**Integrating climate change scenarios for assessing baseline scenario trends: contribution of CDS Toolbox**

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**Abstract:**

Climate change is affecting the environment and ecosystems at all geographic scales. In view of the impacts of this phenomena having the possibility to increase in the future, worldwide experts and the European Commission argue that it becomes relevant to consider this phenomenon on the assessment of the baseline scenario evolution including the potential changes of ecosystem structures and functions, during the Environmental Impact Assessment (EIA) process. This baseline scenario, also called '*Do Nothing Scenario*', requires the use of relevant data and models with the aim to estimate the dynamics of species and ecosystems for the future. Our article aims to introduce the CDS Toolbox that has been developed for this scope. This toolbox is based on two complementary models developed by ASES and CDS, namely the Species Distribution Model (SDM) and the Tlaloc downscaling model. The purpose of SDM is to estimate the potential spatial distribution of suitable areas for species, community of species, ecosystems and landscape units according to 22 relevant ecological variables. Tlaloc model allows downscaling climatic data at very high spatial resolutions (from 1000m to 5m) in order to provide climatic data at a relevant spatial resolution for decision-makers.

## 1. Introduction

Climate change affects, directly and indirectly, almost all aspects of our economy (IPCC, 2014 and 2019) and projects that require an Environmental Impact Assessment (EIA) do not escape of this problem. This aspect is relevant because climate change may influence ecosystem dynamics, species spatial distribution and biodiversity, ecosystem services, the occurrence and magnitude of natural hazards, landscape evolution etc. These topics are usually encompassed during the EIA process to assess the potential impacts posed by a project on the environment and ecosystems. In many cases, this approach is followed by the Avoiding, Mitigation, Restoration and Offsetting sequence that gathers grey and green means which have - a potential duration of decades and may also be affected by climate change.

Awareness to this situation has resulted to- public entities such as the European Commission and professional associations (the International Association of Impact Assessment (IAIA)) to publish documents, namely the European Directive (DIRECTIVE 2014/52/EU), guidance[1] (European Commission, 2013) and best practices[2] (Byer *et al.*, 2018) - to ask decision makers to integrate climate change effects on their project throughout the EIA report. This integration is based on two main

[1] "*Use vulnerability assessment to help assess the evolution of the baseline environment and identify the most resilient alternative(s).*"

[2] "*For project proposals, this should also include the degree to which climate change would affect each component of the project.*"

aspects-. Firstly, the contribution of the project to climate change mitigation (through greenhouse gas emission reduction).Secondly, vulnerability of the project and its site to future changes in the climate, and its capacity to adapt to the impacts of climate change, which may be uncertain.

In parallel to these developments, the International Standard Organization (ISO) published - a norm (ISO 14090:2019) in 2019, which is related to supporting public and private organizations to adapt their territories and activities to climate change impacts. This standard proposes a methodology which assists organizations to define their adaptation plans for facing climate change impacts. In this norm, it is clearly mentioned that the methodology is firstly based on the assessment of the potential impacts of climate change, both positive and negative, on the activities. As proposed by O'Connell *et al.* (2016), this aspect must be applied to projects in order to develop them into a resilient and sustainable way.

In this frame, we propose a methodology for assessing the potential impacts (either positive or negative) of climate change in the frame of EIA. This methodology is applied for evaluating the scenarios of evolution of the baseline that is usually defined in the EIA process by either considering or not considering (do-nothing-scenario) the potential impacts of the project. We apply the methodology on a municipality where a forestry company wants to develop wood production activities . The main uncertainty of the company director is to assess the sustainability of the business in this territory according to the potential impact of climate change on different tree species currently observed or on tree planting projects in other parcels. The company wishes to know if *Quercus rubra* L. (red oak) and *Pinus pinaster* Alton (maritime pine), that are currently observed, can be resilient to climate change. Additionally,to know the possibility of planting *Pseudotsuga douglasii* (Sabine ex D. Don), Carrière (Douglas fir) and *Pinus sylvestris* L. (Scots pine) in this area for their use - in 2050 for developing the wood based energy supply chain.

