Mapping and analysing Human Exposure to Wildfires in a Central European Context

Evripidis Avouris

Contents

Background and Motivation

- Wildfires are an often-disastrous natural hazard in Southern Europe
- 2022 wildfire in two Conservation Areas and two National Parks in Central Europe demonstrated the need to adapt to a new reality
- Adequate preparation can make hazards less disastrous
- Motivation: Use my skills to create a disaster preparedness **map** with focus on settlements

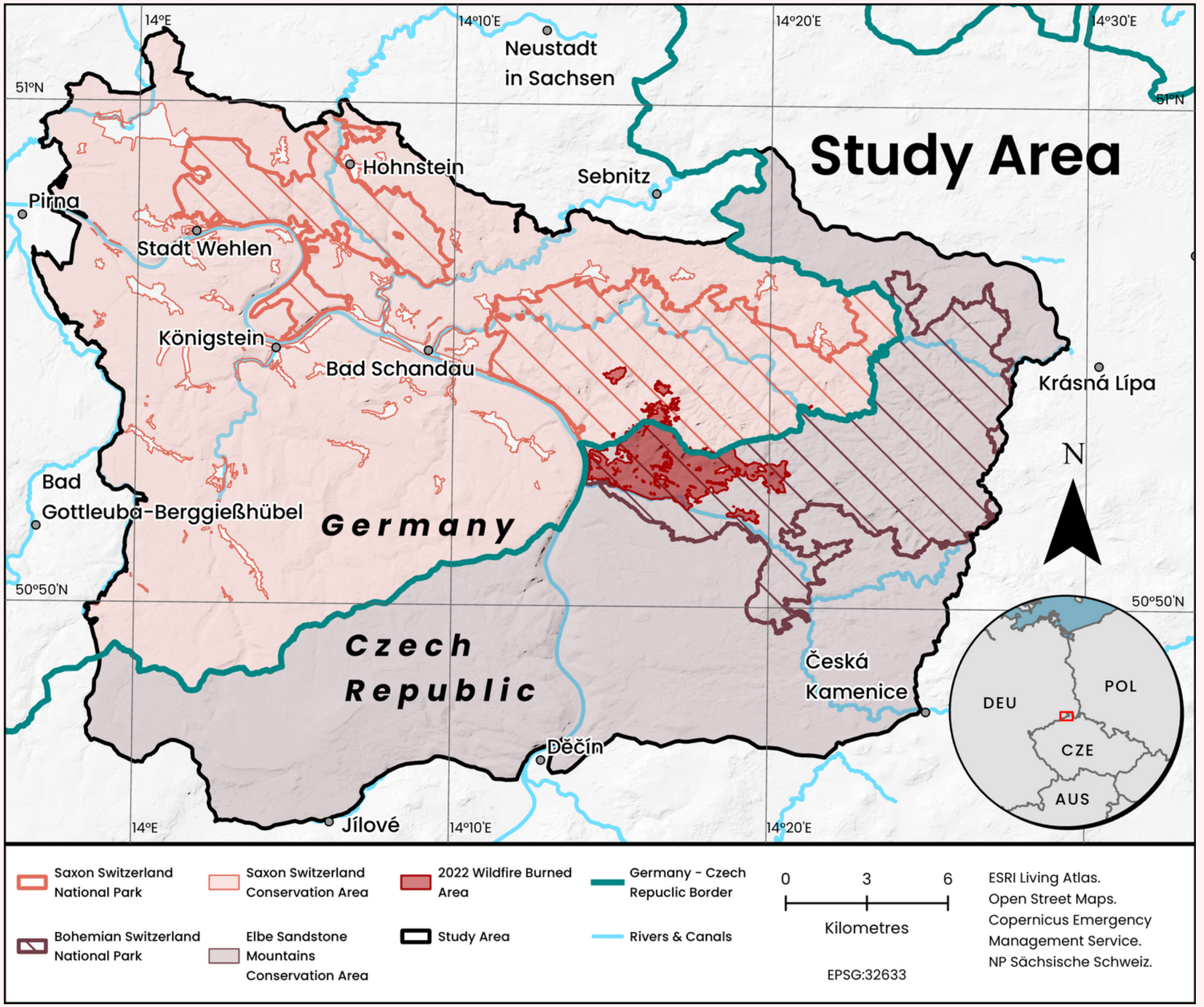
Research Questions

- RQ 1: Can the fire modelling tool FlamMap be used to create an accurate Wildfire Exposure map in the designated study area?

- RQ 2: Is an interactive exposure map derived from FlamMap’s outputs, usable by the general audience and useful for stakeholders?

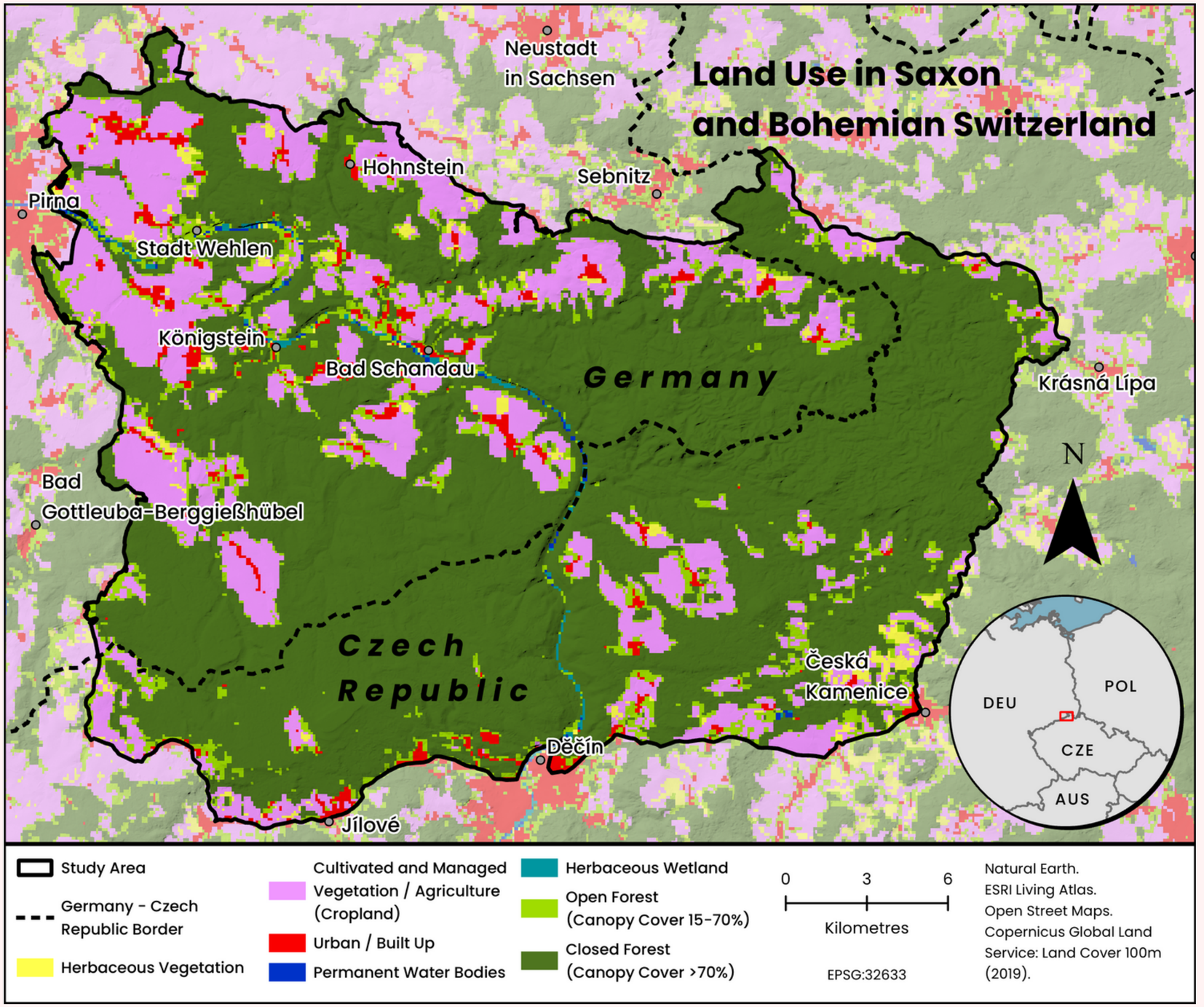
Study Area (1)

- ~700 km²
  transboundary area



Study Area (2)

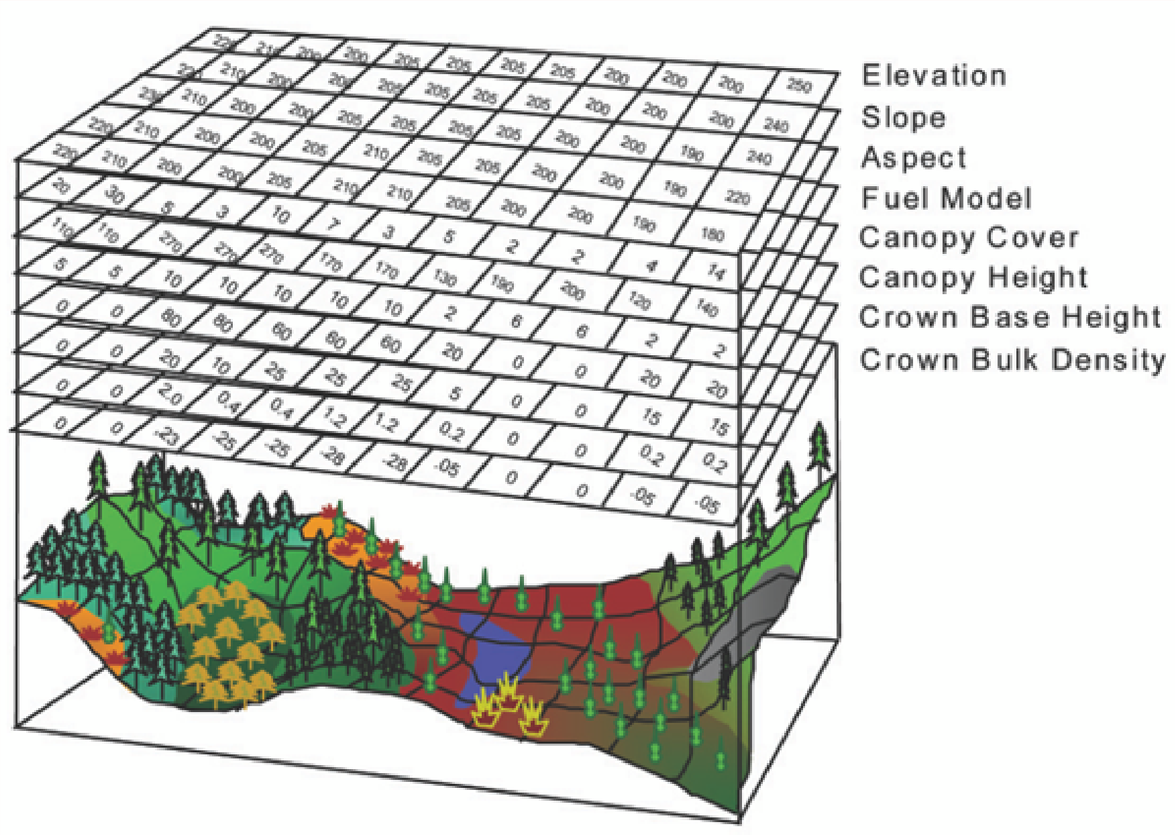
- Significant presence of Wildland Urban Interface



