VAIA - FROm lessons learNT to future options

VAIA - FRONT

A 2-year project funded by the Department of Land, Environment, Agriculture and Forest (Dept. TESAF) of the University of Padova – 2019-2021

Abstract

On October 29th, 2018, the Vaia storm and flood event hit North-Eastern Italy, causing major damages to the forests mainly located in mountainous areas of Veneto, Trentino and South Tyrol, Friuli Venezia Giulia and Lombardy regions. With a damage of more than 8 million cubic meters of standing trees and, more importantly, the sudden reduction of forest-related ecosystem services, including protection against landslides, avalanches and floods, maintenance of biodiversity and cultural values, the storm had regionally unprecedented consequences. Funded by the Department of Land, Environment, Agriculture and Forestry of the University of Padova, the VAIA - FRONT project aims to analyse present and future vulnerabilities of forest socio-ecological systems to wind-related forcings in the target area of North-East of Italy, and to preliminarily test a risk assessment procedure for selected ecosystem services in one pilot case study in Veneto region. To this end, the project includes four actions: i) to collect and organise data on storm events and on their impacts in the European and Alpine areas, included the area affected by Vaia; ii) to review current approaches to wind–related hazard, vulnerability and risk assessment, and governance analysis for forest socio-ecological systems; iii) to adapt existing frameworks for wind-related hazard and vulnerability assessment to one selected Pilot Area in the target region; iv) to implement a preliminary risk assessment and management for key forest ecosystem services in the selected Pilot Area. The ultimate ambition of VAIA - FRONT project is to identify key lessons to be learned from the Vaia event, both for planning and management practices and for policy interventions, to enhance the resistance and resilience of forest socio-ecological systems in the Italian Alps as well as in other Alpine regions.

Research Group

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1. Introduction

On October 29th, 2018, the Vaia storm and flood event hit North-Eastern Italy, causing major damages to the forests mainly located in mountainous areas. The main affected regions have been Veneto, Trentino and South Tyrol, Friuli Venezia Giulia and Lombardy. With a damage of more than 8 million cubic meters of standing trees and, more importantly, the sudden change in the provision of forest-related ecosystem services, including protection against landslides, avalanches and floods, maintenance of biodiversity and cultural values, the storm had regionally unprecedented consequences. These consequences not only affected the natural resources and environment, but also the local and regional economy, the local communities as well as the institutional and governance settings. The Vaia storm and its consequences can therefore be considered as a key lesson to be learned and as an important opportunity to enhance the resilience of forest socio-ecological systems (*forest SES*, hereinafter) in the region, in other Alpine settings as well as in the whole country.

2. Objectives

The overall aim of VAIA - FRONT project is to analyse present and future vulnerabilities of forest socio-ecological systems to wind-related forcing in the target area of North-East of Italy, and to preliminarily test a risk assessment procedure for selected ecosystem services in one pilot case study in Veneto region.

The following five specific objectives (SOs) of VAIA - FRONT will contribute to attain the overall aim:

SO1: To provide an updated review of past storm events, their effects and methodologies for wind-related risk assessment and management of forest socio-ecological systems at the regional, national and European scale.

SO2: To gather, organize and share data and information on the specific elements of the risk system, i.e. i) hazard, ii) vulnerability, iii) damages/losses, associated to Vaia storm and its impacts considering key selected ecosystem services in one pilot area in Veneto region.

S03: To adapt and apply existing approaches, models, tools and methods for the determination of future wind-related risk, considering the region- and site-specific ecological, economic, social and institutional conditions of the selected pilot area in Veneto region.

SO4: To delineate a possible general integrated strategy for wind-related risk management of forest socio-ecological systems in the target area, both in terms of policy and practice, suitable for the local, regional, and national administrations on the basis of the lessons learned from the Vaia storm event combined with earlier available knowledge.

SO5: To create preconditions for establishing brokerage of knowledge, services and products and foster uptake of VAIA - FRONT innovation and international networking for outreach and mainstreaming.

3. Concept and methodology

(a) Concept

Governing and managing forests in a time of transformational change makes the role of research, foresight and innovation more important than ever. Wind is the major disturbance agent for European forests and is responsible for more than 50% of all damage by volume (Schelhaas et al., 2003; Gardiner et al., 2010). The cost of such damage can be very high in economic terms (e.g. € 6 billion in France from storms Lothar and Martin in 1999, and € 2.4 billion in Sweden after storm Gudrun in 2005), as well as having a huge impact on local communities and forest ecosystems. Worryingly, there is evidence that damage levels have been increasing over the past century (Schelhaas et al., 2003), and are likely to continue to increase in the future (Gardiner et al., 2010; Schelhaas et al., 2010). Part of this increase might be due to a changing climate (Usbeck et al., 2010), but most of it is certainly due to factors related to the current stand conditions of the European forests (Gardiner et al., 2010; Brůna et al., 2013). Major challenges for forest science are, therefore, to analyse present and future *vulnerabilities* of forest socio-ecological systems as well as to translate associated risks and their outcomes into forest management, policy and governance recommendations.

On October 29th, 2018, the Vaia storm hit the mountainous areas in North-Eastern Italy with high wind speeds, heavy gusts and extreme rainfall, leading to casualties and causing great damages to forests, buildings and infrastructures, not mentioning the social impacts (two persons perished, entire communities remained isolated for weeks, etc.). With a damage of more than 8 million cubic meters of standing trees and, more importantly, the sudden reduction of forest-related ecosystem services, including protection against landslides, avalanches and floods, maintenance of biodiversity and cultural values, the storm had *regionally unprecedented consequences*. Moreover, depending on the specific administrative regions, the event struggled a wide range of public and private actors (e.g., Regions and their local agencies, Municipalities, forest owners, land, energy and infrastructure managers, associations, citizens, etc.) to find different operational solutions both for the emergency and post-event, based on ad hoc coordination or even sparse and not coordinated interventions and policy measures.

The event provides a concrete representation of the scale of the hazard to forests and of the involved risks and impacts, included those on the economy, institutions and the local communities. The Vaia storm and its consequences can therefore be considered as a key lesson to be learned and as an important opportunity to develop new strategies for enhancing the future resistance and resilience of forest socio-ecological systems in the region, in other Alpine settings as well as in Italy, which necessarily include risk mitigation plans and policies.

