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Alpine Space
MOSAIC

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1. Introduction

1.1 Purpose of Deliverable

This deliverable aims to provide a cohesive definition of hotspots within the scope and context of this project. The shared definition should harmonize work by partners and allow clear discussions and progress in relation to hotspots. In addition, this deliverable aims to describe the context of this project and the decision-making behind our selection of a shared definition, as well as the methodology used to map the hotspots on the project's webGIS atlas. There will be a description of features to be displayed.

1.2 Deliverable Overview

A shared definition of hotspots has been chosen for this project. The definition is specific to forests in the alpine space, and accounts for the multi-hazard focus of the project by providing two interpretations (single and multi-hazard), with the former being a prerequisite for the latter and the latter being a working definition. The definition is provided in section 2, which considered a literature review and various project meeting discussions used to help formulate the definitions. An overview of methodology to map hotspots is provided in section 3, with section 4 providing general descriptions of the planned webGIS atlas.
Of note within the deliverable: often the terms disturbance and hazard are used to describe both disturbances and hazards, although we recognize the importance in distinguishing between the two terms.

1.3 Related Documents

Deliverable 1.2.1 - catalogue of data sources was used to source definitions and determine relevant disturbances and hazards.

2. Hotspot definitions

2.1 Hotspot background and context

The term hotspot is used frequently with various use cases and intended meaning, especially regarding climate-related disturbances and natural hazards (hereafter, hazards). Hotspots can be relational, with a focus on the comparison of disturbance or hazard risk between locations, such as to describe an area with higher sensitivity to a given disturbance or hazard than surrounding areas (Jiménez et al, 2017) or where the risk of a disturbance or hazard is highest (Ferreira et al, 2017). A hotspot may be an area at relatively high risk of loss due to one or more disturbances or hazards (Agwe et al, 2008). It can also be used in an index or ranking system, where multiple layers of various features are considered to identify areas with high or low risk based on separate indices (hazard, vulnerability, exposure) (Satta et al, 2016). Within such ranking systems, there may be more importance placed on a particular hazard or disturbance, or on specific resources and their vulnerability or exposure to this hazard or disturbance. A hotspot may also be an area where there is a high probability of disturbance or hazard occurrence, following a more mathematical definition of an area with that has (or is likely to have) a higher concentration of disturbance or hazard events compared to the expected number due to chance (Chakravorty, 1995). A hotspot may refer to a single, specific hazard or disturbance; a single, non-specific hazard or disturbance; multiple hazards or disturbances; compounding hazards or disturbances; the overlap of multiple hazards or disturbances; or a combination of these.

In the context of MOSAIC, we are interested in a specific resource, namely, (protective) forests in the alpine space. This project is focused on identification of single and overlapping and/or compounding hazards and disturbances, with particular attention paid toward the role of climate change in current and future hazard and disturbance occurrences. Therefore, the identified hotspot definition for this project is specific to (protective) forests in the alpine space. Because we consider multiple hazards and disturbances, we have identified two definitions: our primary usage of the term hotspot will refer to forests with a high probability of one or more natural disturbance, while our secondary definition will refer to singular disturbances in these forests, focusing on probability of occurrence. The impact will also be considered to guide understanding of risk to human life and infrastructure. Compounding hazards/disturbances (eg increased probability of debris flow following damage to a forest) will be considered where possible as both a separate hazard/disturbance and multi-hazard/disturbance event.

2.2 Secondary definition: Singular Hotspot

A *singular hotspot* is defined as a forested area with a high probability (>50%, eg greater than chance) of a natural disturbance or hazard under the chosen conditions (eg under historic, current, or future (projected) conditions) that reduces the (protective) functions of the forest. The hotspot may be rated quantitatively (ie 0-100%, 0-1, etc) or quantitatively (ie low, moderate, high), and the rating may change across time and space such that the identified hotspot area is only applicable to the indicated time step/area.

2.3 Primary definition: (Multi-disturbance) Hotspot

A *hotspot* in this project is defined as a forested area with an accumulation of vulnerabilities towards natural disturbances and/or hazards which threaten the protective functions of the forest. That is, a *hotspot* is where two or more *singular hotspots* which reduce the (protective) functions of the forest have been identified and/or overlap (i.e. if the hotspot map of two or more singular disturbances such as windthrow and landslide overlap).

