Interreg Alpine Space project - **NEWFOR**

Project number 2-3-2-FR

NEW technologies for a better mountain **FOR**est timber mobilization

Priority axis 2 - Accessibility and Connectivity

Workpackage: Forest resources and LiDAR

Quantifying damage and potential recovery following natural disturbances in alpine forests using remote sensing techniques

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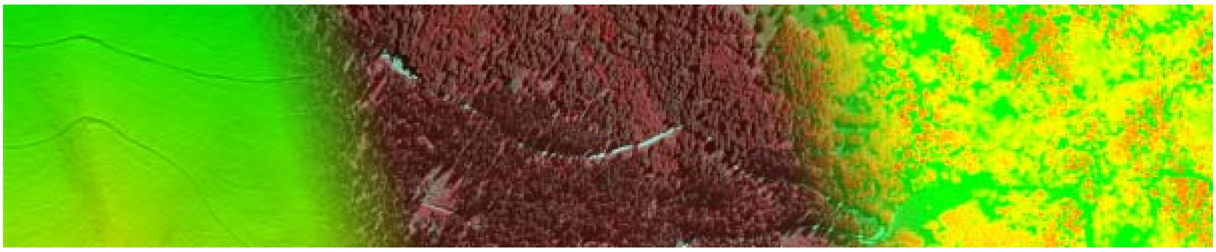
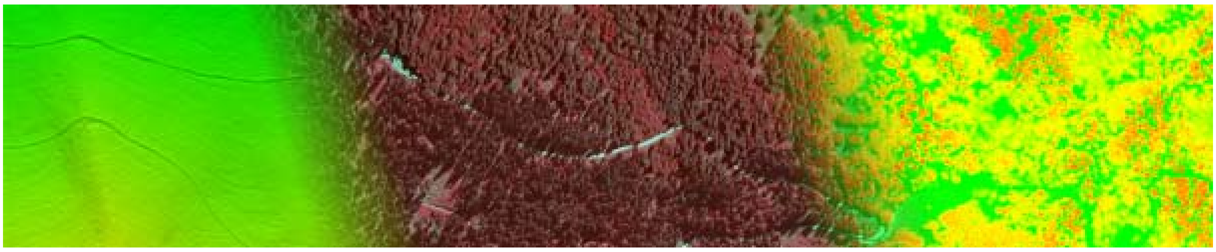


The consortium of the project Interreg Alpine Space NEWFOR



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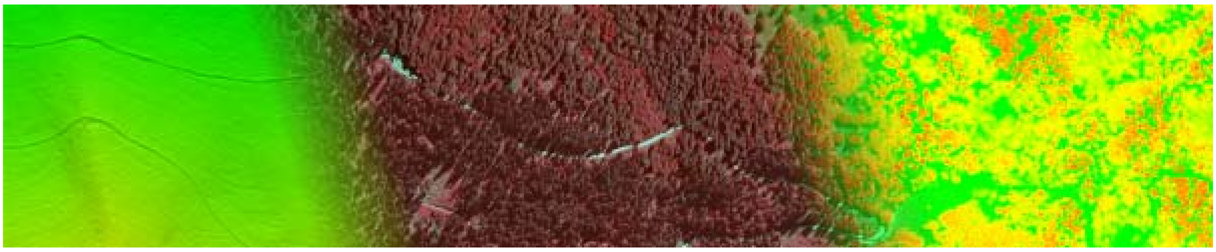
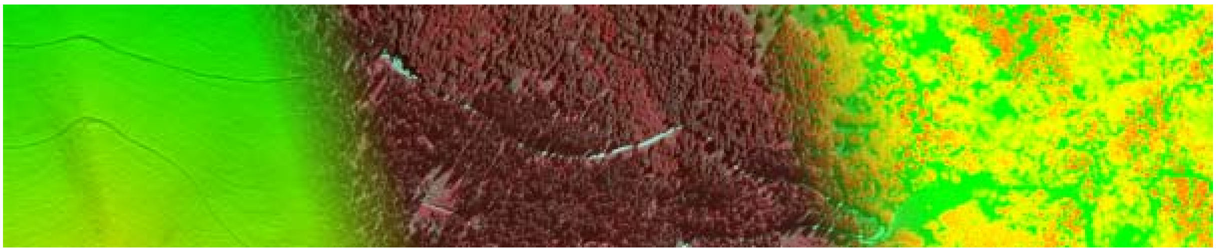


1 ABSTRACT

Remote sensing techniques can offer a robust and quick way for providing forest damage evaluation (localization and qualitative assessment) after anthropogenic or not anthropogenic perturbations. Such techniques offer also the possibility to realize post event damage inventory with ensuring complete safety of the operators. Within the Interreg Alpine Space project, this infusion of LiDAR and remote sensing for forest damage evaluation. were able to be tested successfully after an ice break event in Slovenia. This report presents the work carried out.



2 A SYNTHETIC OVERVIEWOF THE INTERREG ALPINE SPACE PROJECT NEWFOR

2.1 THE CONTEXT

The role play by mountain forests is extremely varied. Their contributions to the stability and overall development of life and economic factors in mountainous regions are highly significant. Due mainly to topographic conditions, managing mountain forests is significantly more cost intensive than in plain ones. A good knowledge of forest biomass location, characteristics, mobilization conditions and connectivity to wood industry is a prerequisite for the development of a sustainable timber supply chain in mountain territories. This knowledge is currently insufficient to provide at reasonable costs, the required guarantees on the wood supply and on its sustainability. Improving an efficient and robust evaluation of the forest growing stocks (volume and quality) and its accessibility are the efficient measures to mobilise sustainably more wood from mountain forests. As building forest roads and other infrastructures are often complex and expensive, the availability of financial resources is a key challenge. This could be achieved by providing technology and financial support. With such knowledge and tools it will be then possible to develop an active and sustainable cultivation of mountain forests and an efficient European mountain forest management policy.

