PROJECT INFORMATION

Project title: *forest@risk (Climate-driven risks and adaptation measures for European forests)*

Project ID: 131

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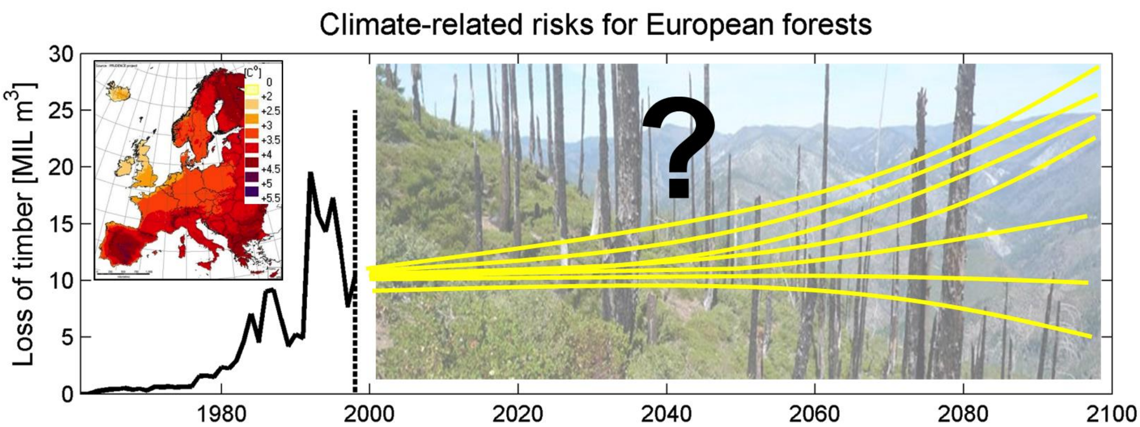
PROJECT DESCRIPTION

Abstract

European forests provide a set of fundamental services that contribute to climate mitigation and human well-being. On the other hand, forests are vulnerable systems because the long life-span of trees limits the possibility of a rapid adaptation to drastic environmental changes. Climate-driven hazards on forests, such as drought, wildfire and insect outbreaks, are expected to rise drastically in view of global warming. As a result, key forest services, such as carbon sequestration and supply of wood products, could be seriously affected in the near future. Despite the relevance and urgency of the issue, little is known about the upcoming risks of multiple climate-related hazards on European forests. To fill this knowledge gap we aim to investigate the evolution of forest disturbances under various climate scenarios. For this scope we will model the long-term changes in species composition, whereas forest vulnerability will be assessed with satellite observations and records of disturbances. The integration of these elements will produce a range of plausible risk estimates to support the definition of effective adaptation strategies, with the goal of increasing the resilience and long-term stability of these fundamental elements of the European landscape.



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Background

European forests cover more than 2 million km^2 or 33% of the land surface[1] and provide a set of ecosystem services that contribute to human well-being and climate mitigation. The average annual sequestration of carbon in forest biomass reached 414 million tons CO_2 in the EU-28 between 2005 and 2015, corresponding to about 9% of the net greenhouse gas emissions. From an economic perspective, the total gross value added in the forest sector in Europe in 2010 amounted to EUR 103 billion[1]. Natural disturbances are large pulses of tree mortality that originate from climate-related abiotic and biotic agents such as wildfire, insect outbreaks or strong winds[2]. They represent serious peril for maintaining healthy and productive forests. In the last decade, about 3.1% of Europe's forests was damaged by disturbances largely attributed to climate change[1]. Impacts associated to these forest losses are expected to rise drastically in view of global warming and key forest ecosystem services, such as carbon sequestration and supply of wood products, could be seriously affected in the near future[2–4]. Examples from other countries, like Canada, show that disturbances driven by the rapidly changing climate may substantially alter the state of forests to the point that they become carbon sources instead of carbon sinks[5].

Understanding forest risks is of particular concern for forest management because the long life-span of trees limits the possibility of a rapid adaptation to environmental changes. For this reason adaptation strategies and measures in the forest sector need to be planned well in advance, because the forests planted today will be exposed to the future climate conditions for several decades, often even more than 100 years.

Quantifying the future risks for forest ecosystem services due to natural disturbances requires the integration of hazard, exposure and vulnerability components (Figure 1). Hazard represents the agent affecting the forest ecosystems; exposure refers to the distribution of forest ecosystem services potentially prone to a hazard; and vulnerability expresses the degree to which an exposed forest system is affected by a hazard. Changes in both the climate system and socio-economic processes may substantially affect hazards, exposure and vulnerability. The substantial knowledge and methodological gaps reported below have hampered so far a quantitative assessment of the effects of future natural disturbances of forest ecosystems.

