



The FOREST4EU Factsheet Collection brings together the key findings, best practices, and innovative tools developed within the project. Each factsheet offers a clear, concise, and accessible summary of a specific topic, ranging from novel wood-based products and climate resilience strategies to advanced monitoring technologies.

FACTSHEETS

BOOKLET COLLECTION

ITHub2

Forest adaptation to
climate change



UAV and multispectral camera to map stressed forest area

Introduction

In the context of precision forestry, and to monitor potential issues related to stress on a per-tree basis for forest managers, it is necessary to employ tools capable of rapidly mapping this information in order to implement adaptive silvicultural practices. Within the GO-SURF project, conducted in forests directly managed by the operational group partners, the use of drones equipped with multispectral cameras (Micasense) was tested and implemented to map stressed areas. The use of the drone, equipped with automatic flight capabilities, allowed for the creation of high-resolution multi-temporal orthophotos and the identification of areas where a reduction in photosynthetic activity was observed. The multispectral cameras and the use of this data have allowed for the prompt identification during GO-SURF of stressed areas, primarily caused by oak forests. In this context, it was possible to monitor these areas affected by prolonged periods of drought. Monitoring with the use of drones allows for the observation of the development of these stresses and the impacts they have on the forests. Moreover, the camera permits to identified not-stressed plant that can be assumed as more resilient.

Lessons learned

The forest managers have highlighted the ease of using drones, even though the multispectral cameras used in the project are quite expensive. Further tests with lower-cost cameras are, therefore, necessary. However, the prompt observation of stress can enable the implementation of silvicultural strategies to mitigate the problem. Furthermore, from the analysis of stress at the individual plant level, it is possible to identify the more resilient plants that could be selected as seed plants to produce seedlings for future reforestation efforts.

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Further information

<https://www.go-surf.it/>



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'Educational module 'foresters, it's your turn to play''

Introduction

Consultation between the various players in the five areas that have signed a Forestry Territory Charter (CFT) in Normandy has highlighted the need for coordinated action between players, as well as the need to explain what is being done in the forest. The aim of EUROFORNORM was therefore to create and run a regional network of forest areas in Normandy. "The future of Normandy's forests in the face of climate change" emerged as one of the priority themes.

Presentation of the educational game

"Forestiers, à vous de jouer" is an educational tool, in the form of a game, specifically on the theme of climate change in forests. It is aimed principally for primary school classes (cycle 3), with a number of players ranging from two to six. The aim is to manage the Normandy forest in the best possible way to protect it from the impacts of climate change. "Forestiers, à vous de jouer" is a board game in which the players have to reach the "Arrival" square by choosing the path of their choice and answering questions on 10 forestry themes. To promote this innovative tool, a copy of the module was given to 200 schools in the 5 departments of Normandy. This tool was designed with the aim of developing an educational resource that could complement other initiatives in the region, such as the "1000 communes, la forêt fait école" programme, developed by the National Federation of Forest Communities, which aims to entrust primary school children with the management of a plot of communal forest in order to raise their awareness of the forest as a central element of their region.

Lessons learned

One of the aims of creating this educational module for schools in the form of a game was to raise young people's awareness of forest management and the changes that can be expected in the face of climate change. Feedback from teachers who have used the game has been very positive, both in terms of the fun aspect of the game, which captures the attention of pupils, and in terms of the rich content of the topics covered. Teachers can integrate the various concepts into their own curriculum. In this way, pupils can learn about forest management and how Normandy's forests are adapting to climate change.



Figure 1. Presentation of the “Forestiers à vous de jouer” educational game box, game board and game cards.

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Further information

https://eu-cap-network.ec.europa.eu/projects/euro-fornorm-14-50-61-emergence-and-animation-innovative-and-operational-network-normandy_en



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Douglas fir in the face of climate change in Burgundy region

Introduction

In Burgundy, Douglas fir occupies 8% of the forested area (68,000 ha) and supplies the French and European sectors. Its growth rate and the quality of its wood make it a very productive species (up to more than 20m³ of wood per hectare per year) and sought after. However, the successive heatwaves of recent years (2003, 2005, 2018, 2019, etc.) combined with a water deficit have caused sometimes significant dieback in the stands. These observations have encouraged foresters to begin thinking about the sustainability of the sector's supply and the modalities by which the Burgundian territory can be favorable to the continuation of Douglas fir silviculture.

Methodology and results

From the establishment of a network of 90 reference forest plots in private forests, representative of the diversity of climates, soils, altitudes, etc.

The partners intended more specifically to:

- Identify the resilience of Douglas stands in a context of climate change using the ARCHI method;
- Establish suitable silvicultural itinerary for Douglas fir in the context of mixed plantings or plantings of replacement species, based on Potential Biodiversity Index (IBP) measurements;
- Help private forest owners in their silvicultural choices using the BioClimSol application;
- Evaluate the carbon stock of a Douglas stand based on its silvicultural itinerary;
- Evaluate sustainability for soils under Douglas fir stands.

Work analyzing the risks to which Douglas plantations are exposed has notably resulted in a modeling of the risk of Douglas fir dieback due to climate change as well as the production of climate vigilance maps. Intended for decision-makers and planners, these provide an overall idea of the future distribution area of Douglas-fir in Burgundy-Franche-Comté if global warming continues with the same intensity. Finally, an analysis of failed plantings and natural regenerations as well as planting experiments - mixed with other species or with new varieties of Douglas fir - were carried out.

Summarized in a synthesis of actions, the results were transferred to Douglas foresters, landowners and forest managers and professionals in the sector through training days, technical sheets and guides including one on the use of the ARCHI method applied to the Douglas.

Lessons learned

From an exhaustive network of reference populations of Douglas fir in Burgundy-Franche-Comté, the project made it possible to collect stationary, dendrometric, ecological and health data which improve knowledge of Douglas fir as well as to launch experiments in order to adapt this important production for the regional wood industry.

The studies encourage foresters to mix Douglas-fir provenances and thus diversify the genetic potential, and to use the California provenance under certain conditions, particularly with its potential capacity to withstand high heat.

Douglas fir monoculture seems to promote nitrification in the soil, and contributes to the increase in nitrate levels in surface waters. It would be recommended to diversify Douglas fir plantations in full and to have a mixed approach at the scale of small watersheds.

Finally, the study made it possible to validate numerous silvicultural concepts indicating that the increase in forest biodiversity and carbon stock in forest soils is favorable to the adaptability of Douglas fir in the face of climate change.



Figure 1. Douglas fir plantation in Burgundy region.

Louis-Adrien Lagneau © CNPF

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Further information

<https://bourgognefranchecomte.cnpf.fr/nos-actions/recherche-et-developpement/douglas-et-changement-climatique-en-bourgogne>



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Assisted tree migration: 70 islands of trees of the future

Introduction

For several years, foresters in the Grand Est region have been witnessing the decline of massifs due to repeated droughts (2018, 2019, 2020 and 2022), heatwaves and other insect attacks (bark beetles or processionary caterpillars). This high mortality affects the main species of the region: spruce, fir, beech and oak. It has now been shown that the climate is changing so quickly that species do not have time to migrate to avoid contexts that become unfavourable for them.

Methodology and results

Faced with this observation, even if we can hope for a natural adaptation of forests, doing nothing constitutes a significant risk for the forest ecosystem as well as for wood production. To counter, or at least mitigate, as best as possible these mass diebacks, one of the responses consists of setting up islands of the future, controlled experiments allowing the testing of non-native tree species on plots of 0.5 to 2 hectares.

OG FuturForEst tested ten new species more adapted to climate change via the creation of a network of 70 islands of the future: 2-hectare plots spread over public and private forests. Five hardwoods (Hungarian oak, downy oak, swamp oak, Byzantium hazel, American sweetgum) and five softwoods (evergreen redwood, Macedonian pine, Calocedra, Cilicia fir, Arizona cypress) were selected for their potential for tolerance to current climate and adaptation to future climatic conditions, as well as for their ability to produce quality timber.

A preliminary survey made it possible to identify and characterize 75 plots (exposure, altitude, pedology) with public and private forest owners. The surface area of the devices is between 1 and 2 hectares with a relatively homogeneous station on the island and the planting work took place from November 2020 to January 2023. Identical on all the plots, the preparation of the land consists of: entire grinding of spontaneous vegetation, prior fencing of the plot and the creation of manual pots when placing the plants in pots (2,000 plants/ha). A guide for the maintenance and monitoring of the devices has also been written to guide owners and managers in monitoring the plantation over the first years.

This OG was also part of the ESPERENSE research project led by the national AFORCE network (www.reseau-aforce.fr) for the adaptation of forests to climate change, integrating rigorous protocols and banking on the

pooling of knowledge to initiate a network of multi-partner experiments . This project aimed to improve knowledge of the behaviour of new species and provenances in different forest station contexts.

Lessons learned

The creation of this network of more than 70 islands now makes it possible to test in the long term new species in varied station conditions observe their response to climate change in the Grand Est region. From these experiments, details are expected on suitable silvicultural routes, as well as on the compatibility of species with forest stations.

The project also strengthened collaboration between the different managers and allowed all the players in the sector to organize themselves to achieve the production of plants of new species: seed supply sector, processing of batches of seeds, production in the nursery, etc. We can note the supply difficulties (problem of fruiting or geopolitical context) of seeds and plants of the species selected and originating from the Mediterranean basin, central Europe or the United States.

The creation of the GO in two phases - emergence then development - made it possible to take the time necessary to establish the partnership and define the common problem among different Franco-Belgian forest management organizations, both public and private, in the service of developing forestry knowledge.



Figure 1. Experimental system in the Prény forest. Planting of two islands of trees of the future as part of the FuturForEst programme (Pubescent oak and Arizona cypress). Pubescent oak root ball plant presenting major root problems.

Sylvain Gaudin © CNPF

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Further information

<https://www.xn-reseau-national-agricultures-ruralits-bkd.fr/centre-de-ressources/projets/futurforest>



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Course on GIS and Remote Sensing Data to monitor forest ecosystem

Introduction

To monitor stress and the impacts of climate change on forests, there is a need to enhance the technical analysis skills of individuals involved in sustainable forest management. In recent years, various tools like Sentinel-2 satellite imagery have allowed for almost continuous monitoring of such stress.

However, technological progress has not led to a real change because many technicians do not know how to use analysis tools, even simple ones. In this context, within the GO-SURF project, it was decided to organize a tailored 24-hour course to teach forest management technicians how to use these tools and the related GIS (Geographic Information System) tools for analysis. The course has been highly successful with over 50 participants enrolled. The course was structured with practical exercises conducted in classroom settings tailored to the forestry sector. In particular, the Google Earth Engine analysis platform and data easily implementable into the QGIS system were used. This enabled the transfer of analytical capabilities to the technicians who attended the course, many of whom had no prior knowledge of the potential of these tools.

Lessons learned

The technicians emphasized that courses of this kind are crucial, especially in a forestry context. The strength of the course lay in its practical aspect, with exercises specifically designed to address forestry-related scenarios

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Evaluation of different microclimatic conditions in a linear planting with rows of hybrid biomass poplars combined with maize

Introduction

Linear planting with rows of hybrid biomass poplar trees associated with maize was used to evaluate the effect of microclimatic conditions on the crop's water status and production. The results show that the two poplar rows reduce wind speed by up to 50-70% and that the height of the trees at the end of the shift has a shading effect on approximately one third of the inter-row area. This is the major limiting factor for the crop, but the degree of competition for water also varies within the inter-row, as the presence of the rows changes evapotranspiration: soil moisture is higher in the central part of the inter-row. If on the one hand shading allows the water status to recover, on the other hand it negatively affects production; when compared to the production of the central part of the plot (the least shaded) the decrease in production is more than 25% . The situation is different when compared to the control in 2022, a year characterised by excessive drought: the presence of the rows of trees (and presumably the positive effect on evapotranspiration) makes a difference of 54% when compared to the control.

Lessons learned

Since drought is becoming a more limiting factor in agriculture, there's the need to improve research looking for innovative and traditional solutions. Agroforestry approach is very important in order to mitigate climate change and make ecosystems more resilient to changing conditions.

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Application of SlideforMap for the hydrological risk assessment in sustainable managed forests

Introduction

Forests are vital in protecting property and people against hydrogeological slope failure. From this perspective, the importance of forest management is crucial, given the increase in the frequency of extreme rainfall events driven by climate change. Knowing a priori the susceptibility of an area to rainfall-induced shallow landslides is, therefore, a pivotal point in avoiding or limiting environmental and social damage.