## 2. Methodology

The definition of the baseline scenario, also called '*Do Nothing Scenario*', requires the use of relevant data and models in order to estimate the dynamics of species and ecosystems for the future. Our article aims to introduce the CDS Toolbox which was developed for this scope.

This toolbox is based on two complementary models developed by ASES and CDS, namely the Species Distribution Model (SDM) and the Tlaloc climatic downscaling model. The purpose of the SDM is to estimate the potential spatial distribution of suitable areas for species, community of species, ecosystems and landscape units according to 22 relevant ecological variables. Tlaloc model allows downscaling climatic data at very high spatial resolutions (from 1000m to 5m) in order to provide climatic data at a relevant spatial resolution for decision-makers.

Figure 1 introduces the different data and models used in the frame of baseline scenario definition and the assessment of its evolution towards climate change.

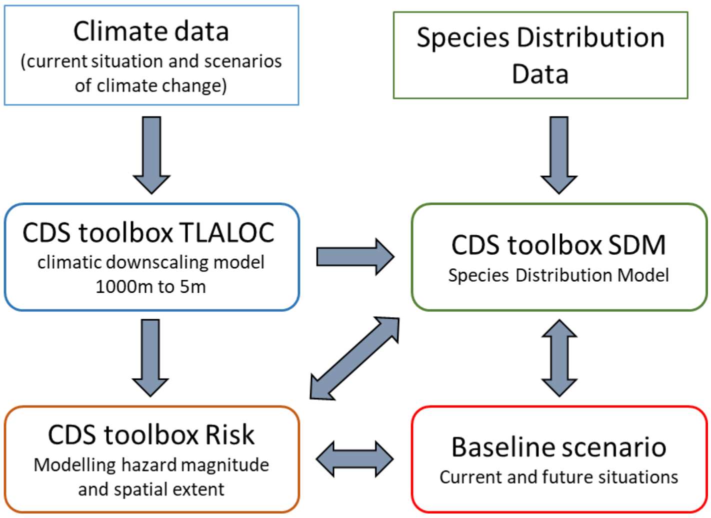



Figure 1: Components of the baseline scenario evolution forecasting in the EIA process.

This climatic downscaling (figure 2) model uses climatic data provided at 8km of spatial resolution by public entities like Meteo France and a set of environmental data that can explain the variations of climatic values at very high spatial resolution (Digital Elevation Model (DEM), localization of hydrographic entities, the distance to the sea etc.). The model calculates the correlation between these explicative variables and the climatic data to estimate the climate at 5m of spatial resolution.

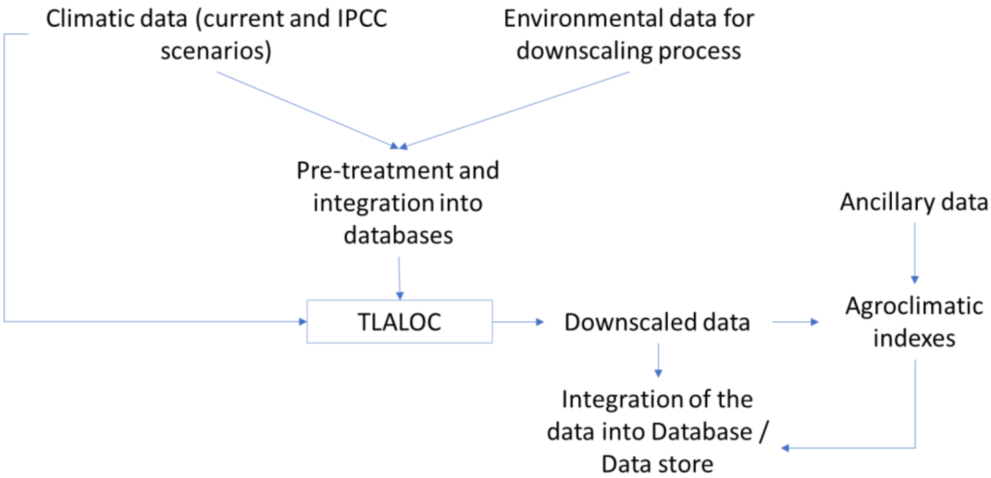



Figure 2: Main steps of the climatic downscaling model Tlaloc.