Method of Work

Fire Modelling Landscape

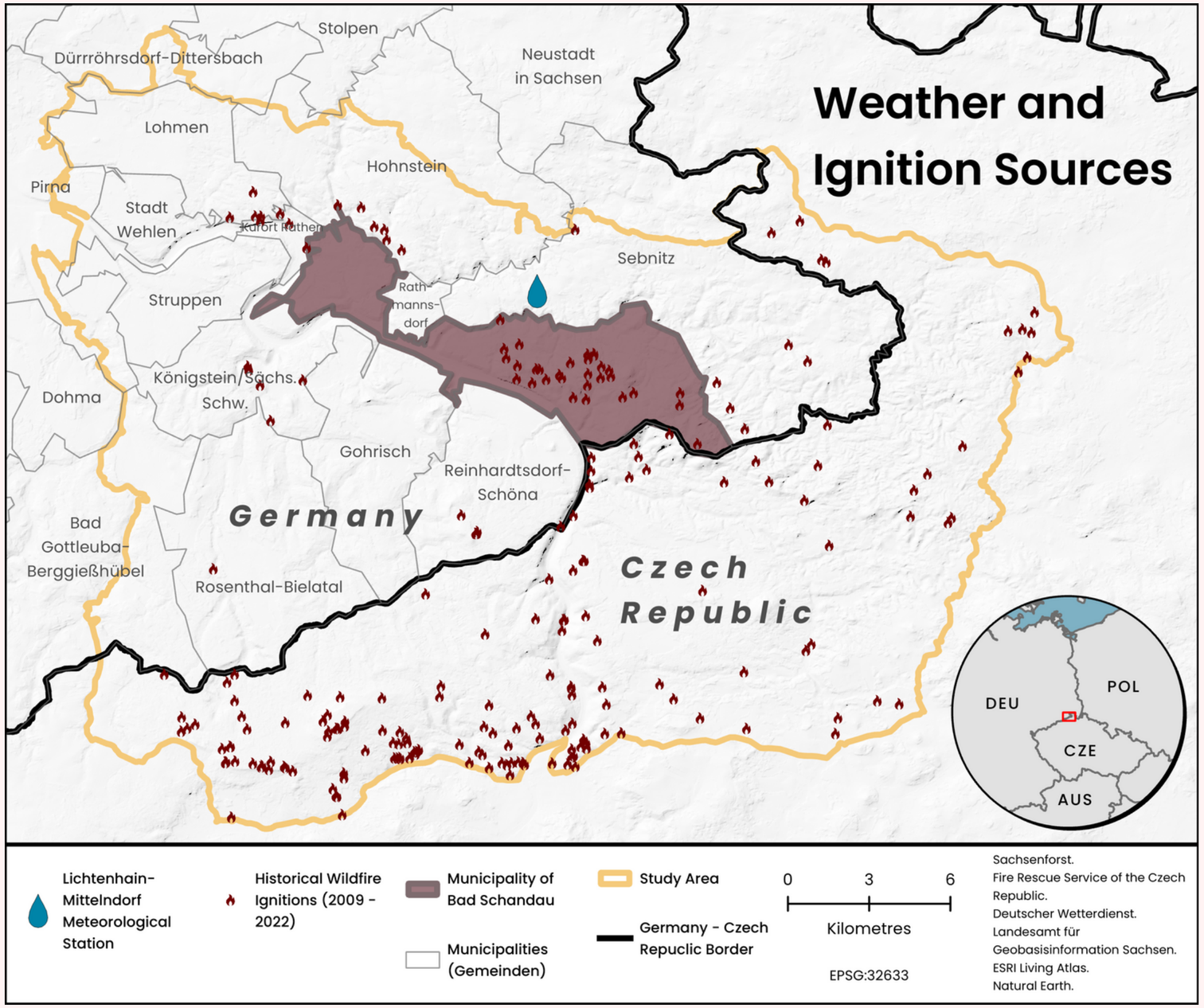
- Elevation
  - DGM from sachsen.de
- Slope and Aspect
  - DGM ArcGIS Pro processing
- Canopy Cover
  - Copernicus' Land Monitoring Service
- Fuel Models Map
  - Derived from Beetz (2023), with two ammendments implemented



(Finney, 2006, p.214)

Wildfire Scenarios

- Ignition Locations (2008-2022)
  - 164 historical ignitions (Czech side)
  - 60 (German side)
- Fire Durations
  - 1, 2 and 3-day long wildfires
- Fire Weather
  - dead fuel moisture variables & wind, from local weather station



Fire Weather - WBI

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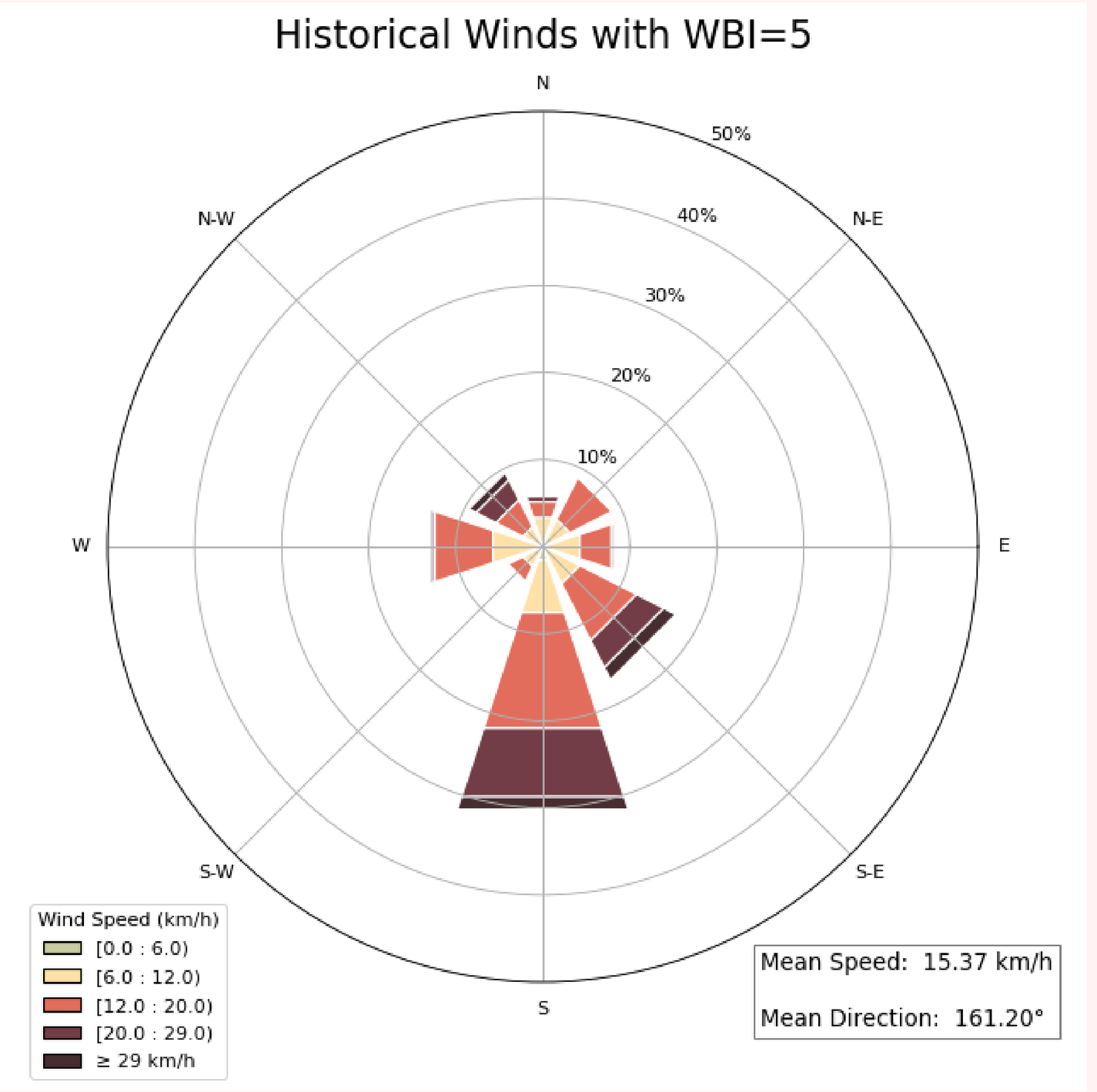
- For Saxony, WBI is calculated per municipality - Bad Schandau was chosen
- Three WBI values considered: 3, 4 and 5

Fire Weather - Wind

- WBI values downloaded for Bad Schandau area for 2009-2022
- Wind velocities downloaded for 1991-2022 duration for local met. station
- Winds categorised according to WBI values for days winds occured
- 3 representative winds considered for each WBI scenario



Deriving Wildfire Exposure

- Flame Length: a proxy for measuring fire **intensity** (Finney et al., 2021)
- Burn Probability: the **likelihood** that a location will burn, taking into account the cumulative number of simulated fires (Sá et al., 2022)

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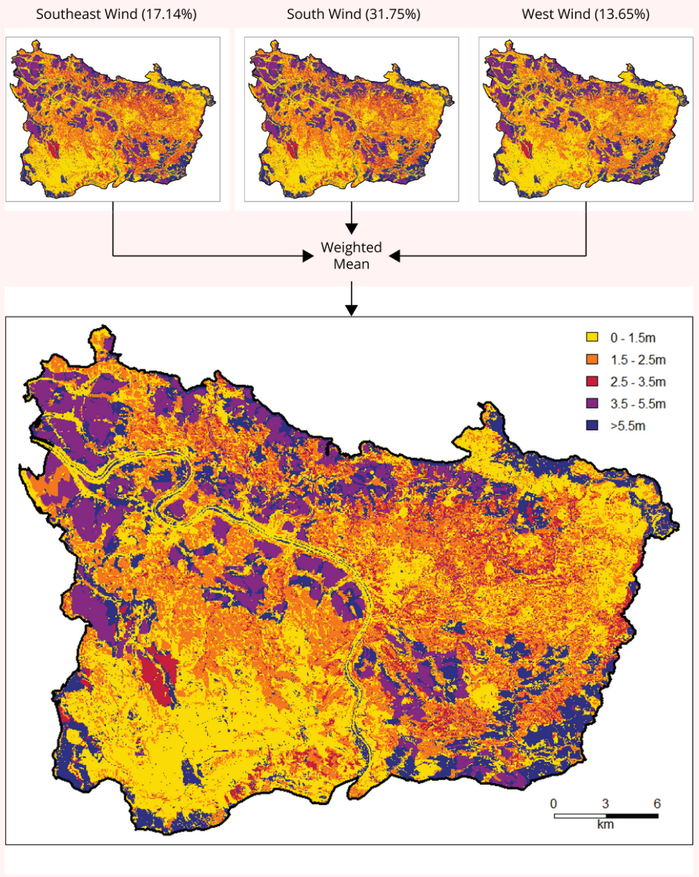
Map showcasing fire intensity and likelihood + Location of Assets = Wildfire Exposure Map

- FL for 3-day, WBI = 5



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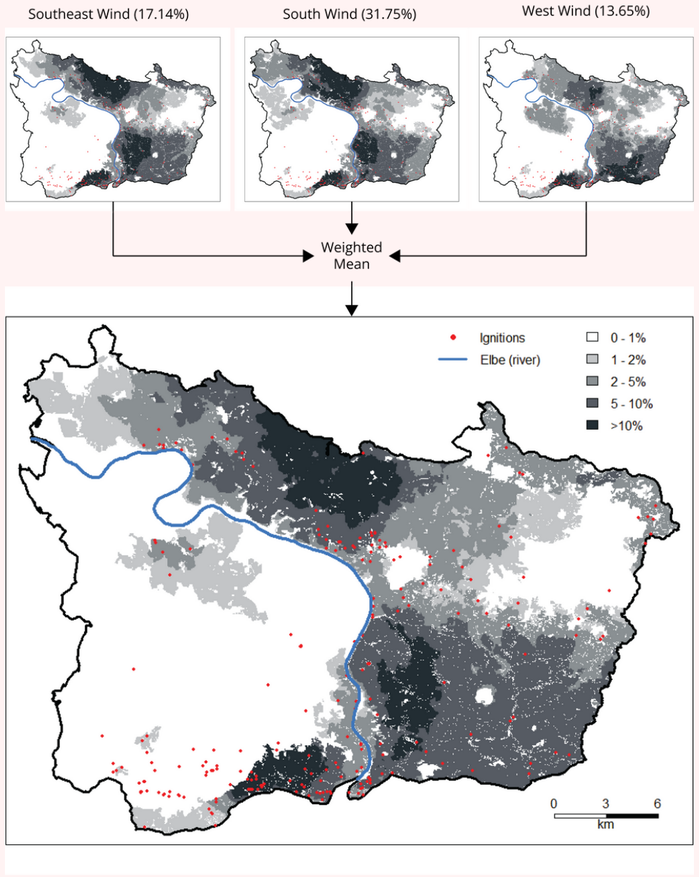
- BP for 3-day, WBI = 5