SlideforMAP is a probabilistic model created by the International Association of Natural Hazard Risk Management, called ecorisQ (ecorisq.org). Its application allows for assessing the probability of shallow landslides triggering on a regional scale, considering the structure and composition of forests as input data in the process. Through the calculation of root reinforcement, both at the scale of individual trees and forest stands, it provides valuable decision support in the planning and managing direct protection forests.

In the BIOSEIFORTE OG, this model was applied to evaluate how land cover changes over the years have affected slope stability in the Mt. Nerone area and also to assess the effectiveness of the current land cover condition in case of extreme rainfall events.

The stability analysis highlighted the central role of forests in warranting slope stability through the contribution of trees root reinforcement. In particular, increased forest cover surface has remarkably stabilized landslide susceptible areas, reducing the impact of hazardous events.

The stability analysis through SlideforMAP allowed to detect areas where geo-environmental factors (e.g. morphology and soil properties) are preeminent, like those near urban settlements and infrastructures, becoming a potential risk and requiring more careful monitoring.

Lessons learned

Analyzing and quantifying the forest contribution to slope stability is essential in research and practical applications. Knowing the probability of rainfall-induced shallow landslides at a regional scale can help to understand how environmental factors variability can influence such dynamics. Using slope stability models such as SlideforMAP is essential for guiding land use planning and providing quantitative information about the stability conditions of an area. Nonetheless, for even better outputs, more detailed information is necessary, including accurate resolutions of digital terrain and surface models, not always easy to obtain from regional and national databases.

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Further information

<https://www.innovarurale.it/pei-agri/gruppi-operativi/bancadati-go-pei/biodiversita-e-servizi-ecosistemici-foreste-e-territorio>



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Management manual for stone pine

Introduction

The management of stone pine forests faces important challenges and threats, many of them interrelated and derived from past, present and future climate and socio-economic change. One of the main factors is water restriction due to changes in climatic patterns and due to densification and competition in vegetation, despite the fact that stone pine is a xeromediterranean species. Associated with this, vulnerability to high intensity forest fires is an increasingly relevant factor, despite the natural resistance of the species to surface fires. Finally, pests are the factor that completes the front line of the challenges to be faced with forest management. The direct affectation by *Leptoglossus occidentalis* is a major problem, but other pests and diseases of great potential that affect these pine forests in a primary or secondary way are also important. The forest management proposed in this manual aims to tackle these adversities in an integrated way by improving stand conditions. The regulation of inter- and intraspecific competition, also taking into account the conformation of the forest structure, means an optimisation of the available resources in the most vital individuals and a limitation of the load and continuity of fuel for fires. Integrated biological pest control also requires these management actions that favour tree vitality. However, management must be complemented by other measures established at landscape scale to complement mitigation and adaptation actions, such as prevention of large forest fires through strategic management points and integrated pest management at regional level. The objective of this Management Manual is to establish management guidelines for *Pinus pinea* stands against biotic threats and for adaptation to climate change, a strategic planning framework for the management of stone pine with the preferential objective of pine nut production. The aim is to provide forest management guidelines both for natural stands and plantations already in production and for the production of other stands with suitable conditions, with the objective of maintaining and improving pine nut production and contributing to the development of its value chain.

Specific objectives:

- (1) To define the main characteristics of the types of stone pine stands considered suitable for pineapple production.
- (2) To establish the general management bases to be implemented in each case in order to optimise pine cone production, taking into account the multifunctionality of the forests.
- (3) To quantify the estimated

production that could be obtained with the implementation of production as described. In order to define the strategic lines of management for pine cone production, and taking into account the surface area considered suitable, 3 typologies of pine cone stands and plantations are defined.

These typologies group together the main situations where this type of management can be considered. In the case of Productive Plantations, the following three phases are described:

- Choice and preparation of the land
- Choice of the base material: planting
- Maintenance work.

In the case of natural stands, there are two types of natural stands. On the one hand, we have mixed natural stands, where stone pine is dominant with a basal area of 50% and 60%. On the other hand, we have pure natural stands, where stone pine is dominant with more than 80% of the basal area. The treatments described for this typology include mixed thinning, resprout selection and scrub control. Finally, other plantations refer to those plantations that were originally planted with the objective of producing *Pinus pinea* timber and therefore have a plantation framework and silvicultural treatments focused on this objective have been carried out. The treatments described for this typology include mixed thinning, pruning and phytosanitary treatments. This manual has a didactic and introductory function to inform about the management of stone pine stands, whether they come from plantations or natural stands. Each stand has particular conditions in which its management will depend on the objective of the stand and its conditioning factors, so it is advisable to contact forestry engineers who are experts in stone pine silviculture so that they can carry out a study and/or advice for the specific case of the stand in question.

Lessons learned

There is a positive effect of pruning on growth and production of female strobiles. - Pruning improves the health of the stand, reducing the presence of the fungus *Diplodia pinea*. - The response of the trees to pruning has been very rapid, with a clear improvement in vegetative and productive response from the first year. However, it is not yet possible to give results on the effect of thinning. This work is a first step to assess in a quantifiable way the interest of recovering production in non-/poorly managed *P. pinea* plantations. The work will have to be continued for at least two more seasons.

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Further information

<https://gopinea.org/wp-content/uploads/2023/03/Manual-de-gestion-del-pino-pinonero-OK.pdf>

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Reducing Input in Forest Operations: A Valuable Opportunity for Carbon Credit Generation

Introduction

Forest carbon credit additionality projects are initiatives aimed at generating carbon credits through sustainable forest management and conservation activities. These carbon credits are then used in carbon markets to offset greenhouse gas emissions from companies or individuals. Typically, these projects focus on sustainable forest management practices that enhance carbon sequestration within forests, known as "additionality," achieved through activities like silviculture treatments that differ from previous management practises (e.g. conversion between coppices to high forest, enlarging the cut periods, fire-preventions).

In the context of carbon emissions, it is not only essential to create additionality projects but also to reduce emissions. Forest operations can contribute to emissions and pollution, even in the context of additionality carbon credit projects. Therefore, employing a "Life Cycle Assessment (LCA)," a systematic and comprehensive methodology used to evaluate the environmental impact of processes, becomes crucial. This assessment helps evaluate the environmental sustainability of forest operations, compare them to the "business as usual (BAU)" scenario, and identify opportunities to reduce emissions. This, in turn, enhances the effectiveness of additionality projects in generating more carbon credits.

Within the context of the CO2MARCHE OG as an additionality project for carbon credit generation, a methodology has been created to quantify the reduction of energetic inputs in forest operations to generate additional carbon credits. Through this analysis, electric chainsaws and the use of alkylated gasoline have been identified as means to reduce emissions from forest operations when compared to traditional gasoline-powered equipment.

In this context, it is also possible to calculate the additionality produced by more sustainable forest operations, leading to the creation of more additionality credits compared to traditional forest operations carried out with traditional gasoline or chainsaws. In this context, CO2MARCHE works within the framework of Sustainable Forest Management certification under the PEFC standard to set-up the methodology to quantify the additionality carbon credit generate by reduction emission of forest operations via a rigorous LCA that contrasts the BAU scenario with the new, more sustainable tools. Ultimately, if forest operations demonstrate greater sustainability in terms of emissions, forest owners and forest operation companies can generate more

carbon credits, resulting in increased revenue. This revenue can not only cover equipment costs but also have a positive impact on the environment as a whole.

Lessons learned

To combat climate change, it is essential to reduce emissions, and within the context of an operational group dealing with CO₂ and carbon credits in the forestry sector, it has proven to be of paramount importance to also strive to reduce emissions stemming from forestry operations. Through the use of the Life Cycle Assessment (LCA) approach, it is possible to calculate the Business As Usual (BAU) for forestry activities and promote the use of machinery or fuels with a lower environmental impact. This is crucial, especially in the context of climate change mitigation, to lower greenhouse gas emissions. Besides providing an environmental benefit, this can also lead to the generation of more credits in an additionality project, potentially resulting in greater financial gain as the generated credits are greater.

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Further information

<https://www.co2marche.it/>



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Cause of the decline of cork oak forests and management strategies

Introduction

The cork oak stands when managed as an agro-forest-pastoral stand creates an ecosystem called “Montado” (Portuguese)/ “Dehesa” (Spanish). This ecosystem allows the creations of different products (timber, livestock, cork, ...) and services (carbon sink, biodiversity, water regulation, ...). For these reasons this ecosystem has a major impact in the national landscape, environment and economics.

In the last decade the geographic distribution of this species has been changing, and the density of the current stands has been declining because the decrease in vitality/increase in mortality and the low success rate of the natural regeneration and the young plantations. The three main reasons are climate change, pests and diseases, and bad management practices. They don't act alone but in an interconnected way since their effects influence each other. In relation to climate change, the current scenario is characterized by higher temperatures all year round, less precipitation with higher periodicity and in events of higher amount of rain. These factors have as consequences the tree growth starting earlier in the year but also finishing earlier, forest fires are becoming more common, and drought events are becoming more common and intense. In relation to pests and diseases, the increase in their severity is related to better climatic conditions for their growth and reproduction and the more and more common monospecific forests lead to more vulnerable stands. Most of times pests and diseases do not kill the tree, but when in conjugation with other factors, such as droughts, it may. In relation to the bad management practices, it is usually associated with the mobilization of the soil, since ploughing breaks the superficial tree roots (most of the water and nutrient capture is done by them) and contribute to the dispersion of fungi spores, the compaction of the soil, done by the machines and excessive cattle, creates difficult condition for root development, the presence of livestock also decreases natural regeneration and their success, the lack of under story vegetation control may create excessive competition between the trees and other plants, however the lack of under story vegetation may also impact the natural regeneration, since they create better climatic condition (shade, lower soil temperatures) for the growth of young plants.

As a solution for this problem two school of thought may be used but remember they should be viewed as a spectrum and not two isolated options. Resilience measures aims to increase the resistance and recovery potential of already established stands to the new climate and natural disturbances. Allowing the

ecosystem to endure and keep their characteristics. In the transition school of thought the objective the creating of a new ecosystem more adapted to the foreseen condition that are the result of the climate change scenarios.

Three main objectives that should be targeted when creating and applying forest policies and management operations to fight the decline of vitality in cork oak stands. The objectives are:

- (1) Maintaining the fundamental ecologic functions
- (2) Maintaining and improving the genetic diversity
- (3) Improving the ecosystem fitness by mixing and transitioning to new species.

To achieve the first objective management practices should aim to decrease the effect of droughts, reduce the impact of the operations and the climate change in the soil and in the nutrient cycle.

To improve and maintain the genetic diversity, the promotion of natural regeneration will allow the growth of plants more adapted to the site, however given the current climate change, plants from different spots, with the genetic potential to resist more severe conditions, may be more adapted.

The ecosystem fitness can be improved by mixing new species in the stand that are more resistant to harsher conditions (higher temperatures, less precipitation) or use the available resources in a different way than the current tree species.

Lessons learned

The management practices that are suggested to fight the decline of cork oak stands are:

- (1) The reduction of stand density, when the competition between trees is a limiting factor
- (2) The promotion of the stand heterogeneity in terms of structure/age and species, allowing the formation a more resistant stand
- (3) The control of spontaneous vegetation using methods that don't mobilize the soil, allows a decrease in competition and don't reduce the quality of the soil
- (4) The monitoring and correction of the soil pH and nutrients increases the quantity and availability of nutrients to the plants, allowing them to be more vigorous
- (5) The correct number of live stoke animals per area or even their exclusion for a period of time in some plots will lead to an increase in natural regeneration success rate.

The study of cork oak growth and survivability from different regions and countries is of extreme importance. When more knowledge about this topic becomes available better and more informed choices can be made about what plants/seeds should be used for a certain plot.

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Further information

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Geosuber Tool - Monitorization of the vitality of cork oak stands

Introduction

One of the objectives of this project was the development of an online tool to identify the dead cork oak trees inside a stand. This tool would use satellite images to identify the dead trees annually, efficiently and accurately, at the property scale, producing cartography that can be used as support for the bureaucratic procedure necessary to fill when cork oak trees are going to be cut (the bureaucratic procedure exist because cork oaks are a national protected tree in Portugal). This tool is also projected to have a mobile application/app, allowing it to be easily used in the field. As a secondary objective this tool would allow the collection of vast amounts of data that can be analysed to better understand the decrease of vitality of cork oak stands at different geographical scales.