2.2 OBJECTIVES OF THE PROJECT

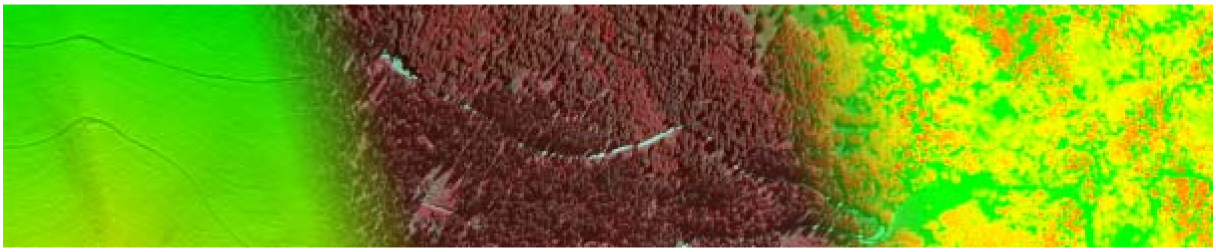
According to this context and based on the use of new technologies (LiDAR: light detection and ranging, Unmanned Aerial Vehicle,...) for forest and topography characterization, the project NEWFOR has been dedicated to enhance and develop tools and adapted policies for decision making in the field of a sustainable and adaptive mountain forest resources management facing the sustainability of mountain forest ecosystems services.

So, the main goal of the project NEWFOR is the improvement of accessibility to the forest for an economically effective wood harvesting and transport related to a sustainable forest management and wood industry in Changing Climate. The 14 partners involved in the project's consortium, have broken down this main goal into five thematic workpackages (wp):

- Forest resources and LiDAR

  Recent developments in LiDAR technology, combined to other available data sources (aerial photographs, aerial photo series by UAVs, …), are now allowing a precise and fine mountain forest resource quantification, qualification and mapping. Integrating this technology will provide an innovative response to the challenges of a precise and robust knowledge on the available growing stocks. The actions of this wp had for objective to test and develop tools for the use by foresters of data coming from this new technology.

- Forest accessibility



After the identification of forest resources, the second step of an efficient forest management is to evaluate the accessibility to these resources. In mountain area the slope is the main constraint to a technical and economically efficient exploitation. This wp demonstrated how to use topographic LiDAR data coupled with geographic information systems (GIS) for an optimal planning of the opening-up of forests according to the current accessibility of forest resources.

- Forest and industry connectivity

Since the forest resources and its accessibility are characterized, then the question of the actors of the wood supply chain is how to feed the wood market from the forest to the wood users? In other terms, the question is: what is the real connectivity between the wood at the road side (inside the forest) and the wood at the mill's timber yard? The objective of this wp was to answer to this question.

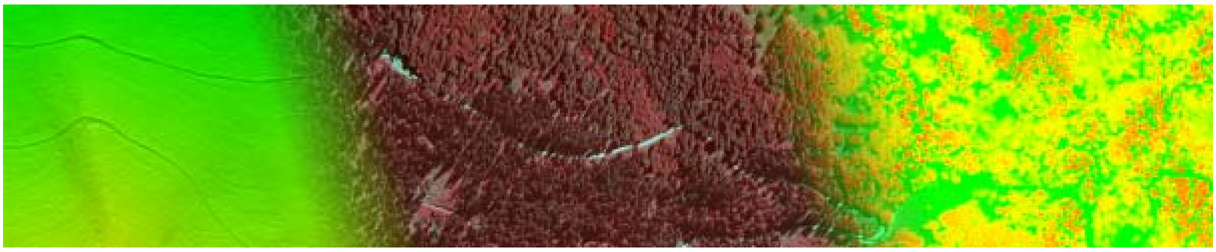
- Costs and benefits evaluation

NEWFOR aims to develop helping decision tools dedicated to defining strategies for sustainable mountain wood supply chain. To fulfil this objective the 3 first workpackages (see above) have been building up with the objective of developing tools for identifying forest resources, their accessibility and connectivity to the wood market. In order to achieve the demarche, and to choose the optimal strategy, it’s necessary to evaluate, from the economical aspect, the costs and benefits of each possible strategies. This was the objective of this wp.

- Logistical planning strategy

There is a need to frequently adjust the planning of forest management to new economical evidence as well as to unforeseeable developments. Such an adaptive management needs to balance ecological, social and economic factors. The main objective of this wp was to provide forest managers and decision makers with reliable information for the evaluation of technical and economical conditions for their decision-making on timber supply chain logistical planning and land use strategies.

This project has been, co-funded by the European Regional Development Funds, and achieved under the third call of the European Territorial Cooperation Alpine Space Programme 2007-2013.

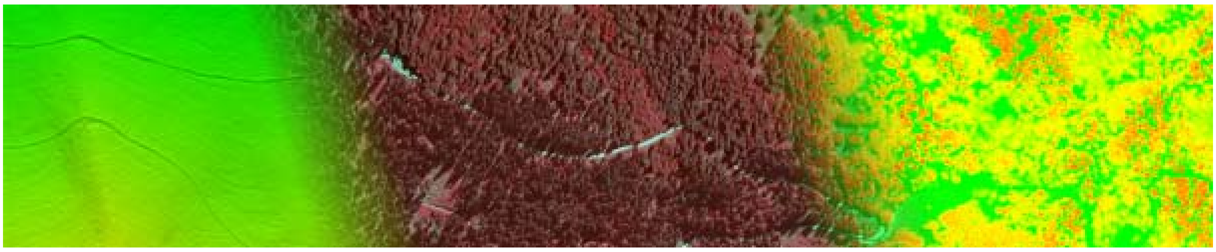


3 QUANTIFYING DAMAGE AND POTENTIAL RECOVERY FOLLOWING NATURAL DISTURBANCES IN ALPINE FORESTS USING REMOTE SENSING TECHNIQUES

Forests in the Alps provide a wide range of ecosystem goods (e.g. wood production) and services (provision of drinking water, protection from natural hazards, preservation of biodiversity). There is increasing concern that provision of these services may be adversely affected by global change. One of the main concerns is that global change may alter natural disturbance regimes (e.g. increases in frequency or severity), which may have a greater affect on forest structure and function than direct changes in temperature.