Typically, the definition of risk mitigation strategies implies the identification of measures and tools able to increase both resistance and resilience of forest socio-ecological systems, taking into consideration not only their technical feasibility but also their economic viability as well as the preferences and capacities of the communities and decision makers. The *resistance* of the system denotes the capacity of coping with stressors, and it can be defined as the ability of the system "to function at close to its normal capacity and carry on normal operations with minimal disruption after the storm" (Riguelle et al. 2016, p. 592). The *resilience* of the system is focused on the capacity of systems to recover from threatening events, and it can be defined as the ability of the system "to absorb a shock wave in such a way that it can return to a normal state with the least possible delay and with the least possible dysfunction" (Riguelle et al. 2016, p. 592). Pulling from an interdisciplinary body of theoretical and policy-oriented literature, Longstaff et al. (2010) regards resilience as a function of resource robustness and adaptive capacity. Both these concepts, resistance and resilience, have been initially adopted in the ecological research but are now extensively used also in social and political sciences. While in *ecological sciences* the focus of the resistance and resilience is on natural and semi-natural ecosystems and their main components (e.g. organisms, soil, water) in terms of disturbance severity assessment, forecasting recovery trajectories and successional pathways, in *social sciences* the focus is on socio-economic systems and their components (e.g. interactions and collaboration among stakeholders, changes in the economic value of ecosystem services, costs and

benefits of interventions, policies and governance structures) in terms of organizational learning, human vulnerability, awareness, reactive and precautionary adaptation capacity, preparedness at various levels from individual to institutional, communication strategies and financial solutions to deal with stress/disaster and their consequences.
In particular, with the perspective of ecological sciences, the VAIA - FRONT project will advance on the following approaches: i) assessment of numerical models for the prediction of tree vulnerability to wind in relation to different variables such as tree species, tree parameters, soil parameters, terrain slope, aspect and type, speed and direction of the wind - the vulnerability will be analysed firstly at single tree level by numerical methods such as Finite Element Methods - FEM and then at forest stand level on the basis of the numerical results; ii) developing field studies of the interaction between forests and avalanches, in order to test available models of energy and mass balance of snow avalanches and help local decision-makers, structural engineers and foresters to design avalanche defences, produce zoning plans, and devise silvicultural measures (Christen et al., 2010)
With the perspective of social sciences, the VAIA - FRONT project will refer to key concepts such as: 1) forest-related ecosystem services vulnerable to climate change, that will be explored through methods that allow the evaluation of monetary values of ecosystem services and their variations after extreme climatic events (e.g. Nieuwenhuis and O'Connor, 2001; Prestemon and Holmes, 2004; Sun, 2016 in relation to wood production; Viner and Amelung, 2003; Weber, 2006 in relation to tourism; Thom and Seidl, 2016; Blennow et al. 2019); 2) risk perception and communication, that will be explored in terms of implications for designing effective risk management strategies (e.g. Scolobig et al. 2012; Blennow et al. 2014; Babcicky and Seebauer, 2017); 3) human/social vulnerability (e.g. De Marchi and Scolobig, 2012) and adaptive capacity of private actors (e.g. forest managers), public authorities and governance structures, that will be explored in terms of their potential for strengthening the resilience of the forest sector and the whole system to face strong storms (e.g. Riguelle et al. 2016).

(b) General approach, methodology and structure

Taking the move from the analysis of the Vaia storm event, the VAIA - FRONT Project aims at identifying and adapting the most appropriate existing frameworks for the analysis of present and future wind-related vulnerabilities of forest SES in the affected region, testing in one pilot area possible approaches and procedures for the identification and management of risks. VAIA - FRONT will translate the analytical outputs of the forest vulnerability and risk analysis, to be carried out in the pilot area in relation to selected key ecosystem services, into preliminary forest management, policy and governance recommendations.

Even if these recommendations will mainly be based on the specific characteristics of one pilot area within the target region and the Vaia storm event, efforts will be devoted for generalizing them as much as possible in relation to the Alpine space and wind-related hazards. This will be done by integrating the Vaia storm observations and data collected in the pilot area with the available literature and reports on previous events occurred in the Italian Alps and other mountainous regions as well as in other European countries.

The biophysical and socio-economic data will be identified and reported on the whole affected area, i.e. the four Italian North-Eastern regions damaged by the storm, i.e. Veneto, Trentino and South Tyrol, Friuli Venezia Giulia and Lombardy.

The selected Pilot Area embraces the Pettorina river basin and the municipality of Rocca Pietore (Veneto). This area is characterized by massive windthrows, heavy damages to key infrastructures (roads, trekking paths), flood damages, and loss of key forest ecosystem services (avalanche risk protection, recreation and tourism for instance). During the Vaia storm almost 125,000 m^3 of timber have been windthrown within the municipality borders, accounting for almost 50 times the yearly timber exploitation (average of the last 10 years). The majority of the affected area were Norway spruce forests at the entrance of the valley and south-facing slopes. As many other municipalities located in remote mountain areas in Italian Eastern Alps, Rocca Pietore has a declining and ageing

population (ca. 1,200 residents in 2018, -17% from 2001 to 2018, ca. 56% of the residents are over 50 years), with tourism as one of the few options for employment in the area. In such a fragile socio-economic context, Vaia storm destroyed famous touristic sites (e.g. “I Serrai di Sottoguda”) and key infrastructures (roads, trekking paths and biking trails), and it significantly increased risks associated to landslides and avalanches, thus creating additional challenges for residents to remain in the area.

The pilot area has been selected on the basis of the following criteria: severity of the damage, co-existence of more ecosystem services that have been negatively affected by the storm, site-specific problems having significant socio-economic impacts (e.g. avalanches), availability of existing datasets (that provide baselines for comparison), ongoing or planned research projects (that allow to create synergies, optimize resources and expand the level of analysis), post-event management actions (salvage logging, stump treatments, restoration of damaged infrastructures), and availability within the same area of forest sites not impacted by the storm (as control sites).

Data will be collected and in-depth explored with the different perspectives, approaches, methods and tools of the various disciplines (ecological and social), thus realizing a high interdisciplinary empirical study of the consequences of the storm. As for the ecological components of the analysis, methods will include both field and remote sensing techniques for assessing wind firmness (pre and post event), forest recovery, and potential and residual protective effect against snow avalanches and rockfalls. As for the socio-economic components of the analysis, methods will include, among other: interviews to key informants, questionnaires to local communities and users of forest resources, content analysis of policy documents as well as analysis of socio-economic datasets about market (e.g. timber prices) and social (e.g. demography) issues. Details on the methods are provided in the Implementation section (Section 4).

The VAIA - FRONT project overall methodology combines both a generic and a site-specific approach. Pilot case is located in a mountainous zone of Veneto region. The project has a two-year duration (from October 1, 2019 to September 31, 2021).