Besides detecting mortality, the project also tried to understand the relation between the change of leaves in the tree canopy and the ideal timing to start debarking, which is when the cork cambium/phellogen starts its activity. In theory the activity should start at the same time as the secondary growth of the tree, however it is very difficult to accepted this as a fact since no technic allows the measurement of the cork growth without also measuring the growth of wood. For the sake of this experiment and the discussion of the results it was hypothesised that the wood cambium/vascular cambium starts the activity at the same time as the cork cambium.

For the creation of the previously mentioned tool 1 field visit was done to install the continuously measured plots, 24 flights with drones using a multispectral image capturing device were done between 2018 and 2020, and 12 multispectral satellite images from Sentinel-2A and Pleides-1A were analysed. In the plots installed it was quantified, besides the measurements of the trees and the characterization of the plot, variables related to the tree phenological state, such as dead fallen leaves biomass and cork humidity. The data collected was analysed, corrected and different vegetation indexes were created. The data and indexes, plus climatic data, was fitted into different models, possible correlations were analysed and the adjustment of the models was done by verifying their predictions in the field.

The results show that the blossoming of new leaves is controlled by the sum of time in which the temperature is above a certain base value. It was proven that the secondary growth of the tree started with the blossoming of the new leaves. By this statement and what was told above we can hypothesise that the cork cambium also starts the activity at the same time. The availability of water is the factor that determines the duration of time in which secondary growth is active.

The model created to detect the vitality trees, analysed multispectral images creating vegetation indexes, allowing the detection of dead trees with an accuracy between 85% to 70% (best and worst result in the plots used), however it was demonstrated that the model needs to be fitted to each study area, so a “correction” plot needs to be installed wherever the model is used. From the two time periods that the data was collected (Spring and Autumn), the model differentiated between healthy and unhealthy trees with more accuracy in the period of September to October. The accuracy of the model is affected by the existence of saplings/small trees, because they are miscategorised. This model allowed the tool to differentiate between healthy trees, dead/sick trees, and suspicious trees (maybe dead/sick trees), producing a report and cartography that is delivered to the forest owner.

Lessons learned

Typically forest management is done by plots, with the same characteristics and applied operations. A new management approach, with a more adapted scale in relation to space and time is needed to face the new challenges that are coming with the climate change. By continuously monitoring the trees of a stand, using resources such as LIDAR, Drones and satellite images it is possible to know the vitality state of each individual in a stand, in this way creating a tool that allows the detection of less vigour trees, that can be cause for example by pest and diseases or water deficits, and even detecting the trees that are dead.

The tool created by this project is going to allow forest owners and forest workers to have an up to date knowledge about the state of vitality of their property, being able to quickly identify the location of dead trees. This tool has a huge potential in Portugal, since identifying the location of dead cork oak trees is necessary to fill the paper needed to cut dead cork oak trees.

In the future, it is of most importance that this tool continues to develop and leaves its prototype stage, for it to be able to be used in the “real world”.

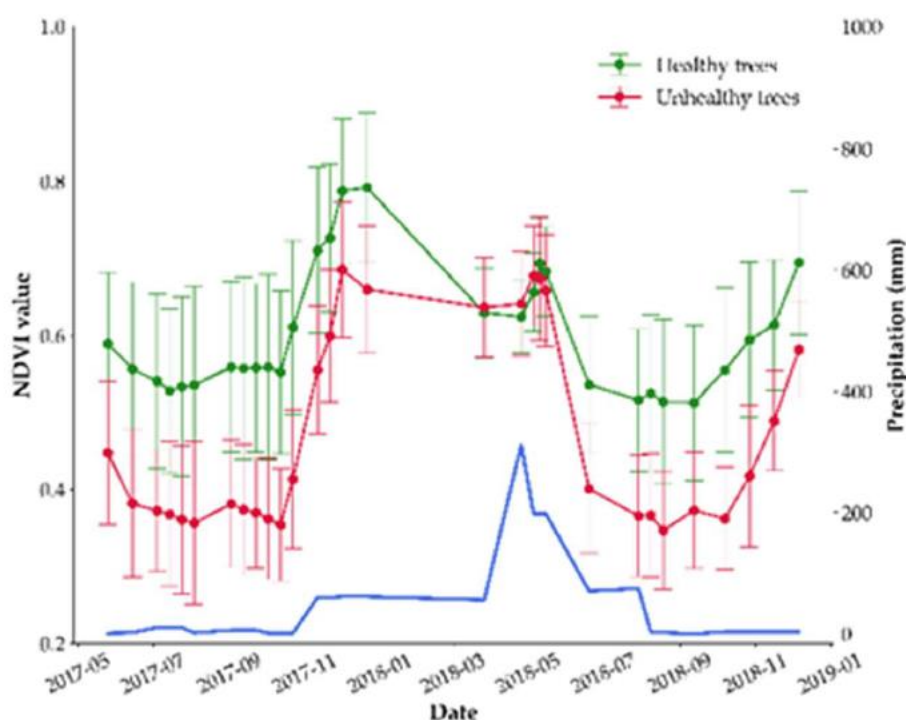


Figure 1. Tree vitality state using tools such as LIDAR, Drones and satellite images

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Precision fertilization of Cork Oak (*Quercus suber* L.) in intensive cork production stands.

Introduction

This project had as an objective the study of irrigation and fertilization in young and old Cork Oak stands, to decrease mortality in new plantations, and increase the vitality, growth and cork production of the trees. Using the least amount of water and fertilizer in function of the site and stand characteristics.

In the case of new plantation, irrigation should only be done where water is easily available. If necessary, a ripper can be used to break deep impermeable soil layer, using one tooth until one meter of depth. The density of the plantation should be between 625 trees/ha (4m x 4m) and 1111 trees/ha (3m x 3m).

The installation of the irrigation system should be done before the plantation. The plants used should be grown in container deeper than 20cm and should be planted with a maximum of 1 year old.

The irrigation and fertilization can be used for at least 15 years, so it is recommended the use of durable materials. Quality materials may be more expensive, but they will decrease the maintenance costs. Drip irrigation is recommended because it is the most efficient method of irrigation. The irrigation can be superficial, optimal in the first years and when the soil is sandy, or it can be underground, more expensive to install but there is no waste of water to evaporation and makes easier the operations of spontaneous vegetations control. Underground systems should be buried at 40 cm of depth, and between 30 to 60 cm way from the plantation line.

The water flow of the emitters should be 2 L/hour, in the cases that the soil composition is very sandy the flow should be 4 L/hour. Until the subjects reach 5 years old, the water used should be between 20 and 45 m³/ha/week, after that age it should be between 45 and 90 m³/ha/week. The frequency of the irrigation should be between 3 and 4 times a week, in the initial phase it can be applied more frequently in smaller periods of time. The frequency should increase with the percentage of sand in the soil. After the first couple of years the frequency of irrigation should decrease, as an incentive to grow the radicular system. The period in which irrigation should be applied is normally 16 weeks, the summer months, but it can also be applied during the spring, when the precipitation is lower than usual, or it is the first year of the plantation.

It is suggested the installation of a monitoring system, continuously sampling the field in different points with a soil moisture profile probe. In general, sandy soils should have higher than 6% relative humidity and clayish soils should have higher than 25% relative humidity.

The fertilization should be done closer to the end of the irrigation, as it decreases the leaching of the nutrients, finishing the irrigation with only water for about ten minutes to clean the irrigation pipes. Until the tree reaches 5 years it should be applied 2kg of N/ha in each irrigation.

The operations of spontaneous vegetation control should never be done by moving the soil layers. The pruning operation should be done annually and from early ages because the fertigation will increase the growth rate of the plants. The pruning objective is to create trees with a single straight trunk increasing the profitability of the tree cork extraction.

The cork produced by the stand submitted to fertigation, is thicker, has higher porosity, and thinner cell walls. However, after processing the cork, it has very similar technological properties when compared to the control samples.

Lessons learned

In plantations the selection of the plants is of extreme importance, never using plants older than 1 year and their root should be well developed. The plantations should only be done after the irrigation system is already in place.

The dripping system can be with fix or attachable emitters. Fixed emitters normally are less prone to leak and have less space between them than the distance between the trees, which can lead to an initial waste of water but as the trees develop their radicular system horizontally it will be advantageous to not only irrigate near the tree trunk. For this reason, it is advisable to use fixed emitters.

The subjects irrigated when compared to the control subjects have a 12% increased diameter growth in the period which they were irrigated. In the case of sandy soils, the efficiency of irrigation is linked to the frequency and not to the quantity of water used. The irrigation allowed the debark, of some subjects, for the first time in only 8 years after their plantation, which shorter than the normal 12 years. The properties of cork produced by irrigated trees are different from the control, however after processing the cork it has similar characteristics."

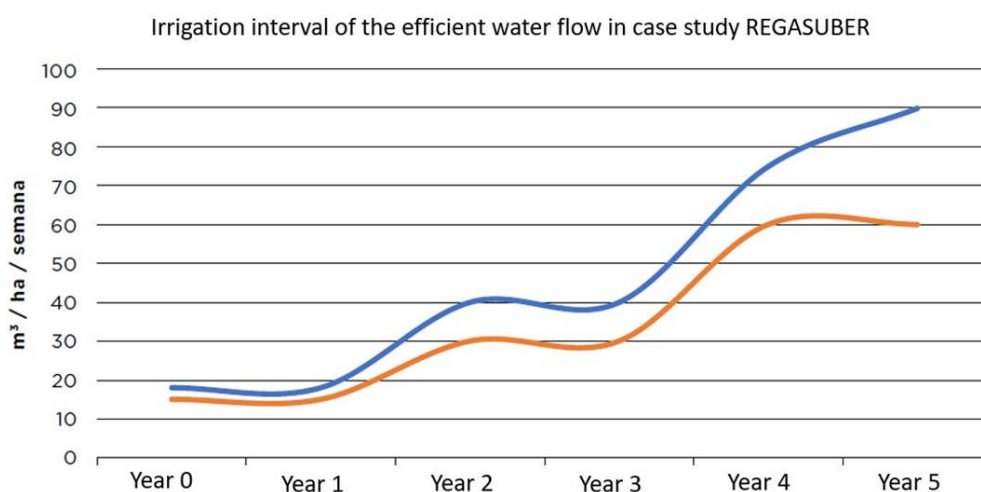


Figure 1. Irrigation interval of the efficient water flow in case study REGASUBER

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"New" pruning method for fertigated Cork Oak (*Quercus suber* L.)

Introduction

The irrigation and fertilization of the plants during the dry season leads to an increased growth rate and to the creation of a larger number of branches in the tree trunk. In normal conditions (cork oak stand without fertigation) the trees are pruned with the objective of creating better conditions for the production of cork and acorns, also allowing more sunlight to reach the ground enabling it to be use for agricultural or livestock activities, and creates a tree with a single trunk, few branches and most of the time with 2,3 or 4 ramification, evenly spaced, between the height of 2 and 3 meters.

In the case study REGASUBER the pruning applied was different. The "style" of the prune was similar to the ones done in high quality wood trees, prioritizing the formation of a single straight trunk, without ramifications, and leaving most of the branches that are in the horizontal position, cutting any branch inserted in the main trunk with an acute angle, because that kind of branches are the ones that will compete with the main stem for apical dominance. One other matter to take in mind when pruning fertigated cork oak trees is that it is necessary to start the pruning operation at a very young age since the trees grow faster, and it is necessary to do the operation annually to be sure that the tree trunks keep a good shape (straight without ramifications)."

Lessons learned

The young cork oak trees under optimal conditions, without water and nutrient deficits, will grow much faster than in normal conditions and will have way more branches. For this reason, a "new" kind of pruning was applied.

The results are not yet fully understood since the trees did not reach adulthood, but it is expected that the trees will grow taller, the diameter of the trunk will be higher and with a straight shape.