Figure 1: Broken stems, damaged tree crowns and uprooted trees in the forest reserve ''Risov žleb'', Dinaric silver fir - European beech forest.

The dynamics of forests in the Alps are controlled by both anthropogenic (mainly forest management for wood production and other forest functions) and natural disturbances, namely, windstorms, ice and snow damage (Figure 1), and insect outbreaks. These natural disturbances often make up a substantial portion of harvested timber, timber that would otherwise be harvested under regular silvicultural plans. This results in rather severe logistical problems due to the urgency of post disturbance harvest operations.



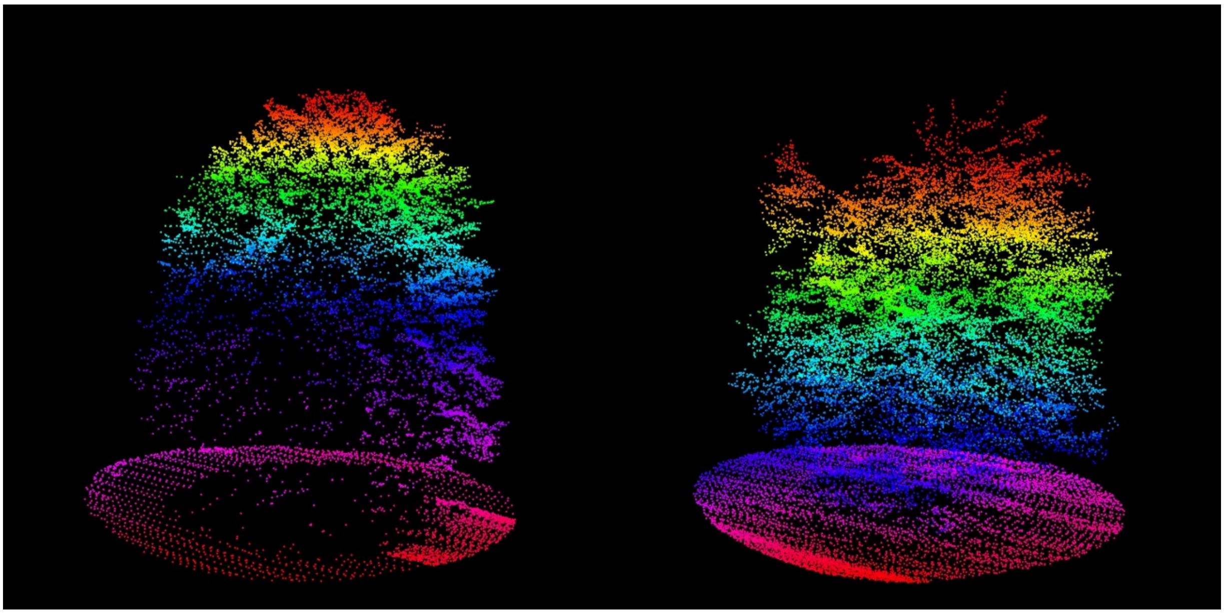
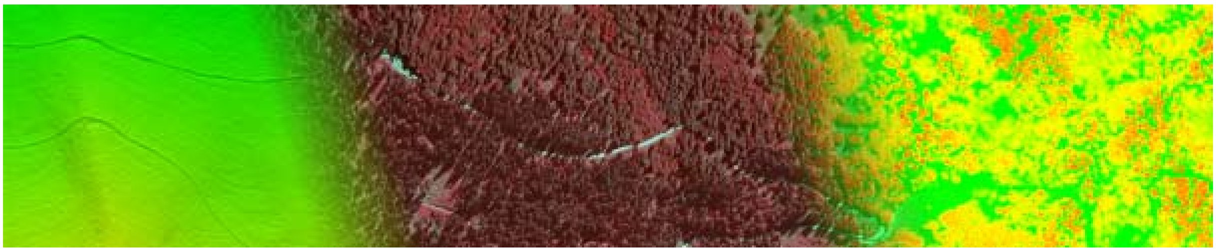


Figure 2: An example of open grown European beech (*Fagus sylvatica*) before (left, 2009-11) and after (right, 2014-04) ice break event in February, 2014.

Currently, management decisions following natural disturbances are largely based on rapidly collected data in the field. There are several problems or challenges associated with field based approaches. First, it is costly and time consuming to properly sample large forest areas damaged by disturbance. Second, widespread, but less severe disturbances, are often completely ignored or missed in field sampling, yet they may have an important influence of forest structure and function because their return intervals are shorter than stand replacing events. Many natural disturbances, in fact, create heterogeneous damage patterns across large forested landscapes, ranging from small gaps, intermediate sized patches of partial canopy damage, to large areas of total canopy removal. Capturing this variability is difficult to capture with field-based methods of inventory.