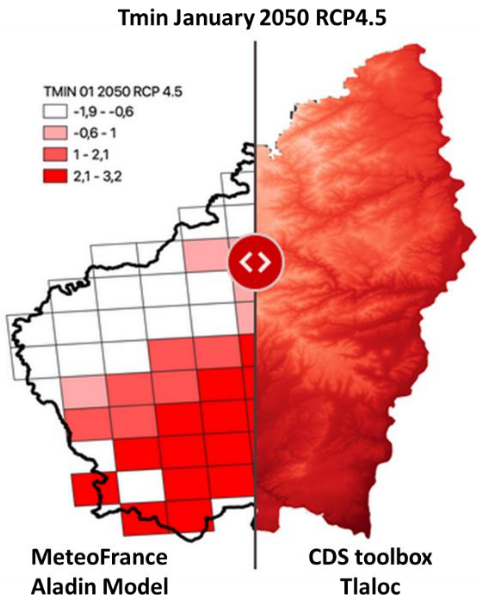



Figure 3: Comparison of climatic data provided by Meteo France (Aladin model, on the left) and downscaled climatic data (Tlaloc model, on the right). This example is given for the temperatures of the night in January 2050 according to RCP4.5 scenario.

The downscaled climatic data are used to assess the probability of finding suitable areas on a small territory represented by a municipality in France. CDS Toolbox SDM has been applied for this purpose. Figure 4 presents the main steps of the Species Distribution Model.