To develop and implement its methodology and the general research approach, the VAIA - FRONT project is structured into five Work Packages (see Fig. 1):

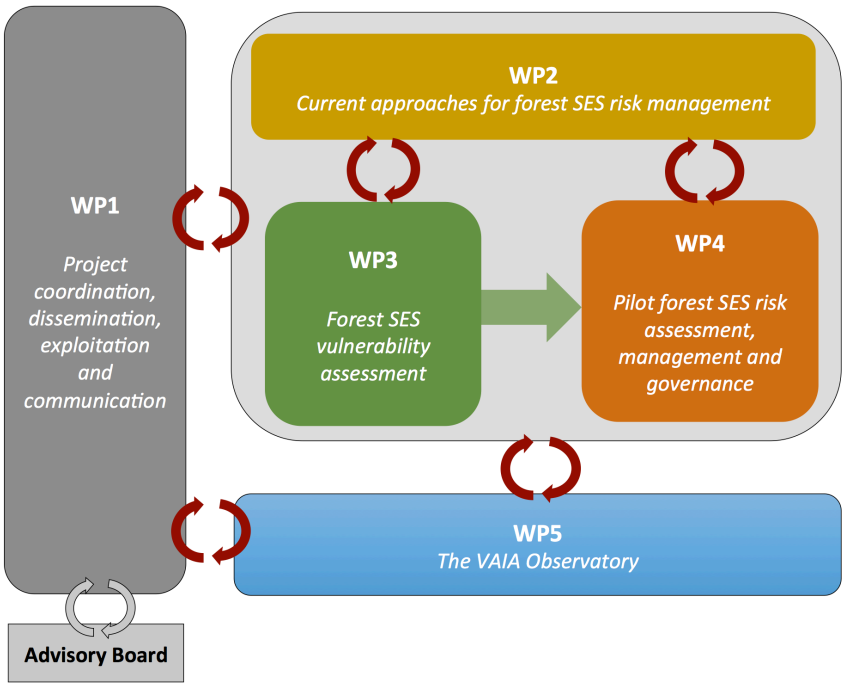

Fig.1 *Project structure*

WP1: Project coordination, dissemination, exploitation and communication. Key Tasks are the establishment of web-based knowledge brokerage, uptake and international networking.

WP2: Current approaches for forest SES risk management. Tasks will include also review of previous experiences on similar wind storm events in Europe.

WP3: Forest SES hazard and vulnerability assessment. Key Tasks will refer to the analysis of: i. wind-related hazard; ii. forest and socio-economic vulnerability for specific exposed elements, namely: trees and forest stands, ecosystem services (e.g., protection against rockfall and landslides and snow avalanches, biodiversity and wood), linear infrastructures (road, power-line) and human communities in the selected pilot area.

WP4: Pilot forest SES risk assessment, management and governance. Key tasks are the analysis of current governance structure and model, general estimation of damages and loss analysis and preliminary risk assessment for selected key ecosystem services in the pilot area, the formulation of guidelines for forest management practices and policy recommendations that will integrate in a systemic way both technical-ecological and socio-economic-institutional aspects based on both empirical data from the pilot area and information derived from literature analysis.

WP5: The Vaia Observatory. Key Tasks will include i) platform development; ii) data collection and organisation; iii) development of ways to maximise the public use of the data.

A Scientific Advisory Board of three international experts will assist in monitoring and evaluation of the VAIA - FRONT project and its outputs. International experts include specialists on both ecologic and socio-economic disciplines, thus contributing to the interdisciplinarity of the project. Members of the Advisory Board already provided an initial feedback on the overall coherence, clearness, completeness and feasibility of the proposal. During the duration of the project, the Advisory Board members are expected to offer: 1) further feedback to support the Dept. TESAF research team in possibly adjusting the activities and objectives if needed at the earliest stages (*ex ante* project evaluation); 2) a mid-term evaluation, after 1 year, for checking whether activities and outputs are aligned with plans or whether adjustments are needed (*in itinere* project evaluation); and 3) finally, an evaluation immediately after the end of the project for checking whether the outputs were consistent with the expected outputs and the planned objectives reached (*ex post* project evaluation).

The wide range of methods, tools and good practice guidelines, together with repositories and data platforms for long-term accessible information to be developed and disseminated, will facilitate the innovation at local, regional, national and international level during and far beyond the project. To this end, the VAIA - FRONT project will rely not only on the Scientific Advisory Board but also on a wide range of Key Stakeholders (Tab. 1), which will be further extended during the Project life. Key Stakeholders will be kept informed and involved on progressive project outputs. (e.g. on preferred communication tools, specific concerns or needs). Involvement with stakeholders is essential to ensure a continuous verification of the project's activities at local level. In this way the project activities can possibly be adjusted in relation to the real needs of the stakeholders. Furthermore, the involvement of the stakeholders should allow to increase a continuous updating and exchange of opinions also on the activities that the same stakeholders will activate during the project period and in the following years.

Tab. 1 *Provisional list of Project Key Stakeholders*

Regione del Veneto	Commissario Delegato “Pianificazione degli interventi”	Nicola Dell’Acqua
Regione del Veneto	Soggetto Attuatore “Settore rilievo e opere agricolo-forestali”	Fabrizio Stella
Regione del Veneto	Soggetto Attuatore “Settore ripristino ambientale e forestale”;	Gianmaria Sommavilla

Regione del Veneto	Soggetto Attuatore "Settore agricoltura/aziende agricole"	Gianluca Fregolent
Regione del Veneto	Soggetto Attuatore "Settore ripristino viabilità"	Silvano Vernizzi
Regione del Veneto	Soggetto Attuatore "Settore rischio valanghivo"	Italo Saccardo
Regione del Veneto	Unità Organizzativa Forestale	Gianmaria Sommavilla
Regione del Veneto	Direzione AdG FEASR Foreste	Franco Contarin
Ministero della Difesa	Comando Regione Carabinieri Forestale Veneto	Alberto Piccin
Provincia Autonoma di Bolzano	Direzione Foreste	Mario Broll
Provincia Autonoma di Trento	Servizio Foreste e Fauna	Giovanni Giovannini
CIFORT	Consorzio Imprese Forestali del Triveneto	Luca Canzan
ENEL Italia	Affari Istituzionali Territoriali Triveneto	Michela Coletto

c) Other research projects

The project aims not only to undertake the various activities as specified in the Implementation section, but it also has the ambition of providing an overall conceptual structure that will allow to connect each other the various ongoing and future research initiatives focused on Vaia storm and other similar events, as well as to assemble different perspectives and integrate different scientific disciplines.

Considerable research is being done on the Vaia storm and flood event in parallel projects, funded by diverse Agencies (Regione del Veneto, University of Padova, Ministry of the Environment, etc.) and managed by researchers who are involved in VAIA - FRONT (Tab. 2). Moreover, the Doctoral School LERH at Dept. TESAF funded 3 PhD positions on three different topics (Tab. 2) related to the analysis of the dynamic, impacts and management options related to the Vaia storm. The initiative is called "Young scientists for Vaia" and the 3-years PhD researches, which are expected to be developed from Autumn 2019 to Autumn 2022, will be designed as much as possible for being complementary with the VAIA - FRONT project, as in their first 2 years they will overlap the project time schedule.

The purpose of VAIA - FRONT is complementary to these projects essentially by: i) focusing on the concept of forest socio-ecological risk; ii) embracing a wide-range multi-disciplinary approach. Nevertheless, linkages will be designed with these projects in order to create synergies, optimize resources and expand the level of analysis.