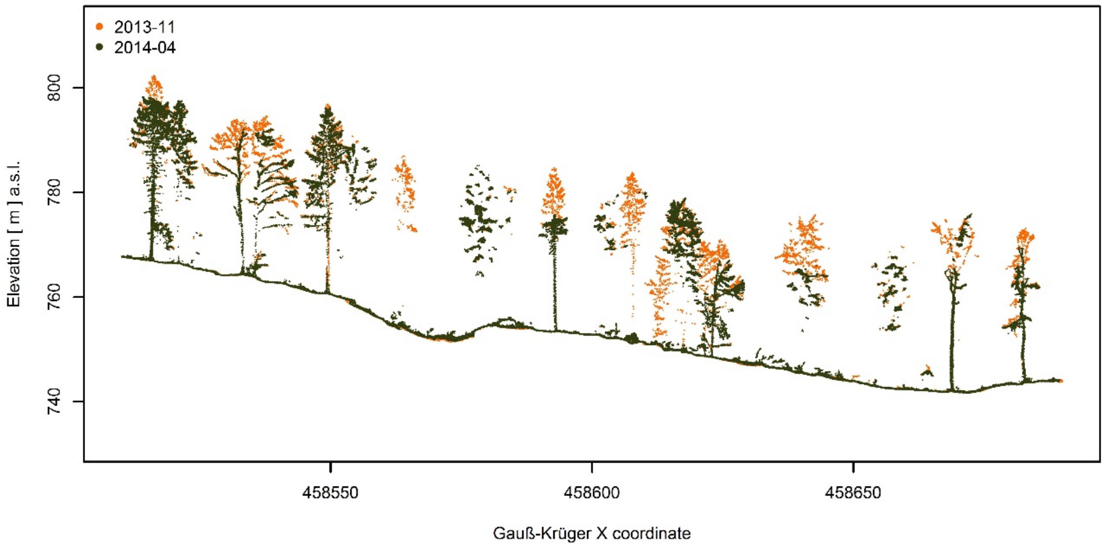


Figure 3: Slice of lidar data showing vertical profile through mixed forest stand before (orange dots, 2013-11) and after (dark green dots, 2014-04) ice break event in February, 2014.

There are a variety of remote sensing approaches that would provide ideal solutions to address these challenges. Remotely sensed data would improve the decision making process by reducing the response time of managers, cover large landscapes with less cost, and improve objectivity of the quantification of damage patterns and post disturbance forest structure (needed to assess potential recovery patterns). Taken together, remotely sensed data would facilitate and optimize post disturbance management strategies, such as whether to use salvage logging and actively or passively restore disturbed areas.

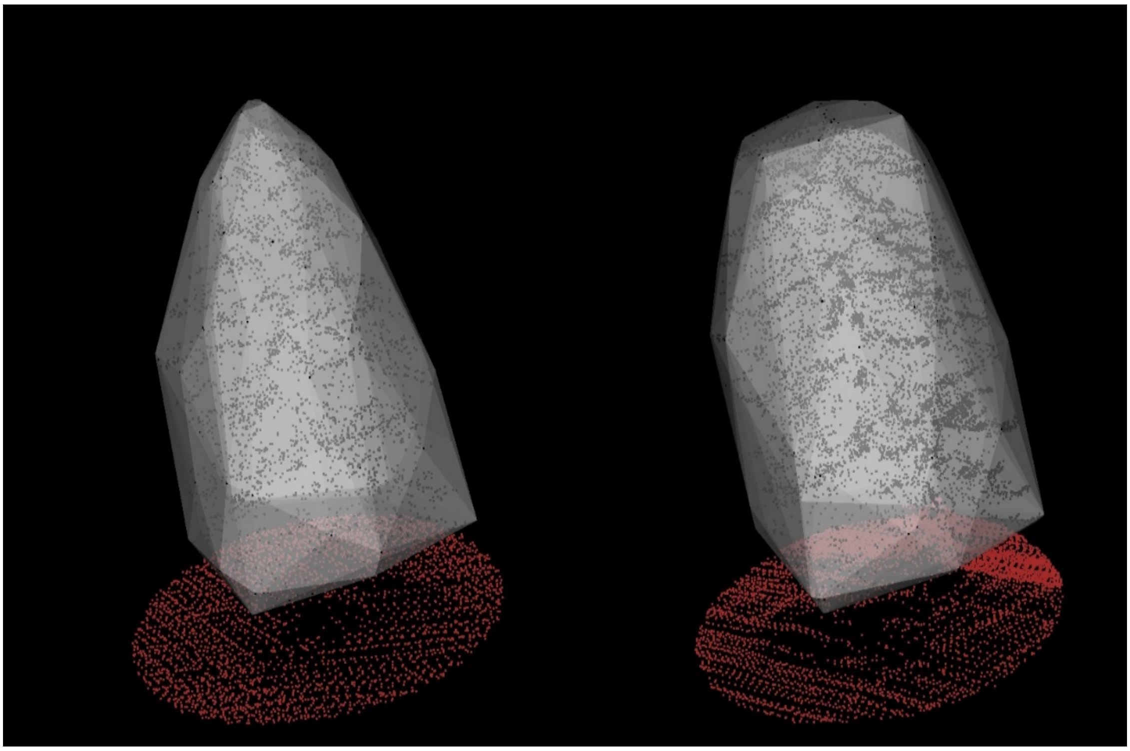
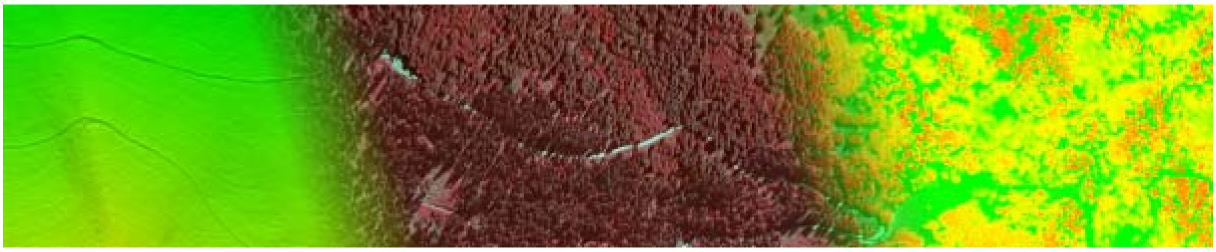


Figure 4: An example of wrapped surface reconstruction of crown damages for open grown.

