintaining the status quo" **Stakeholder representations**: Public administrations, technical and scientific farming and forestry community, owners of degraded agricultural land, forestry companies, agricultural	• Existing reforestations are maintained, but there is no significant investment in new reforestation of degraded land. • Investments are made in reforestation and maintenance of	• Public administrations and landowners. • Ecosystem services are monetised, but revenues are not sufficient. • Very limited rents are obtained in carbon markets.	• Reforestation programmes for degraded agricultural land are very specific and insufficient for the territory. • Reforestation pilot projects for carbon sinks. • Decarbonisation strategy in Spain 2050.

associations, nature conservation associations	reforestations, but they are not sufficient to improve the employment structure in rural areas.	• Research investments to curb desertification predominate over implementation investments for reforestation, leading to mismatches between science, technique and real solutions. • Better management practices by landowners following investments in training and regeneration.	
Scenario 3 *(The population crisis in rural areas worsens)*: "No significant investment in afforestation of agricultural land" **Stakeholder representations:** Public administrations, technical and scientific farming and forestry community, owners of degraded agricultural land, forestry companies, agricultural associations, nature conservation associations	• Abandoned agricultural land is progressively deteriorating, aggravated by drought and the advance of desertification (2050). • Erosion increases and desertification advances in the Iberian Peninsula. • No solutions are found and the abandonment of agricultural land increases due to the lack of profitability (2040). • The problems of rural depopulation worsen.	• Public administrations and forest owners. • CAP • Payments for ecosystem services are non-existent or very low. • Public aid for reforestation of agricultural land and investments by landowners are insufficient to halt land degradation. • Quercus plantations and pasture improvements only in very specific areas.	• Administrative bureaucracy is not simplified. • Forestry policy does not take into account the demography of rural areas. • State budgets do not provide for sufficient investment to make life and welfare attractive in rural areas.

4.2. Quantitative storylines: pace of implementation for each LMT

	Current situation (baseline)	**Scenario 1** ***(Go all Green)*****:** **SH perspective:** Public administrations, technical and scientific community, landowners, agricultural associations, private sector, nature conservation associations		**Scenario 2** ***(Halfway is enough)*****:** **SH perspective:** Public administrations, technical and scientific community, landowners, agricultural associations, private sector, nature conservation associations		**Scenario 3** ***(The population crisis in rural areas worsens)*****:** **SH perspective:** Public administrations, technical and scientific community, landowners, agricultural associations, private sector, nature conservation associations	
Year	Now (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)	2030	2050
LMT 1: Dehesas management	Area: 2 million hectares of dehesa in Spain in need of efficient management (Extremadura and Andalucia Regional Government).	15% of the territory with improved management (Extremadura and Andalucia Regional Government)	40% of the territory with improved management (Extremadura and Andalucia Regional Government	10% of the territory with improved management (Extremadura and Andalucia Regional Government	20% of the territory with improved management (Extremadura and Andalucia Regional Government	10% of the territory is degraded (Extremadura and Andalucia Regional Government)	25% of the territory is degraded (Extremadura and Andalucia Regional Government)
LMT 2: Grasslands management for soil regeneration and carbon storage	1,27 million hectares of permanent pasture in organic farming in Spain (Government of Spain)	0.25% annual extensive grasslands in organic farming area increase. 35% Sustainable management practices in grasslands (Government of Spain)	1% annual extensive grasslands in organic farming area increase. 70% Sustainable management practices in grasslands (Government of Spain)	0.10% annual extensive grasslands in organic farming area increase. 15% Sustainable management practices in grasslands (Government of Spain)	0.25% annual extensive grasslands in organic farming area increase. 25% Sustainable management practices in grasslands (Government of Spain)	0.15% annual extensive grasslands in organic farming area decline. 10% Sustainable management practices in grasslands (Government of Spain)	0.35% annual extensive grasslands in organic farming area decline. 20% Sustainable management practices in grasslands (Government of Spain)
LMT 3: Forest planning and management	Forest area: 27 million hectares of forest in Spain (Juntos por los bosques)	0.6% annual forest area increase.	0.7% annual forest area increase.	0.25% annual forest area increase.	0.35% annual forest area increase.	0.25% annual forest area decline.	0.35% annual forest area decline.

		50% Sustainable maintenance of the forest area (Juntos por los bosques)	70% Sustainable maintenance of the forest area (Juntos por los bosques)	30% Sustainable maintenance of the forest area (Juntos por los bosques)	50% Sustainable maintenance of the forest area (Juntos por los bosques)	20% Sustainable maintenance of the forest area (Juntos por los bosques)	30% Sustainable maintenance of the forest area (Juntos por los bosques)
LMT 4: Afforestation/reforestation of agriculture degraded areas	Baseline: 730,000 ha of degraded agricultural land reforested (Iglesias Ranz et al 2021)	2% annual increase in reforestation of agricultural land and maintenance programmes (Government of Spain)	4% annual increase in reforestation of agricultural land and maintenance programmes (Government of Spain)	0.5% annual increase in reforestation of agricultural land and maintenance programmes (Government of Spain)	1.5% annual increase in reforestation of agricultural land and maintenance programmes (Government of Spain)	No annual increase in agricultural land reforestation and maintenance programmes. 0.5% annual increase in agricultural land degradation. (Government of Spain)	No annual increase in agricultural land reforestation and maintenance programmes. 2% annual increase in agricultural land degradation. (Government of Spain)

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