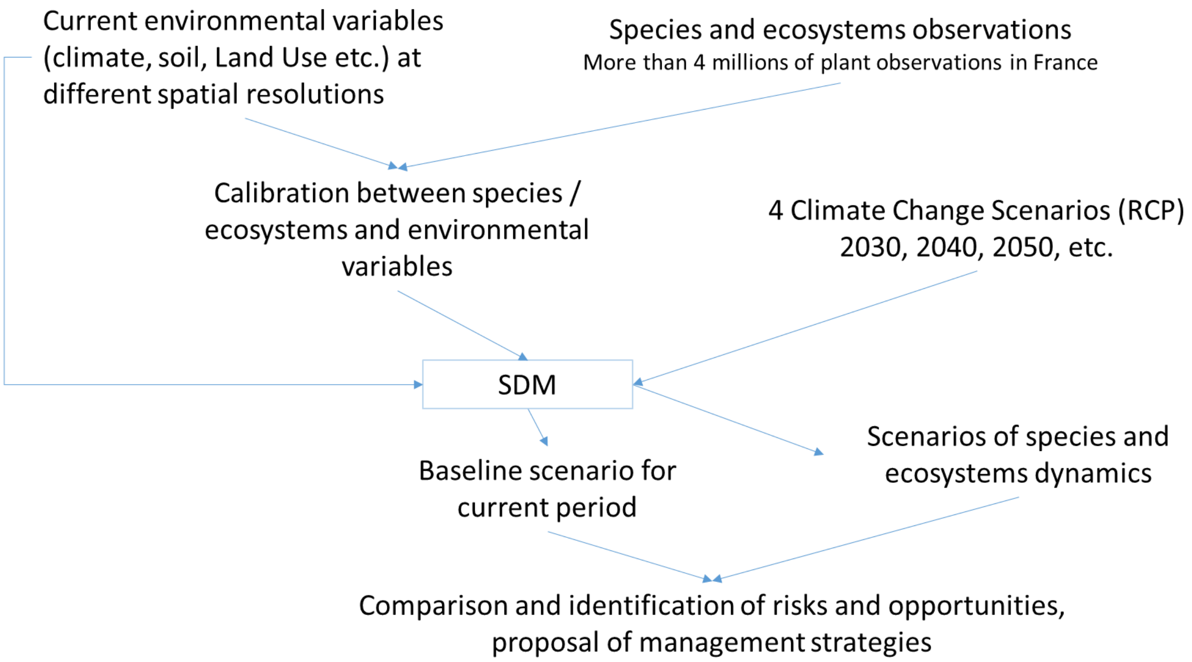



Figure 4: Main steps of the CDS Toolbox Species Distribution Model (SDM) used in order to identify the suitable areas for 4 tree species at very high spatial resolution (5m).

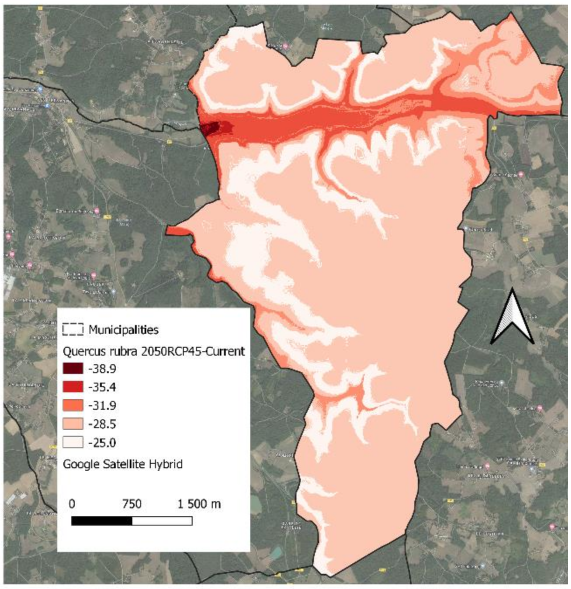
The calibration of the ecological niche of each species has been performed at the scale of France, by coupling observations of each species and climate data at a spatial resolution of 1km. The calibration was performed by using a probabilistic methodology (Garbolino *et al.*, 2007; Garbolino, 2014). Then, we used the CDS Toolbox SDM (Hinojos Mendoza *et al.*, 2020) in order to assess the potential location of suitable areas for each species. Thereafter, we discretized the territory of the municipality into 713.857 pixels of a 5m spatial resolution in order to estimate the suitable areas of each species for the current and the future climatic situations.

## 3. Results and discussion

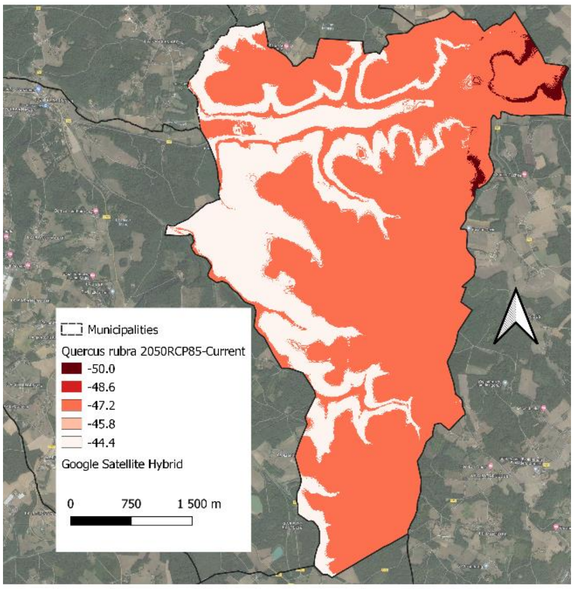
We present here the maps and the statistics for each tree species that represent the differences of probabilities between the current situation and the future situation according each climate change scenario (RCP4.5 and RCP8.5).

The first set of results is related to the two current species (red oak and maritime pine) managed by the forestry company on the municipality.