A number of studies have shown the comparative advantages of LiDAR over passive remote sensing techniques for mapping changes in forest structure (e.g.), because instruments directly measure the vertical and horizontal structure (i.e. 3D) of forests using the principle of laser altimetry (Weishample et al., 1996). Canopy structure (the organisation in space and time) contains much information about the state and development of forests (Parker) and it usually undergoes major changes after natural disturbances.



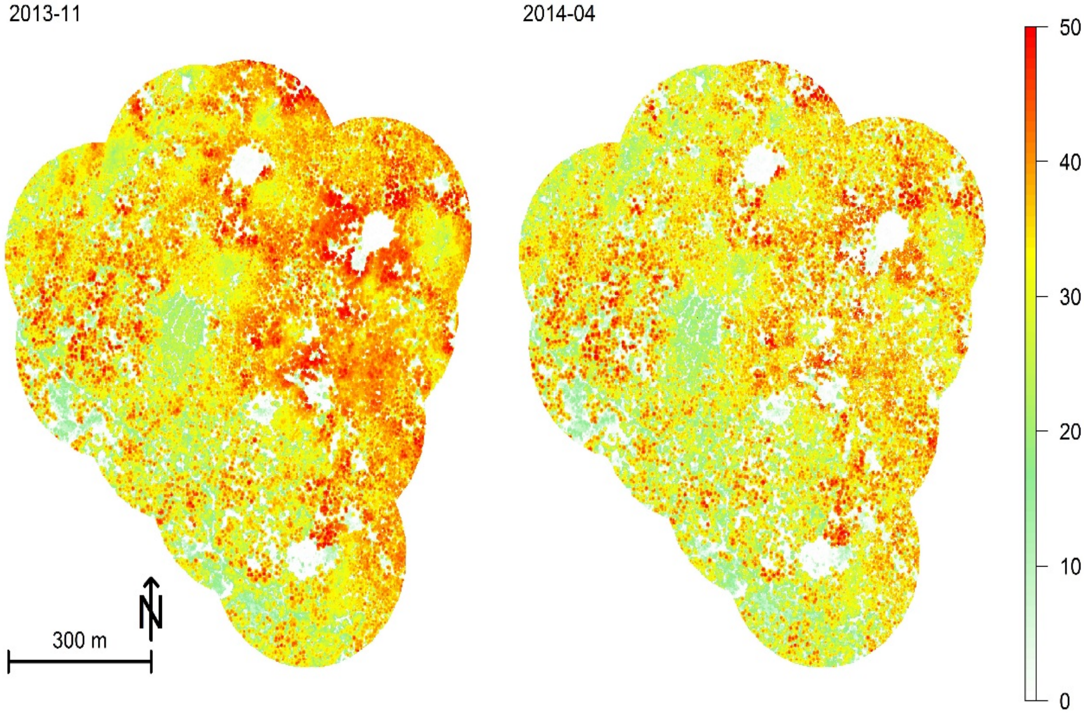
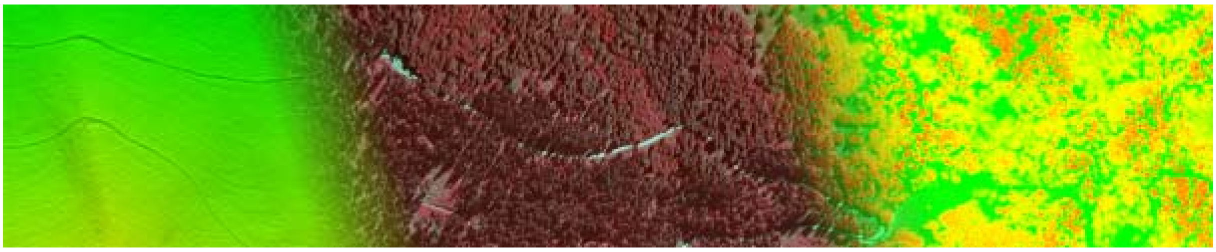


Figure 5: An example of canopy height model of study area (0.72 km^2) before (left, 2013-11) and after (right, 2014-04) ice break event in February, 2014.

The changes in structural characteristics of forests using multi-temporal LiDAR data can be assessed with two different principal approaches: 1. classification of changes based on the visual inspection of profile (Figure 3) or point cloud (Figure 2) representation of forest stands before and after the disturbance and/or 2. quantification of changes applying different computational algorithms (e.g. Figure 4, Figure 5, Figure 6 and Figure 7). Since visual classification can be more or less subjective, the use of computational algorithms represents a more accurate and unbiased way to determine the actual changes in stand structure. The latter approach can include simple (e.g. $\Delta CHM = CHM1 - CHM0$; Figure 6) or more advanced analytical procedures (e.g. CVP - Canopy Volume Profile method; Figure 8). While quantification of changes in canopy height provide the basis for describing the structural changes in terms of spatial pattern of disturbance, it is not necessarily the most relevant variable for describing canopy structure and forest dynamics, especially from the ecological point of view.



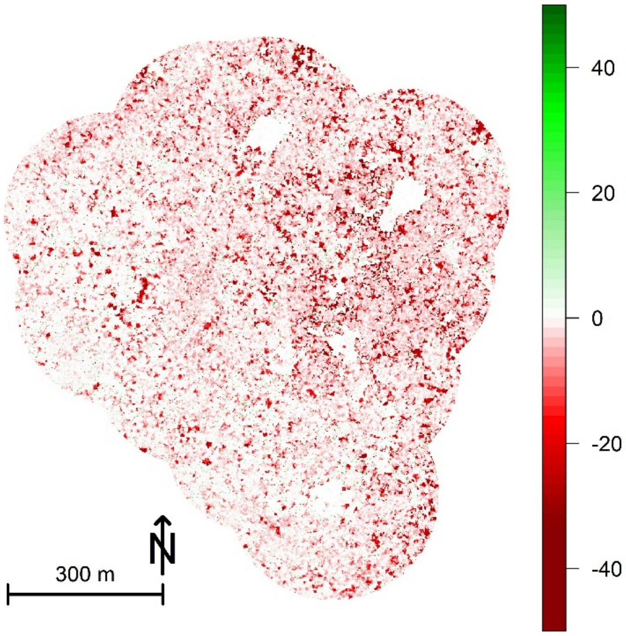


Figure 6: An example of differences in canopy height model of study area (0.72 km^2) after ice break event in February, 2014.