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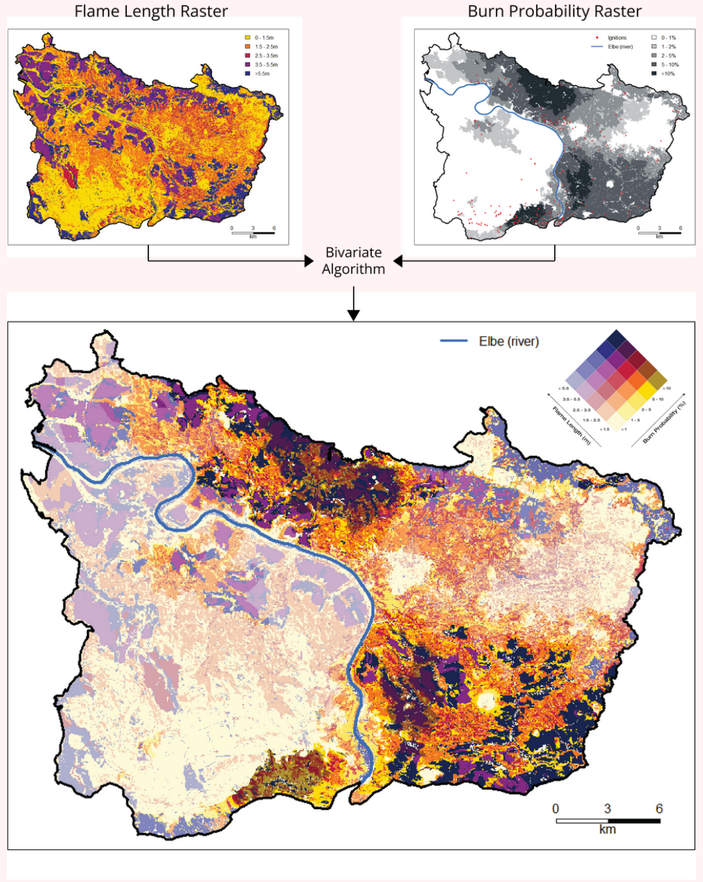
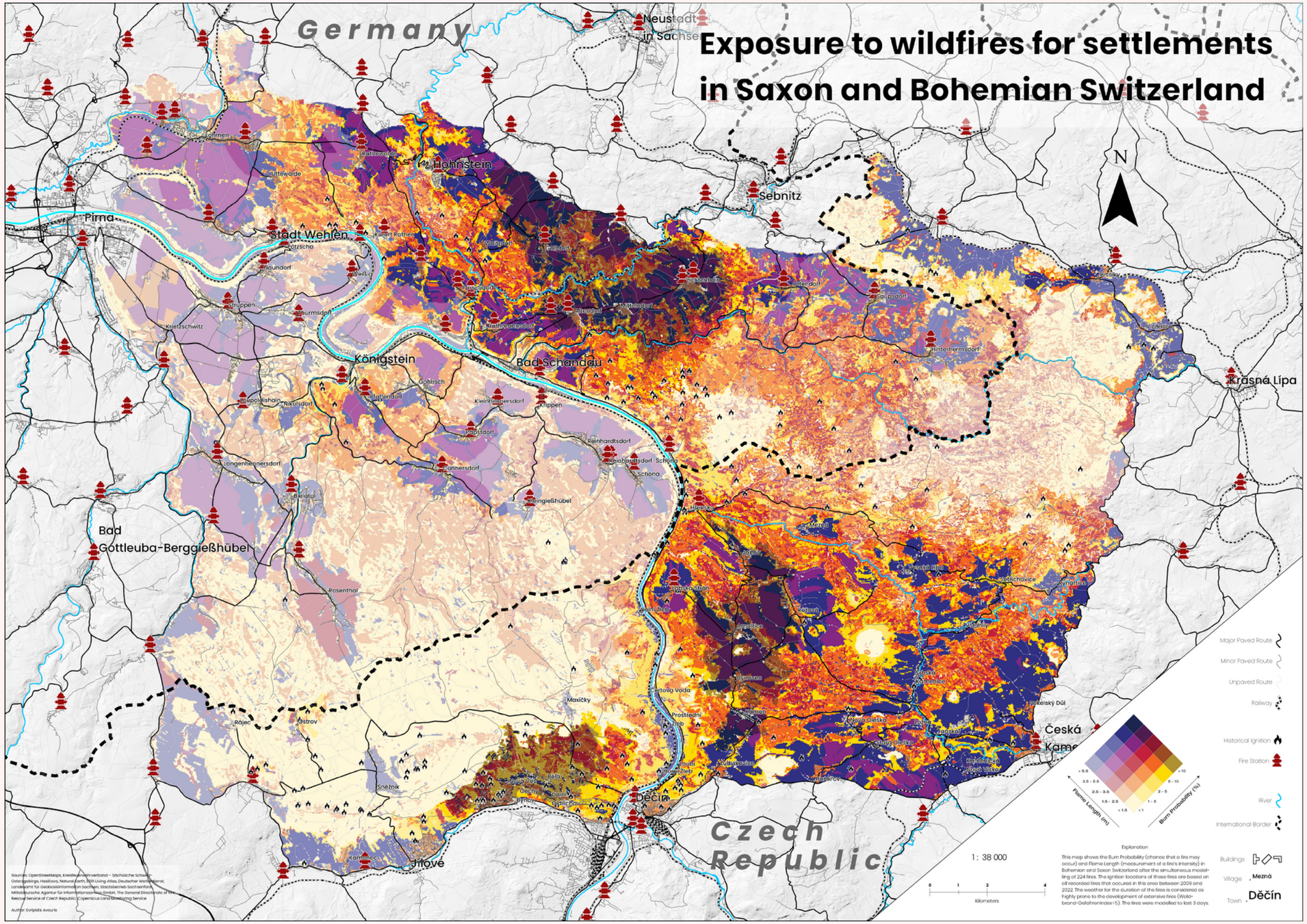
- Likelihood and Intensity combined



Results

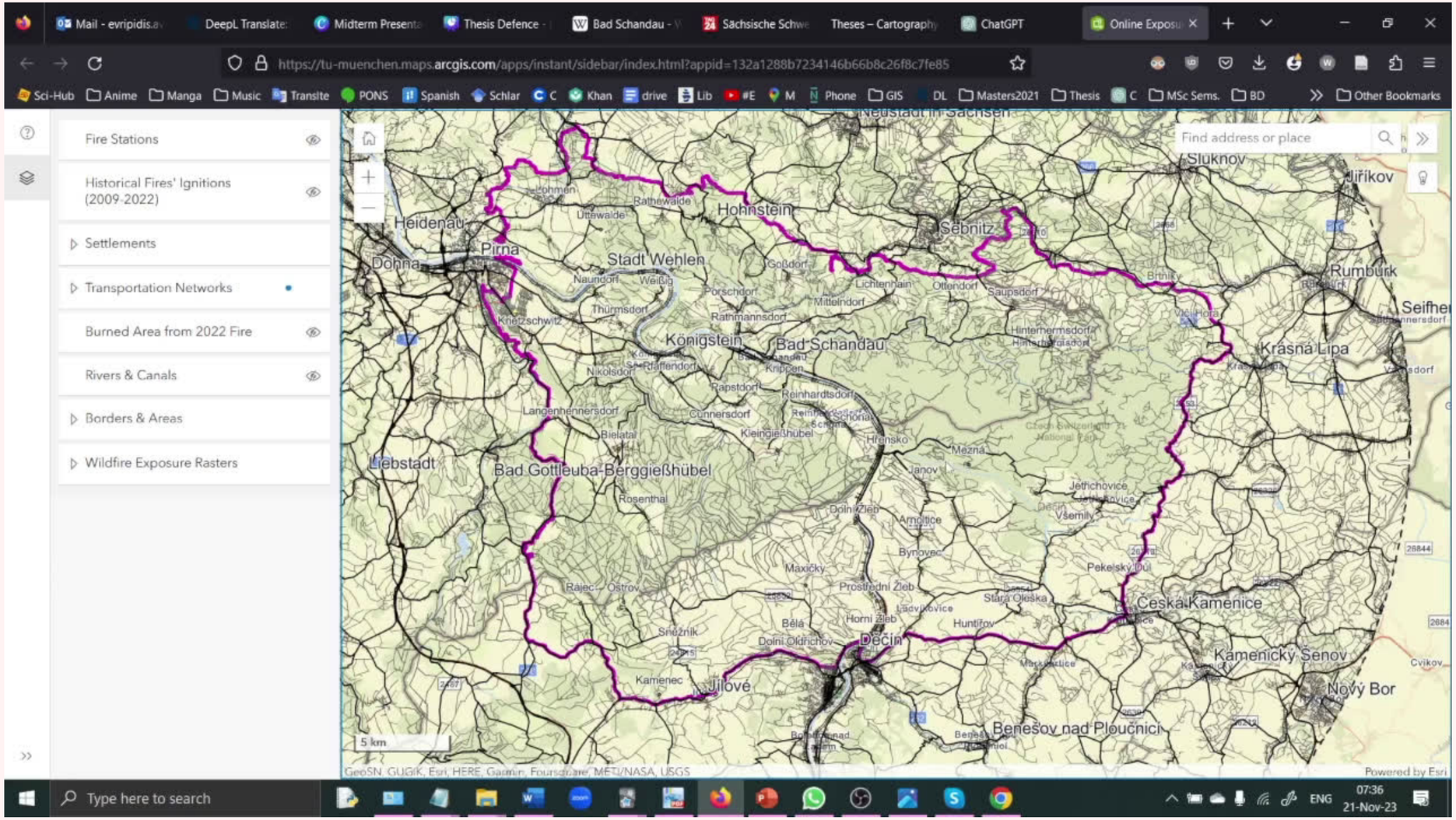
Static Map

- Settlements
- Support capability indicators
  - Fire Stations
  - Transportation Network