For the current situation, the probability to find suitable areas for *Quercus rubra* L. (red oak) is very high, from 88.9% to 94.4%, and that shows an interesting bioclimatic situation to manage this species for current wood production. With regards to the 2050 RCP4.5 scenario, the range of probabilities is from 50% to 63.9% and this shows a significant decrease. The probabilities decline from 41.7 to 47.5% for the RCP8.5 scenario. Figure 5 shows the differences between the probabilities in 2050 and the current ones. The two maps show- a general and significant decrease of such probabilities for the future, showing a risk for the management of such species.




Difference between 2050 RCP4.5 scenario and current situation for *Quercus rubra* L. (red oak)




Difference between 2050 RCP8.5 scenario and current situation for *Quercus rubra* L. (red oak)

Figure 5: Differences of probabilities to find suitable areas for *Quercus rubra* L. (red oak) in 2050 according to RCP4.5 and RCP8.5 scenarios.

For *Pinus pinaster* Alton (maritime pine), the current probabilities varies from 77.8 to 83.3%, and from 86.1 to 88.9 for RCP4.5 and equal to 83.3 for RCP8.5 scenarios in 2050. This shows that the future climate would be a little more advantageous for the development of this tree on this territory. Figure 6 shows the maps where the increase of probabilities would be observed in 2050.

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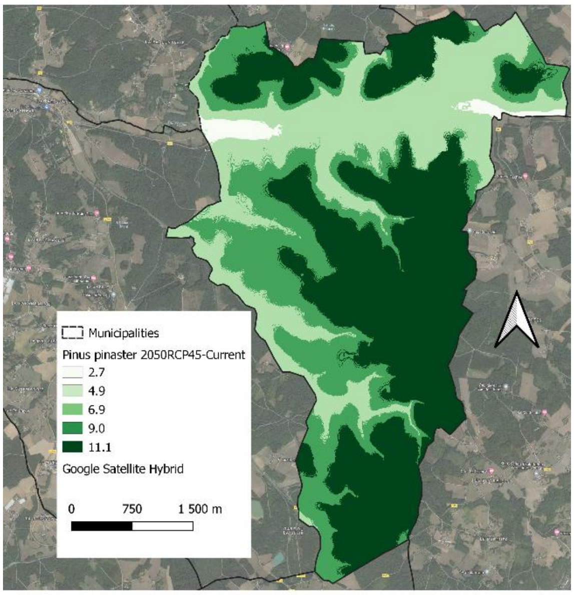
<td>
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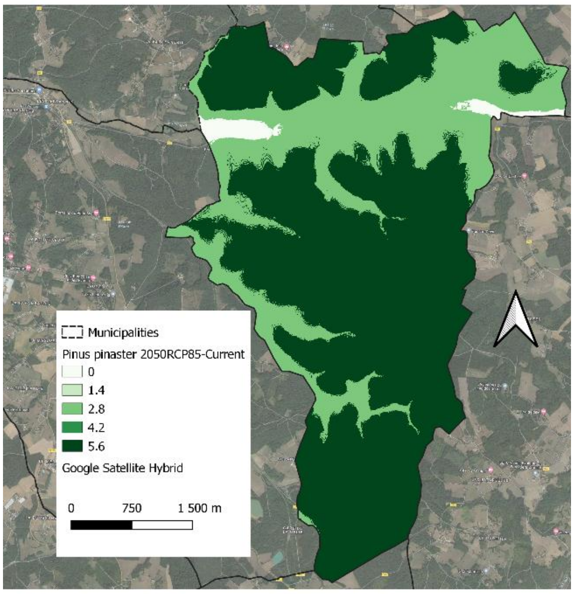
<td>
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<td>Difference between 2050 RCP4.5 scenario and current situation for Pinus pinaster Alton (maritime pine)</td>
<td>Difference between 2050 RCP8.5 scenario and current situation for Pinus pinaster Alton (maritime pine)</td>
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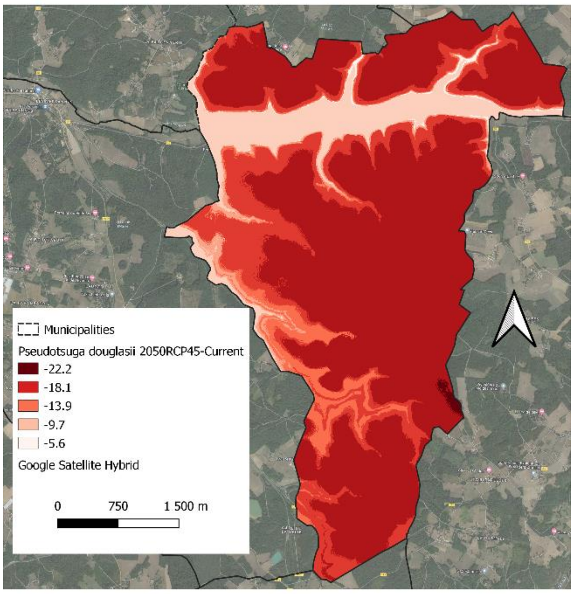
Figure 6: Differences of probabilities to find suitable areas for *Pinus pinaster* Alton (maritime pine) in 2050 according to RCP4.5 and RCP8.5 scenarios.