HAZARD: unsatisfactory representation of natural disturbances in land models. The current generation of land models incorporates a mechanistic representation of biogeochemical and biophysical processes in coupled climate-vegetation systems[6]. However, models do not include a mechanistic representation of natural disturbances and the effects of extreme climate events, thus they can only partially predict the effects of climate hazards on forests[7]. Furthermore, their level of aggregation in plant functional types does not allow capturing tree species-scale processes relevant for impact assessments.

EXPOSURE: poor integration of human and natural drivers in forest species projections. Future forest ecosystems services depend on where individual tree species will grow. Projections of future forest composition have been provided by employing environmental predictors into statistical models to explain the presence/absence of individual tree species[8]. However, these methods do not account for the pace at which ecosystems will migrate following their natural ecological niches, neither incorporate socio-economic processes, such as forest management practices.

VULNERABILITY: limited availability of data and incomplete understanding of forest vulnerability. Despite the recent efforts in developing shared and standardized databases of observed forest disturbances, the coarse resolution at which data are usually recorded (e.g., country level) strongly masks the spatial variability of the phenomena. This has inevitably limited the quantitative evaluation of tree species vulnerability to climate-related hazards. To date, no analytical functions reflecting the degree of susceptibility of trees have been documented in literature[10]. The few pioneering studies on the topic have not been supported by empirical evidences[11].

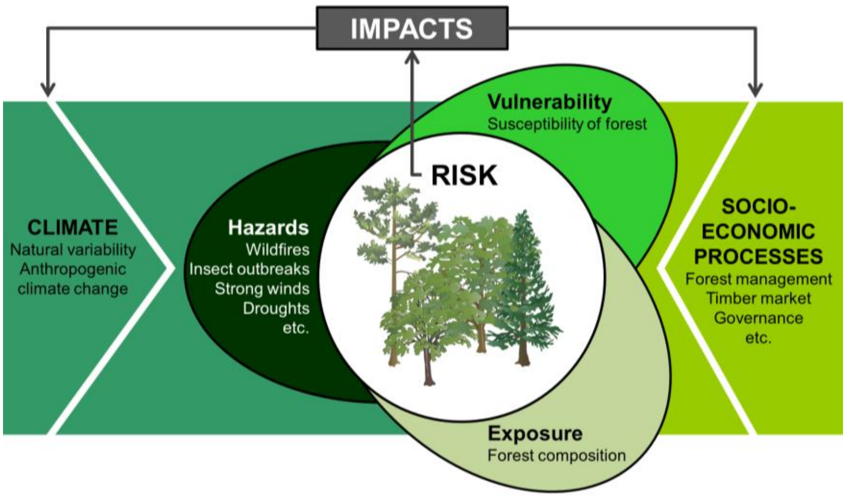


Figure 1. Risk of climate-related impacts results from the integration of climate-related hazards with the vulnerability and exposure of natural systems. Changes in both the climate system (left) and socio-economic processes (right) are drivers of hazards,

exposure and vulnerability. Adapted from ref. ([12]).

Rationale

Understanding and quantifying future risks is crucial for planning suitable adaptation measures to safeguard Europe's forests. For this purpose we propose an innovative methodological framework to synergistically exploit large datasets of satellite observation of the Earth surface with historical databases of forest status and disturbances and high resolution land-climate modelling.

This approach will be 1) **quantitative**, as it would provide an assessment of climate impacts on forest carbon storage and the economic damages to forest sector, 2) **society-oriented**, as risk assessment would focus on ecosystem services that are particular relevant for human well-being and 3) **innovative** since it will merge and integrate knowledge from different scientific domains.

In addition to being a very relevant issue in climate science[12], understanding and quantifying the potential impacts of climate on forests is extremely important for a series of EU policies that rely on a viable and sustainable forest sector. In particular:

- **Climate mitigation policy (UNFCCC COP21)**. The key role of forests in the climate system and the need to account for forest carbon uptakes in mitigation plans are highlighted in the Paris agreement (art. 5.1 and 5.2). The European Parliament is currently discussing new legislation on this sector to define the rules for accountability and reporting carbon budgets of the forest sector and the EC relies on the future carbon uptake in EU forests to meet the reduction target of CO_2 emissions. These policies heavily rely on a stable carbon uptake in the forest sector[13].
- **EU Climate Adaptation Strategy.** EU adaptation actions include mainstreaming of climate change (mitigation and adaptation) into EU sector policies and funds, including forestry. A key goal of the EU Adaptation Strategy is to promote better informed decision-making by addressing gaps in knowledge about climate impacts and adaptation.
- **Forestry and Bioeconomy**. Bioeconomy is increasingly recognized at EU level as a sustainable way to deal with climate change issues by increasing the use of biological resources to produce food, feed and energy[14]. The sustainable use of forest resources in view of global warming is an important challenge that the bioeconomy policies have to face.
- **EU Forest Strategy.** The forest sector is interested in an increasing number of EU policies, such as the energy and climate policy. At present, EU coordination on the adaptation policies in the forest sector is still lacking and the initiative is in the hand of Member States that are proceeding at different speeds. In order to have a coordinated strategy on the management of climate risks for forests it is essential to

produce an EU-wide assessment of the current and future potential climate impacts on this sector.