A *hotspot* indicates that a forest has high vulnerabilities to two or more disturbances/hazards; in other words, two or more disturbances individually have a greater than 50% chance of occurrence in the same area under the same scenario/conditions. This includes areas where multiple disturbances have a high probability of occurrence, or where the occurrence of one disturbance or hazard results in a secondary disturbance or hazard meeting the criteria of a *singular hotspot*.

In the first case, this could occur if, under current climate and management conditions, a forested area is identified as having a high probability of both windthrow and wildfire. In the second case, a *hotspot* may also be where the occurrence of a windthrow event raises the probability of a wildfire event to greater than chance (50%).

The focus of this project is mainly on current and future conditions and hotspots, however historical hotspot maps will also be provided where possible. Recognized disturbances and hazards for this project can be found in section 2.4.

2.3.1 Data Sources, Contradictions, and Overlap in Hotspots

Project data is sourced from the project partners, previous Interreg projects, and various open sources. As a result, there is a high probability that data from one source will overlap data from another source, especially in instances where data is provided for a specific country/region versus for the entire alpine space. When such an overlap between data sources occurs, the project partners will do their best to explain the specificities of their map/data (such as input data, resolution, criteria, definitions, model, etc). Further, project partners will strive to provide an analysis or explanation for how to best interpret or utilize each data source or data layer.

In instances where data from one source contradicts data from another source, eg the disturbance map produced by one partner for their country/the alpine space provides differing or conflicting information than the disturbance map provided by another partner or source, the project partners will do their best to explain why this might have occurred and how they would interpret the results. Such a contradiction highlights the uncertainty inherit in modeling, specifically in the scope of climate change and highly variable regions such as the Alps.

Similarly, the project partners will strive to highlight where different sources/methods for disturbance hotspot mapping have resulted in congruent results. Such an overlap emphasizes the reliability of the results, as different methodologies have still resulted in the same outcome.

2.4 Recognized disturbances and hazards

This project will consider the following disturbances and hazards in relation to forested areas, determined in part by those present in the alpine space as well as by the availability of historic disturbance/hazard data across the partner countries/alpine space:

- Debris flow
  - Avalanche
  - Landslide
  - Rockslide/rock fall
- Insects and diseases
- Storm damage
  - Wind throw
  - Snow breakage (where available)
  - Ice storms (where available)
- Torrential waters (flooding)
- (Extreme) drought
- Wildfire

In addition, attention will be paid to projected climate change conditions in relation to temperature and precipitation. Tree species suitability and distribution maps will be considered as well under the theme of climate change impacts, as tree species have an outstanding effect on various disturbances and hazards (eg vulnerability to landslides, soil erosion, slope stability, etc).

3. Methodology

3.1 Singular hotspot

Individual disturbance and hazard maps will be sourced from project partners. These will be sorted based on the recognized type (see section 2.4) as well as categorized based on the area which they cover (eg region, country, alpine space). In addition to the map, each partner will provide a short explanation for their methodology on creating the map where possible (such as input data, the name of a model or technique used if applicable, etc).

These maps (with this term used to describe data layers in the atlas) will serve as the singular hotspot maps. A list of the data to be provided in the project's scope per partner is available in Deliverable 1.2.1. The atlas will host a depository with the publicly available data, which includes those which are completely open-source (free to download) and those with restricted access (visualization only). Atlas users will be able to visualize regional, country-level, or alpine space specific hotspot maps in the form of these individual hazard maps, as well as overlay them as they see fit.

3.2 Hotspot (multi-disturbance/hazard hotspot)

Hotspots will be created in several ways: by the partners with their own data where applicable, by the website editors/developers where necessary, and by the atlas user at their discretion. The end goal of this project is to produce one overarching hotspot map spanning the entire alpine space, with consideration of all the recognized disturbances. However, due to differences in data availability (both depth and breadth), the final map may contain some inconsistencies (eg torrential water data is available in Slovenia for flood mapping but may not be accessible in Austria).

For partners who have multiple disturbance maps available, especially for the same extent, hotspot maps will be produced on the partner side using their own data. This is especially true for partners who already have such maps available. Partners have the most expertise with their own data or data from their country; therefore, this is the preferred option where possible, to take advantage of their more localized expertise. Similarly, where possible, data from the partner countries will be used for multi-hazard hotspot mapping in that country.