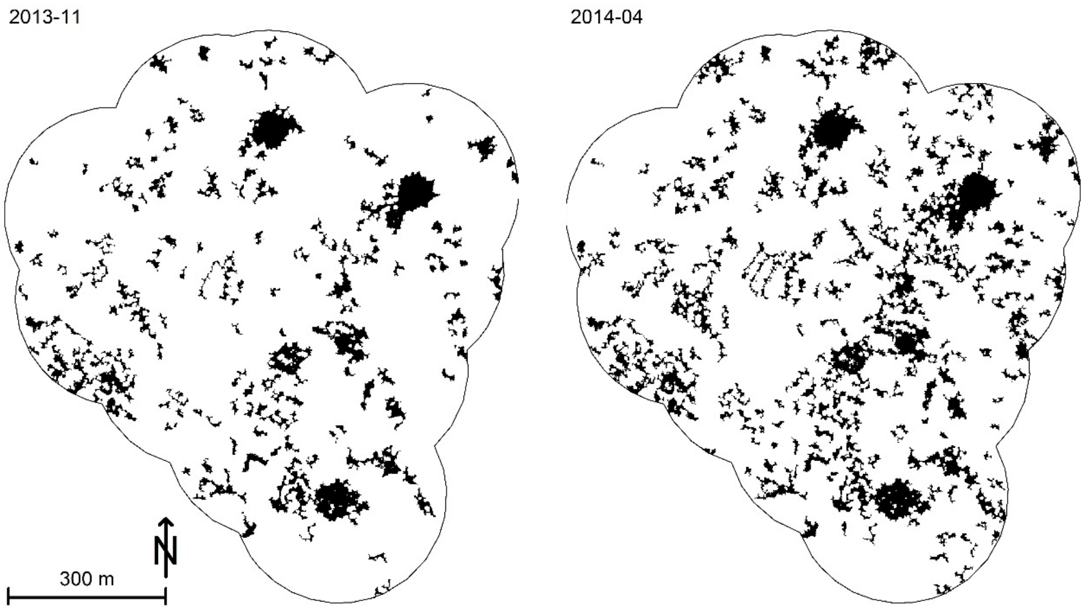
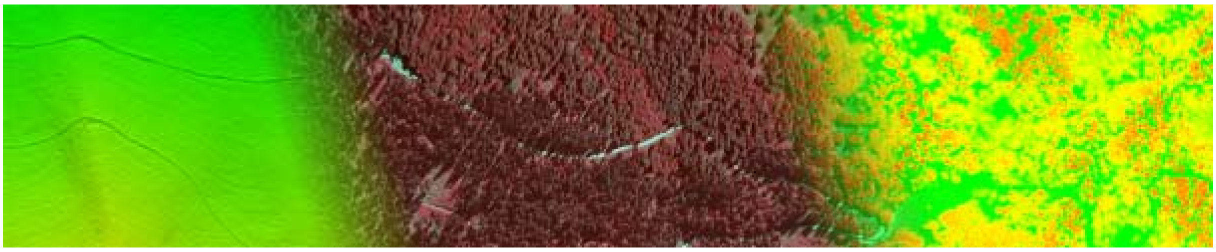


Figure 7: An example of canopy gaps distribution at study area (0.72 km^2) before (left, 2013-11) and after (right, 2014-04) ice break event in February, 2014.



The vertical distribution of biomass within the canopy, defined as the CVP (Lefsky et al., 1999), represents the three-dimensional geometry (horizontal and vertical distribution) of the forest canopies (Figure 8, Figure 9). This method is explicitly volumetric as it uses voxels to characterize the forest canopy as a three dimensional matrix.