Objectives and expected impact

The project aims **to quantify the potential losses in carbon storage and economic value of European forests due to climate-related hazards.** For this purpose current and future climate impacts on forests will be explored at the level of individual tree species for the definition of optimal adaptation strategies and risk reduction measures.

The complexity of the problem requires the integration of different scientific disciplines across physical, social and economic fields in a comprehensive assessment framework for appraising climate-related risks on forest under future climates.

Four main challenges will drive the research within the project.

1. **Hazards**: Understanding how multiple climate hazards relevant for European forests will evolve during the twenty-first century. A consistent assessment of multiple climate-related hazards accounting for possible regional variations in intensity and frequency from present up to the year 2100 will be explored to identify the forested areas more exposed to climate change. The hazard datasets will provide useful input for the development of multi-hazard risk scenarios with potential applications to various ecosystem services (e.g., pollution control, soil protection and formation, nutrients cycling, biodiversity protection, water regulation and supply, recreation) in addition to the carbon sequestration and commercial forestry considered in this project.
2. **Exposure**: Quantifying current and future forest carbon storage and the corresponding economic value for the main tree species of Europe. Outcomes of this activity will provide a new archive of present and future tree species distributions and corresponding forest products that will support a spatially detailed assessment of the forest exposure to climate risks. These products will constitute a highly valuable asset to fill the current data gaps existing in many operational activities at the JRC related with the forest sector. Furthermore, it could potentially represent an added-value product to the current portfolio of the Global Land Service of the Copernicus programme.
3. **Vulnerability**: Determining the forest vulnerability to climate-related hazards. We will establish a set of vulnerability functions of forests to climate-related hazards based on the synergic use of satellite vegetation data and disturbance databases. Output of this exercise will be essential to describe the degree at which forests are affected when exposed to natural pressures and climate change. This activity may produce noteworthy results for the scientific community, as damage functions have not been previously explored in the forest sector, and may open a new line of research in the field of process-modelling of forest disturbances and EO data synergy.
4. **Risk assessment**: Assessing the impacts on the carbon budget and economic values European forests due to climate-related hazards. We will integrate hazard, exposure and vulnerability within a prognostic framework to translate modelled impacts into cost figures. Resulting risk projections, expressed in terms of expected carbon storage losses and monetary damages, will be analysed accordingly to a range of forest management scenarios to assess their potential effectiveness in terms of climate adaptation. The methodology could in principle be employed for the risk assessment of different ecosystem services, and may thus expand the JRC expertise

on assessing the potential impacts of climate change on ecosystems other than forests.

Scientific novelty of the project and expected progress beyond the state-of-the-art

Our contribution will provide a comprehensive assessment of climate-related risks for European forests until the year 2100. For this purpose, we will develop a novel methodology that combines satellite observation of the Earth surface and climate-related disturbance records with a set of climatic hazard and ecosystem service projections. Expected impacts on forests are quantified in terms of carbon storage losses and direct economic damages to the forest sector.

We believe that our data-model integration approach adds significant value in the following ways:

1. We will predict how the most harmful climate-related pressures/hazards for forests (e.g., heatwaves, droughts, wildfires, windstorms, insect outbreaks) will develop in space and time in Europe in view of global warming. *Previous assessments of forest disturbances focused mostly on the variations on average climate changes*.
2. We will develop a modeling platform to derive high-resolution projections of carbon storage allocated in forest tree species and the economic value of the corresponding biomass. The analysis will be based on projected tree species distributions, accounting for climate and forest management practices and observational-based estimates of ecosystem migration rates. *Previous studies focusing on mapping tree species distribution have used only climate and topographic predictors. Current projections of carbon storage are generated at the coarse spatial resolution provided by land models, while information on the present and future economic value of forests is completely missing*.
3. We will derive analytical functions of forests vulnerability accounting for diverse observation-based susceptibility factors including: the typology of ecosystem service considered (e.g., carbon storage, economic value), the nature of the disturbance (e.g., wildfires, windstorms, and inset outbreaks) and its intensity, the socio-economic context. *Vulnerability of forest ecosystems documented in literature is mostly descriptive and qualitative.*
4. We will quantify the impacts of climate-related hazards on carbon storage and economic value of European forests at a spatial and temporal resolution useful to the development of future forest policy and management. *In previous assessments the impacts on the carbon storage have been provided only at country level up to 2030, whereas the economic consequences have never been quantified*.

