General information

Description	A tool to assess and monitor defoliation in Eucalyptus stands	
Geographical area	Eucalyptus distribution area	
Group of tree species	Eucalyptus species	
Date	May 2018	
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Tool type	Map remote sensing	Case studies
Tool format	Cartography layers (GIS)	
Language	English	
Risk management plans to which the tools can be added	Risk management plans for the Eucalyptus weevil from Portugal, Asturias and Cantabria	
Risk management plans link	https://plurifor.efi.int/wp-content/uploads/WP2/plans/Gonipterus-platensis-risk-plan_ES.pdf https://plurifor.efi.int/wp-content/uploads/WP2/plans/Gonipterus-platensis-risk-plan_PT.pdf	
This tool is…	☒ a new tool	

Topic

Risk	Eucalyptus weevil risk		
Risk component	☐ hazard	☒ impact	☐ vulnerability
Risk area	Risk planning		
Risk phase	surveilling/monitoring/early warning		
Risk phase (alternative terms)	preparedness		
Level	Global		
Sendai priorities	☐ Priority 1: Understanding disaster risk ☒ Priority 2: Strengthening disaster risk governance to manage disaster risk ☐ Priority 3: Investing in disaster risk reduction for resilience ☐ Priority 4: Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction		
Contribution to Sendai targets	☐ Reduce global disaster mortality ☐ Reduce the number of affected people ☒ Reduce the direct disaster economic loss ☐ Reduce disaster damage to critical infrastructure ☒ Increase the number of national and local disaster risk reduction strategies ☐ Enhance international cooperation to developing countries ☒ Increase availability of and access to multi-hazard early warning systems and disaster risk information and assessment		

Description and analysis

Summary

This tool is based on the analysis of sequential images obtained with multispectral cameras mounted on UAVs. The final product is a map where, based on vegetation indexes, different sub-areas can be individualized according to weevil defoliation level.

Place in national/regional policy

This tool is part of the weevil risk management plan (RMP) developed for each region. The RMP is a strategic risk plan addressing the research areas and governance measures which need to be adopted and developed in order to minimize this forest risk.

Goals and achievements

The fact that areas that are both extensive and difficult access can be monitored through the use of UAVs, meaning that high resolution information can be collected at any time, allows temporal information related to the behavior of the weevil to be obtained. This information can be summarized as defoliation maps that are easy to interpret and compatible with other data sources and management tools (e.g. GIS), providing crucial information in the definition of management plans and decision-making processes.

Stakeholders involved

Public and private forest managers, forest owners, public administration, researchers, service providers.

Implementation stage

For the implementation of this tool it will be necessary to define guidelines for:

- Obtaining the images: (1) Platform type; (2) Flight parameters - Trajectory, overlap and altitude; (3) Sensor type
- Image processing: (1) Definition of the most appropriate indexes with the objective of evaluating defoliation
- Visualization of information - creation of maps

State of technical knowledge

At the image classification level - e.g., transition between strata of different cover types, segmentation of understory/tree crowns - there are gaps in knowledge that are reflected in the “quality” of the maps currently available. The use of images to evaluate defoliation needs to be complemented with field work which can be used for the "calibration" of the classification.

Regulatory and/or socio-economic contexts

This tool can be integrated into planning systems, enabling timely decision making, reducing possible loss of forest production associated with pest attacks, and contributing to the maintenance of the various forest functions.

Impacts of the tool

Knowing that there is a gap between demand and supply of Eucalyptus wood in Portugal and Spain, the tool being developed will be important because it will permit the monitoring of the health condition of Eucalyptus stands, allowing timely intervention by owners - small private owners, pulp industries or public administration – and, eventually, quantification of growth losses, an aspect that is essential for the definition of management plans and decision-making processes of the owners and the definition of the medium-term strategies of the industry.

Implementation requirements and durability

Description of the implementation steps

In order to assess defoliation with this tool, the following steps must be followed: (1) Capture of multispectral images using a UAV, (2) Calculation of vegetation indexes, (3) Reclassification of index values to obtain the different levels of defoliation present in the area according to the scale of ranges provided by the statistical analysis of the areas evaluated.

Governance

The tool for estimating defoliation is public and can be used by all stakeholders at the regional or national level.

Regulatory framework

Within Europe, the use of UAVs is regulated by the specific legislation of each country, thus data collection must always be carried out according to the relevant regulations (Spain RD 1036/2017 and Portugal regulation 1093/2016). EASA (European Aviation Safety Agency) is currently preparing a common regulatory framework relating to the use of UAVs throughout Europe, therefore in the coming years it will be necessary to pay special attention to changes that may occur in terms of the management and security of aerial vehicles.

Human resources requirements

Currently there are many companies providing data collection with multispectral cameras mounted on UAVs. Most of them also provide image processing with photogrammetry softwares to obtain vegetation index maps if required. In order to analyze the resulting data and carry out the reclassification of the maps at different levels of damage, personnel with GIS knowledge is needed, as well as knowledge of the biology of *Gonipterus platensis* and its interaction Eucalyptus stands.

Financial requirements

If the interested stakeholders do not have the equipment for data capture, this service can be purchased from an external company. In this case, the stakeholder must have the financial capacity to pay for such services. Prices vary greatly depending on the company, the image resolution needed and the type of camera to be used in each case. As a reference, prices are often around 600 € per flight day or 100 € per hour, with a minimum of 4 hours needed to capture acceptable quality data. Alternatively, the stakeholders must have their own UAV-mounted multispectral cameras, as well as a licensed pilot and personnel with image analysis and processing skills.

