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Data Paper

# A georeferenced dataset of drought and heat-induced tree mortality in Europe

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## Abstract

Global warming is altering climate patterns and the frequency and magnitude of heat and drought events affecting ecosystems worldwide. One of the effects of these changes is tree mortality driven by heat and drought, which have effects in forest ecosystem functions, services and biodiversity. Therefore, systematic observations and georeferenced data on tree mortality is a fundamental prerequisite for a more comprehensive understanding of the complex interactions between climate and forests. Tree mortality is a complex process for which literature presents major knowledge gaps, making predictions on the fate of climate change challenging. Some of the gaps are due to limited spatio-temporal data on tree mortality. Despite extensive tree mortality and forest dieback, associated with drought and temperature stress, have been reported in Europe, a publicly available systematic collection of georeferenced data reporting tree mortality is lacking.

The dataset presented in this paper is a contribution to mitigate the lack of information on tree mortality. Our dataset builds on scientific and peer-reviewed literature and provides a georeferenced set of documented tree mortality occurrences in the period 1970-2017 in Europe. The aim of this study is to describe the creation of the dataset and to provide the data file to interested users.

## Keywords

Tree mortality, forest mortality, drought, heat, climate change, Europe

## Overview and background

Global warming is altering climate patterns and the frequency and magnitude of extreme events, affecting ecosystems worldwide (Settele et al. 2014). Specifically, long-term changes in the frequency, duration and severity of drought and heat stress could alter the composition, structure and function of forest ecosystems (Lindner et al. 2010; Seidl et al. 2017; Urban et al. 2012). More intense drought and heat would strongly affect forest ecosystems with impacts on forest functions, services and biodiversity. A particular concern requiring further information and data is tree mortality, associated with climate-induced physiological stress and interactions with other pressures, such as insect outbreaks and wildfires.

Tree mortality is a complex process for which literature presents major knowledge gaps limiting its understanding (Hartmann et al. 2015) and, therefore, making predictions on the fate of climate change challenging. While some gaps concern tree physiological processes leading to decline and death, some others are due to limited spatio-temporal data on tree mortality. For instance, questions such as whether tree mortality is increasing in Europe remain unanswered. However, there is evidence indicating increased levels of tree mortality in specific regions, such as in southern Europe (Carnicer et al. 2011). Studies in other regions indicate upward trends of mortality such as in Canada's boreal forest (Peng et al. 2011). Additionally, georeferenced data on tree mortality in Europe is limited and scattered amongst a number of sources, countries and languages. Thus, these gaps limit our understanding of where and when mortality occurs and, hence, our ability to integrate this information with bioclimatic parameters that can shed light on the drivers of mortality.

Despite the mentioned knowledge gaps, emerging evidence suggests that climate variability seems associated with an increased likelihood of tree death in Europe (Neumann et al. 2017), a fact that is consistent with the hypothetical relationship between increased temperatures, mostly in summer and increased tree mortality. In addition, according to the study of Neumann et al. (2017), the effects of water scarcity are more complex than a monotonic relationship with mortality. Their findings suggest that mortality is associated with wetter-than-average summers followed by drier-than-average springs.

Despite extensive tree mortality and forest dieback, associated with drought and temperature stress, have been reported in Europe and in all other vegetated continents (Allen et al. 2010; Allen et al. 2015; Settele et al. 2014), a publicly available systematic collection of georeferenced data reporting tree mortality, associated with drought and heat, is lacking. The dataset presented in this paper is a contribution to mitigate the lack of information on tree mortality. Our dataset builds on scientific and peer-reviewed literature and provides a georeferenced set of documented tree mortality occurrences as a consequence of drought and heat in the period 1970-2017 in Europe. The aim of the paper is to describe the creation of the dataset and to provide the data file to interested users.