Why should the research be carried out as exploratory research and not in the framework of institutional work?

The level of novelty and innovation in the methodology is particularly high since it foresees the combined analysis of information streams of different origin in a novel and previously unexplored way. In particular satellite retrievals of vegetation properties and surface observations of forest composition and disturbances will be merged to derive the climatic characteristic of the habitat of the main forest tree species and to quantify the climate sensitivity and vulnerability of the various forest ecosystems. Empirical relations found for the observational period will be propagated to future scenarios accounting for global warming and alternative forest management pathways.

This topic has never been investigated with such an holistic approach and therefore it is appropriate to test the approach in an exploratory project before proposing it to partner DGs via the institutional work program.

Why should the JRC carry out the project?

JRC should carry out this activity for the following reasons:

- JRC holds the unique combination of knowhow required in the various domains of the study, namely remote sensing of vegetation, land based forest information systems, high resolution climate hazard modelling and climate risk assessments.
- JRC is the only research institution that has access to some specific datasets required for the study and in particular to the plot level data of national forest inventories for EU28 countries.
- There is a broad interest in this scientific domain from at least three DGs (AGRI, CLIMA, ENV) since this study may lead to important development in areas where the EC is currently asked to provide inputs for new legislation or for the development of the EU strategy (e.g. development of the forest strategy; development of adaptation strategy for ecosystems; new legislation on land-based mitigation, etc.).
- On several issues related to forestry at present the initiatives are taken at national level and a EU wide perspective is missing. Given the EU-wide interest, this activity would be less credible if performed by a specific Member State.

Work to be carried out, research methods/techniques, and list of expected deliverables.

a) Description of the work plan and deliverables

We will employ the risk framework proposed by the IPCC[12] (Figure 1) and define impacts on forests, expressed in terms of carbon and economic losses, as a multiplicative function of hazard (H), exposure (E), and forest vulnerability (V): R=H·E·V. Each of the risk components, visually represented in Figure 2 by a different color, is detailed in the following WPs.

WP1 HAZARD (H): Development of a consistent set of projections of climate-related hazards for European forests. *Lead E1 (Feyen), contributions from D1 (Beck)*
Task 1.1. Selection of climate related-hazards. The most harmful natural pressures/hazards for European forests will be selected based on literature review, and a correlation analysis between forest disturbance (e.g., EFI-DFDE, EFFIS) and weather observations (E-OBS). The selection will include primary pressures, such as wildfires, windstorms, insect outbreaks, plus other climate hazards, such as droughts and heatwaves which may trigger or intensify the former ones.

Task 1.2. Projections of climate related pressures/hazards. Time series of climate-related pressures/hazards will be generated for the present and future scenarios using an ensemble of high resolution regional climate simulations (e.g., EURO-CORDEX) under different Representative Concentration Pathways (RCPs). Quantification of the uncertainty of hazard projections will be assessed.

- *Deliverable 1.1.* High-resolution dataset of current and future climate-related hazards for European forests.
- *Deliverable 1.2.* Technical report describing the methodological approaches implemented.
- *Deliverable 1.3.* Scientific paper on projections of climate-related hazards to Europe's forests.

WP2 EXPOSURE (E): Mapping current and future tree species distribution and forest ecosystem services. *Lead D1 (Beck) contributions from D1 (Cescatti)*

Task 2.1. Processing of environmental drivers of forest distribution. Collection and harmonization of average climate conditions (e.g., precipitation, temperature) (e.g., EURO-CORDEX, E-OBS) and soil/topography information (e.g., ESDAC, EU-DEM) for present and future time slices (RCP emission scenarios).

Task 2.2. Processing of forest tree species migration rates. Collection and harmonization of forest tree species migration rates based on observational-based data and proxy documented in previous studies[15].

Task 2.3. Designing of alternative future forest management strategies. Future forest management storylines will be hypothesized. Scenarios will be consistent with projections of climate change used along the project. Examples: forest regeneration, tending and thinning, harvesting modalities[10].

Task 2.4. Projections of tree species distribution. High-resolution modelling of forest tree species distribution based on species distribution models (SDMs). SDMs will predict species ranges with the environmental drivers selected in Task 2.1.-2.3. as predictors through regression and machine learning methods calibrated on current forest distribution (e.g., EU-Forest). Projections of tree species distribution will be provided under different RCPs and forest management scenarios expanding previous studies performed at EU level[16].