Interactive Map

- Zooming & Panning
- Search Bar
- Layers Menu

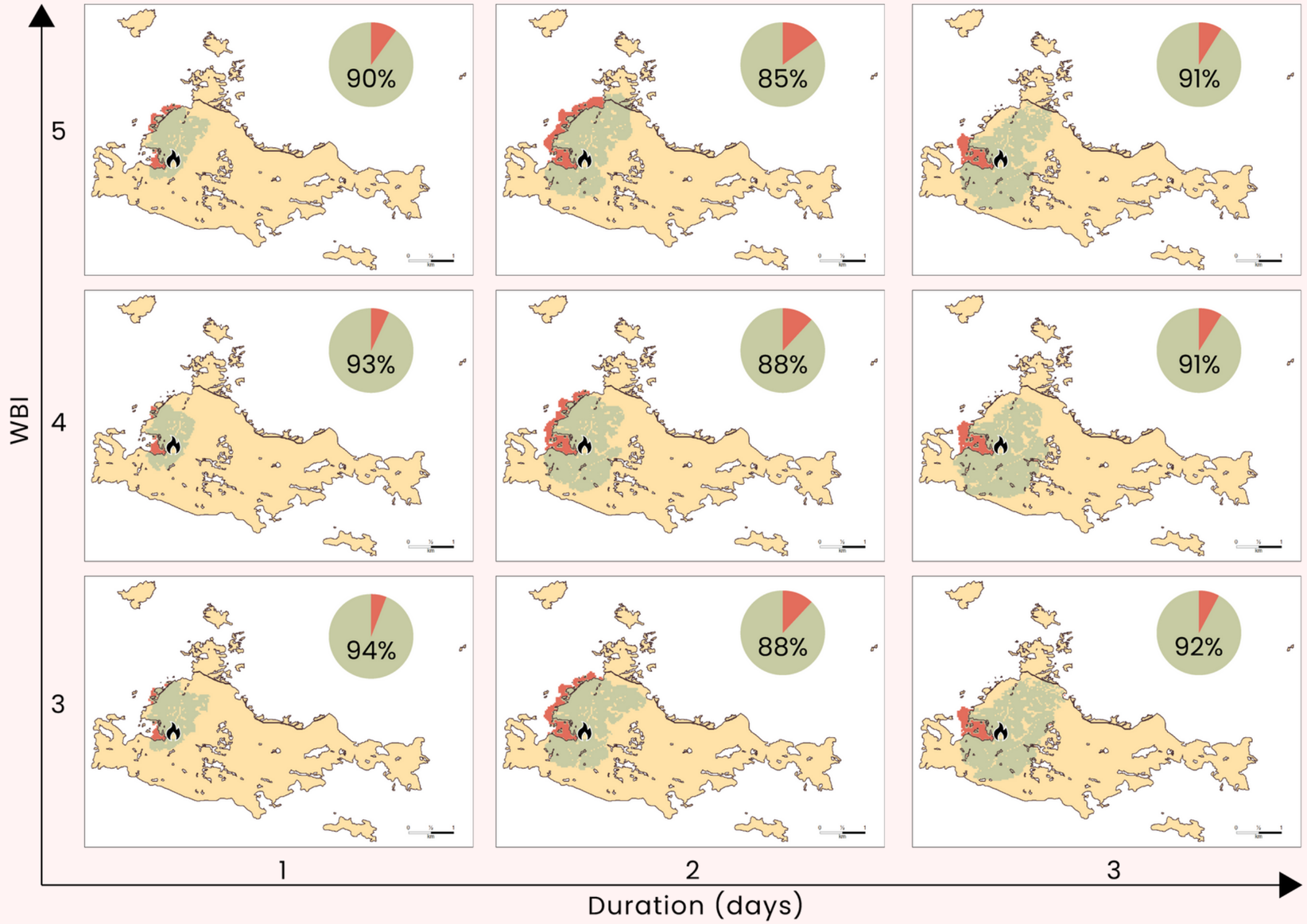


Evaluation

Scenarios Evaluation

- Actually burned 2022 area VS modelled

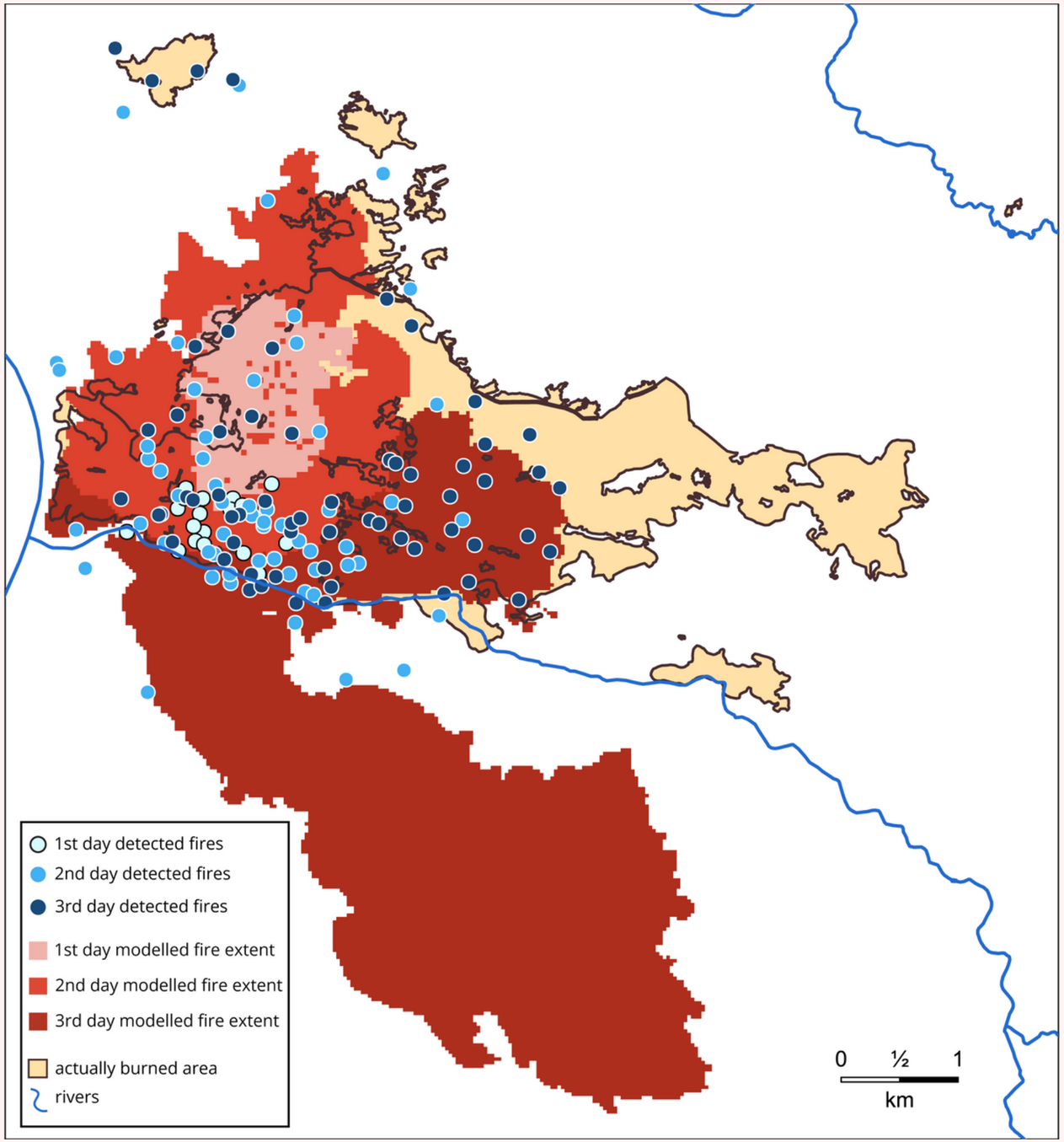
- Good accuracy but low coverage due to short duration



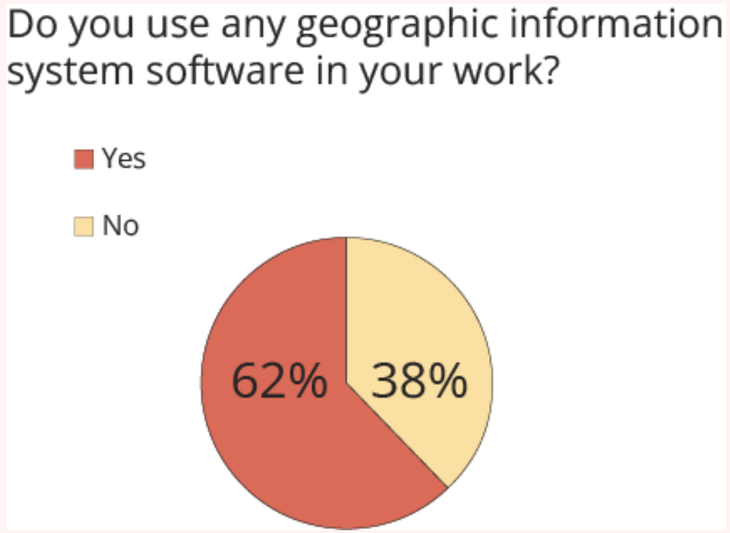
FlamMap Evaluation

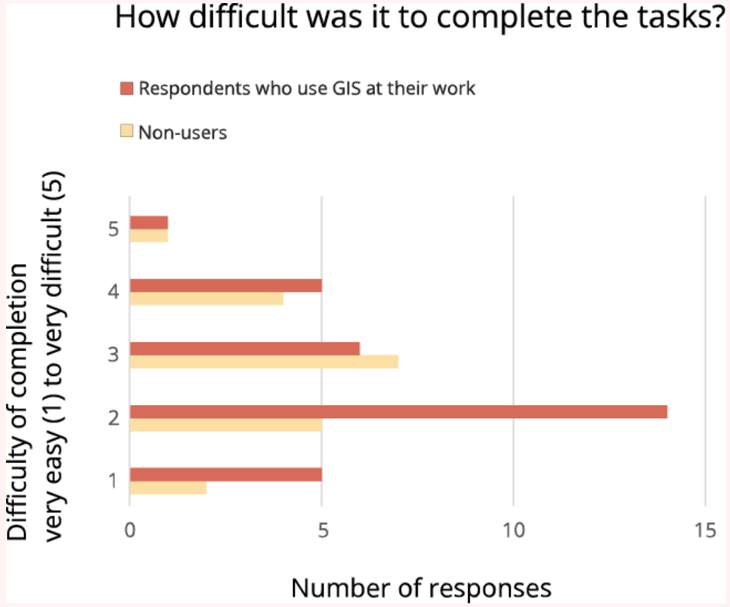
- 3 daily consecutive wildfires modelled imitating conditions of 2022 wildfire
- VIIRS (375m acc.) and MODIS (1km acc.) detected active fires compared to modelled fires

	Percentage inside FlamMap-modelled burned area for that day
1st day detected fires	11%
2nd day detected fires	52%
3rd day detected fires	69%
Total detected fires	**84%**



Usability Questionnarie





- Ease of use of the taskbar (13) and colour coding (6) were found to make the map easy to use by some respondents

- However, others found the colours difficult to understand (8)

Usefulness Questionnaire

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    - respondent B is associated with the Virtual Operations Support Team (VOST) of Germany's federal civil protection organisation (THW)
        - suggested map could be of integrated into VOST as they also work with Esri products
        - proposed easier access (static / open access software) to make map more accessible

Discussion and Future Work

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- Vegetation in study area experiences bark beetle infestations, constantly altering it

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  - Fieldwork validation would also increase accuracy

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    - Nevertheless FlamMap is able to provide metrics for wildfire exposure maps
- Comprehensive validation data a necessity for future work

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- Nevertheless, two responses are insightful
- Need to establish earlier contact with stakeholders

Answering the Research Questions

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  - Map was usable by the general audience, though familiarity with GIS and with interactive maps makes the map more usable.
  - In terms of usefulness for stakeholders, there is more uncertainty

Thank You for your Attention!

References

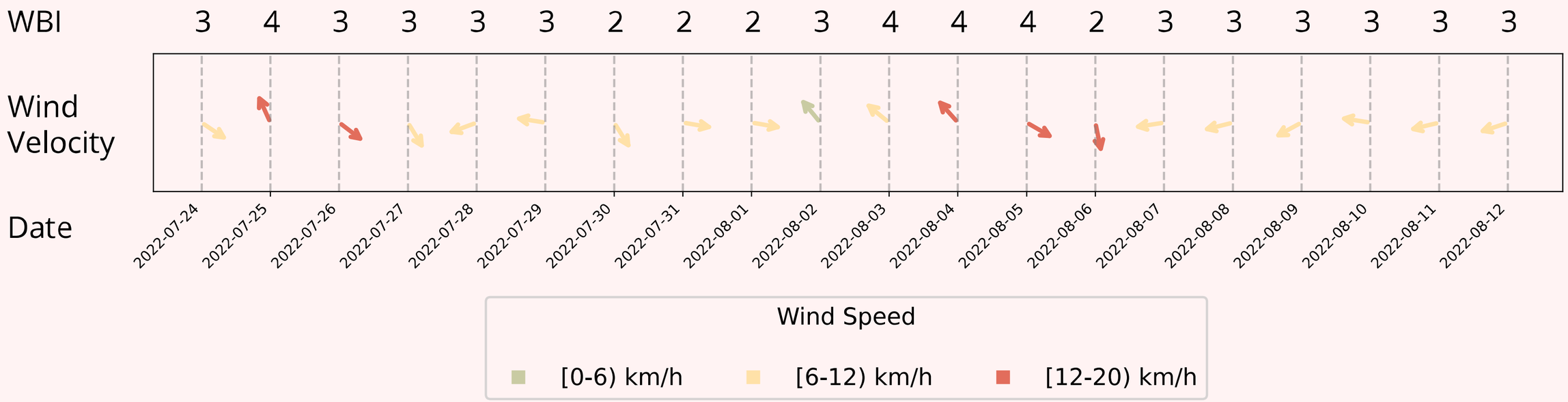
Beetz, K. (2023). Forest fires in the Bohemian-Saxon Switzerland in 2022: Mapping and analysis of fuel types, fire dynamics and severity using remote sensing data [Unpublished master's thesis]. TU Dresden.