Tab. 2 *On going research projects on the Vaia storm and flood event and relevant impacts*

Project Acronym	period	Main aim	Funding Agency
IT-FOR	2019-2022	IT-FOR project was launched in Spring 2019 and aims to develop a digital platform to support the local timber marketing. TESAF Department is involved to monitor the timber prices in Veneto region, one of the regions mostly affected by Vaia storm. As a consequence, IT-FOR can support the analysis of the timber price and the terms and conditions of the wood contract following the Vaia storm event.	AVEPA, Veneto Region

InForTrac	2018-2020	InForTrac project is a specific project for the Agordino area, in the North-West of Veneto region. The project is developing a monitoring system with satellite data on damaged forest areas. The monitoring system will be available to the VAIA - FRONT project to implement the dataset on the damaged forest.	Unione Montana Agordina, University of Padova
UOF-EST	2019-2020	The Project will develop guidelines and tools for hydrogeological risk mitigation works in the Upper Cordevole river basin	Veneto Region,
Riqualificazione morfologica del torrente Tegnàs	2019-2020	The Project aims to develop guidelines for the maintenance and integrated management of the flood-sediment-vegetation nexus in the river basin	Ministry of the Environment
PhD Project	2019-2022	Post-windthrow short-term regeneration dynamics: monitoring the effect of deadwood manipulation	University of Padova: LERH PhD School
PhD Project	2019-2022	Eco-efficiency forest operation and wood transportation logistics in complex scenarios and the rule of primary and secondary road network.	University of Padova: LERH PhD School
PhD Project	2019-2022	The Vaia flood event: observations and prediction of sediment and large wood dynamics	University of Padova: LERH PhD School

4. Implementation

4.1 Work plan — Work packages, deliverables

WP1 - Project coordination, dissemination, exploitation and communication

Objectives

The WP1 includes three main objectives: i) Project coordination that ensures a sound transdisciplinary approach and establish linkages with other running research projects on Vaia-related topics; ii) identification of the network of stakeholders and generation of the project network; iii) dissemination, exploitation and communication of project results

The Project management structure includes an Advisory Board to evaluate project progress and provide guidance

Description of work

Task 1.1: Project coordination

The Task ensures robust coordination of the project that ensures a sound transdisciplinary approach with an appropriate quality of the results. The Coordination Task is based on regular monthly meetings between the Project Coordinator and the WP leaders, and relies on an Advisory Board, which will include National as well as International experts, to evaluate project progress and provide guidance regarding future work. The Advisory Board will provide: 1) an initial feedback on the overall coherence, clearness, completeness and feasibility of the proposal; the feedback will support researcher in possibly adjusting the activities and objectives if needed at earliest stages (*ex ante* evaluation); 2) a mid-term evaluation, after 1 year, for checking whether activities and outputs are aligned with plans or whether adjustments are needed (*in itinere* evaluation); and 3) finally, an evaluation immediately after the end of the project for checking whether the outputs were consistent with the expected outputs and the planned objectives reached (*ex post* evaluation)

This Task will include also the identification of the key Project Pilot areas. The criteria for identifying and selecting the pilot areas will include, among others: severity of the damages, site-specific problems (e.g., avalanches), distribution among regions (that will allow to explore different conditions), availability of existing datasets (that will provide baselines for comparison), existing or planned research projects in the same areas (that will allow to create synergies, optimize resources and expand the level of analysis)

Task 1.2: Identification of the network of stakeholders and generation of the project network

The networking activity will be a key Task in this WP. Networking fosters communication to create an active community of European (e.g.: EFI) and international experts from academia, administration, businesses and civil society as well as forums for exchange between providers and clients of information, services and products such as planners, managers, and land users. Beyond these specific activities, communications will also addresses general audiences through broad and mass media communication channels and external communication

Task 1.3: Dissemination, exploitation and communication of project results

This Task will cover dissemination, exploitation and communication of the project results using a wide spectrum of formats and activities to trigger innovation in forest risk management

Key Dissemination measures: i) the Project will organise two Conferences (one on Tuesday October 29 for the First Anniversary of the Event, and one at the Project End). ii) Journal and conference papers; iii) Online repositories and information marketplaces for innovation data and knowledge (VAIA Observatory)

Key Communication measures. Communication activities will promote the project and provide general information on its make-up, upcoming events and findings to interested actors (identified above). A project design and a logo will ensure the recognition value of the project. The activities are as follows: i) VAIA - FRONT

website, a fully functional site by month 2. It will represent the nexus for all interested stakeholders and for communication/dissemination to the public. The website will be maintained by the Dept. TESAF after the end of the project; ii) Newsletter: A biannual newsletter will be developed and distributed among interested parties informing them of the status, current findings and upcoming events. At the beginning of the project a mailing list will be set up by inviting interested parties for newsletter subscription; iii) Flyer: A project flyer (in Italian and in English) will be developed at the beginning of the project for promotion purposes and providing general information on the project; iv) Social Media: VAIA FRONT will make use of social media for establishing channels of communication and discussion between the consortium and with stakeholders; v) Press Releases: The daily press, wide-audience and specialised magazines, local/national TVs, radios will be kept aware of important project activities and outcomes via press releases and social media. This includes promotion materials for local engagement actions

Deliverables (D) and Milestones (M) (brief description and month of delivery)

D1.1 – Identification of Project Pilot Areas (M1)

D1.2 – Project flyer (M3)

D1.2 – Newsletter 1 (M6)

D1.3 – Newsletter 2 (M12)

D1.4 – Newsletter 3 (M18)

D1.5 – Newsletter 4 (M24)

M1.1 – Website (M2)

M1.2 – Take off Project Conference (M1)

M1.3 – Finalisation of the network of Key Stakeholders (M3)

M1.4 - Mid-term Scientific Advisory Board evaluation (M13)

M1.5 – Project Final Conference (M24)

WP2 - Current approaches for forest SES risk management

Objectives

The WP provides the conceptual foundation of the VAIA - FRONT project activities and a comprehensive reference on frameworks and methodologies related to the forest Socio-Ecological Systems (SES) risk management. The WP refers to the challenges involved in the i) development of a comprehensive concept of risk assessment and management and in the ii) integration of multiple hazard sources and vulnerability characteristics

Description of work

The development of a comprehensive concept of risk assessment and management and the integration of multiple hazard sources and vulnerability characteristics will be based on the implementation of a structured review on forest SES risk management. Finally, the relevance of the framework will be ensured by comprehensive literature review, reflection of real-world activities and involvement of international experts

Task 2.1 Implementation of a structured review on forest SES risk management

The WP will implement a structured review on forest SES risk management issues including:

i) hazard analyses and assessment for past European wind storms (including forest SES impacts);
ii) assessment of forest SES vulnerability to wind storm;
iii) cascade of hazards and risks (wind, rains, floods) and interaction between different types of risks;
iv) forest ecosystem resilience to wind storm;
v) dynamics and impacts due to short/long-term expected climate variability and societal change
vi) forest SES risk communication;
vii) integrated and systemic management of storm damage at various scales.