Technical requirements

It is necessary to obtain, process and analyze images captured with a multispectral camera mounted on a UAV. The data collection and processing can be undertaken by a specialized company which has the necessary technical knowledge, or can be done by the stakeholders themselves, in which case, it would be necessary to have a data capture team and qualified personnel for the processing and analysis of the images and the creation of vegetation index maps. Additionally, a GIS software (proprietary or open source) is essential for the analysis of the vegetation index maps and the establishment of defoliation levels. The use of vegetation index maps should to be complemented with field plots so that "calibration" of the indexes in order to estimate defoliation can be carried out.

Priorities identified for successful implementation of the tool (political, technical, human, financial…)

To design an effective tool for defoliation estimation it is necessary to collect a large amount of images covering different periods of time, levels of attack, growing and phenological states, climate conditions etc. Thus the vegetation index maps represent all possible types of *Eucalyptus* stands. Therefore, cooperation between all parties involved is necessary to achieve a common database which can be used to analyze the sensitivity of vegetation indexes to defoliation in different scenarios

and areas.
Challenges or risk factors (legal, financial, safety…) expected during the implementation and solutions proposed Related to the previous point, the main challenge is to ensure coordination between the administrations in charge of forest management, companies in the sector and private owners in their capture and sharing of data so this can be used to obtain reliable defoliation estimation models for different degrees of attack as well as for different phenological stages and climatic conditions.
Additional and non-formal experiences to help the implementation of good practice The transmission of information between all the stakeholders involved in *Gonipterus platensis* management is an essential issue to improve the tool in question and to implement it in the ordinary workflow of the people in charge of the pest management. For this reason it is important to promote workspaces where research centers and companies can share their knowledge and goals with the other stakeholders and transmit the wide range of possibilities that remote sensing tools can offer in the fight against *Gonipterus platensis* .

SWOT analysis

Strengths	Weaknesses
- Extensive areas can be monitored with very little fieldwork - Areas of difficult access can be easily monitored - Through the use of UAVs, high resolution information can be obtained at a specific moment, for example, when the strongest attacks are taking place. - Obtaining images at different time intervals, allows the temporal analysis of the behavior of the pest which can be used to predict the damage to be expected in the future. If quality climate data is available, its influence on the development of the attacks can be monitored. - The resulting defoliation maps are very easy to interpret and they are created in a format which is compatible with other data sources. - The analysis of the vegetation maps from multispectral cameras can be done in an open source GIS software, without the need to purchase licenses of any kind.	- When the level of defoliation is low, the current indexes are not sensitive enough to describe the damage. - More data are needed to provide robust models that are valid for different geographical areas, periods of time, phenological stages and climatic conditions - Understory vegetation present in some areas can cause the value of certain indexes to saturate - In young stands which do not have tangential crowns it is necessary to remove bare soil pixels in order to calculate vegetation index values, and this is not always easy to do. - The 7 defoliation levels measured in the field cover very small intervals, so in most cases, the indexes are not sufficiently sensitive to distinguish between them. - It is difficult to assess the influence of the sensor type and light conditions on the results obtained.
Opportunities	**Threats**
- Democratization in the use of UAVs and their images will reduce the price of data acquisition in the future so this tool will be more affordable for all the stakeholders interested on it. - Due to the development of new technologies in the field of sensorics, many different sensors to study vegetation health status are available.	- Climate change may alter the behavior pattern *Gonipterus platensis*, making it difficult to make future predictions of the damage it will cause. - The legal framework pertaining to UAVs is very restrictive in Europe, so there may be damaged areas where data capture cannot be carried out

Morever, the increase of competition between the sensors suppliers is causing prices to fall. -GIS and statistics open source softwares, are increasing their analysis capacities year by year, so there is a wide range of opportunities to deal with the data and obtain different kinds of results.	by this means.

Lessons learnt

Evaluation process, if exists (internal or external)

Within the GT3 task of the PLURIFOR Project, a process of evaluation of the tool will be carried out in other study areas to those used for its creation.

Assessment of results (quantitative and qualitative) and comparison with main goals

Significant differences were found in some of the values of the vegetation indexes to estimate the different levels of defoliation when compared to the field data, especially when these levels are high. The indexes based on the red edge and the NIR showed the greatest sensitivity. In conclusion, multispectral cameras mounted on UAVs proved to be useful to monitor Eucalyptus defoliation, and can serve as a support tool for the monitoring and control of *Gonipterus platensis*.

Negative aspects identified

- When defoliation level is low the tool does not work optimally
- It is difficult to define the defoliation categories to be used. Each person employs subjective criterion when measuring the degree of defoliation in the field. When using 7 categories it is difficult to distinguish between neighboring categories. Morever most of the indexes are not sensitive enough to identify- intervals.
- The type of sensor used in data capture influences the values obtained for the same index, which makes it difficult to homogenize the relationship between index value and degree of defoliation. Also phenological status and climate conditions have an influence that is not easy to quantify.
- When analyzing the different field plots used to create the tool, different defoliation levels have been found. However, in those plots where trees are not georeferenced is not possible to relate each defoliation level with its index value. As a result, even if the field measurement is detailed, the only option is to work with average values of defoliation and indexes per plot, so there is a loss of accuracy in the statistical models (See Methodology and results.pdf in « Access to complete tool »)

Unexpected consequences (short- / mid- / long-term) and corrective measures implemented

When the plantations to be evaluated are very young and the tree stands have no tangential crowns, the aerial images show areas of bare ground. These soil pixels introduce noise in the plots when calculating the indexes, so we propose carrying out a supervised classification of the index maps to isolate the vegetation zones

Access to complete tool

Files	Methodology and results.pdf
Web links	https://plurifor.efi.int/wp-content/uploads/WP2/tools/Gonipterus-platensis-tool-3_3.pdf