Deutscher Wetterdienst. (n.d.). Erläuterungen zum Waldbrandgefahrenindex. Retrieved 27 October 2023, from https://www.dwd.de/DE/fachnutzer/landwirtschaft/dokumentationen/allgemein/basis_waldbrandgefahrenindex_doku.html?nn=16102

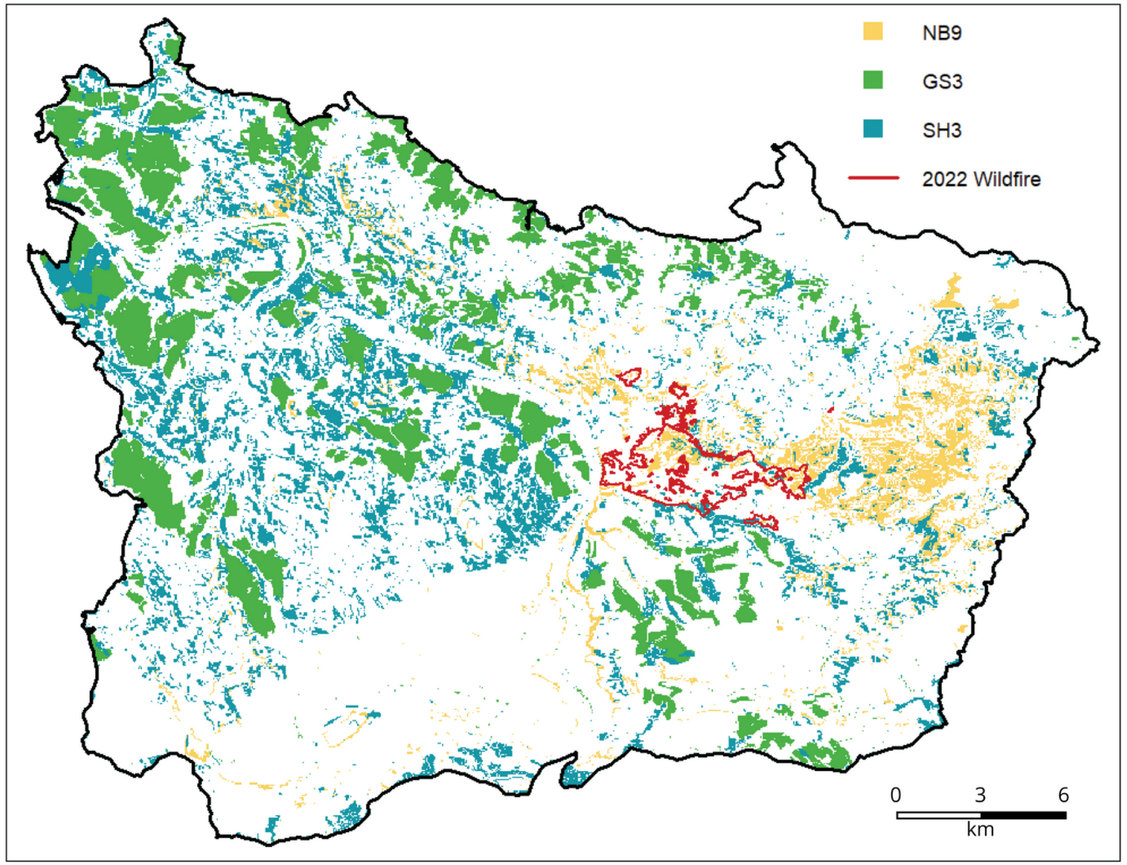
Finney, M. A. (2006). An Overview of FlamMap Fire Modeling Capabilities. In: Andrews, Patricia L.; Butler, Bret W., Comps. 2006. Fuels Management-How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 213-220, 041. https://www.fs.usda.gov/research/treesearch/25948

Sá, A. C. L., Aparicio, B., Benali, A., Bruni, C., Salis, M., Silva, F., Marta-Almeida, M., Pereira, S., Rocha, A., & Pereira, J. (2022). Coupling wildfire spread simulations and connectivity analysis for hazard assessment: A case study in Serra da Cabreira, Portugal. Natural Hazards and Earth System Sciences, 22(12), 3917–3938. https://doi.org/10.5194/nhess-22-3917-2022

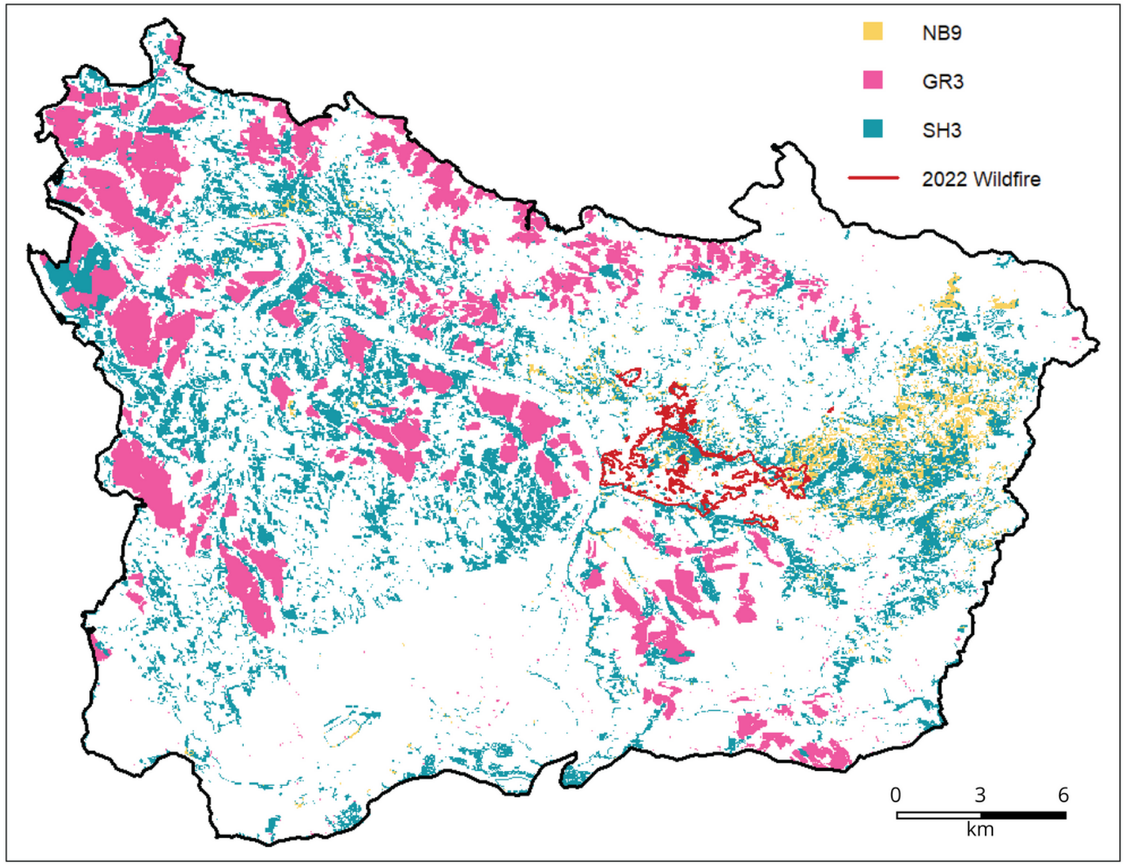
https://tu-muenchen.maps.arcgis.com/apps/instant/sidebar/index.html?appid=132a1288b7234146b66b8c26f8c7fe85



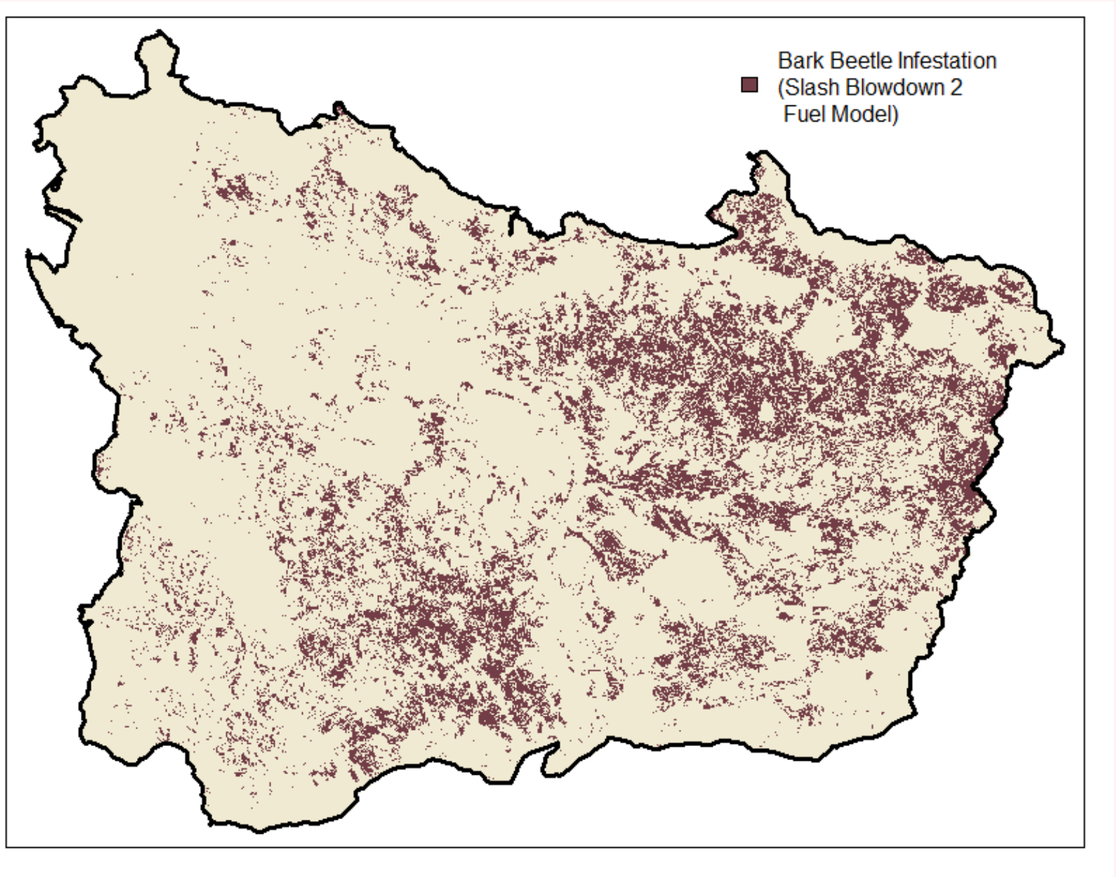
Time series showing wind velocity (speed and direction), as well as daily WBI values throughout the duration of the 2022 study area wildfire.



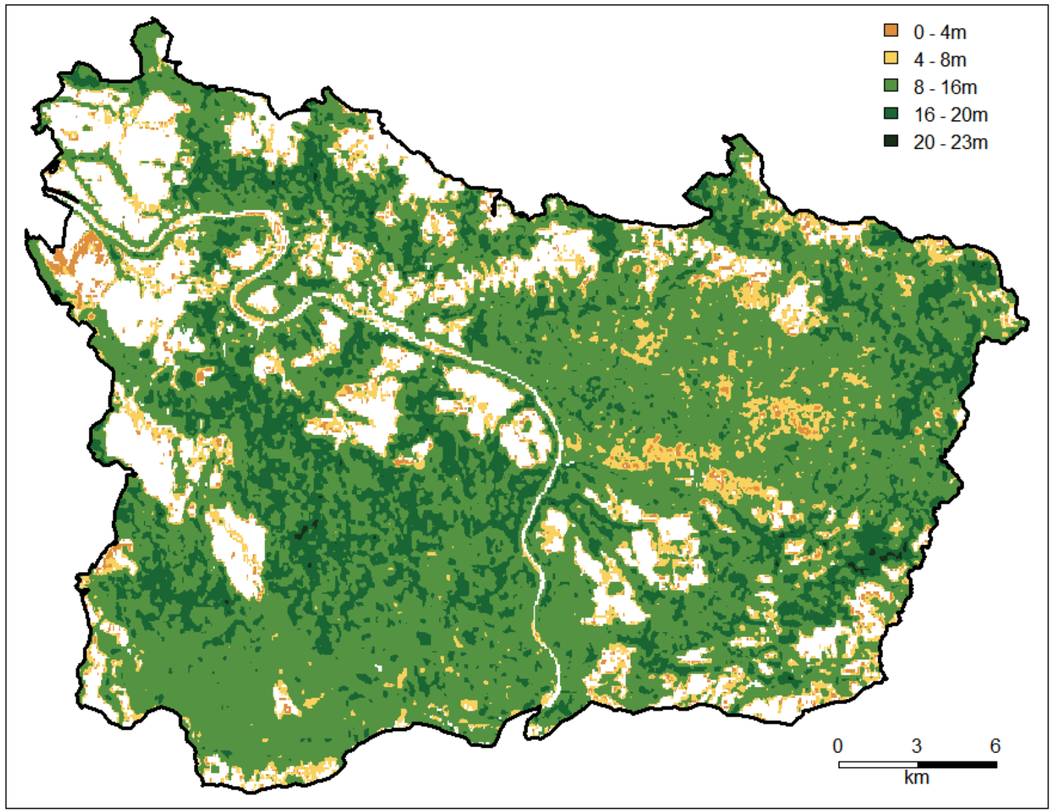
Original Fuel Models map derived from Beetz (2023), showcasing the three fuel models that were altered.