The structured review will take advantage of databases like Forestorm (http://www.iefc.net/storm/), the Extreme Wind Storms Catalogue (http://www.europeanwindstorms.org/) and NatCatSERVICE (https://natcatservice.munichre.com), review studies like those by Gardiner et al. (2013), Stucki et al. (2014) and Gregow et al. (2017), as well as additional literature retrieved from international scientific literature databases and other sources, including specialised grey literature, such as reports developed by insurance companies both on regular basis and, in particular, on the backwash of large events. The collected literature on the different questions (i-vii) will be organized in a unique database which will be part of the Vaia Observatory (WP 5)

Task 2.2 Common terminology as a component for the project harmonisation

The Task will undertake the definition of the common terminology. This is seen as a particularly important component of the project harmonisation, given the different uses of technical terms within the broad forest SES risk community. This activity will develop a common language of risk (including uncertainty assessment, risk terminology etc.), both in the ecological and socio-economic domains

Deliverables (D) and Milestones (M) (brief description and month of delivery)

D2.1 – Common terminology glossary (M12) (Public)

D2.2 - Review on forest SES risk management (M24) (Public)

M2.1 – Literature database on forest SES risk management **(**M9) (Public)

WP3 – Framework for forest SES and vulnerability assessment

Objectives

This WP will develop a comprehensive framework for assessing the vulnerability of forest SES to wind related hazards. The WP will focus on the assessment of current susceptibility to windthrows of forest stands in NE Italy and the potential shortcoming in their provision of forest ecosystem services, by adopting a multi-scale and multi-disciplinary approach

Description of work

Task 3.1 Assessment of the vulnerability of trees and forest stands to wind forcing

This Task will be tackled considering different variables such as tree species, tree parameters, soil parameters, terrain slope, aspect and type, speed and direction of the wind. The vulnerability will be analysed firstly at single tree level by numerical methods such as *Finite Element Methods* - FEM and at forest stand level on the base of the numerical results. The obtained information will be used to implement a spatially explicit decision support system based on LiDAR data to assess the vulnerability of forest according to tree and stand characteristics and terrain morphology. The area affected by Vaia storm will be used to validate the models and the goodness of the windthrows susceptibility map. Already available models (such as ForestGale – Forest Research, UK) will be used in order to test their suitability in the Alpine context

Task 3.2 Assessment of the vulnerability of forest Ecosystem Services (ESS) to wind disturbance

The *vulnerability of forest ESS to wind-disturbance* will be assessed through a literature review (starting from WP2 results/deliverables) and by means of some specific analysis aimed at collecting data that currently are not available in the scientific literature. This information will be used for combining the windthrow susceptibility map derived from i) with a map of the preeminent forest functions derived using available methodologies (i.e. C3Alps project), in order to obtain a map showing the more critical forest stand (concerning Ecosystemt Services provision). The analysis will be tested in some municipalities and after validation will be applied on a valley scale. Particular relevance will be provided to the protective function against rockfall, shallow landslides, and snow avalanches, recreation (access to and use of trails) and biodiversity protection The aim is to provide a support for the prioritization of restoration intervention and basic data for a pilot risk assessment on some of the ecosystem services (Task 4.2)

Task 3.3 Assessment of the vulnerability of linear infrastructures to wind disturbances

The *vulnerability of linear infrastructures* (road, power-line, water-line) to wind-related forest impacts will be evaluated in this specific task, accordingly to the forest vulnerability model and the localization of linear infrastructures

Task 3.4 Assessment of the human vulnerability during storm events

This task aims to understand how people actually i) detected the potentially dangerous circumstances; ii) reacted; and iii) managed to timely adapt their routine to cope with the speed of the hazard evolution during the Vaia event. Data collection will be carried out based on online surveys to quantitatively document behavioural responses associated with the Vaia event. The data will be used to develop a multivariate statistical analysis among different variables that define the social structure, and, secondly, to estimate probabilistic models that allow segregating respondents (and hence the population of reference) in different groups/classes within which people share a similar profile in terms of behaviour and attitudes towards the catastrophic event under study

Task 3.5 New susceptibility to snow avalanches after storm events

This task has two objectives: i) to provide a methodology on data collection and model application to predict how windthrow will affect and increase risk of snow avalanche on steep mountain sites; ii) to compare different scenarios of post-disturbance intervention (salvage logging, deadwood release, building of eco-engineering structures snow nets, etc.) in affecting protection against snow avalanche release

Task 3.6 Vulnerability of the wood market to storm events

The vulnerability of the wood market to windstorms like Vaia will be addressed with regards to both (a) forest resources -in terms of potential windthrows (and their indirect effects) affecting the amount of different timber assortments - and (b) the forest-wood value chain and system, with particular reference to forest

owners, forest enterprises and the wood industry in North-Eastern Italy. In particular, the working capacity of the wood market system under ordinary conditions (number of companies, employees, equipment, technology, economic data etc.), as well as under critical conditions due to extreme events, will be explored. The impacts of windstorms on the timber market will also be explored. Data will be collected based on both primary (face to face and/or phone interviews with selected key-informants from both the public and private sectors) and secondary (scientific and grey literature, databases and other online resources) sources. Data and information from on-going projects (e.g. Life Prepair and IT-FOR) will be capitalized whenever possible

Deliverables (D) and Milestones (M) (brief description and month of delivery)

D3.1 – Report on forest vulnerability to wind disturbance (M18)

D3.2 – Forest-related socio-economic vulnerability associated to storm events (M18)

WP4 – Forest SES pilot risk assessment, management and governance

Objectives

While contributing to enhance the understanding of the role of governance models in effective risk management and the knowledge of forest-related practitioners on how to prevent and react to these types of events, the final aim of this WP is to provide a possible general preliminary integrated strategy for wind-related risks management in the North-East of Italy, to support resistance and resilience capacities of forest SES at local and regional level in case of future events

Description of work

The WP will be divided into four tasks, interconnected each other, as follows

Task 4.1 – Understanding the governance structures in relation to forest SES risk management

This task will include the analysis and description of the governance structures currently existing in the area affected by the storm. Interactions and networks both horizontal (among private and public stakeholders) and vertical (among various institutional levels) will be explored, through content analysis of key policy documents and interviews to key informants. The analysis will provide a general overview of the legal frameworks on risk management and related key issues (e.g. property rights), the current decision-making structures (actors involved, power and tasks distribution, hierarchical links) and processes (flows and direction of decisions and authoritative rights) in relation to forest SES in the whole area. A detailed analysis will be carried out for Veneto region and the municipality of the selected Pilot Area. A qualitative-based network analysis will be used for mapping actors and governance structures. Current and future global and European economic and social trends will be identified by means of literature review, and explored in terms of possible future socio-economic and institutional scenarios and their implications for forest SES risk management and communication in the target region. The main output of Task 4.1 will be a report (Milestone 4.1) describing the current governance situation and possible future scenarios of the institutional-administrative targeted context

Task 4.2 – Preliminary test of forest risk assessment in relation to key ecosystem services in the pilot area