Task 2.5. Projections of forest ecosystem services. Projections of forest carbon and timber based on large-scale forest simulation models forced by climate scenarios used along the project and forest distribution generated from Task 2.4. Spatially aggregated results will be downscaled based on high-resolution forest distribution. Quantification of the uncertainty introduced by the modelling exercise will be assessed.

- *Deliverable 2.1.* High-resolution dataset of current and future tree species distribution.
- *Deliverable 2.2.* High-resolution dataset of current and future carbon storage and forest economic value.
- *Deliverable 2.3.* Technical report describing the methodological approaches implemented.
- *Deliverable 2.4.* Scientific paper on projections of tree species distribution in Europe in view of climate change and different forest management strategies.

WP3 VULNERABILITY (V): Retrieval of forest vulnerability to climate-related hazards.

Lead D1 (Cescatti), contributions from E1 (Feyen)

Task 3.1. Collection of remote sensing data of vegetation structure. Long-term remote sensing data of vegetation structure (e.g., leaf area index) will be collected from multiple sensors (e.g. AVHRR, MODIS, COPERNICUS) covering the present climate period.

Task 3.2. Change detection analysis. Changes in vegetation structure before and after a hazardous event will be derived from satellite remote sensing data of vegetation properties. The timing, location and intensity of the hazardous event will be derived from Task 1.1. Changes will be expressed as the ratio of vegetation loss and express the degree to which the given area (pixel) has been affected (ranging between 0, no damage, and 1, total destruction) by the given hazard intensity. For wildfires such information is already systematized within a dedicated database (e.g., EFFIS).

Task 3.3. Retrieval of vulnerability functions. Identification/calibration/validation of vulnerability functions linking the forest losses analyzed in Task 3.2. and the intensity of the hazard that has caused the change in vegetation. Country-scale forest losses recorded in databases of natural disturbances (e.g., EFI-DFDE) will be also integrated in this analysis to maximize the complementary information gathered from multiple sources. For each climate-related hazard and tree species considered vulnerability functions will be derived per country in order to account for the different socio-economic contexts. Quantification of the uncertainty introduced by the modelling exercise will be assessed.

- *Deliverable 3.1.* Set of vulnerability functions defined for different tree species, hazards, ecosystem services and socio-economic contexts.
- *Deliverable 3.2.* Technical report describing the methodological approaches implemented.

WP4 RISK (R): Risk integration and uncertainty propagation. *Lead D1 (Cescatti)*

Task 4.1. Projections of single- and multi-hazard risks. Losses in carbon and economic value of forests due to climate-related hazards will be quantified as a multiplicative function of hazard (Task 1.2), exposure (Task 2.5.) and vulnerability (Task 3.3.): $R=H \cdot E \cdot V$. Risks will be expressed as expected annual damages and separately calculated for each hazard, ecosystem service, climate realization, RCP scenario, forest management strategy. The overall climate impact will be computed as the sum of the single-hazard impacts obtained under common climate configuration. All the uncertainty sources (Task 1.2., Task 2.5. and Task 3.3.) will be diagnosed and propagated into the risk integration to quantify their marginal contribution and assess the robustness of the resulting signal.

Task 4.2. Assessment of climate adaptation options. Results from Task 4.1. will be evaluated with respect to the effectiveness of climate adaptation options as implemented by alternative forest management strategies (Task 2.3.).

- *Deliverable 4.1.* High-resolution dataset of current and future carbon storage losses and economic damages due to climate hazards to European forests (per hazard type, RCPs scenario, climate configuration, forest management scenario).
- *Deliverable 4.2.* Technical report describing the methodological approaches implemented.

WP5 Compilation of the final report. *Lead D1 (Cescatti), contributions from D1 (Beck) and E1 (Feyen)*

- *Deliverable 5.1.* Final report summarizing the main results from the project.
- *Deliverable 5.2.* Scientific paper of the risks and adaptation strategies to European forests under global changes