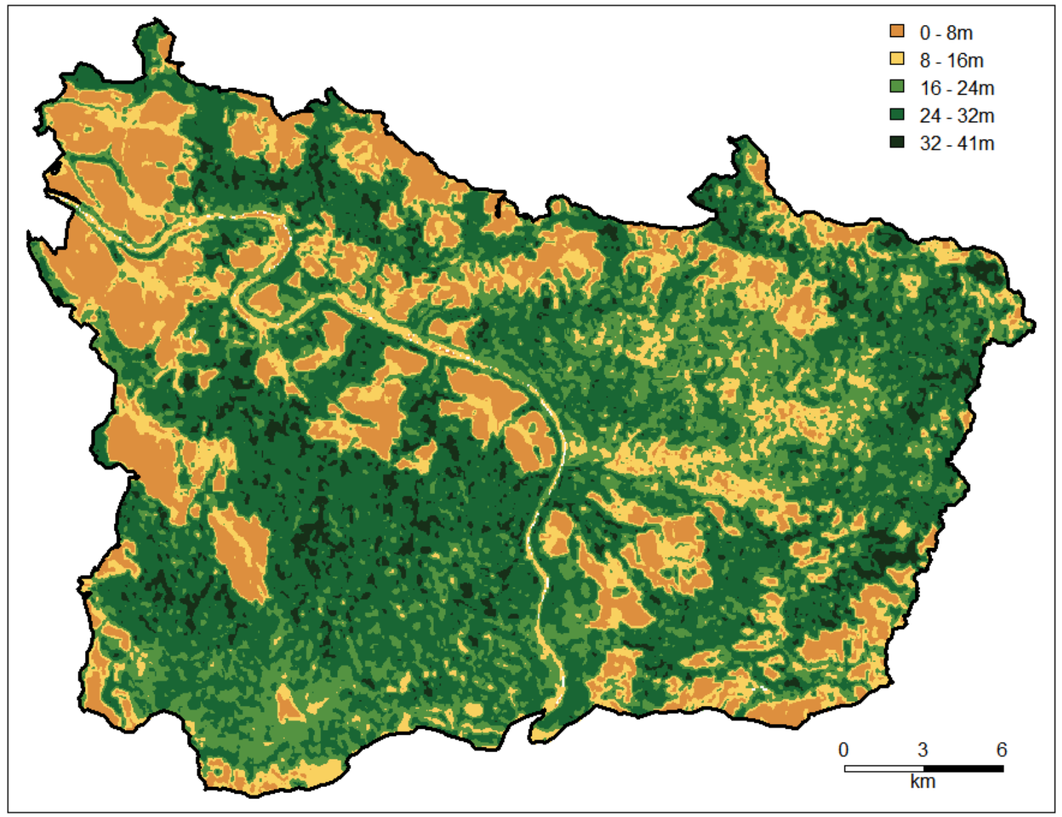
Updated fuel models map after two alterations; Notice replacement of NB9 (yellow area) with SH3 (blue) inside the limits of the 2022 wildfire, as well as the complete replacement of GS3 (green areas in the previous Figure) by GR3 (magenta).



Parts of the study area infested by Bark Beetle. These are areas classified by Beetz (2023) as belonging to fuel model ‘Slash Blowdown 2’ according to the fuel models of Scott & Burgan (2005).



2020 Canopy Base Height in the Study Area (Francesco et al., 2023)



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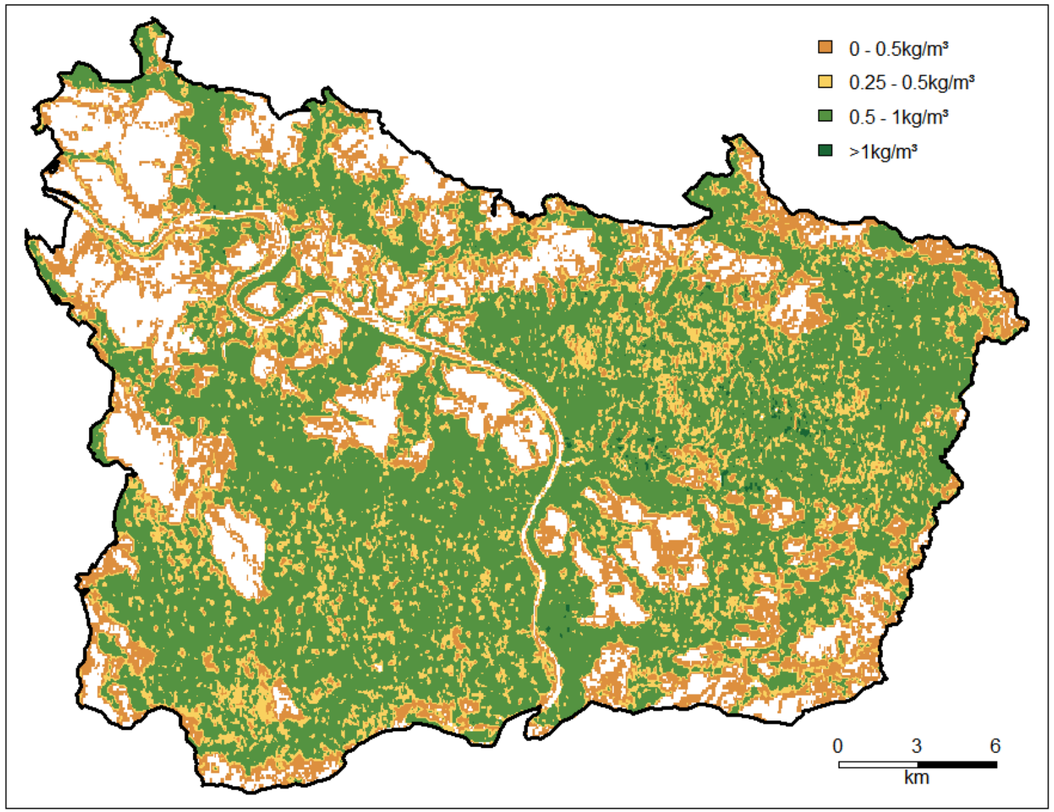


Canopy Bulk Density in the Study Area (Francesco et al., 2023).

Layer Name	Layer Description
Fire Stations	Layer showing location of fire station in the area contained within a 30km radius from the study area's centroid.
Historical Fires' Ignitions (2009-2022)	Layer presenting the location of all 224 fire ignitions used to derive wildfire likelihood and intensity metrics in FlamMap.
Settlements	Layer containing three sublayers; the first displays buildings' polygons in the study area, the second towns and cities (Ústí nad Labem is the only city; it is located inside the buffer but outside the study area) within the 30km buffer and the third villages inside the study area.
Transportation Networks	Layer encompassing four sublayers, each for a type of transportation route (major paved routes, minor paved routes, unpaved routes, pedestrian routes, and railways)
Burned Area from 2022 Fire	Layer showing the area burned by the 2022 wildfire that occurred in the study area.
Rivers & Canals	Layer displaying major waterways within the 30km buffer.
Borders & Areas	Layer containing seven sublayers; two for the study area's Conservation Areas, two for the study area's National Parks, the Germany-Czech Republic border, the limits of the study area and the limits of the 30km buffer.
Wildfire Exposure Rasters	Layer containing nine bivariate rasters, each for one of the nine wildfire scenarios defined by three different WBI conditions (3, 4, 5) and durations (1, 2, 3 days).

Interactive web map layers and layer descriptions.

Flame Length (m)	Fire suppression difficulty
< 1.5 (very low)	Fire can generally be attacked at the fire head or flanks using hand tools.
1.5 – 2.5 (low)	Fires are too intense for direct attack on the fire head using hand tools. Equipment such as plough, dozers, pumpers and retardant aircraft can be effective in suppression.
2.5 – 3.5 (moderate)	Fires may present serious control problems – torching out, crowning and spotting. Control efforts at the fire head will probably be ineffective.
3.5 – 5.5 (high)	Crowning, spotting and major fire runs are frequent. Control efforts at the fire head are ineffective. Aircraft are required for fire suppression.
> 5.5 (very high)	Any combat attempt (even with aircraft) is ineffective.

Flame Length classes and suppression difficulty. Adapted from Sá et al. (2022, p. 3933)

		Wind Direction (%)							
		N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
WBI Values	**3**	12.54	9.98	5.41	9.03	24.84	5.04	15.65	17.5
	4	14.17	15.14	9.18	8.5	19.16	2.98	13.26	17.61
	5	6.03	8.89	8.57	17.14	31.75	4.44	13.65	9.52

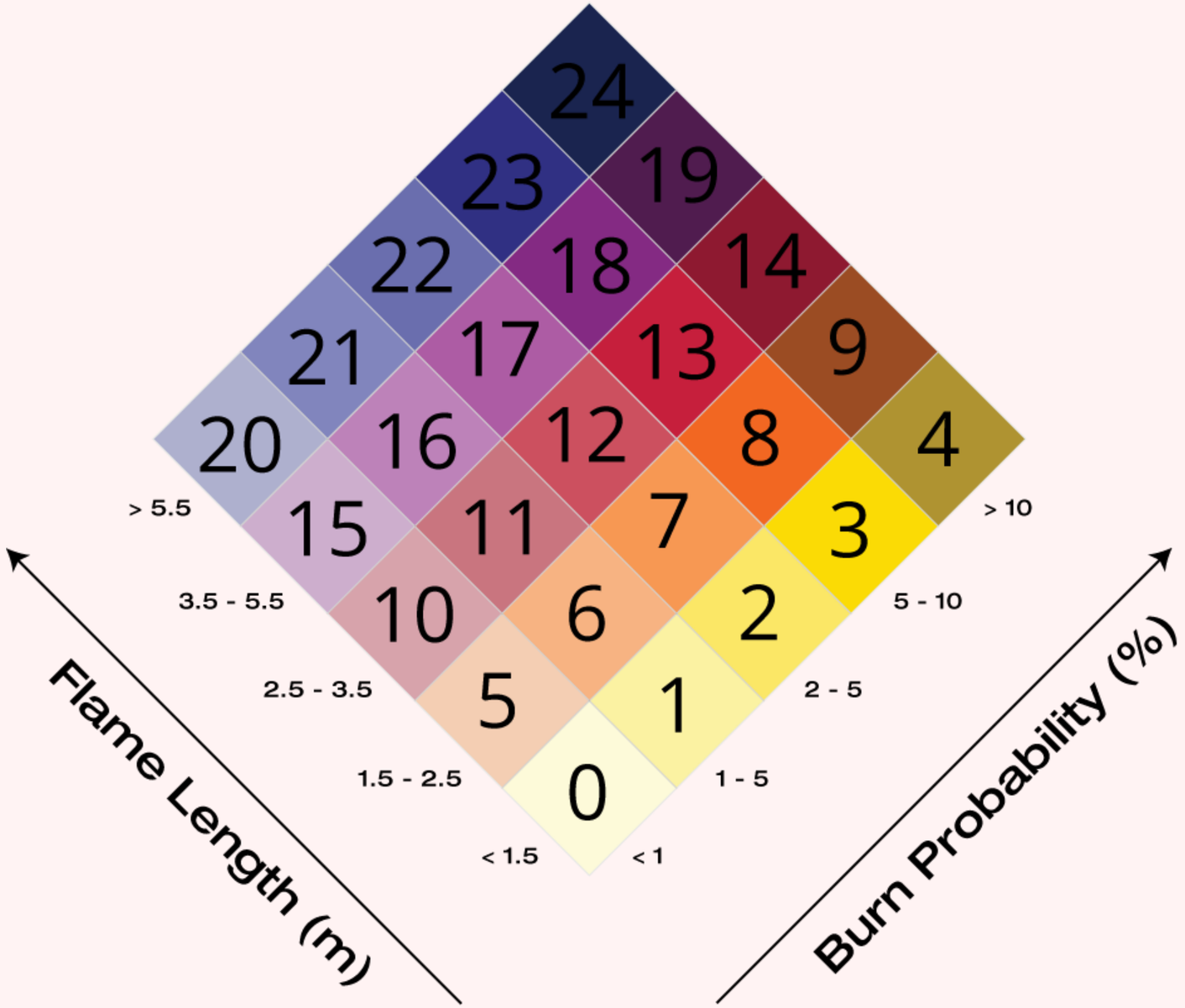
Prominence of each wind direction for each of the three datasets with hourly winds.
The three most prominent wind directions for each WBI value are highlighted.