This task will focus on: i) identifying the most appropriate risk assessment method and its implications for the risk management strategy in the area, on the basis of existing methods and approaches; ii) trying an economic estimation of damages and loss analysis associated with the Vaia storm based on the map of key ecosystem services and their changes (from WP3); iii) testing the combination of data on damages and loss with the vulnerabilities assessment (from WP3). The analysis will focus on a few key ecosystem services (namely, biodiversity, recreation, and wood production and snow avalanche susceptibility mitigation) in the selected Pilot Area. This will allow preliminarily identify and test a procedure for forest risk assessment and

communication strategies suitable for the target area and other similar areas. A mixed quantitative and qualitative approach will be used for the analysis, carrying out specific primary data collection and analysis by means of interviews to key informants and questionnaires to stakeholders (e.g. residents, tourists, policy makers, forest managers). Existing secondary data (e.g. timber prices before and after the storm) will also be used when available and needed. Various possible future scenarios, which are based on possible interventions for reducing forest SES vulnerability (from WP2 and WP3), and possible changes in the socio-economic and institutional conditions (from Task 4.1), will be considered for the analysis

Task 4.3 – Formulating technical guidelines for resistance and resilience of forest SES in the target area

Based on forest SES vulnerability (from WP3) and pilot risk assessment results in the selected Pilot Area (from Task 4.2), a set of preliminary guidelines for forest and forest resources management and planning interventions to be adopted by practitioners to strength the resistance and resilience of forest SES in the target area will be formulated. The technical guidelines will be targeted to different groups of practitioners (e.g. public forest owners, private forest owners, logging companies, civil associations, etc.). In particular, lessons learned from Vaia storm event as emerging from the empirical data that will be collected in the selected Pilot Area will be exploited and integrated in tools (e.g. technical handbooks and other appropriate communication tools) that might be useful for guiding future actions and reactions in the target as well as in other Alpine regions and contexts. The tools and methods will be designed and developed building on existing material and guides developed by other countries and sectors affected by storms in the past, but they will be adapted to the specific conditions of North-East Italy and in particular Veneto region. The main output of Task 4.3 will be a set of tools/guidelines, specific to each thematic area as identified in WP3 and target users, suggesting possible practical interventions and communication strategies to prevent or react to the effects of a storm event

Task 4.4 – Proposing a preliminary approach for integrated and systemic management of forest SES risk in the target region

Based on outputs of previous tasks, Task 4.4 will develop a general, preliminary integrated and systemic management strategy for wind-related risk of forest SES specifically suitable for the local and regional public authorities of the affected area but likely/possibly useful for other similar contexts. This will encompass ideas for financial, communication, policy and governance instruments and approaches for increasing the resistance and resilience of the forest SES in the target area. Particular attention will be given to the social preferences, attitudes and needs of both local communities/stakeholders, included policy makers, to be identified and explored through interviews to key informants (Task 4.1 and WP3). Overall recommendations for integrating risks in forest-related policies will be developed, together with solutions for reducing financial, legislative, technical and practical hindrances and improving the effectiveness and efficiency of governance. Both immediately post-event (contingency) and long-term (prevention and resilience) phases will be considered

Deliverables (D) and Milestones (M) (brief description and month of delivery)

M4.1 – Current governance and possible future scenarios of forest-related management in the target area (M12)

D4.1 – Preliminary technical guidelines for forest SES vulnerability and risk management in the target area (M18)

D4.2 – Integrated and systemic management of forest SES wind-related risk: preliminary policy and governance solutions for resistance and resilience in the target area (M24)

WP5 - The Vaia Observatory

Objectives

The objective of the VAIA observatory is to create a repository of data and tools related to the project activities The repository is an infrastructure that allows to collect, manage, and store data sets and documents, related to storms impact on forested areas. The final objective is data analysis, sharing, reporting and public engagement. This WP will manage data in the broader sense. The project will collect heterogeneous data sources and documents, from simple tables to geo-located information in raster or vector model formats, to textual documentation. Data will be shared; therefore, the objective is to create a collector that allows for different sources to provide data (e.g. uploading) and share it with other project participants and with the broader public

Description of work

This WP is divided into three tasks:

Task 5.1 – Creation of the framework for hosting the web-based infrastructure

The framework for sharing data will be created on cloud-based services, which will provide physical data storage space, access through the web and analysis capabilities. All modules used for implementation of the repository will be based on Open Source (OS) software. Most VAIA-related data are implicitly spatial, therefore the data repository itself will be based on a spatially-enabled relational database (Postgresql+PostGIS). Data will be shared through implementation in the cloud of a spatial catalogue (GeoNetwork) and through web-based services following international standards from the Open Geospatial Consortium (OGC). GeoNetwork will provide the possibility of inserting, tagging and searching VAIA-related datasets

Spatial data (e.g. damaged forest areas) will be visible on a web-gis portal that will also allow interactivity with open data from ESA's Copernicus Programme – e.g. Sentinel 1 and Sentinel 2 satellite data. This will allow researchers to cross information from the observatory with information from other available spatial data

Task 5.2 – Implementation of the interactive platform via web-gis and web robot

A collaborative WebGIS will be implemented, leveraging crowdsourced data. In practice this means a web portal where users can add information via a dedicated web robot (BOT) called TESAF4VAIA and an API – Application Programming Interface – linking an app like Telegram to a programming interface. A user will select in the WebGIS the area that was hit by Vaia storm and contribute with geolocated photos, videos, comments or other media. This will help evaluators through a distributed source of geolocated information that can be used for better understanding of degree of damage, resiliency and future renovation of vegetation

The cloud-based services are hosted by University of Padova's digital high-connectivity infrastructure, CSIA-VSIX, that already has a specific agreement with Dept. TESAF under the Hyperearths "strategic infrastructure" funding network

A last objective is to add value through linking data; therefore, this WP will also establish links from the VAIA Observatory with other data sources from related projects to create a confederated repository

Task 5.3 – Definition of Data Management Plan

A Data Management Plan (DMP) will be drafted in which the participants will outline the procedures for handling the research geospatial and non-geospatial data during the project and after the project completion. Once the project has started a first version of the DMP will be produced within 6 months. The policy of data access will follow the EU document 'Guidelines on FAIR Data Management in Horizon 2020', i.e., to make research data related to this project Findable, Accessible, Interoperable and Reusable (FAIR)

Deliverables (D) and Milestones (M) (brief description and month of delivery)

D5.1 - Data management plan (DMP) – table of data description for each WP, with approximate expected data size, storage format and access license from each of the project's WPs (M8)

D5.2 – The framework itself, with access page to the geo-catalogue (GeoNetwork, e.g. https://vaiafront.tesaf.unipd.it/geonetwork) allowing access to the project's data in spatial and non-spatial formats (e.g. respectively a WebGIS with study areas and charts with data representation) (M18)

M5.1 – A web address – to be determined e.g. https://vaia.tesaf.unipd.it - that will point to the framework access point. This will provide access to the repository (M18)

M5.2 – The web robot connected to the framework in the previous deliverable (M20)