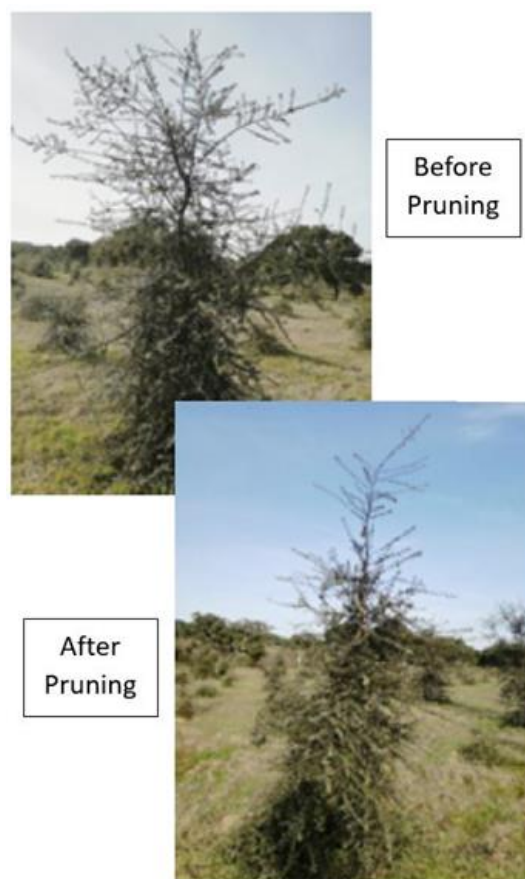


Figure 1. Cork oak tree before and after pruning.

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Increase and transfer knowledge to producers about precision fertigation of Cork Oak (*Quercus suber* L.) in intensive cork production stands.

Introduction

The production of cork in the last decades have been decreasing in quantity and quality, because of bad management practices, biotic factors (pests and diseases), and harsher weather conditions (less precipitation and higher temperatures).

This project had as an objective the study of fertigation in cork oak stands, to increase the profit of the stakeholders and create a simple guide for the landowners to be able to follow. A few landowners, by their own initiative experimented watering some cork oak trees in their lands, which started this experiment. After they have seen some progress, they contacted diverse institutions to share the results and to create a proper trial to evaluate the growth differences. The results were gathered in chapters available online and printed in "Cork Oak with fertigation: Support handbook for the first years." ("Sobreiros com fertirrega: Manual de apoio aos primeiros anos"), "Young stands - Case study REGASUBER" ("Povoamentos jovens - Caso de estudo REGASUBER"), Young stands in pre-first debarking - Case study IRRICORK" ("Povoamentos jovens em situação de pré-desbóia - Caso de estudo IRRICORK"), and "Old stands" ("Povoamentos Adultos").

This chapters were freely distributed to forest owners associations and diverse entities related forestry, which allows the information to reach the landowner."

Lessons learned

This project was a case of success because it allowed the forest owners to have their own initiative and be rewarded for such behaviour. It was a rich experiment in terms of knowledge share because different kind companies, institutions and landowners were involved in this project.

The connections and communication between the different concerned parties was one of the key factors for this project success.

All the results of the different case studies allowed the creation of different scientific articles, in this way sharing the results with the academic and scientific community. And the creations of handbooks, easily

available to the landowners, which allow them to recreate the experiments and see for themselves the results in different stand and site conditions. "



Figure 1. The printed chapters related to the project.

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Good practices for the management of pests in Stone Pine (*Pinus pinea* L.)

Introduction

The objective of this project was to identify the biotic entities (pest and diseases) that affect the development of the plants and the pine nut production, describing the ways to detect them, and which management practices could be applied for their control.

Three major pests were identified: Western conifer seed bug (*Leptoglossus occidentalis* H.); Pine cone moth (*Dioryctria mendacella* S.); Pine cone weevil (*Pissodes validirostris* S.).

Three minor pests were identified: Pine processionary (*Thaumetopoea pityocampa* D. & S.); Common pine shoot beetle (*Tomicus piniperda* L.); Pine shoot beetle (*Tomicus destruens* W.).

The *L. occidentalis* can feed on pine nuts, at every stage of the cone development but it a preference for pine cones in the third year of development. It may dry the cones that have 1 or 2 years, however in cones that have 3 years the damage can only be visible in the pine nuts, since no hole or other sign of their attack can be visible from the outside of the pine cone. Their life cycle is the following: adults feed and lay eggs in April/May, in June/July a new generation is created by laying eggs again, if the climate conditions are favourable a third generation may be created in October/November, the adults from the last generation will gather in big groups and hibernate during the colder months. This life cycle leads to small population numbers in the beginning of the cycle reaching a maximum in July/August. It was observed that the adults most of the times will stay feeding in the same branch or tree but are capable to fly more than 15 km per day if searching for new resources. The population numbers are very different each year for the same place, no explanation was found for this behaviour. This population dynamic leads to very different production damage each year.

As a rule for damage assessment if the insect is detected in one third of the tree in the stand a 25% loss of pine nuts per pine cone can be expected, if they are detected in one fifth of the tree the expected loss is 15%.

The specie *D. mendacella* is affecting the most the pine nut production at a national level, since it's the most numerous pest in our country. The larvae feeds inside the pine cones, mostly in cones with 2 or 3 years, but can also affect cones in their first year. The adult lays a single egg in a pine cone, that hatch between 7 to 10 days. This specie larvae can be identified by their brown body with legs. When leaving the pine cone the hole has an irregular shape, and resin, excrement, silk and sawdust can be seen in the

misshaped pine cone. This specie life cycle was not yet fully understood. It is suspected that it has 2 overlapping generations per year, since the insect can be seen in different life stages simultaneously year-round. The maximum population size is reached in June/July, and it stays the winter hibernating.

The specie *P. validirostris* in their adult stage feed on the pine shoots creating small superficial wounds that do not affect the development of the tree. However, when in their larvae stage they feed in the inside of the pine cone. This specie larvae can be differentiated from the larvae of *D. mendacella* by their white compact body without legs, and can usually be seen more than one larvae inside the pine cone. The hole left in the pine cone is round and usually resin, sawdust and silk is not detected. This specie life cycle has only 1 generation each year, and the adults can live up to 2 year. In April/May the adult lays some eggs in each pine cone, reaching the adult stage in the beginning of the fall, during the winter the adults hibernate in the tree bark.

One management practice that helps in the prevention of pests and reducing their impact is the plantation of mixed forest instead of monocultures. Its is not yet quantified its effect, however it helps by reducing the food source availability and creating more habitats for potentials predators."

Lessons learned

Two pest control methods are suggested for the *L. occidentalis*. In extreme cases of production loss, pesticides with 50% concentration of Flonicamid, can be used to a maximum of 20gr/hl. However, it should be taken in mind that each country has different regulations related to insecticides, in the case of this study (Portugal), only the brand Teppeki is allowed to be used. This brand only kills the nymph stages, after 24 hours, and was proven to not leave residual traces in the pine nut. Another method is installing traps with aggregation or sexual pheromones. This technic has less environmental impact since it targets only the pest and no other living beings.

In the case of *P. validirostris* and *D. mendacella* the most efficient control method is detecting and collecting the pine cones that have been attacked before the larvae reach the adult stage, and destroying the affected material with the use of fire. For the specie *D. mendacella* the use of pheromones together with traps in the last years had a huge development. The use of the female sexual pheromone had demonstrated a high success in the capturing of the specie males while they are flying in their reproduction period.

Level of impact each biotic agent as in the different stages of the <u>pine cone</u> development					
Year	Month	Insect			
		lepto		dio	piss
		adult	nymph	larvae	larvae
0	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
1	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
2	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
3	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				

Figure 1. The level of impact each biotic agent has in the different stages of the pine cone development.

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Good practices for the management of diseases in Stone Pine (*Pinus pinea* L.)

Introduction

The objective of this project was to identify the biotic entities (pest and diseases) that affect the development of the plants and the pine nut production, describing the ways to detect them, and which management practices could be applied for their control.

For a long time the only significant disease found in the stone pine was from a fungi named *Diplodia sapinea*. However in the last years diseases related to the dieback of the tree shoots are becoming more common.

The main fungi associated to the dry of the apical branches are: *Diplodia tip blight* (*Diplodia sapinea*); *Pestalotiopsis dieback* (*Pestalotiopsis pini*); *Dieback of pine* (*Sydowia polyspora*).

Other fungi were identified as minor diseases since the tree normally restore their prior vigour and the fruit production is not affected. They are: *Lophodermium Needle Cast of Pine* (*Lophodermium seditiosum*); *Blight of Aleppo pine* (*Thyriopsis halepensis*); *Red band needle blight* (*Dothistroma septosporum*); *Black spot needle blight* (*Heterotruncatella* sp.).

The fungi *D. sapinea* normally only affect the tree branches causing them to dry. It can also affect directly the pine cone, misshaping it, reducing its size and the quality of the pine nuts produced. The main visual signs of this fungi presence is the drying of the apical shoots, the leaves get a brownish/greyish colour, the leaves dry from their base, cankers are developed in branches, resin is expelled in branches and pine cones are misshaped. The fungi *P. pini* mainly affects the apical tree branches, causing them to dry and die, it also dries the leaves and creates black spots in them, which are the fungi reproductive structure. The *S. polyspora* only visible sign is the drying of the apical branches.

The minor diseases signs and symptoms are described for each fungi as: in *L. seditiosum* the tree shoots grow slower, the branches dry from the base to the top, the leaves from the second year turn brownish or even die and black oval dots can be seen in the dry leaves; in *T. halepensis* the leaves turn brown/yellow, creating a uniform yellowing of the crown, it affects particularly the older leaves; trees affected by *D. septosporum* have apical branches with a "wisp" like formation where a lot of leaves grow from, in initial phases the leaves get a yellow then brown colour, leaving the base of the leaf still green, yellow/brown rings around the leaves are usual; the fungi from *Heterotruncatella* genus has a sign the yellowing of the branches and the leaves dry from top to bottom.

The trees are more susceptible to the different diseases when they are younger or when they are old and there is a deficit of nutrients or water. This means that plant nurseries and young plantations are the ones more affected by diseases than the trees already established in the forest. However severe attacks in adult trees can also lead to their death.

Lessons learned

The control methods to fight the major diseases are the following: Good management practices that keep the vigour of the plants are the best way to prevent infections; Sanitary pruning is the method most used since no homologated fungicides exists in the country (Portugal) for the diseases. The pruning should be applied in the dry season, so the spores are not dispersed, and the removed branches should be burn; in the case of *S. polyspora* there are some reports with good results of forest owners using calcium chloride when the trees are starting to grow the shoots of the year.

It is also known that insects are a vector, contribution for the dissemination of the diseases. Most of the times the diseases described are not powerful enough to kill the trees, however the mixture of the effects of both the disease and other pest are what leads to the dead of adult trees.

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Increase and transfer knowledge to producers about good practices for the management of pests and diseases in Stone Pine (*Pinus pinea* L.)

Introduction

The stone pine is mainly planted for the production of the pine cones, more specifically for the production of pine nuts, since it's the most profitable way to explore this species. However, in the last years the producers and industry have been witnessing the decline in cone production and in the yield of pine nuts per cone.

The main objective of this project was to develop strategies of integrated management of pests and diseases, with emphasis in *Leptoglossus occidentalis* H. creating new ways of detection, damage assessment and control methods. The life cycle of the pest and the stages of development of the pine cone were also studied. The results were gathered in chapters available online and printed in "Technical handbook - Good practices for the management of pests and diseases of pine cones and pine nuts." ("Manual técnico - Boas práticas para a gestão de pragas e doenças da pinha e pinhão"), "Damage in pine cones - How to identify the organism?" ("Danos nas pinhas - Como identificar o agente?"), "Fungal diseases in stone pine - New threats" ("Doenças fúngicas em pinheiro manso - Novas ameaças"), "Western conifer seed bug" ("Sugador de pinhas"), and "Pine cone moth" ("Lagarta da pinha").

This chapters were freely distributed to forest owners associations and diverse entities related forestry, which allows the information to reach the landowner.

Lessons learned

The success of this project was achieved because of the hard work done by the researcher team, the availability of the landowners to participate in the project and the expressed concern of the private companies. The practical knowledge of the forest owners was reported and tested in trials, which opened new "doors" for future experiments.

All the results of the studies and research were summarized which allowed the creation of different scientific articles, in this way sharing the results with the academic and scientific community. The creations of handbooks, easily available to the landowners, allows them to have a simple way for a primary identification of sanitary problems in their forests, most of the times being able to identify the specie. It

also gives the landowners the methods to control and fight the dispersion and the adverse effects of the pests and diseases.



Figure 1. Published work related to the project.