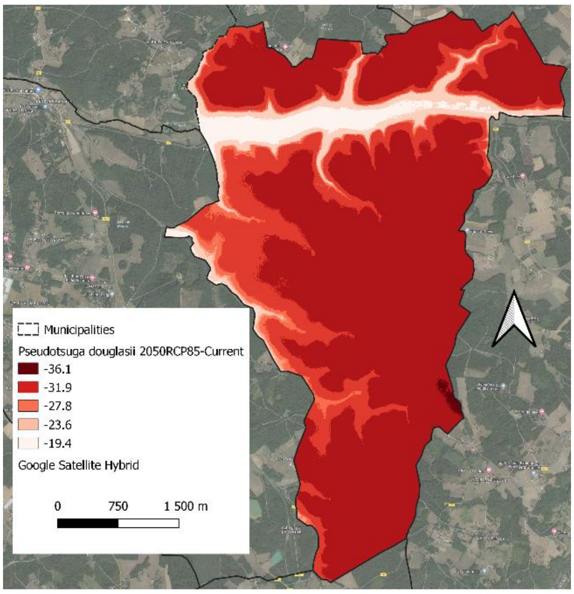
These results show the potential interest for managing and promoting *Pinus pinaster* Alton (maritime pine) plantations in order to have a sustainable and resilient business of wood resource. At this stage, it should be interesting to replace red oak, after cutting operations, by maritime pine in the upcoming years and decades.

The second set of results is related to the tree planting project that the company would like to develop on other parcels of the municipality. This project would be about the planting of Douglas fir and Scots pine.

For the Pseudotsuga douglasii (Sabine ex D. Don) and Carrière (Douglas fir), the current probabilities are averagely low on the main parts of the territory, from 36.1 to 50%. This implies- that this species is not very well adapted to such territory. For 2050, the climatic situation would therefore be worse, with a significant decrease of probabilities.




Difference between 2050 RCP4.5 scenario and current situation for *Pseudotsuga douglasii (Sabine ex D. Don) Carrière* (Douglas fir)