4.2 Gantt Chart

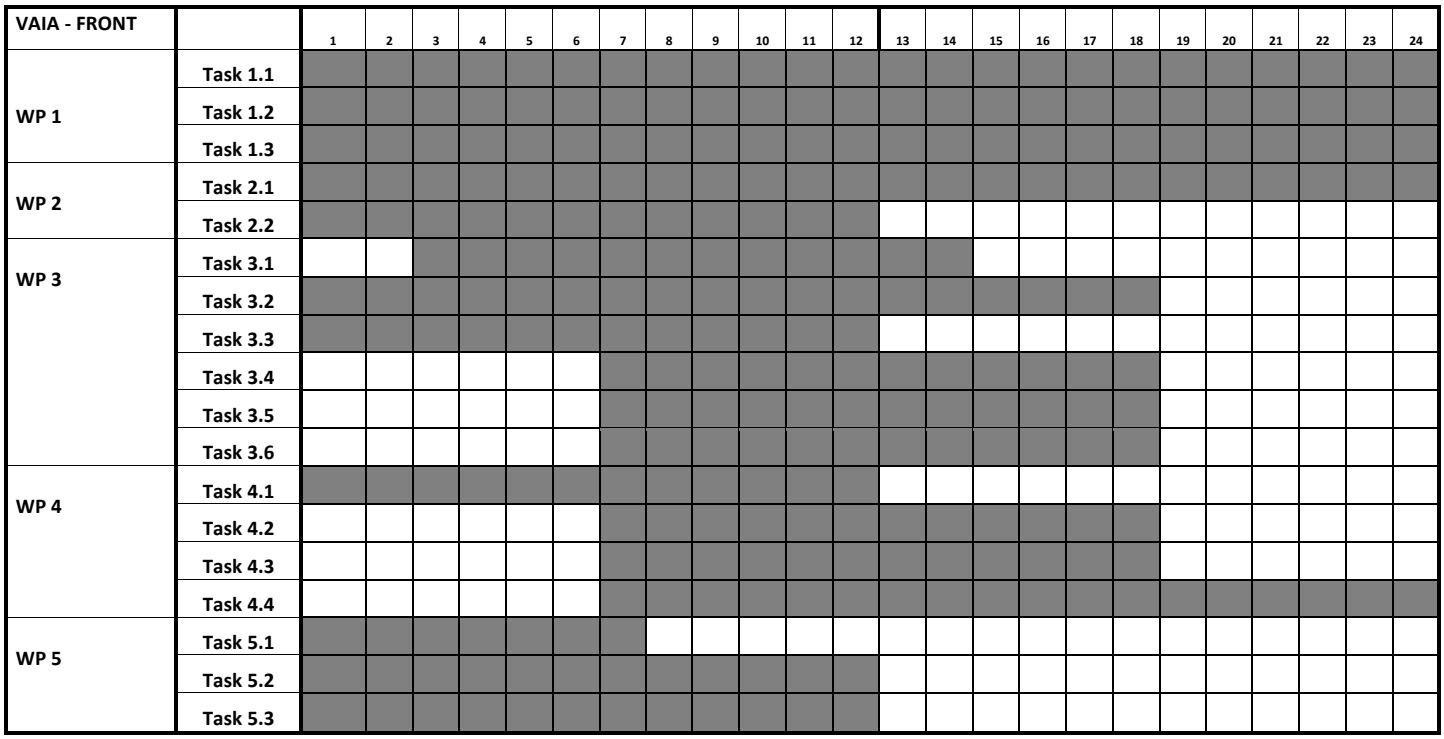

Fig. 2. *Timing of the* VAIA - FRONT *Work Packages and Tasks*

5. Budget

The total project costs for VAIA - FRONT are 153.000,00 Euro with a requested Department-funding of 115.708,00 Euro (percentage of co-funding: 32,2%). From the total costs 72% are allocated for personnel costs (funding of 4 Annual Research Grant) and 24% for other direct costs (consumables and equipment, travel costs, costs for meetings and events and costs for dissemination and communication). The remaining 4% are for a subcontract which will be used for the survey of forest risk perception. Tab. 3 below provide details of the distribution of project costs across work packages.

Tab. 3. *The VAIA_FRONT project costs*

	Personnel	**Consumables**	**Travel**	**Equipment**	**Subcontract**	**Meetings and publications**	**Total**
WP1	-		2,000			9,000	**11,000**
WP2	-		2,000			2,000	**4,000**
WP3	55,000		5,000		6,000	3,000	**69,000**
WP4	27,500		5,000			3,000	**35,500**
WP5	27,500		1,000	4,000		1,000	**33,500**
Total	**110,000**		**15,000**	**4,000**	**6,000**	**18,000**	**153,000**

6. Research Group

The VAIA - FRONT Research Group includes the following Researchers from the Department of Land, Environment, Agriculture and Forest of the University of Padova. The Group is organised to meet the challenges of the project for high-quality transdisciplinary research, involving different disciplines.

Raffaele Cavalli Full Professor. Expert in forest operation management and biomass utilization. He is currently member of the Editorial Board of Forests, European Journal of Forest Research, Croatian Journal of Forest Engineering. L'Italia Forestale e Montana, Forests e authored or co-authored 371 papers in international and national scientific journals. He coordinated the participation of the Department in several international, national and regional research projects. He coordinated one EU-funded project. He is member of advisory boards and committees of national and international associations (Federlegno Arredo, UNACOMA) and institutions (Accademia dei Georgofili, FORMEC, IUFRO)
Marco Borga Full Professor. Expert in flood risk management and forest hydrology. He is currently Editor in Chief of Journal of Hydrology (Elsevier) and member of the Editorial Board of Journal of Flood Risk Management (Wiley). He authored or co-authored 160 papers in international scientific journals, with H index equal to 45. He coordinated the participation of UNIPD in several international research projects funded by EU and other funding agencies. He coordinated three EU-funded projects, among these 'Hydro-meteorological data resources and technologies for effective flash flood forecasting – HYDRATE'.
Vincenzo D'Agostino Full Professor. Expert in mountain river dynamics and protection measures against mass movements (debris flow/flood and snow avalanches) and floods in steep areas. He authored or co-authored papers in international scientific journals on hydrology, hydraulics and river morphology (ORCID: 0000-0003-2261-9069; H index equal to 13). President of the UNIPD BSc Course in Land restoration and landscape preservation (2013-2019), and Coordinator of the Erasmus Mundus+ International Course: SUFONAMA-Sustainable Forest and Nature management (I-III edition, 2003-2019). He is currently coordinating (Dept. TESAF unit) the EU-funded project: LIFE Climate Governance and Information, Project LIFE 17 GIC/IT/000091 "BEWARE" BEtter Water-management for Advancing Resilient-communities in Europe (2018-).
Paola Gatto Associate Professor. She teaches Forestry Economics and Policy, Valuation of Ecosysem Services and Marked-based Instruments for Ecosystem Services. She has long term research experience in forest and environmental economics. Her current research activities focus on ecosystem services mapping and modelling and related design of Payment of Ecosystem Services (PES) mechanisms; analysis of farmers' and forest owners 'attitudes and perceptions into provision of ecosystem services; forest commons, community forests and analysis of their adaptation patterns and resilience; Cost estimates of Natura 2000 areas. She is author and co-author of more than 120 papers (23 ISI/Scopus).
Stefano Grigolato Associate professor. Expert on technologies applied to logging and wood transport system and on the management of forest operations. He provides thorough theoretical and practical experience in the application of GPS and GIS-based analysis on forest operation and the development of Spatial Decision Support System model on forest biomass exploitation. A key topic is the analysis of the forest road network and trails network in mountain area to support the multi-functionality accessibility of the forest. Current international scientific activity is documented in SCOPUS by 39 articles, with more than 350 citations and H-Index of 12. He has joined actively and led different national and international research and cooperation projects under the frame of Interreg projects, the 7th Framework Program and Horizon 2020.
Emanuele Lingua Associate Professor. He teaches "Natural Disturbance Ecology and Management" and "Applied Silviculture and Forest Management" at the Master Programme in Forest Science. His scientific activity is mainly focused on forest dynamics (succession, competition and facilitation mechanisms, natural disturbances), and forest management (silviculture, post-disturbance restoration), by adopting methodology inherent spatial analysis, remote sensing, and