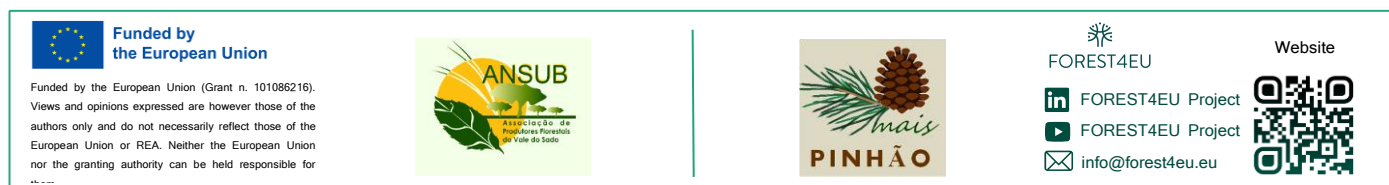
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Identifying the presence of Flathead Oak Borer (*Coroebus undatus* F.) in Cork Oak (*Quercus suber* L.)

Introduction

This project had as its main objectives the development of strategies to detect, monitor, and control the attacks of *Coroebus undatus* F.. Based on monitorization works developed by this project a guide to identify the specie and its presence was created.

The larvae of this specie has a thin white body with ten segments, no legs and can be found in the phellogen (meristem that gives rise to periderm), where it feeds and creates the galleries. This species can attack many different broadleaf trees, such as *Quercus* spp. (Oaks), *Fagus sylvatica* L. (European beech), *Castanea sativa* M. (Chestnut) and *Corylus avellana* L. (Common hazel). The life cycle is not yet fully understood, since part of its life is spent under the bark. It is suggested the life cycle takes two years to complete, but in favour conditions it may only take one. After reaching adulthood the females lay, generally, a single egg in the cork fissures, between May and July. Two or one year are spent under the bark in the larvae stage. When reaching maturity in the spring, they drill a hole in the cork to pupate. After 15 to 30 days the adults leaves the tree in the end of Spring/ beginning of Summer, living between two to three weeks in this life stage.

Clear signs of the presence of this pest can only be found after the debarking of the tree. Galleries in the belly (the part of the cork that is turn to the tree) are clearly visible. From the outside, the back of the cork, scars may be seen, however these scars are from previous attacks and can't give any information if the insect is currently attacking the tree. The galleries can measure up to 2 meters in length, are arranged horizontally and vertically, and usually some crossing points are present. The width of the gallery, first is 1 to 2 mm growing as the larvae also grows, reaching 5 to 6 mm.

The presence of galleries in the phellogen results in a higher adhesion of the cork to the tree, which complicates the extraction process in some cases breaking the cork boards, ripping the phellogen, and scaring the meristematic tissue for a lifetime. These open wounds increase the tree susceptibility to be colonized by other biotic threats, such was wood borers.

Some commonly possible visible signs and symptoms of the pest attack were tested, to check their truthfulness. White spots in the bark, made from exudated compounds, may be related to the presence of the pest however it does not have statistical significance to be used with accuracy. This symptom is also correlated with other biotic and abiotic effects. Woodpecker holes can be related to the presence of insects

in the tree however it does not give any information about which specie or its quantity. The bad vigour of the tree, defoliated crown or dried leaves, are not a visible sign since the negative impacts of this pest are not pronounced, only if the tree is under very bad conditions. One other sign, the presence of a “straw” (“palhinha”) in the bark, little pupa shell, was believe for many years and by many to be a sign of the pest presence. This sign is not from *C. undatus* but from a moth specie. A very similar insect is the black-banded oak borer (*Coroebus florentinus* H.), but its larvae feed on new branches, so it may only impact cork production indirectly by reducing the plant vigour not affecting the quality of the cork directly. "

Lessons learned

This work made clear what are the damage, sign and symptoms expected from this insect presence, before and after the attacks. Clarifying some common knowledge forest workers and landowners previously had about this specie.

Before debarking the tree, it's very hard to know if the tree is being attacked or not. Some technics were tested, and the results are the following. An acoustic detection tool was used as a non-destructive method, however the results showed a low success. The reason for this was, that in field trials very low noise or no noise at all was detected by the tool, the suggested explanation was the tiny size of the larvae and its low activity in conjunction with the great soundproof qualities of the cork.

The other method tested was sampling the cork. This method is still the one that gives the best results. The distribution and quantity of the insects in the tree was found to be higher above the height of 50 cm. Other observations, even though without statistical significance, were higher presence of the insect in the parts of the trunk turned to south. This technic is the one suggested to be used to monitor the presence and intensity of attack in the forest.



Figure 1. Photograph of a larvae of *Coroebus undatus*.

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Further information

<https://www.unac.pt/index.php/id-i/grupos-operacionais-accao-1-1-pdr2020/undercork>





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Monitoring the population of Flathead Oak Borer (*Coroebus undatus* F.) in Cork Oak (*Quercus suber* L.)

Introduction

Even though *C. undatus* does not affect the vigour of the host tree it's the most important pest in cork oak stands, since it creates a defect in cork that decrease its value. No pest control method is yet available, since no pesticide as a viable success rate, because the larvae is protected by the bark, few or none predator and parasitic species are known, and no pheromone is available to be use together with traps. Monitoring technics for this species are constantly advancing since the pest is increasing its presence in cork oak stands. The knowledge of the population dynamics is of extreme importance to predict future attacks and to evaluate the susceptibility of the stand. In particularly how the population of the insect and its life cycle will react to the changing climate.

To monitor the presence of the pest in the stand, three monitorization methods were used, the sampling of cork, traps (nets placed around the tree) and vibrant colour slabs with glue. The data collected form this operation was gather and analyse.

In terms of success in capturing the insect, none show potential to be use as a control method. But they were very useful to better understand the population distribution and dynamics. Most of the galleries created by the larvae can be found in the tree between the height of 50 to 100 cm, and there was a preference for the side of the tree exposed to south, it's believed to happen because it is warmer. More attacks were detected in thicker trees, and trees with thicker bark had less attacks, this is thought to happen because vigorous trees (higher bark production) would have enough resources to fight the infestation. For thinner barks opposite results were found in different experiments. Debilitated trees (less bark production) would not be nutritious enough for the insect which can decrease the attacks, but on the other hand thinner bark is easier to be drill by the larvae and trees in stress conditions are more susceptible to biotic and abiotic threats. For the same reason trees grown in deeper soils (more vigorous) had less attacks than tree grown in shallow soils (more stressful conditions). In relation to the stand composition different trials found different results. Some results indicate that mix stands with a diverse understory have less attacks, but other studies show the opposite result. More research is absolutely needed to better understand this question. It was shown a big difference in the attack intensity between sites and trees. The lack of a homogeneous distribution of the

attacks in the trials, suggest the insect specifically selects the tree it's going to attack. By capturing the insect adults after they emerge from the tree, it was possible to define the ratio between female and male, which was above 1 for every year (meaning the population has always more female than males), and the period in which the adults start to emerge which was between June and July.

The data collected from the monitoring operations was crossed with data of the climate, soil, biodiversity and cartography, to establish a relation between the attack intensity and exterior factors. Another model was created to study the variation of the population with the climate change."

Lessons learned

The tested variables with the biggest impact in the population size were: Mean annual temperature, higher population were present in the sites with higher values when compared to sites with lower ones, this variable was the most relevant for the prediction model; Altitude, population were bigger between 200/400m when compared to populations in lower altitudes; Annual mean insolation, the sites with less time of sun light had less attacks when compared to other sites; Type of soil, of all the types of soils present in the sample sites podzo soil was the one that had the smallest populations.

In the climate change model, the best prediction variables found were the minimum temperature reached in the winter and the standardised precipitation evapotranspiration index. The conclusions that can be taken from this work is that higher populations are found in places with higher lower temperatures in the winter and in places with severe droughts (in the model the best response of this variable was for a period of 3 years). For these reasons the climate change is expected to increase the population size and speed up their life cycle.

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Further information

<https://www.unac.pt/index.php?id-i/grupos-operacionais-accao-1-1-pdr2020/undercork>



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Innovative Silo for the Supply of Wood Chip (SISE)

Introduction

The SISE platform, the Catalan acronym for Innovative Wood Chip Supply Silo, is an automated logistics warehouse for chip distribution, which allows quality chips to reach all points of the region, thus optimising the biomass distribution chain and reducing the CO₂ footprint from transport. The SISE platform has a storage capacity of 190 m³ chips. The chips are supplied in 90-m³ trailer trucks from the main production plant in Celrà. Next, small, authorised local trucks (30-40 m³) are responsible for local distribution from the SISE platform to the end customer's silo. The SISE platform works without personnel thanks to an automated system that allows the persons responsible for transport, whether loading or unloading the chips, to work without additional help. The platform automation provides significant flexibility in wood chip delivery times to customers' silos, as it depends only on local carriers unloading over short distances. Automation and absence of staff with the SISE platform means a monitoring system had to be developed which was capable of predicting and managing demand, learning automatically as the platform delivers chips to customers, thereby optimising the transport flow to ensure the silo always has enough chips. The SISE platform is strategic for the development of biomass as renewable energy. The actions involved in the SISE project started with drawing up a master plan to provide the technical documentation for its construction. At the same time, while the master plan was being produced, a field study was carried out in order to find the ideal location to build it. Building started once the master plan was complete, the location established, and all administrative documents were prepared. Now built and in the testing phase, its operation is being analysed. No mechanical deficiencies or problems that impede loading and unloading have been observed. Analyses were also carried out to ensure the chips in the SISE maintain their quality standards and technical specifications. At the same time, a survey system analysed the degree of satisfaction among both logistics operators and end customers. Finally, the carbon footprint before and after the implementation of the SISE was calculated.

Lessons Learned

The most conclusive end-result from the SISE platform shows that this new logistics distribution model reduces CO₂ emissions by over 110%. A standard 7-tonne load of wood chips at 30% humidity transported 120 km by pneumatic truck with 30 m³ (24.59 MWh) of storage capacity, where the chips are kept until delivered to the end customer, produces 94.67 kg of CO₂ emissions, while with the SISE system, a standard 7-tonne load of wood chips at 30% humidity over 120 km, 100 km by trailer (90m³) to the SISE and 20 km by 30 m³ pneumatic truck

(24.59 MWh) to the end customer, produces 44.51 kg of CO₂ emissions. Thus, the SISE system cuts CO₂ by 50.16 kg per trip (113% reduction in CO₂ emissions using the SISE). A further conclusive result found there were no significant differences after testing chip samples obtained from the SISE, based on current regulations (UNE-EN-ISO 17225, UNE-EN-ISO 18122, UNE-EN-ISO 18125, UNE-EN-ISO 18134), hence the chip maintains its quality and technical specifications within the SISE. General conclusions regarding the use of biomass as fuel are:

- It reduces greenhouse gas emissions
- It reduces external energy dependence by improving supply security and internalising the energy bill.
- It improves sustainable forest management.

Regarding the SISE system, it may be concluded that:

- It ensures regularity and homogeneity of supply. A frequent problem with the supply of wood after 9-month drying period is that it does not coincide with the period of demand for wood chips in a region (mostly in colder periods).
- Biomass reaches the end customer's silo with:
- A smaller CO₂ footprint.
- Guaranteed quality.
- Fast order delivery response. - It boosts the number of potential customers, who would otherwise not consider biomass as a fuel, thus helping reach established countrywide penetration targets for renewables.
- Quality biomass is provided throughout the country.
- Data on chip quality and real-time consumption are obtained, which were hitherto unavailable outside the academic world.
- Greater reliability, as it is a non-seasonal supply.

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Further information

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An experimental laboratory in forestry on the classified site of Mont Beuvray

Introduction

Covered by a 950 ha forest estate managed by Bibracte, Mont Beuvray constitutes an exceptional archaeological and natural site, recognized for its landscape quality and for its important heritage dimension: it sheltered the capital of the Aedui, a Gaul people Celtic, in the 2nd and 1st centuries BC. The last few years of severe drought have had a strong impact on the forest area. Since 2018, spruce stands (around 100 ha) have had to be fully exploited (clear cuts) following massive bark beetle attacks, while beech and silver fir stands also show serious signs of dieback. Faced with the challenge of adapting forests to climate change, forest stakeholders must also implement multifunctional silviculture, capable of producing quality wood while preserving biodiversity and the environment as well as societal uses of the forest.

Methodology and results

In a regional context presenting a strong demand for involvement from civil society in forest management, the project partners have set themselves the objective of setting up an experimental system intended to study changes in the forest ecosystem, to experiment with different sustainable management methods and to open a space for dialogue on forestry subjects.