		Mean Speed (km/h)							
		N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**
WBI Values	**3**	13.0	16.01	12.6	7.02	16.65	12.28	14.85	14.93
	4	13.29	16.86	14.94	16.2	10.03	13.21	14.62	17.23
	5	12.64	12.42	12.09	17.4	17.21	11.08	13.59	17.62

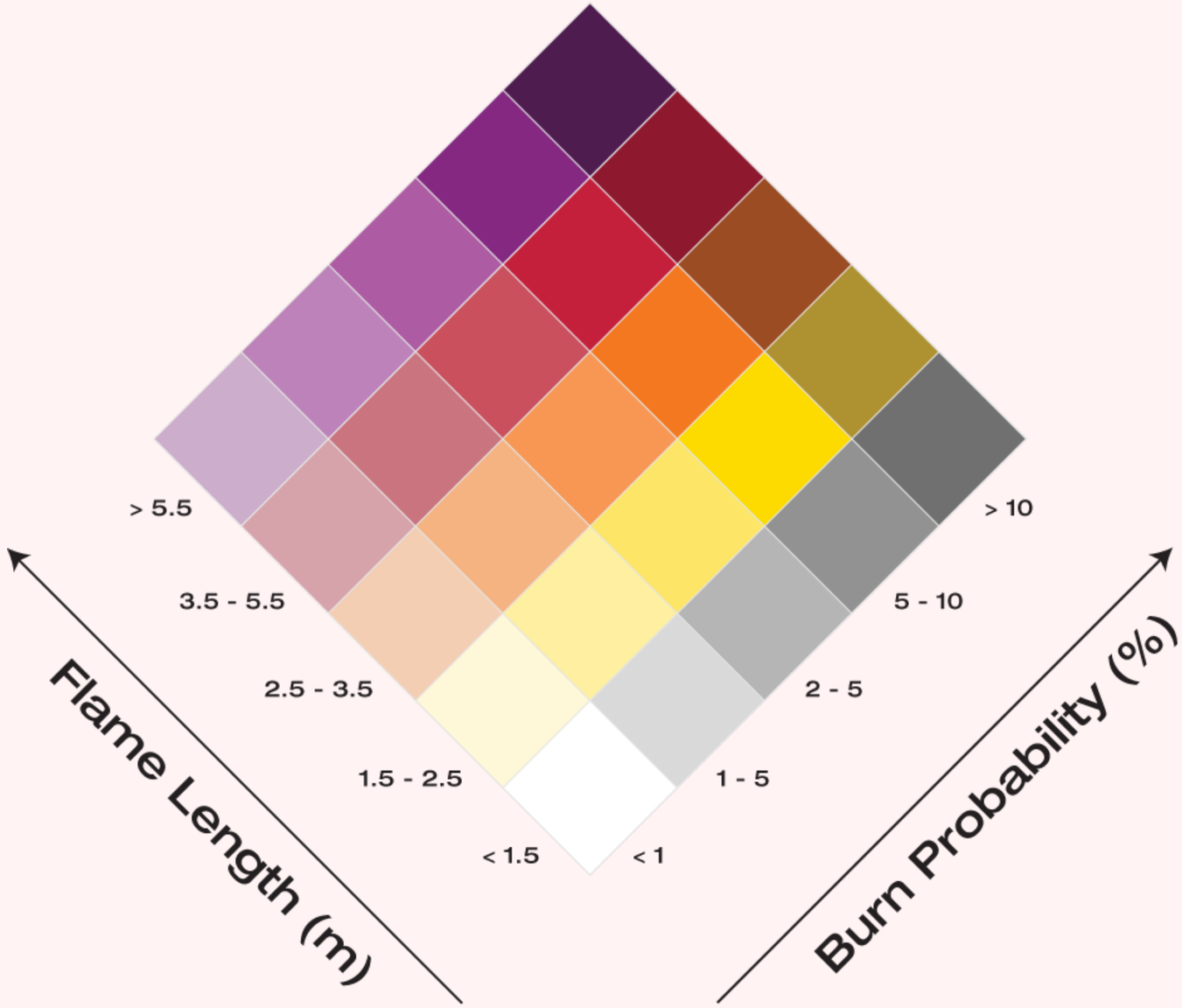
The mean speed of every wind direction for each of the three hourly winds' WBI datasets is shown here.
The mean speeds of the three most prominent wind directions for each WBI value are highlighted.

Flame Length (m)	Burn Probability (%)	Bivariate Raster Value
< 1.5	< 0.01	0
< 1.5	0.01 ≤ x < 0.02	1
< 1.5	0.02 ≤ x < 0.05	2
< 1.5	0.05 ≤ x < 0.01	3
< 1.5	≥ 0.1	4
1.5 ≤ x < 2.5	< 0.01	5
1.5 ≤ x < 2.5	0.01 ≤ x < 0.02	6
1.5 ≤ x < 2.5	0.02 ≤ x < 0.05	7
1.5 ≤ x < 2.5	0.05 ≤ x < 0.01	8
1.5 ≤ x < 2.5	≥ 0.1	9
2.5 ≤ x < 3.5	< 0.01	10
2.5 ≤ x < 3.5	0.01 ≤ x < 0.02	11
2.5 ≤ x < 3.5	0.02 ≤ x < 0.05	12
2.5 ≤ x < 3.5	0.05 ≤ x < 0.01	13
2.5 ≤ x < 3.5	≥ 0.1	14
3.5 ≤ x < 5.5	< 0.01	15
3.5 ≤ x < 5.5	0.01 ≤ x < 0.02	16
3.5 ≤ x < 5.5	0.02 ≤ x < 0.05	17
3.5 ≤ x < 5.5	0.05 ≤ x < 0.01	18
3.5 ≤ x < 5.5	≥ 0.1	19
≥ 5.5	< 0.01	20
≥ 5.5	0.01 ≤ x < 0.02	21
≥ 5.5	0.02 ≤ x < 0.05	22
≥ 5.5	0.05 ≤ x < 0.01	23
≥ 5.5	≥ 0.1	24

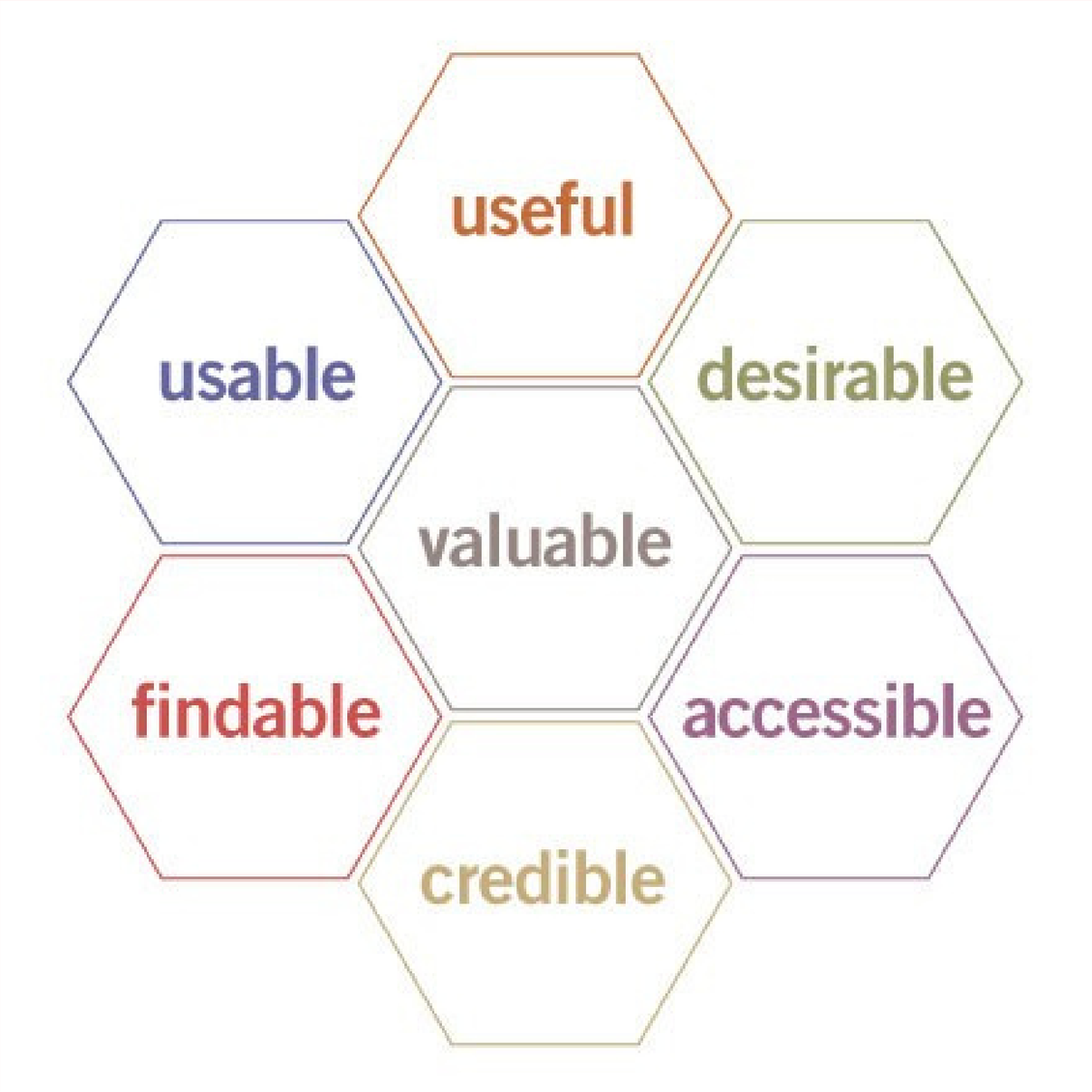
Combination of FL and BP classes and the respective bivariate raster value that is assigned.



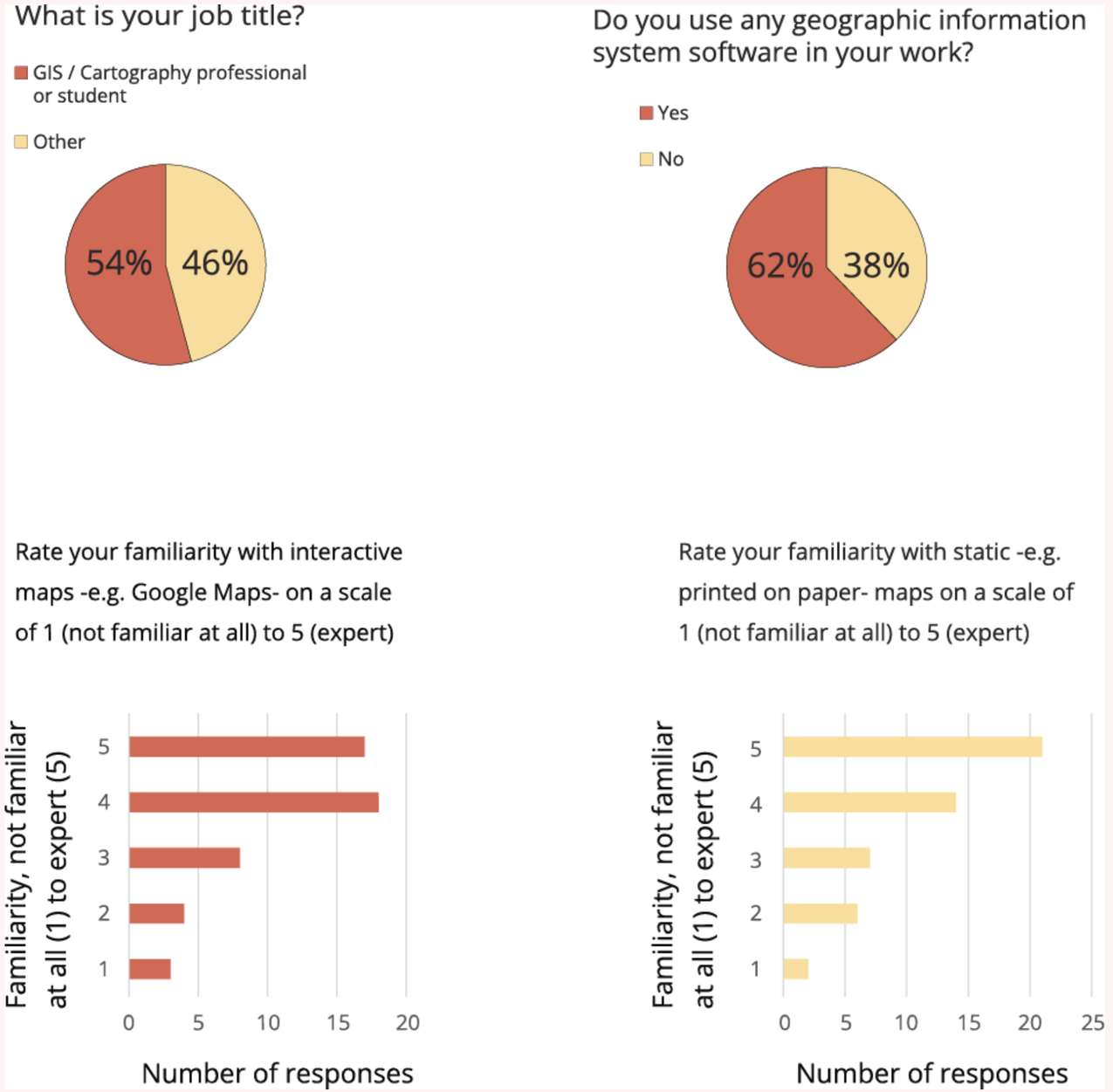
Bivariate raster legend. The bivariate raster's possible cell values are assigned to the respective colours used to represent them.