## Methods

We created a dataset on tree mortality occurrences in Europe departing from the global study of Allen et al. (2010) that covers the period 1970 to 2009. Then, we collected data from Allen et al. (2015) that updated the original dataset with post-2009 occurrences according to Settele et al. (2014). Finally, we conducted a bibliographic survey for collecting information on tree mortality occurrences not covered in the previous references.

The literature survey was done using Google and Google Scholar search engines with combinations of the key words “tree”, “mortality”, “drought”, “dieback” and “heatwave”. The aim was to find different types of bibliographic sources reporting tree mortality occurrences, such as peer-reviewed papers, reports from national authorities, forest sector documents etc. Then, we verified that the reported tree mortality is attributed directly or indirectly to drought or heat. We used only those sources reporting:

1. impacted tree species,
2. detailed localisation of the occurrence and
3. years (start and end) of the drought and of the tree mortality.

For each documented tree mortality occurrence, a spatial point was mapped in a GIS layer. In case of more impacted species or drought periods for the same location, multiple points were mapped with the same coordinates, but were differentiated in the attributes' table of the layer. Information on the locality of each mortality event was retrieved from the source reference. Three types of information were used for mapping the points. First, reported geographical coordinates of the events were used for mapping whenever available in the reference. In this case, the coordinates, projected to the WGS84 latitude and longitude system, were included in the GIS layer for creating the spatial point. Second, some references provided a map of the reported mortality. In this case, the maps were georeferenced and projected to the WGS84 system, then the coordinates of the mortality event were retrieved using GIS tools and mapped in the GIS layer. Finally, in a few cases when coordinates or maps were not reported in the source reference, toponyms of the reported locality were used together with on-line baseline maps and gazetteers for obtaining the coordinates of the locality. Then, they were mapped in the GIS layer.

We improved and expanded the data in Allen et al. (2010) and Allen et al. (2015) using information from the survey, for example, by including additional mortality occurrences or a more precise geographical localisation of some events. Our survey provides an updated collection of references reporting and mapping observed cases of tree mortality caused by drought or heat in Europe from 1970 to 2017. The geographical domain of the dataset covers the European Union (EU), Switzerland, Norway and the Balkan countries.

The attribute table of the tree mortality layer includes, for every mortality occurrence, detailed information of the reference source, tree species affected, localisation and years of the drought and the mortality (Table 1).

Table 1.

Information provided in the tree mortality GIS layer for every point.

| FIELD | DESCRIPTION |
|---|---|
| REFERENCE | Reference reporting the tree mortality ocurrence |
| SOURCE_REF | The source where the reference was found. “Survey” if sourced from the survey done in this paper |
| HEAT_START | Starting year of the drought period |
| HEAT_END | Ending year of the drought period |
| MORT_START | Starting year of tree mortality |
| MORT_END | Ending year of tree mortality |
| CNTR | Country of the mortality occurrence (ISO 3166 codes) |
| ZONE | Zone or region name of the mortality occurrence |
| SPECIES | Tree species affected |
| LON | Longitude in decimal degrees of the mortality occurrence (WGS84) |
| LAT | Latitude in decimal degrees of the mortality occurrence (WGS84) |
| GEO_SOURCE | Type of source used to map the point: coordinates, map, toponym |

## Results

The survey provided 69 references containing useful information for creating our dataset (Table 2). Using data from Allen et al. (2010) and Allen et al. (2015) and the references found in the survey, we created a dataset (Suppl. material 1) containing 293 tree mortality occurrences (Fig. 1). The map in Fig. 1 shows the documented mortality occurrences induced by drought and reported in this study.

Table 2.

References sourced from the survey done in this study.