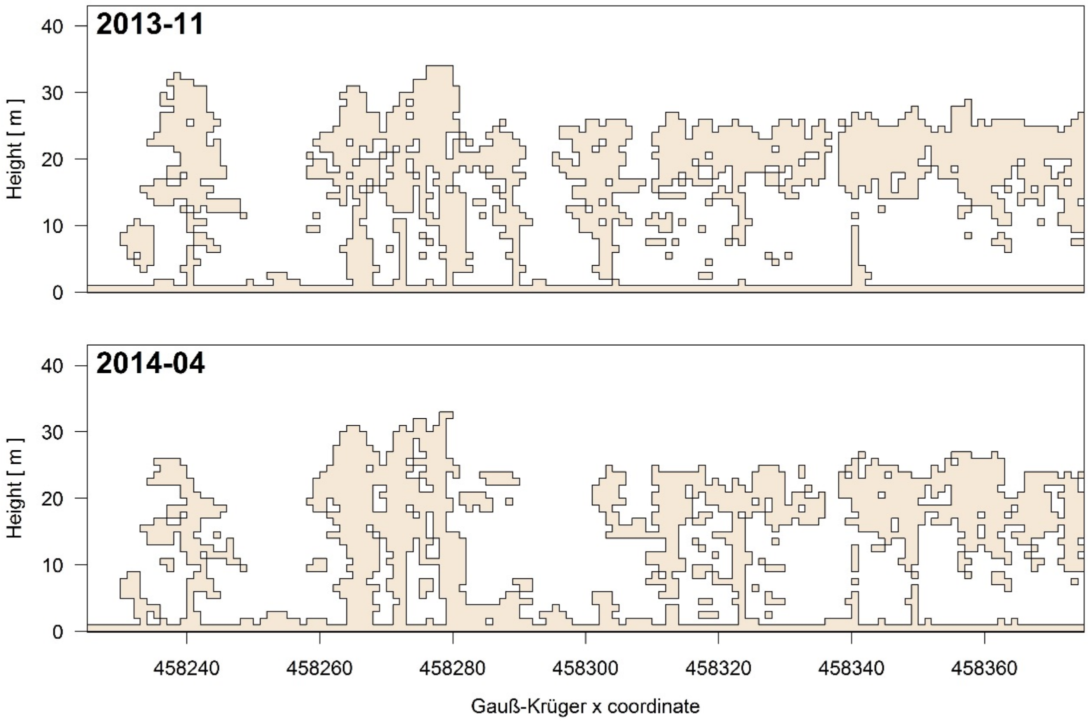


Figure 8: An example of canopy volume profile CVP through mixed forest stand before (top, 2013-11) and after (bottom, 2014-04) ice break event in February, 2014.

Classification of ‘‘filled’’ or ‘‘empty’’ voxels is based on presence of LiDAR return in each voxel that represents a value on a regular grid in three-dimensional space. The usage of voxels could provide an improved calculation of biomass distribution in the stand. The quantification of changes in the 3D space results in the possibility to discriminate the changes in stand structure into three categories: a) no change, relocation of plant material which involves both, accumulation (b) or loss (c) (Figure 9, Figure 10).

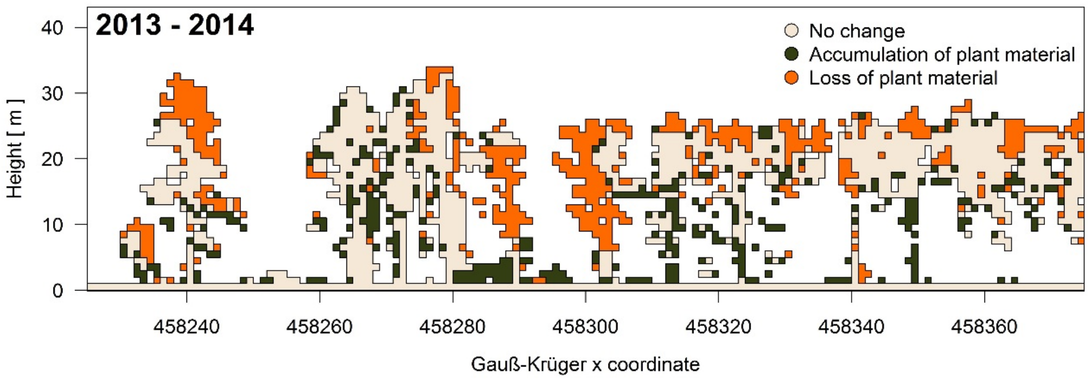


Figure 9: An example of changes of canopy volume profile CVP through mixed forest stand before (2013-11) and after (2014-04) ice break event in February, 2014

The described approach seems relatively promising for studying the immediate effect of a disturbance and post- disturbance dynamics.