This forest laboratory will take into account in a concerted manner three issues related to forest management in the face of climate change: the preservation of wood resources, the characterization and preservation of ecosystem services, and the social acceptability of silvicultural practices. The 2nd objective of the project consists of setting up observation protocols, carrying out a first series of field data collection campaigns and initiating the analysis of this data. Finally, the project partners intend to establish and lead a permanent consultation system in order to consolidate the laboratory and strengthen cooperation between scientists, practitioners and residents.

Several actions have already been implemented:

1) Design and organize a laboratory

- 50 organic matter sampling points as part of a thesis.

- Opening of 30 soil pits and associated analyses.
- Installation of 3 soil temperature and hygrometry probes as well as soil respiration measuring devices.
- Geological identification of the substrate and petrographic analyses.
- Compilation of available data on the history of the forest massif.
- Establishment of a shared cartographic tool for sampling soils and forest stands.

2) Observation, collection and analysis of field data

- Regeneration of 96 ha of old spruce stands with experimental afforestation methods on 68 ha.
- Conducting a wave of measurements of forest stand observation plots (PSDRF protocol).
- Monitoring of experimental plantings (1200 permanent seed plots) and dieback.
- Summer hunting experimentation on approach in order to contain the deer population.

3) Establish and lead a consultation system

- Practical workshops in the forest with the general public.
- Study trip to Central Europe to meet forest professionals and experts.

Lessons learned

The project brings together stakeholders wishing to be integrated into forest management around a common subject of concern: the future of forest areas under climatic constraints. The result will be technical forest management decisions, scientifically supported and representative of the diversity of opinions and issues.

Carried out on a small territory, the project allows for extensive transdisciplinary experimentation with precise results and easy local action possibilities. The size of the territory nevertheless remains a technical challenge for carrying out certain studies (such as climate modeling) in which the project is part of a larger scale on a cooperative basis.

The data could also be shared with the scientific and technical community via the Sentinel Forest Observatory of the Natural Reserves of France.

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Further information

<https://forestlab.hypotheses.org/>



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Pilot silo with an automated biomass (forest biomass) supply system

Introduction

To provide a solution to the limitations in the distribution of forest biomass and to optimise the SALA FORESTAL SL Celrà production centre, the aim is to design and plan an automated silo that supplies forest biomass and decreases transport costs outside the current radial distribution area. Objectives:

- a) To facilitate the supply and use of renewable sources of energy such as biomass (forest biomass) and promote carbon sequestration in the forestry sector.
- b) Technology transfer between the Catalan Forestry Technology Centre (Centre Tecnològic Forestal de Catalunya, CTFC) and SALA FORESTAL SL, regarding biomass (forest biomass) storage and supply technologies.
- c) To design and plan an automated forest biomass supply silo.
- d) To lower biomass (forest biomass) transport costs from the SALA FORESTAL SL production centre to locations over 100 km away.
- e) Dissemination and promotion of the automated forest biomass supply silo

Lessons Learned

It can be concluded that the project is both technologically and financially viable. And the management and logistics improvements lead to a very significant decrease in CO₂ emissions into the atmosphere. On the other hand, the project provides a consolidated and stable method of consuming forest biomass, which revitalises the sector and brings a product that up to now has been undervalued into line with other energy sources. The project also helps revitalise the rural sector, origin of the raw material.

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The "sustainable bee forest" concept and implementation

Introduction

The project "sustainable bee forest" develops and implements a new forest management concept that improves the habitat of flower-pollinating insects during re- and afforestation from the very beginning while generating new sources of income from non-wood forest products. This concept is a response to the need for adaptation strategies in forest management in the face of climate change. The main target group are smallholder farmers who are faced with forest dieback in the face of climate change. Large tracts of forest underwent major disturbances over the last years (pests, storms, fire). The German ministry of agriculture and food (BMEL) estimates that over the next years almost 500.000 ha of forest land will need to be afforested (status: Oct 2023).

Concept and implementation

The inventors of the "sustainable bee forest" concept perceive of their approach as an innovative, useful and urgently needed idea that differs from the existing forest management concepts in the federal state of Hesse. According to them, the aspect of multifunctional forest management has received little attention in Central Europe. Moreover, the idea of an insect- or bee-friendly forest is a real gap in current silvicultural practices. The "sustainable bee forest concept" is based on the view that forests are ecosystems, in which natural processes such as succession, growth heights, light and shade requirements of the plants are utilized in order to generate an economic benefit in addition to the high ecological benefit right from the start.

The "sustainable bee forest" OG focuses primarily on honey and wild bees in a young stage of forest development. In contrast to previous approaches to pollinator promotion in the forest area, profitable stemwood species are combined with other food plants for pollinating insects. The OG has afforested a former spruce-dominated forest of 3,5 ha in 2022 with: robinia, chestnut, linden, bird cherry, and walnut. The afforestation includes: preparing the forest land, buying the tree seedlings, planting the tree seedlings, maintenance measures, and building of a fence or other measures to protect the young plants from browsing.

The species selection is based on scientific evidence. Recommendations for area-wide implementation are developed. An economic analysis was conducted which examined the profitability of managing for NWFP in the climate-adapted and pollinator-friendly bee forest.

Lessons learned

One success factor was that the specific idea of a bee forest corresponded very well with the practical needs of small private forest owners. In addition, there was access to various networks of experts who were willing to support the project with their specialist knowledge. Due to the completely new idea, the transdisciplinary cooperation and the different demands of the participants, it was challenging to establish a suitable experimental design that could map the practical research questions. Experienced scientists with the appropriate methodological expertise are absolutely essential for this, so that meaningful results can be generated.

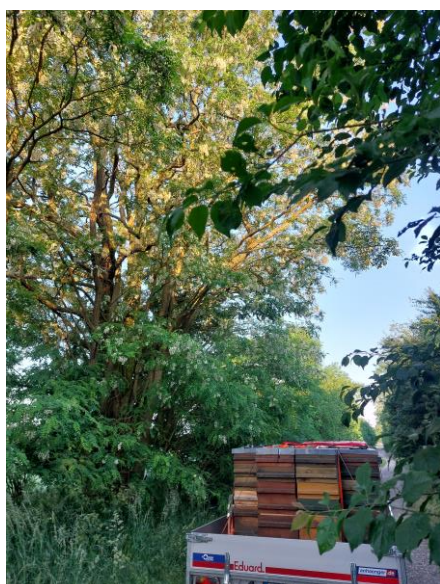


Figure 2: Honey from pollinating trees



Figure 1: Afforestation for the bee forest

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Further information

www.bienenwald-hessen.de



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BioClimSol: a decision support system integrating future climate and ground conditions

Introduction

"Forecast by BioClimSol" is a digital application that enables foresters to benefit from the expertise of BioClimSol, a decision-making tool for helping forests adapt to climate change. It has been deployed in the Nouvelle-Aquitaine region as part of the SPNA operational group. The forest managers who use the application have all received the necessary training to gain access to it. This training enables them to acquire and validate the skills required for field diagnosis, and is also essential for a good understanding of how the models work and how to interpret the expert results provided by the tool.

Presentation of the decision support system BioClimSol

The aim of BioClimSol is to help forest owners and managers make management decisions at stand level that take account of the risks associated with climate change.

Two approaches have been developed:

1. an assessment of the risk of dieback of standing stands (for around fifteen heritage species that have been studied in a dieback process);
2. an assessment of the risk of ecological incompatibility (taking into account climatic, topographical and soil characteristics) for around forty other species that represent interesting afforestation solutions for the future.

To make its algorithms work, BioClimSol takes into account the effects of interactions between:

- biotic factors affecting the health of the stand (Bio);
- current climatic conditions in the plot and future conditions under different scenarios (Clim);
- the soil conditions in the plot (Soil), which can compensate for or catalyse the effects of stresses of all kinds (climatic, biotic, etc.).

This application is structured into modules, each of which represents a field data acquisition and/or calculation engine output interface. It should be noted that the climatic data and certain topographical data are filled in automatically via the GPS location of the plot by spatial models stored in the device's memory.

These data are linked using algorithms parameterised by statistical models unique to each species.

At the end of the calculations, BioClimSol provides its expertise in the form of indices that give a relative reading of the risk according to species and climatic scenarios. This can then be used to draw up management recommendations based on classes of vigilance associated with these risks of dieback or ecological incompatibility with the conditions encountered.

For each level of vigilance, depending on the type of stand (or afforestation project) encountered and the projected forecasts for future climate scenarios, silvicultural recommendations are proposed. These recommendations appear as general management advice for the adaptive management of forests in a context of climate change, and help to initiate a more in-depth technical reflection that can then be adapted to the local context (from the technical itinerary to the management strategies for forests and territories). When a level of vigilance is alerted, it is necessary to clearly identify the factors involved in the risk dimension, in particular by looking at the parameters that have the greatest influence on the decline of the species studied.

Lessons learned

Over the last twelve years, BioClimSol's expertise has grown and it has constantly innovated, particularly in its modelling methods (now validated and supported by research via the current thesis by Jean Lemaire, its designer at the IDF).

The development of this tool has enabled certain scientific conclusions to be drawn, opening up important areas of research:

- It is possible to model dieback with a high degree of accuracy, although this requires a large number of variables to be taken into account and therefore very consistent databases.
- Biotic and soil factors play a major role in the mechanisms involved, and climate does not explain everything!
- The specific nature of dieback phenomena often means that models can only be valid at regional level, and requires calibration over several regions for the same species.

In addition, the data on which BioClimSol has been able to build its models (40 field studies, 5,000 plots, 100,000 trees described, etc.), its digital application and its collaborative system (a community of 500 users who have already recorded more than 10,000 diagnoses in the database) make the BioClimSol tool a recognised example of technological innovation for foresters (winner of the 2021 LifeAwards and the 2022 ITAINNOV technical institute competition).

But it is its modular configuration and scalability that hold out the greatest promise of future opportunities and prospects. The various modules, which interact via digital algorithms and scripts, make it possible to automate the processing and analysis chains based on the field data that the user community is consolidating

in its databases, and also to integrate new parameters to answer the ever-increasing number of questions that the various dimensions of the risks associated with climate change are raising more and more every day.



Figure 1. logo of "Forreccast by BioClimSol" digital application.

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Further information

<https://www.cnpf.fr/nos-actions-nos-outils/outils-et-techniques/bioclimsol>





Survey of atypical tree species in Normandy thought to be resistant to climate change

Introduction

Regional players are increasingly concerned about the multiple effects of climate change, and it seems necessary to increase the number of feedbacks and experiments, and to analyse them, in order to increase knowledge and anticipate the effects of climate change. As part of the RAISON project, an inventory was made of the stands of atypical species present in Normandy. The aim was to study their behaviour in relation to the soil and climate conditions in which they were planted. The ultimate aim was to identify the species that might be best adapted to climate change in Normandy.

Methodology and results

Lists of potential substitute species were proposed for each forest region and each type of site, including Pubescent Oak, Cormier, Oriental Beech, Tulip Tree, Atlas Cedar, Calabrian Pine, Douglas Fir, Taeda Pine, Nordmann Fir, Western Red Cedar, Japanese Cryptomeria, Evergreen Sequoia and Calocedar. During the summer of 2019, the National Forestry Property Centre contacted all forest managers and owners, as well as forestry contractors and nurserymen, to find out whether such species had been planted. At the same time, an article in a regional technical journal (Bois & Forêts de Normandie) and a page devoted to the project on the CNPF website were published, with an opportunity to fill in a form reporting atypical stands in the study area. The French National Forestry Office (ONF), which is responsible for managing public forests, was also approached. Between December 2019 and May 2021, 384 stands were inventoried from a list of 500 stands of interest. The individual results were systematically sent to the owners.

The majority of alerts concerned softwood species, with 317 alerts, compared with 67 for hardwood species. The most common softwood species reported, in order of importance, were Maritime Pine, Atlas Cedar, Western Red Cedar and Evergreen Redwood. Sixteen other softwood species were reported. The most common deciduous species reported, in order of importance, were Virginia Tulip Tree, Corsican Alder, Nothofagus obliqua and Pubescent Oak. Nine other deciduous species were reported. Many species have all their age classes represented, but these are not in balance and may reflect a dynamic in the use of the species. For example, maritime pine was heavily planted more than 50 years ago, but the area planted has since fallen sharply.

Western red cedar shows a similar trend, although there has been renewed interest in the species over the last 10 years. Other species reflect a fashion effect. For example, *Nothofagus obliqua* was planted extensively in 1980, but the harsh winters damaged these plantations, and they have not been planted since. Calabrian pine has been put aside in favour of Corsican laricio pine for reasons of quality and branching. Conversely, *Sequoia sempervirens* and Corsican Alder have been used for silvicultural purposes for some forty years. It is important to have trees in all age classes, so that we can study the behaviour of the species throughout the life of the stand and begin to examine the various possibilities in terms of silviculture.