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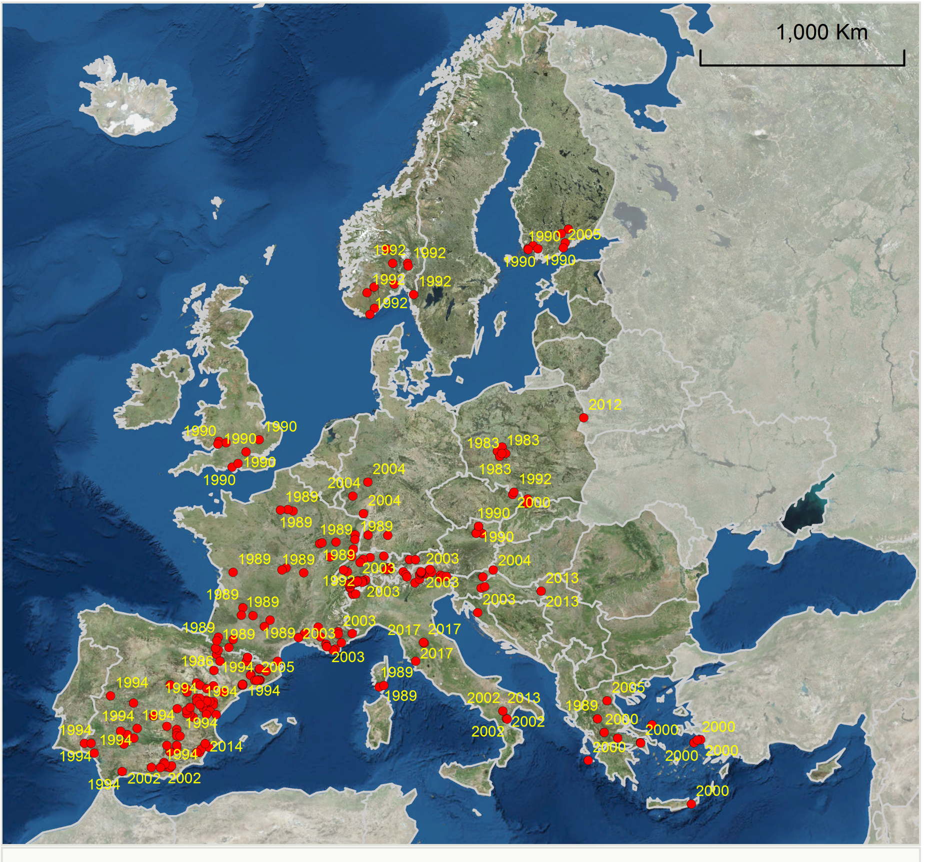


Figure 1.

Documented tree mortality occurrences (red dots) induced by drought 1970—2017. Numbers represent an example of the information associated with each point, they indicate the starting year of mortality for a sample of points and refer to one or more points. The geographical domain of the dataset covers the European Union (EU), Switzerland, Norway and the Balkan countries. Information on tree mortality in the EU outside the map extent was not found. Satellite map of Europe sourced from: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, Swisstopo and GIS User Community.

In the dataset, each drought/heat event reported in the attribute table is represented by one or more points where mortality occurred. Therefore, the user can query and retrieve the locations where mortality occurred as a consequence of specific drought/heat events. Additionally, the source reference of the information of each record is also provided. Thus, each point is associated with its source reference (see Table 2).

We did not compute a temporal trend of tree mortality occurrence because the dataset is not the result of a systematic monitoring schema. Therefore, this might limit computing trends. The dataset was created from available scientific literature, therefore, some gaps might be present regarding mortality occurrences not reported in the scientific literature. Despite this, the dataset is a valuable reference providing an overview of the extent of documented occurrences that contribute to forest degradation in Europe.

## Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect an official position of the European Commission.

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## Supplementary material

### Suppl. material 1: Supplementary materials doi

**Authors:** Giovanni Caudullo, José I. Barredo
**Data type:** CSV
**Brief description:** The dataset contains 293 tree mortality occurrences induced by heat and/ or drought in the period 1970—2017. The geographical domain of the dataset covers the EU, Switzerland, Norway and the Balkan countries. Tree mortality occurrences in the dataset were sourced from scientific and peer-reviewed literature as described in the paper. The dataset is georeferenced using latitude and longitude in decimal degrees (World Geodetic System: WGS84).
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