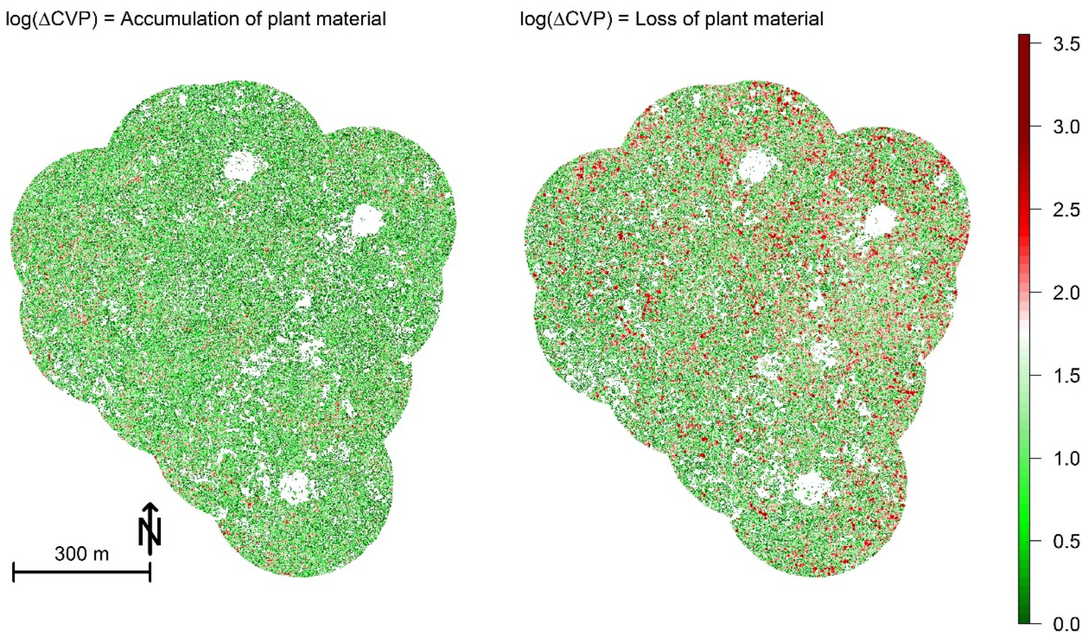
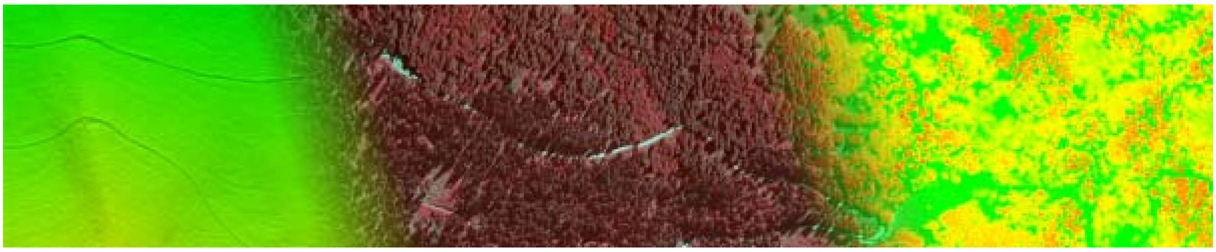
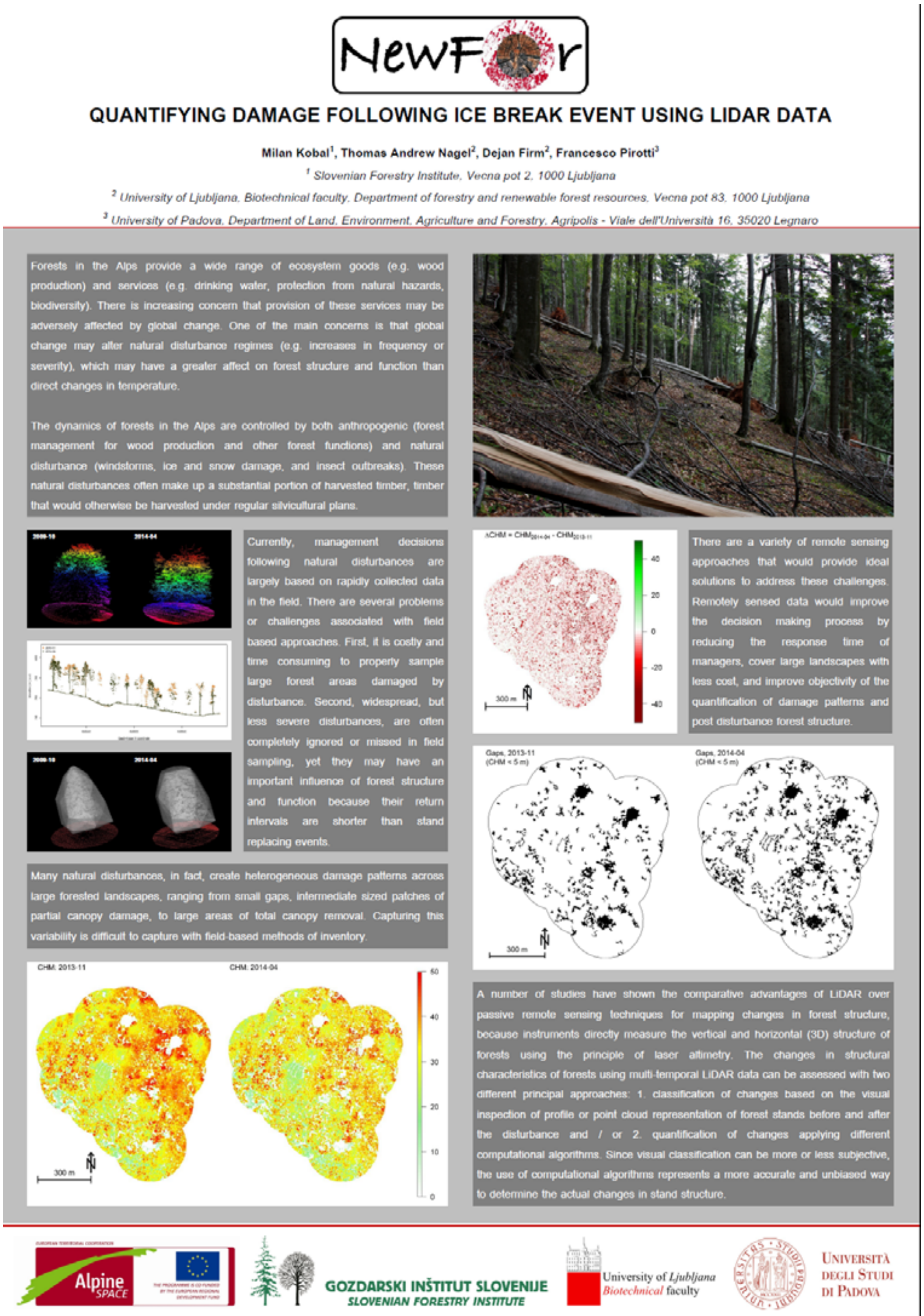
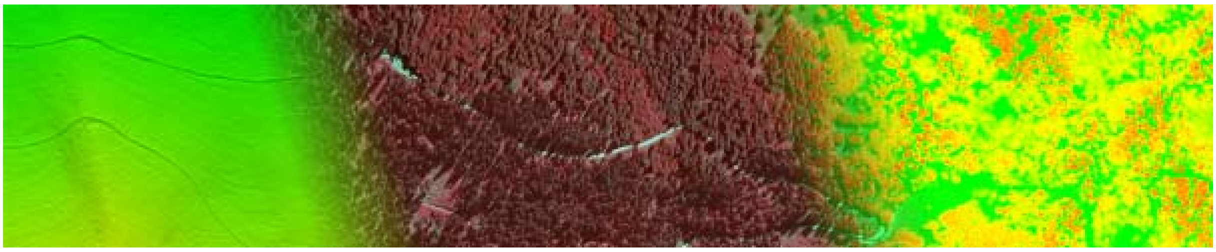


Figure 10: An example of changes of canopy volume profile CVP (left – accumulation of plant material, right – loss of plan material) of mixed forest stand before (2013-11) and after (2014-04) ice break event in February, 2014.



4 POSTER ON THE US EOF LIDAR FOR ICE BREAK DAMAGES EVALUATION





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