For partners with maps that 1) span various extents or 2) only contain select disturbances, the website editors or partners will create depositories for the various spatial scales and extents. This will be achieved by:

1. Inventorying available data, as it is provided by the partners (with consideration of the data listed in the data catalogue of D1.2.1.

2. Categorizing data based on spatial coverage, from lowest to highest resolution, with a main consideration of extent (eg local, regional, national, alpine space). This will follow a similar methodology as that used to catalogue data in D1.2.1; however, the focus will be on spatial extent rather than disturbance/hazard type.
    a. Secondary to spatial extent, an overview will be made of available disturbances and where there is overlap. For example, the University of Padova will provide a wildfire hotspot map for a specific region, while IIASA will provide a wildfire hotspot map covering the entire alpine space – such an overlap will be noted.
3. After data categorization (primary and secondary), several databases will be established:
    a. Per disturbance: each disturbance, regardless of scale/extent and time range, will have a separate layer containing all data from all partners
    b. Per country: each country will have a map of all local/regional and national level disturbance data, including from broader extents (eg IIASA's wildfire hotspot map cropped to Italy, if using the example from above)
    c. Per time range: 3 time periods will be identified to help sort through data, including historical, current (considered to be 2023-2025 for this project) and future (any modeled data using projected climate)
    d. Alpine space: all data which covers the entirety of the alpine space will be cropped to fit the alpine space per the definition from Interreg
4. Based on the outputs of 3, an analysis will be made of “missing” disturbances in the alpine space map. "Missing” disturbances will be sourced, where possible, first from the individual partners then from the country (if not available directly from a partner). This places an emphasis on data from local experts
5. Based on the findings of 4, a map containing all available recognized disturbances across the alpine space will be produced
6. Using the map produced in 5, web editors and/or partners will then create a (multi-disturbance) hotspot map. This will follow the definition described in section 3.2, to classify hotspots as any forested area which has two or more mapped disturbances/singular hotspots. Two maps each will be produced for the past, current, and future* time periods as seen in a and b below
    a. Hotspot map with no grading: hotspot map which highlights all areas with two or more singular hotspots
    b. Hotspot map with grading: hotspot map as above, which grades hotspots based on the number of overlapping disturbances. For example, a forested area with singular hotspots for wildfire and wind throw would receive a grade of 2; an area with singular hotspots for wildfire, wind throw, drought, and landslides would receive a grade of 4; and so on.

*At least two maps will be produced for future conditions, with the total number depending on how many future time ranges are provided (eg 2020-2100 vs 2050-2100 vs 2020-2050). An effort will be made to harmonize this in such a way that as few maps will be produced as possible.

The products of 6a and 6b will be made available to atlas users, with an explanation of which data was used where and why (like the methodology described above).

Finally, atlas users will be able to create their own hotspot map by selecting individual layers to overlay singular hotspot maps. The methodology used by end users will not be described here, as their own motivations will guide their use and methods.

3.3 Rationale

By separating singular and (multi-disturbance) hotspots, we emphasize the importance of individual disturbances in the alpine space and highlight the compounding impact of multiple disturbances, especially under climate change. Creating multiple depositories/databases helps end users focus on their needs if their focus is on a specific region or country versus the entire alpine space.

With regards to the (multi-disturbance) hotspot maps produced in 6a and 6b, we account for as many disturbances/hazards as possible and place emphasis on local data to best capture local understanding and knowledge of the alpine space, disturbances, and hazards. These communities likely have a history with these hazards, and we would like to respect this local insight as much as possible.

4. Hotspot maps

4.1 Displayed disturbances

The disturbances to be displayed are found in section 2.4. Generally, the disturbances will be visualized through a 2D map on the atlas and will allow users to select which disturbances to map, for which spatial extent, and in which time range (ie past, current, future).

4.2 Displayed features

Displayed features will be discussed in greater detail in a later deliverable, once the web atlas is functional and available for input from partners. In general, the various disturbance, hazard and hotspot maps will be displayable. Various input data will also be available, such as climate projections, topography, DEM, and similar variables. In addition to maps, the ability to graph values or produce alternative visualizations (eg charts) is a planned feature of the web atlas.

4.3 webGIS interface

The webGIS interface is still under development and will depend on the data provided by the various partners as well as ongoing needs or identified use cases. In general, the webGIS interface for hotspot maps will allow users to access the databases described in section 3.2 under points 3 (a-d) and 6 (a-b), as well as unprocessed data.

5. Other

5.1 References

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