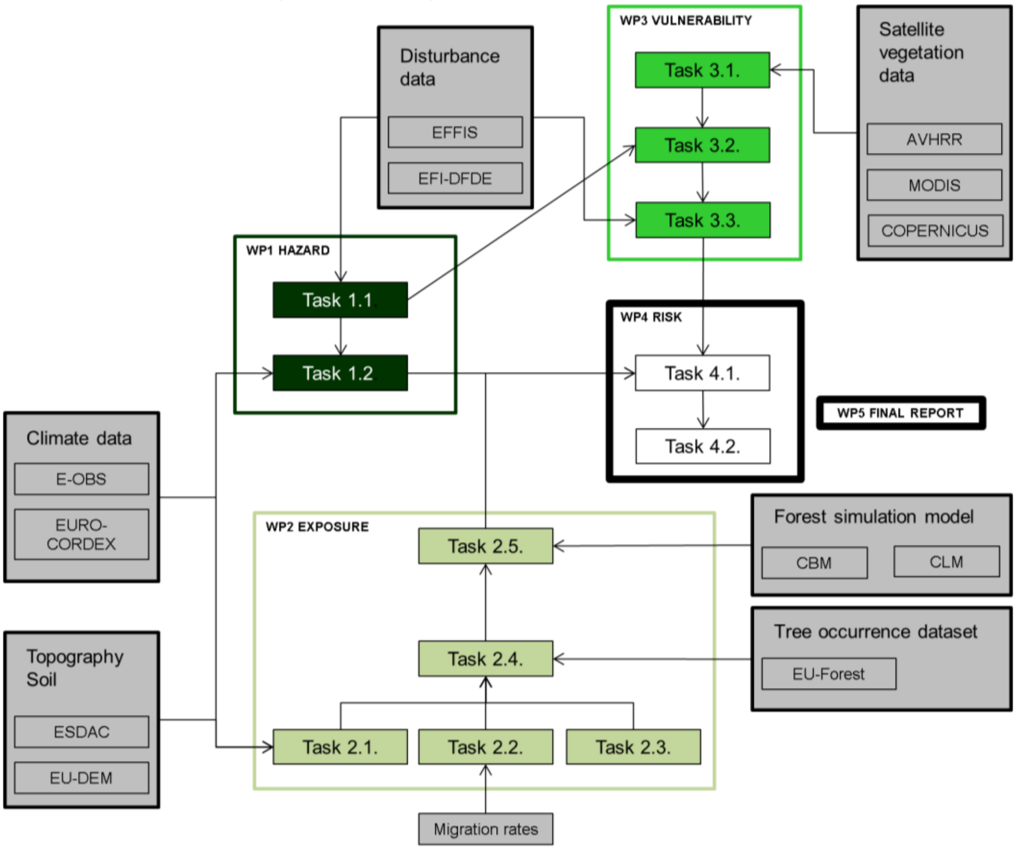


Figure 2. Schematic overview of the methodological approach. Potential datasets and tools to be used in the project are labelled in gray boxes.

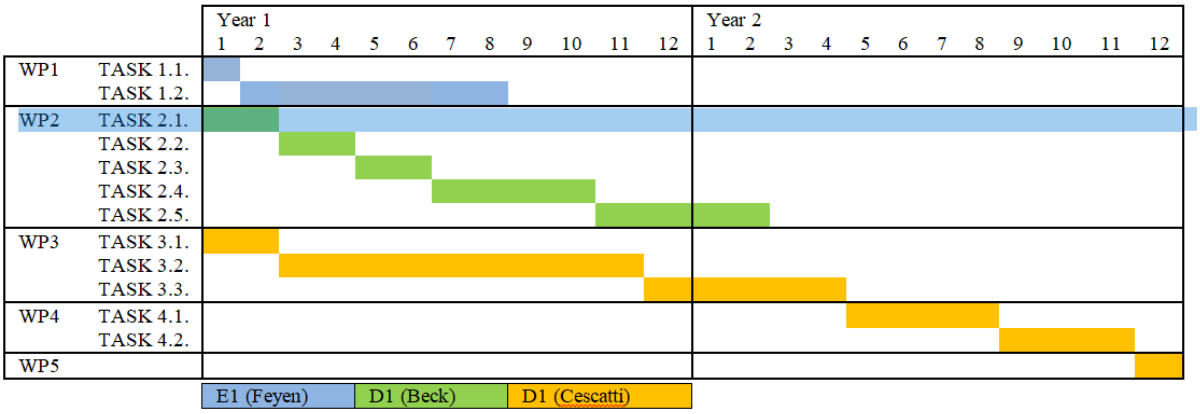
b) Risks and contingency plans

The proposed project properly addresses the feasibility issues in terms of scientific expertise. The research team presents complementary competences that are essential for finalizing the project. The extensive use of in-house database and tools (e.g., EURO-CORDEX, EU-Forest, EFFIS) will represent a further asset in terms of availability of ready-to-use data. Specific team's competences on the use of the HPC cluster available at the JRC-Ispra will allow for the execution of computational intensive tasks for data analysis and computer modelling. Nevertheless, the project relies on the access to external data, whose reliability and level of processing will have to be evaluated. The following critical points have identified a priori as potential concerns:

- Spatial, temporal and thematic accuracy of disturbance observations. The EFFIS forest-fire database is produced at the JRC, and its' accuracy is well-known, and sufficient for the proposed research. For data on biotic disturbances, we will rely primarily on the Database on Forest Disturbance in Europe (DFDE) maintained by EFI, an institute with which the JRC has ongoing collaborations. Should the DFDE not contain sufficiently accurate data, we will gather the needed data through a framework contract with the National Forest Inventories that is currently being procured. Furthermore, extensive spatial data of vegetation losses due to natural disturbances will be derived from satellite data and will provide complementary information to disturbance databases.
- The reliability of the specialization of the migration rates obtained from previous studies can be not sufficient to fulfill the requirements of the proposed Task 2.2. In such case, we will assume no forest migration over the considered temporal period. Given the presumably minor role of natural dispersal compared to forest management practices, results should not be significantly affected by this approximation.
- An additional risk comes from the availability of human resource. Out of the total amount of staff resources needed (69 person months PM in two years), there will be the need to recruit staff for 48 PM as the workload cannot be completed with existing resources. The recruitment of additional staff is therefore a pre-requisite for the feasibility *forest@risk*.

c) Work plan schedule, resources and dates of delivery

The GANTT diagram below illustrates the work plan schedule, the duration and links of the tasks and the time of delivery for the different deliverables. *forest@risk* will make use of a total of 69 PM of staff resources.



Brief description of the scientific background of the team members

JRC-D1 Bioeconomy

Alessandro Cescatti will coordinate the project. He holds a degree in forest science and a PhD in forest ecology (University of Padova, Italy). In the last decade he has been working on the combined use of land models and remote sensing observations to investigate the interactions between climate and vegetation at different spatial and temporal scales. He has a broad publication record in the field of plant ecology, terrestrial biogeochemistry and climate change science.

Bright R. M., Davin E., O'Halloran T., Pongratz J., Zhao K. and **Cescatti A**. (2017). Local temperature response to land cover and management change driven by non-radiative processes. Nature Climate Change DOI 10.1038/nclimate3250.

Alkama, R., **Cescatti, A**., 2016. Biophysical climate impacts of recent changes in global forest cover. Science 351, 600–604. DOI 10.1126/science.aac8083

Carvalhais, N., Forkel, M., Khomik, M., Bellarby, J., Jung, M., Migliavacca, M., Mingquan, M., Saatchi, S., Santoro, M., Thurner, M., Weber, U., Ahrens, B., Beer, C., **Cescatti, A**., Randerson, J.T., Reichstein, M., (2014), Global covariation of carbon turnover times with climate in terrestrial ecosystems. Nature 514, 213–217. DOI 10.1038/nature13731

Pieter Beck is an ecologist who specializes in the remote sensing and modelling of vegetation, particularly in forests and at higher northern latitudes. He studies the effects that disturbance and climate have on the phenology, distribution, and carbon dynamics of vegetation as well as the associated land-atmosphere feedbacks. He holds a doctoral degree from the University of Tromsø (Norway) and worked at the Woods Hole Research Center in Massachusetts (USA) prior to joining the JRC in December 2013. Pieter was a contributor to the European Atlas of Forest Tree Species, and, since the beginning of 2017, leads JRC's research group on forest information in Europe (FISE APPS, CanHeMon and XF-ACTORS work package). Recently, his research is expanding to include biotic disturbance agents that are of particular concern to the EU.

Beck, P.S., Atzberger, C., Høgda, K.A., Johansen, B., and Skidmore, A.K. (2006). Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. Remote Sensing of Environment *100*, 321–334.

Beck, P.S., Goetz, S.J., Mack, M.C., Alexander, H.D., Jin, Y., Randerson, J.T., and Loranty, M. (2011a). The impacts and implications of an intensifying fire regime on Alaskan boreal forest composition and albedo. Global Change Biology *17*, 2853–2866.

Beck, P.S., Juday, G.P., Alix, C., Barber, V.A., Winslow, S.E., Sousa, E.E., Heiser, P., Herriges, J.D., and Goetz, S.J. (2011b). Changes in forest productivity across Alaska consistent with biome shift. Ecology Letters *14*, 373–379.

Giovanni Forzieri has a broad expertise in monitoring the state of vegetation with remote sensing to investigate climate driven dynamics in ecosystem status. Recently he was involved in multi-hazard assessment of climate-risks in Europe.

Forzieri, **G.**, Feyen, L., Russo, S., Vousdoukas, M., Alfieri, L., Outten, S., Migliavacca, M., Bianchi, A., Rojas, R., Cid, A., 2016. Multi-hazard assessment in Europe under climate change. Clim. Change 1–15.

Forzieri, G., Feyen, L., Cescatti, A., Vivoni, E.R., 2014. Spatial and temporal variations in ecosystem response to monsoon precipitation variability in southwestern North America. J. Geophys. Res. Biogeosciences 119, 1999–2017.

Forzieri, G., Castelli, F., Vivoni, E.R., 2011. Vegetation Dynamics within the North American Monsoon Region. J. Clim. 24, 1763–1783.