Lessons learned

The lack of experience of the behaviour of these species means that it is not possible at present to draw up a list of new species to be planted on a large scale, but the monitoring of experiments should enable us to respond with greater certainty in the future. For newly planted species, it is important to continue to monitor the growth of stands when they are young and to restart the planting of those that are no longer used or are used infrequently, in order to improve our knowledge of the behaviour of these species in their first years of life.

The number of surveys carried out does not allow statistically robust conclusions to be drawn about their behaviour, but it does illustrate certain trends, particularly for the Atlas Cedar. It is therefore necessary to multiply this type of initiative, already present in public forests, within private forests and to pool the results to enable more robust studies to be carried out, for all types of site conditions. Identifying these atypical species and experimenting with different management methods is a long-term project for the forest and requires long-term sources of funding to enable these stands to be monitored.

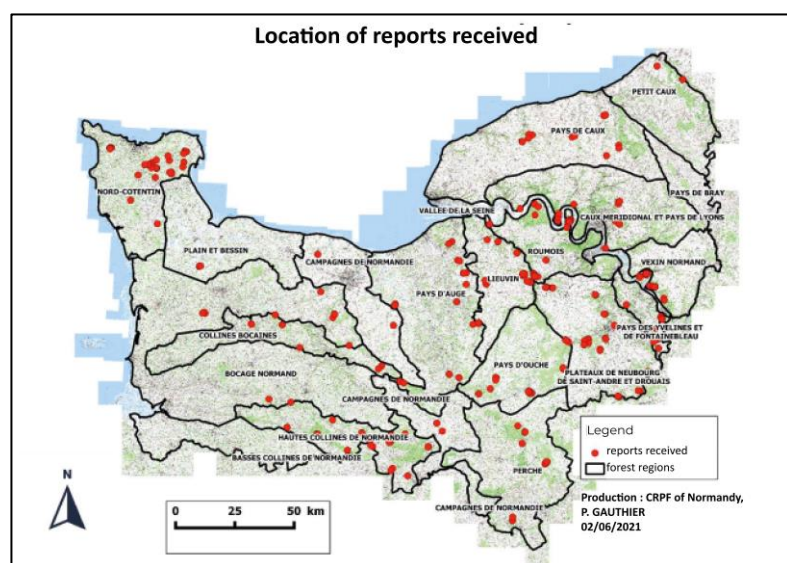


Figure 1. Location of reports received on atypical tree species in Normandy.

Pierre Gauthier © CNPF

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Further information

<https://hautsdefrance-normandie.cnpf.fr/projet-raison>



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Setting up innovative silviculture trials

Planting on waterlogged soil

Introduction

Waterlogging is a major constraint for many forest species, and can affect stand productivity and even the survival of seedlings. Its impact varies according to criteria such as its intensity and depth of appearance. The effects of climate change could exacerbate this problem by increasing winter rainfall and summer drought.

A full soil analysis is essential to determine which tree species are best suited to the site. Soil preparation may also be a solution in the case of reforestation, in order to reduce the waterlogging problem. One of the aims of the RAISON project is to identify the most favourable planting method(s) for developing a production forest stand on waterlogged soil.

Methodology and results

A property located in the commune of Saint-Gatien-des-bois was selected by CETEF members to set up a system on a 4.6 ha plot, occupied by a Sitka spruce forest planted in 1972 and characterised by fairly acid soil with surface hydromorphy (at shallow depths). Numerous diebacks have led the owner to harvest the spruces in full in 2019, with a view to replacing them with a species more suited to the site. A test comparing 4 planting methods on waterlogged soil was carried out on 1 ha of this plot. The planting scheme involved a row spacing of 3.5 m and a spacing of 3 m between each plant. The initial density was 1143 plants/ha. Each plot has 14 rows with 20 plants/row. Thus, 280 Sessile Oak seedlings will be planted on each of the 4 plots of 25 acres according to the following methods: "1" manual planting without subsoiling, "2" planting on domed ridges, "3" planting on domed posts and "4" planting on domed posts and biological drain (tamping with Willow). The plot for modality 4 had a tamping between each oak plant and 266 willows were therefore planted. There were no replications. In order to avoid edge effects, the lines planted at the edge of the plot were not measured, forming isolation strips.

The ends of the plot were marked with 1m20 stakes and the outside trees closest to the plot were marked with a line. Measured trees will be marked by painting a horizontal line at 1.30m and will be numbered once they have reached a sufficient diameter. All the species will be planted at the same time (winter 2021-2022). The plots of land where the system will be installed have been clear-cut, followed by a full-scale shredding operation in the summer of 2020 and renovation of the existing ditches. The waterlogged nature of the soil means that subsoiling is out of the question.

The factors studied are changes in growth, shape and the general behaviour of the species. A comparative analysis of the costs of each method will be carried out. At installation, the height of all the trees is measured. Over the following three years, the following variables are measured: the condition of the trees (alive, dead, etc.), their height and the presence of phytosanitary problems. Then, the above variables are measured on a minimum sample of 30 trees, chosen randomly or systematically, as well as the circumference (if the tree reaches 1m30 in height and as soon as $\frac{3}{4}$ of the trees exceed 10 cm in circumference). Before the 1st thinning, all the trees are measured for the above variables. The height is measured on a sample of 20 trees evenly distributed in 5 diameter classes of the same amplitude.

Finally, the silvicultural interventions (protection against game, clearing and thinning) must be the same for all modalities in order to avoid bias when comparing them. Monitoring for at least 30 years is planned.

Lessons learned

This experiment is the only one of its kind in Normandy, and in future it could serve as a reference protocol for increasing the number of experimental planting sites on waterlogged soils. The data measured will be used to assess the impact of planting methods on stand growth. Integrating these data into a database containing all the systems of this type at national level could enable these comparisons to be refined. Experimenting with the effect of different planting methods on the survival and productivity of tree species is a long-term project for the forest and requires long-term sources of funding to enable these stands to be monitored.



Figure 1. Oak plant in its protective cover.
Sylvain Gaudin © CNPF

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Further information

<https://hautsdefrance-normandie.cnpf.fr/projet-raison>



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Specialised logging trailer - solution for efficient use of transportation resources

Introduction

Currently there is trend that allowed total loads for trucks on public roads are increasing. That allows transportation of bigger volumes per truck and generates less pollution to environment. OG has developed a version of a long logging trailer that is convenient in use also for transportation of short logs thanks to specific construction of bunks that can be moved closer to lifting crane and away from that when cradles are filled.

Innovative technical solution of the long logging trailer provides possibility to fill it 100% also with shorter logs. This is mostly impossible with standard long trailers. Problem is that it is very difficult or impossible to balance short log and load it to far end of a long trailer. You need to hold the log at one end and it is too difficult for hydraulics. In this innovative trailer bunks are movable. Empty cradles can be moved forward, shorter logs loaded closer to the crane and filled cradle moved to far end of the trailer afterwards. Thus trailer can be filled 100% also with shorter logs. Full load results in lower CO2 emissions per cubic meter of transported timber.

Lessons learned

Question that may arise: Why are such trailers not available widely already now? This is innovation that arose following trends that bigger and bigger loads are being allowed on public roads. This is long trailer and can pick up what is required at the road side only. So far logging trucks often are double trailers where truck has a manipulator for loading timber. Truck may leave a trailer on the road, drive deeper to the forest, pick up logs, transport them to the road side and re-load to the trailer, then drive back and load up another portion on the truck itself. Finally go back to main road, attach trailer and transport cargo to destination point. Nowadays often companies use more efficient specialised off-road tractors for transporting logs to the roadside.



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Douglas-fir silvicultural management with strips cuttings to enhance natural forest regeneration

Introduction

Between 1960 and 1980, Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) was the most abundantly cultivated species for abandoned lands reforestation in Tuscany. Given its high growth rate, high productivity and carbon stock capacity, as well as other biological characteristics (adaptability by resisting aridity and wind, phytosanitary resistance) it can therefore be considered for all intents and purposes a viable option for the achievement of sustainable development goals as mitigation and adaptation to climate change in mountain areas. Moreover, Douglas-fir forests constitute an element of landscape diversity in the Tuscan Apennine, enhancing its recreational, naturalistic, runoff-regulating and productive value of the territory, thus contributing to the sustainability and economy.

The project Do.Na.To. aims to promote Douglas-fir forests natural regeneration in Tuscany (Italy), through application and adaptation of a silvicultural management systems already tested in other European countries.

During the project, a group of technicians travelled to France to get to know the techniques adopted by their colleagues, and subsequently set up 26 demonstrations areas where different silvicultural systems were applied. Currently, Douglas-fir stands in Tuscany are managed with clear cutting and artificial regeneration postponed to the first useful dormant season, with bare-root plantings or phytocells. This is a simple method, but it is not free of problems, both technical and economic.

Douglas-fir renews with extraordinary facility, both in full light and in half-shade conditions. The ecological benefits of natural regeneration are numerous and underlie the formation of more resilient forests, rich in biodiversity and genetically better adapted to the environment, being the result of local selection processes from the earliest life stages and occupying each species the micro-stational conditions in which it is most suitable. With natural regeneration, the root system turns out to be more efficient, without damage to the taproot and better interconnected to the mycorrhizal network and root system of the released plants. The silvicultural systems tested during the project have been shelterwood cutting followed by seed cutting, strips cutting and selection cutting.

The best regeneration results were obtained by clear cuts on strips, on the order of several tens of thousands of plants, with strips of the same width of the height of the bordering plants, not wide as the double-height as suggested by previous literature (la Marca et al., 2017; la Marca and Pozzi, 2016). The proximity of the

strips promotes the formation of a favourable light-shady microclimate, less impacted by atm agents such as drought or wind.

The fundamental aspect is the planning of cuttings in order to wait until the seeds are mature, not before, so from late summer onward. In addition, it's preferable to make them in conjunction or the year before the last year. The entry of natural regeneration occurs massively in the presence of seed and light in the first and in the second dissemination season following cutting, it's not really appreciated by wild ungulates, but it's endangered by weed flora, in particular bramble. In spite of significantly greater technical/executive difficulties if compared to traditional clear cutting, the treatment with strips cutting enhances natural renovation establishment, presents lower environmental and landscape disturbance, and confers greater resilience to the forest.

Lessons learned

The research produced very interesting results, Douglas-fir forest natural regeneration can be considered a viable option for addressing the negative effects of ongoing climate change and an opportunity to pursue an ecological transition for sustainable development. Strips cutting system with strips of the same width of the height of the bordering plants, enhances natural Douglas-fir regeneration and reduce the environmental, economic, landscape and social conflicts (related to the execution of clear cutting for regeneration).

Still, in Italy there are several constraints that limit the method and timing of silvicultural actions, so that, for example, if strips cutting is done, replanting is still mandatory, and often timings of acquiring permits and carrying out the cuttings are slow.

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<https://www.progettodonato.it/>



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Valorisation and energy use of precommercial thinning products in forest stands of Aleppo pine (*Pinus halepensis*) regenerated after forest fires.

Introduction

The objective of the group is the energetic valorization of the forest residues that are generated when carrying out clearings in Aleppo pine forests. After the forest fires that affect the Mediterranean area, the masses of Aleppo pine usually regenerate spontaneously in very high densities, and it is necessary to carry out clearings to increase the resilience of the mass. 2A- Improvement of the economic results of the aforementioned actions and, therefore, the overall results of the farms, generating a product that can be used for the energy self-supply of the farm, for sale in the local or international market. 4A-Return the ecosystems of the burned forests in a state of greater resistance and resilience against climate change and greater biodiversity both of forests included in Natura2000 zones, mountain municipalities, and others. Make feasible and, therefore, be able to carry out clearings on regenerated Aleppo pine, which increases its growth and the role of CO₂ sink in these forests. At the same time, it allows concentrating the productive potential of the plot in a number of morphologically selected trees, reducing in the future Obligatorio / Mandatory the carbon footprint derived from logging, logging and transport of wood from forestry operations. To valorize the waste generated by thinnings, wood and branches of small dimensions, are not currently usable to increase the performance of clearing actions that are urgently needed in the Mediterranean peninsular arc. Analyze the different current technologies for the collection and extraction of biomass of small dimensions and define the conditions of applicability. Define the type of forest biomass that can be generated by thinning (small-sized wood) and analyze the physico-chemical characteristics and properties as fuel. Analyze the availability, stock and location of forest stands of Aleppo pine in the post-fire regeneration phase.