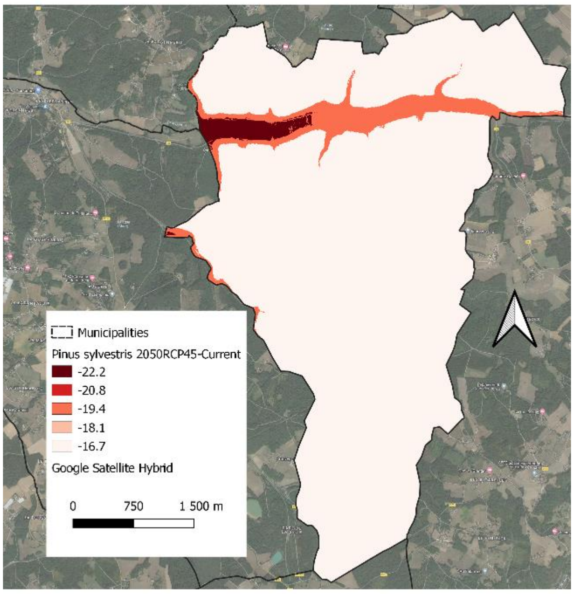



Difference between 2050 RCP8.5 scenario and current situation for *Pseudotsuga douglasii* (Sabine ex D. Don) Carrière (Douglas fir)

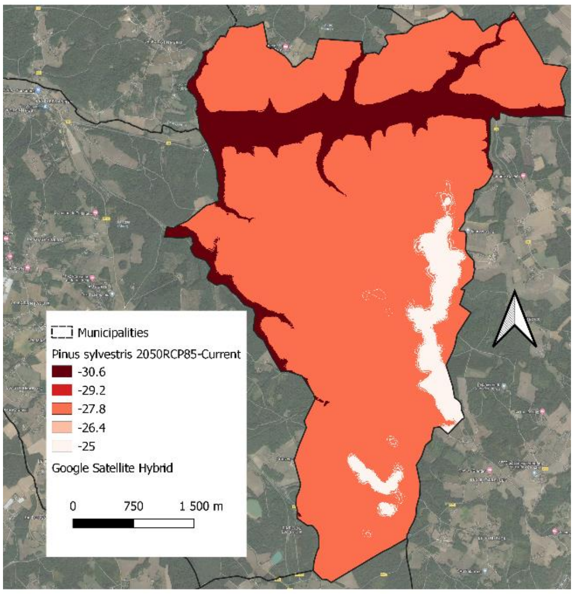
Figure 7: Differences of probabilities to find suitable areas for *Pseudotsuga douglasii (Sabine ex D. Don) Carrière* (Douglas fir) in 2050 according to RCP4.5 and RCP8.5 scenarios.

These results demonstrate that this species should be in stress situation currently and especially in 2050, making its management very difficult, with a high level of death risk for the stands of this tree.

For *Pinus sylvestris* L. (Scots pine), the probabilities for the current climatic situation is 100% on all the municipality and for 2050, the probabilities will decrease as it is presented in figure 8.




Difference between 2050 RCP4.5 scenario and current situation for *Pinus sylvestris* L. (Scots pine)




Difference between 2050 RCP8.5 scenario and current situation for *Pinus sylvestris* L. (Scots pine)

Figure 8: Differences of probabilities to find suitable areas *Pinus sylvestris* L. (Scots pine) in 2050 according to RCP4.5 and RCP8.5 scenarios.

Even if the decrease of probabilities is significant for Scots pine, especially for RCP8.5, its probabilities will never be lower than 69.4%, which can be considered as a high level of probability to ensure its growth.

## 4. Conclusion

The approach presented in this study shows the role of coupling models of climate downscaling and Species Distribution Model - which are utilized to assess the potential suitable areas of 4 tree species. The results underline the importance of distinguishing different ways of management for the forestry activities according to the potential impacts of climate change. The following findings were obtained:

- For the currently tree species managed, maritime pine seems to be currently well adapted - with a promising resilience to climatic change and thus its development should be sustainable in this territory. On the other hand, red oak stands may be significantly stressed by climate change, and therefore it should be useful to envisage to cut some stands and replace them with a more adapted tree, such as the maritime pine.
- For the project of tree plantations, it is not recommended to plant Douglas fir due to the current and future low probabilities. For Scots pine, it is possible to plant it knowing that climate change may have a little impact on its development. In this case, maritime pine should be a better solution for forestry business.

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