JRC-E1 Disaster Risk Management

Luc Feyen is an expert in the field of climate change impacts and adaptation. He holds a degree in environmental engineering (University of Leuven, Belgium) and a PhD in hydrology (University of Brussels, Belgium). He has worked mostly on weather-driven hazards and their impacts. He has participated in several international projects (e.g., ClimateCost, IMPACT2C, ENHANCE, HELIX) on the impact of climate change. He led the JRC CCMFF (Resilience of large investments and critical infrastructures in Europe to climate change) project and coordinates the JRC PESETA studies. He has an extensive publication record in academic literature on climate change impacts, including damages and economic losses from extreme weather.

Mentaschi, L., Vousdoukas, M.I., Voukouvalas, E., Dosio, A., **Feyen, L**., 2017. Global changes of extreme coastal wave energy fluxes triggered by intensified teleconnection patterns. Geophysical Research Letters, 44, doi:10.1002/2016GL072488.

Vousdoukas, M.I., Mentaschi, L., Voukouvalas, E., Verlaan, M., **Feyen, L**., 2017. Extreme sea levels on the rise along Europe's coasts. Earth's Future, 5, doi:10.1002/2016EF000505.

Alfieri, L., Bisselink, B., Dottori, F., Naumann, G., de Roo, A., Salamon, P., Wyser, K., **Feyen, L**., 2017. Global projections of river flood risk in a warmer world. Earth's Future, 5, 171–182, doi:10.1002/2016EF000485.

Name of the institutional project(s) and/or cluster(s) to which the research proposal is linked and a brief description of the nature of the link

The project is link to the institutional project "Agriculture, Forestry and Climate Change" to which it will contribute by providing an assessment of the potential climate change impacts on the future carbon budget of the European forest sector. The project is related also to the project BIOECONOMY that has the objective to assess the current and future availability of biomass to support the development of the bioeconomy in EU. To date within the BIOECONOMY project the potential climate risks on the future supply of biomass have not been addressed. *forest@risk* will therefore integrate the project on this important aspect. In addition, the project will complement the ADAPTATION (Institutional) and PESETA VI (AA DG CLIMA) projects by filling the existing knowledge gap of climate impacts on ecosystems.

forest@risk will benefit from a close interaction with these projects by implementing a common climate risk framework including scenarios of climate hazards.

Possible follow-up (e.g. competitive projects) and collaborations, including beyond the JRC

This project could open a new area of research at JRC on the interaction between climate and vegetation that might further develop within the framework of the Memorandum of Understanding between JRC and the National Center for Atmospheric Research (NCAR, Boulder Colorado).

Given the scientific relevance of the topic, the experience gained with the project may also lead to the application to H2020 call in collaboration with other EU research institutions. Concerning long-term initiatives ongoing at JRC, this activity may feed into the Bioeconomy Knowledge Centre, the PESETA studies on the issue of ecosystem adaptation to climate change and into the future development of the BIOECONOMY project on the future supply of forest biomass under climate change.

Resources: specific credits and staff allocation

14.a. Specific costs and allocated credits specified per unit

Most of the work foreseen in the project will be conducted with data already available at JRC and remote sensing observations that are freely available. We therefore don't foresee the use of specific credits.

14.b. Staff allocation in person months

Project coordinator Alessandro Cescatti (D01) PM4

Staff 1: Pieter Beck	*(D1)*	*PM2*	*available in the JRC: yes*	*to be recruited: no*
Staff 2: Luc Feyen	*(E1)*	*PM2*	*available in the JRC: yes*	*to be recruited: no*
Staff 3: Giovanni Forzieri	*(D1)*	*PM3*	*available in the JRC: yes*	*to be recruited: no*
Staff 4: Achille Mauri	*(D1)*	*PM3*	*available in the JRC: yes*	*to be recruited: no*
Staff 5: Giovanni Strona	*(D1)*	*PM2*	*available in the JRC: yes*	*to be recruited: no*
Staff 6: Gregory Duveiller	*(D1)*	*PM2*	*available in the JRC:*	*to be recruited:*

			yes	*no*
Staff 7: Jonathan Spinoni	*(E1)*	*PM3*	*available in the JRC: yes*	*to be recruited: no*
Staff 8: Additional staff	*(D1)*	*PM22*	*available in the JRC: no*	*to be recruited: yes*
Staff 9: Additional staff	*(D1)*	*PM21*	*available in the JRC: no*	*to be recruited: yes*
Staff 10: Additional staff	*(E1)*	*PM5*	*available in the JRC: no*	*to be recruited: yes*

☐ The Head of Units of all involved JRC units are informed about the proposal.

☐ We have verified that proposed activity (or similar) is not on-going elsewhere in the JRC.

References

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