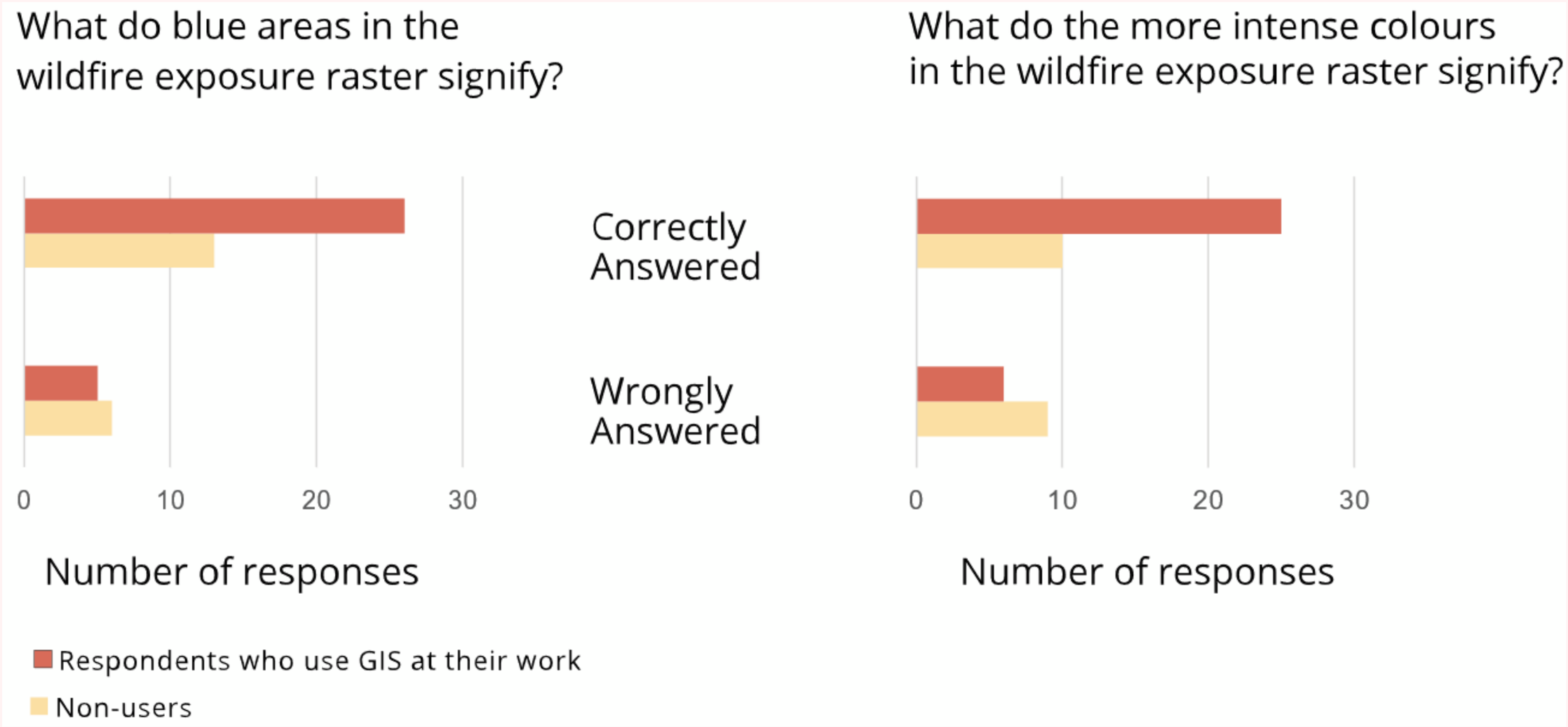
Preliminary version of bivariate raster's legend.



User Experience honeycomb developed by Morville (2004)



Usability questionnaire profile questions



Answers to the questions regarding understanding of the map's colours

The five most mentioned user-friendly aspects of the map included:

• The ability to easily turn on and off layers on demand to focus on needed information as well as the ease of use of the taskbar (13 mentions)

• The colour coding, which was found to be easy to understand and made the individual colours distinguishable (6 mentions)

• The overall map design (4 mentions)

• The ease of zooming in and out, and the overall ease of navigation (3 mentions)

• The ability to search locations with the search bar (3 mentions)

The five most mentioned suggestions for making the map more usable included:

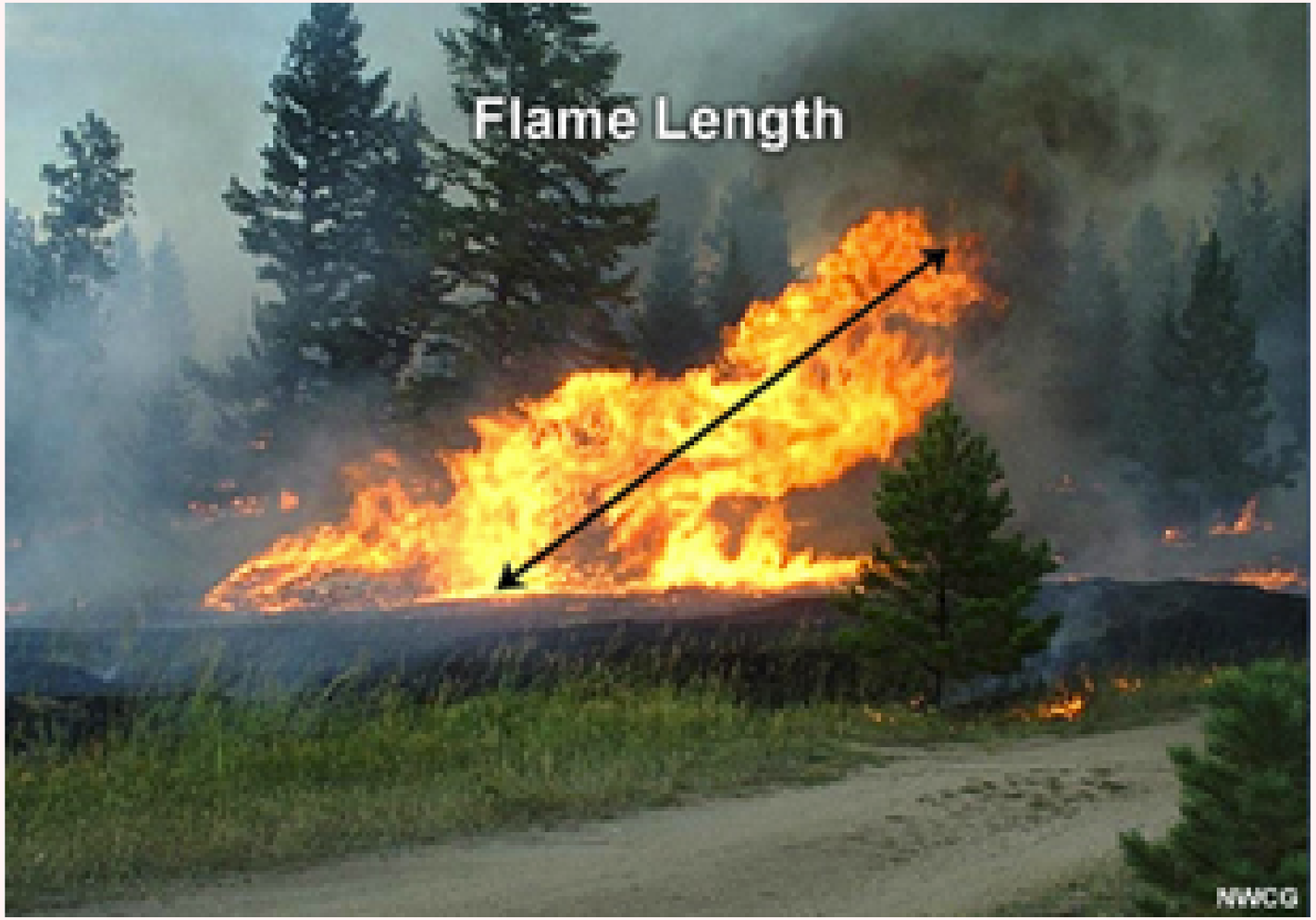
• A change in the exposure raster's colour coding: 3 respondents suggested a use of less colours and 5 recommended a change of the existing colours (e.g., a green / yellow / orange / red / brown scale).

• Making the legend more accessible and easier to find (5 mentions). This is tied to the problem some mobile users experienced, where the legend button was not where it was expected to be in mobile devices (as the questionnaire only described the legend button's position on a PC)

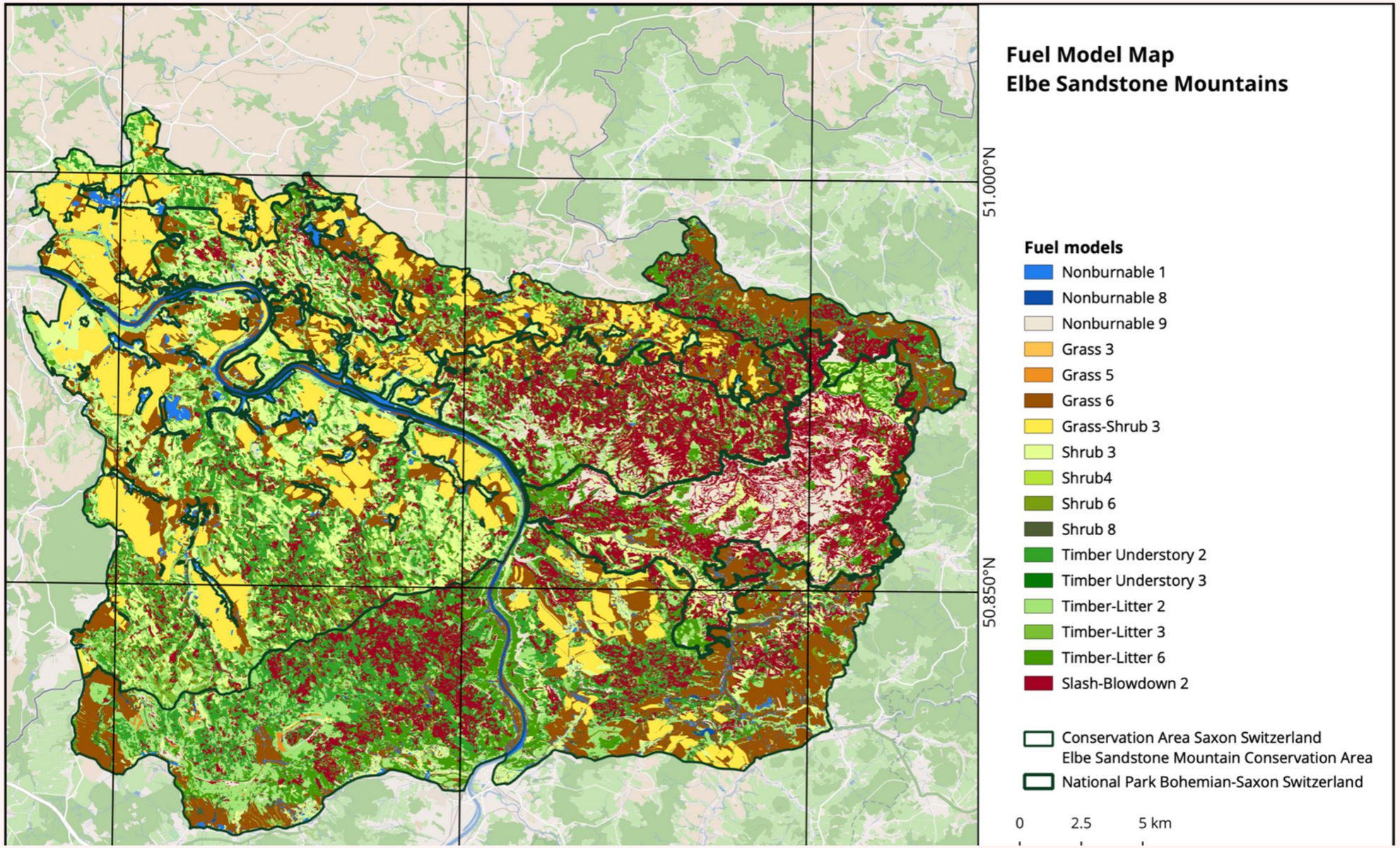
• Adding more contrast between the routes and the exposure rasters as they were not clearly visible (5 mentions)

• Change the colour or size of the fire station symbol to make it more visible (4 mentions)

• Adding a transparency control for the raster layers (2 mentions)



Flame Length, retrieved from 4.1 Flame Length | National Wildfire Coordinating Group (n.d.)



Fuel model map Elbe Sandstone Mountains pre-fire 2022 (Beetz, 2023, p. 42)