dendroecology. He is author or co-author of more than 100 papers (41 ISI/Scopus). He has been reviewer for several international scientific Journals and Funding programs. He is Associate Editor for iForest-Biogeosciences and Forestry, Forests, and he has been AE for Dendrochronologia (2008-2018).
Francesco Marinello Assistant Professor. Since 2011 he is researcher at the University of Padova in the field of agricultural mechanics, and adjunct professor with courses on “Agricultural Mechanics”, “Applied Statistics” and adjunct professor at the University of Georgia (USA) with a course on “Precision Farming”. The scientific activity is mainly related to the study and integration of sensors and analysis of data for the improvement of agricultural practices. He published over 100 papers indexed by Scopus. He is member of the Editorial Board of Agriculture (MDPI) and Heliyon (Elsevier).
Mauro Masiero Assistant Professor. He teaches “Social Responsibility and Certification”, “Climate Change Policy” and “Rural Appraisal”. His research activities focus on forest policy and economics, including the analysis of markets for forest products and the economic assessment of ecosystem services and market-based instruments for their remuneration. He has been involved in about 30 research projects and initiatives and worked together with many national (ISPRA, CNR) and international (CIFOR, EFI, FAO, IFAD) organisations. He has published about 90 papers (peer-reviewed articles, monographs, chapters on books, etc.).
Lucio Montecchio Associate Professor. His research focuses mainly on the ecology, epidemiology, survey, diagnostics and management of tree diseases, with special emphasis on root parasites. Co-author of 4 patents; technology transfer activities are performed through the University Spinoff PAN srl (www.drp.bio). He is a core member for Pest Risk Analysis and Management at the European and Mediterranean Plant Protection Organization (EPPO), and member of the Panel on Forest Quarantine at IPPC/FAO. Author of ca. 150 technical and scientific papers and book chapters, further information is available at www.luciomontecchio.it
Davide Pettenella Full Professor. He teaches “Forest Policy and Economics”, “Social Responsibility and Certification”, “Economics” and other modules in Bachelor and MSc courses. He is the Coordinator of the Land, Environment, Resources and Health (LERH) PhD program. His research activities focus on economics and marketing of forest-based products and ecosystem services as well as forest and rural development policy. He has been involved in several research projects at both national and international level and had the responsibility of research activities within many of them. He has published more than 400 papers in the field of forest economics and wood products marketing (45 ISI/Scopus). He participates, as invited expert, to several Ministerial Committees and Boards related to forest, forest products and markets.
Francesco Pirotti Associate Professor. His research focuses on remote sensing and spatial analysis systems applied to the environmental sciences. He is in several scientific committees, national (SIFET, ASITA) and international (ISPRS). He teaches remote sensing and geographic information systems in TESAF and post-graduate courses. He is author of 90+ articles in national and international journals; 82 of which peer-reviewed scientific journals. Editorial Activity: Chief Editor of Open Geospatial Data, Software and Standards (Springer - from 2019). Editorial Board for the following Journals: ISPRS Journal of Photogrammetry and Remote Sensing (Elsevier) [2012-2016], Remote Sensing Applications: Society and Environment (Elsevier) , Remote Sensing (MDPI), Geomatics Natural Hazards and Risk (Taylor and Francis), Applied Geomatics (Springer), Bollettino SIFET (Società Italiana di Fotogrammetria e Topografia)
Laura Secco Associate Professor. She teaches “Forest Policy, Governance and Conflict Management” at the Forest Science MSc course, and “Social and Environmental Responsibility” at the Local Development MSc course. Her scientific activity is focused on forest and natural resources governance, forest policy, rural development, social-environmental responsibility, social innovation and its impact evaluation. She has an extensive research experience, participating in several international and national projects. Currently, she is involved in three Horizon 2020 projects: scientific coordinator for UNIPD in SIMRA; member of the research team in ALTERFOR

and SINCERE. She acts as peer-reviewer in many international scientific Journals. She published more than 100 scientific papers (34 ISI/Scopus) and research reports.
Tommaso Sitzia Associate Professor. Forest ecologist. His research interests are in the interactions between the management and use of forest and semi-natural habitats and biodiversity conservation. He is expert in planning of protected areas and forests, and in environmental impact assessment. His field abilities are in vascular plant surveys, vegetation mapping, and grouse sighting. He runs projects across a range or ecosystems, with a particular focus on the temperate ecosystems of central and southern Europe. He is author and co-author of more than 80 papers (46 ISI/Scopus), with H-index equal to 15.
Tiziano Tempesta - Full Professor. He teaches "Land and Environmental Resources Evaluation" and "Farmland Appraisal". His scientific activity is mainly focused on the following field of research: Natural areas management and planning; Monetary valuation of environmental benefits and damages (e.g. wildlife, landscape, forests, water, etc.); Rural Tourism Economics; Landscape evaluation and planning. He is author or coauthor of more than 200 papers (29 ISI/Scopus). He has been reviewer for several international scientific Journals and is member of the Scientific Committee of the Journals Aestimun and the Italian Review of Agricultural Economics.
Mara Thiene Full Professor. She teaches "Environmental Appraisal", "Environmental Resource Valuation" and "Industry and community project" in MSc courses. She has extensive research experience in environmental economics, and participated in several international and national research projects. Her main research is on environmental resource valuation, food choice, agricultural and forest economics, energy economics, with a focus on quantitative approaches (discrete choice models). She is author and co-author of more than 120 papers (40 ISI/Scopus). She has been reviewer for several international scientific Journals and is associate editor of the Australian Journal of Agricultural and Resource Economics and in the editorial board of European Review of Agricultural Economics.
Daniel Vecchiato – Assistant Professor. He teaches "Intermediate microeconomics". His scientific activity is mainly focused on Environmental economics, resource economics, discrete-choice modelling, non-market valuation, agribusiness, consumer demand, energy economics, landscape valuation, ecosystem services valuation. He is author or co-author of 31 papers. He has been reviewer for several international scientific Journals.

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