Lessons Learned

Improvement of the economy process of exploitation of the regenerated masses Aleppo pine for its use as biomass: it improves the performance of exploitation, reducing of the number of work phases and means to be used, Improve the returns of mount with stock of regenerated post pine fire carrasco: it is promoted and favored the use of this type of masses, Raw material market opportunities are facilitated, the forests are valued with better development and capacity of trees after thinning actions Environmental improvement of the

forests: the ecosystem is improved by lowering densities of Aleppo pine and encourage the entry of light to the undergrowth, the risk of fire is reduced by reducing the amount of fuel with a high flammability, the carbon balance is improved by being able to replace the use of fossil fuels for renewable fuels and neutral balance The environmental quality of rural territories is improved: the environmental quality of rural territories is improved, the intangible values of the forest are favored by promoting biodiversity, an improvement in the quality of the landscape is promoted, by not abandoning forests (prevention of fires and elimination of pests, as well as mitigation/adaptation to climate change There is a social improvement of the people, owners, producers and processors of raw materials: the social perception of concern is improved for improvement and management of the forests, the creation of a market with high impact on rural populations, generating rural employment direct in all phases of management, Improvement of the territory: the creation of new activities related to the biomass utilization, the adoption of alternatives to fossil fuels is facilitated, promotion of the relationship between different sectors related to the exploitation and use of the forests.

Figure 1: "Meeting in the forest"



Figure 2: "Meeting in the office"



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Chestnut forests management for quality products and promote C sequestration

Introduction

CASTANI-CO promotes chestnut groves as a semi-natural system suited to carbon sequestration and as a productive source of quality food (nutritional and environmental).

Chestnut tree cultivation is typical of the hilly-mountainous environment of Emilia-Romagna with deep roots in the culture and tradition of these territories. It plays an important role in climate change mitigation, thanks to the high environmental sustainability of the agro-ecosystem characterised by low greenhouse gas emissions (low use of agricultural machinery), carbon sequestration in soil and plants, high environmental biodiversity, thus a good impact within climate change mitigation strategies. Similarly to the Italian situation, it is undergoing a slow and constant crisis caused by the presence of pests and the recurrence of unfavourable weather events that, over time, have led to the abandonment of cultivation.

Despite the sharp contraction of cultivated areas and the market, chestnut producers in Emilia-Romagna are very active and have organised themselves into specific consortia of producers committed to enhancing chestnut cultivation, cultivation techniques and specific local varieties as well as promoting the production area.

The main objective of the project was the monitoring of the carbon footprint of the chestnut grove, which involves assessing the organic carbon sequestered in soils and plants, depending on the soil environment and also on different management practices of the chestnut grove. Monitoring was carried out through field observations, soil studies, sampling and chemical analyses in the chestnut groves of partner companies located in different soil environments. Finally, 'guidelines for the best management of fruit chestnut groves to obtain a quality product and favour carbon sequestration' were identified and shared.

CASTANI-CO pointed out how traditional chestnut groves, thanks to their firm soils that are never tilled, can contribute to the storage of carbon in soils and plants. The valorisation of traditional chestnut groves cannot neglect the knowledge and traditions transmitted from generation to generation, which are indispensable for the preservation of the hill and mountain landscape of Emilia Romagna. From the 'voice' of the chestnut growers, custodians of the territory, emerged the need for training activities and suitable tools to improve the management and recovery of chestnut groves, as well as processing and marketing opportunities.

Lessons learned

CASTANI-CO pointed out how traditional chestnut groves, thanks to their firm soils that are never tilled, can contribute to the storage of carbon in soils and plants. The valorisation of traditional chestnut groves cannot neglect the knowledge and traditions transmitted from generation to generation, which are indispensable for the preservation of the hill and mountain landscape of Emilia Romagna. From the 'voice' of the chestnut growers, custodians of the territory, emerged the need for training activities and suitable tools to improve the management and recovery of chestnut groves, as well as processing and marketing opportunities.

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Further information

<https://ec.europa.eu/eip/agriculture/en/find-connect/projects/castani-co-%E2%80%99Cil-sequestro-di-carbonio-nel-sistema.html>



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Evaluation of the soil response of different types of pruning of chestnut tree

Introduction

The aim of the Castagni Parlanti is to assess the ecological footprint of chestnut tree recovery in the current crop year with Tree Talkers within a forest matrix, in terms of carbon fixation and sequestration in the soil-plant system, water use and soil cover, drawing concrete indications for effective and sustainable forest management for the joint production of wood and fruit.

With regard to the evaluation of the soil response of different types of chestnut pruning, the Tree Talker data revealed advantages and disadvantages of the different forms of pruning proposed for chestnut restoration on small areas.

In the project, three pruning methods were therefore compared (in addition to an unpruned control) of different intensity, characterised by a different impact on plant shape and vitality and a different cost of implementation: strong pruning, intermediate pruning, low pruning.

Pruned plants reduce their water requirements compared to the control during almost the entire first vegetative cycle following pruning, and then align their water consumption to unpruned plants from the second year onwards. Considering that future climate change conditions foresee an intensification of prolonged drought periods, favouring pruning that has less impact on soil water status could be an adaptation strategy. Lighter pruning (light and medium pruning) ensured a higher C sequestration capacity through the canopy per unit area than more intensive pruning. However, this advantage disappeared at the end of the first vegetative cycle following pruning, in which all the plants subjected to different pruning intensities recovered their carbon sequestration capacity on a par with the unpruned ones, maintaining it throughout the second year.

Even the most intense pruning does not seem to have compromised the health of the plant canopies, showing transmitted NDVI values that align in the second season for all treatments. The great carbon uptake that occurred in the autumn is interesting: higher temperatures in autumn stimulate photosynthetic activity and delay leaf senescence, thus expanding the useful period for carbon sequestration.

Lessons learned

Indicators calculated from the IoT sensor data have proven to be useful and reliable for monitoring plant health and determining the responses of chestnut trees to phenological cycles and different pruning treatments. The data analysis allowed a deeper understanding of the interaction between chestnut cultivation, forest management and the environment.

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Further information

<http://www.castagniparlanti.it/>



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Participative simulation game "Foster Forest"

Introduction

Consultation between the various stakeholders in the five areas of Normandy that have signed a Territorial Forest Charter (CFT) has highlighted the need for coordinated action between stakeholders, as well as the need to explain what is being done in the forest. The aim of EUROFORNORM was therefore to create and run a regional network of forest areas in Normandy. "The future of Normandy's forests in the face of climate change" emerged as one of the priority themes.

Presentation of the role-playing game

Foster Forest is a role-playing game, a prospective and participative simulation workshop on the evolution of the forest in the face of climate change. It was born in 2015 from the realisation that, in the face of future social, economic and climatic uncertainties, forestry research needed to involve foresters in its work. Prospective workshops would enable a cross-disciplinary approach to be taken, bringing together the visions of environmental, ecological and social sciences, based on modelling approaches.

It was developed as part of his thesis by Mr Timothée FOUQUERAY (PhD student in the Ecology, Systematics and Evolution laboratory at UMR CNRS/UPS/AgroParisTech 8079).

The "game" consists of taking forest management initiatives in a climate change context and being confronted with simulation results a few decades later. This indoor workshop is led by a facilitator.

Using a digital platform, each player is given objectives and possible actions and can carry out forestry management activities (regeneration, maintenance or harvesting, as well as hunting, monitoring water quality or biodiversity, certification and/or sales, etc.).

Each session includes 5 players whose roles are set out below:

- A public forest manager from the French National Forestry Office (ONF), who may be a territorial unit manager, an agent in the forestry department, a planner or a forestry technician ;
- Two representatives of the private forest, who may be an owner, a manager or an employee of the National Centre for Forest Ownership (CNPF) ;

- One representative of the "environment", who could be an agent from a Regional Nature Park, a conservatory, etc ;
- A representative of the elected representatives, who may or may not be a forest-owning local authority, a land-use planner, a regional union of forest communities, etc.

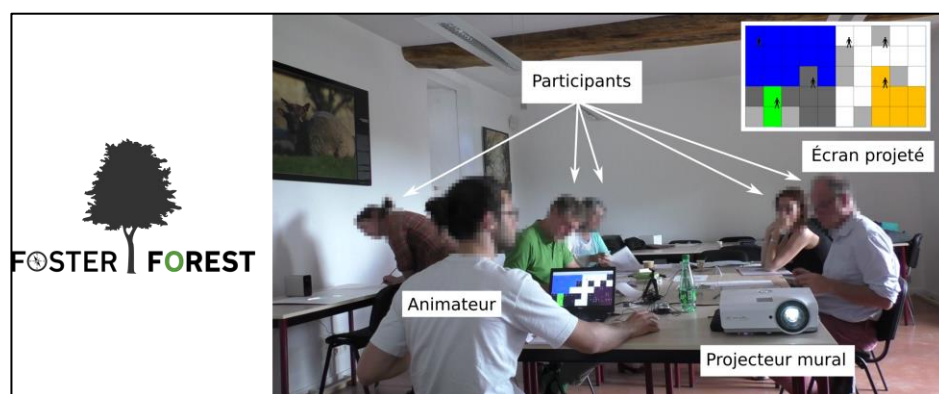
After each session, a debriefing is held in two stages, with a round-table discussion of the strategies implemented by the participants in relation to the game, as well as free discussion of the elements that they could re-use in real life, the limits and the various contributions of the exercise. Each player can come up with alternatives and suggest changes to the scenarios.

Lessons learned

The actions undertaken have encouraged the sharing of knowledge and a better understanding of the positions and expectations of the various forestry stakeholders. Players highlighted the need to listen to each other and understand the different points of view.

Foster Forest tool proved its worth, with very positive feedback from participants. The debriefings highlighted the strengths such as awareness-raising among the players involved through a diversity of specialisations and positions. The discussions enable the perception of the objectives and criteria of the other players and the relevant choices to be made were debated in the context of climate change. Desires to pool technical and financial resources and to build local governance between the public and private sectors emerged.

The game puts the players in a situation of uncertainty, which will become increasingly frequent as a result of climate change. Finally, the workshop provided an opportunity for players to discuss issues relating to biodiversity and climate change mitigation.



*Figure 1. Presentation of a role playing session of Foster Forest with an animator, using his laptop along with a video projector to animate the session and several participants.
@fosterforest*

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Further information

https://eu-cap-network.ec.europa.eu/projects/euro-fornorm-14-50-61-emergence-and-animation-innovative-and-operational-network-normandy_en



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Theatrical forest excursions

Introduction

Consultation between the various players in the five areas that have signed a Forestry Territory Charter (CFT) in Normandy has highlighted the need for coordinated action between players, as well as the need to explain what is being done in the forest. The aim of EUROFORNORM was therefore to create and run a regional network of forest areas in Normandy. "The future of Normandy's forests in the face of climate change" emerged as one of the priority themes.

Methodology and results

The EUROFORNORM project has held a number of meetings in the field, with the aim of raising awareness among a wider audience of the issues associated with the consequences of climate change and the anticipated changes in the region's forests, and encouraging them to express their views, understand their expectations of the forest, and be the driving force behind proposals for the future of local forests. The operational group decided to create and organise dramatised outings followed by debates. These two-hour outings were equally divided between the theatrical performance and the debate between the participants. The theatrical performance, via a pedestrian circuit illustrating certain points with concrete visuals, made it possible to bring out certain points of view, but also to accentuate various character traits of the actors or to make the participants think through the prism of humour. The participants were then encouraged to express themselves and listen to each other, and were able to collectively highlight their points of agreement and disagreement. Two complementary models of outings, one on the future of hardwoods in the context of climate change and the other on the future of biodiversity, were developed and organised in 4 different areas of Normandy.

Lessons learned

These outings provided an opportunity to discuss the impact of climate change, how climate change effects can be anticipated and how forests can be adapted, the expectations of the public and the actions and commitments they can undertake. They provided an opportunity to explain the forest of today and the current methods used to try to anticipate and mitigate climate change.

These innovative meetings were very well received, with over 150 people attending and participating. These initiatives have also been the subject of regional communications through articles and reports, confirming the general public's interest in this type of subject.



Figure 1. Outing in a forest area of Normandy held within the EUROFORNORM project.

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