DELIVERABLE D.T2.2.1

Testing of the WebGIS tool for landscape protection.

Version 0

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CONTENTS

1 Introduction

This document represents the relevant Deliverable to be considered for the Output O.T2.2 "Pilot implementation of improved WebGIS tool at local/regional level" concerning the testing of the "Risk Mapping Tool for Cultural Heritage Protection" (WGT) carried out at case studies representative for the landscape protection.

This Deliverable reports the results obtained at the case studies during the testing of the WGT highlighting strengths and criticalities in its applicability.

The instructions for the use of the WGT and the additional information on the correct application of the methodology for testing the WGT itself are reported in the Deliverable D.T1.3.3 Tutorial development for user-friendly transfer of the WebGIS tool.

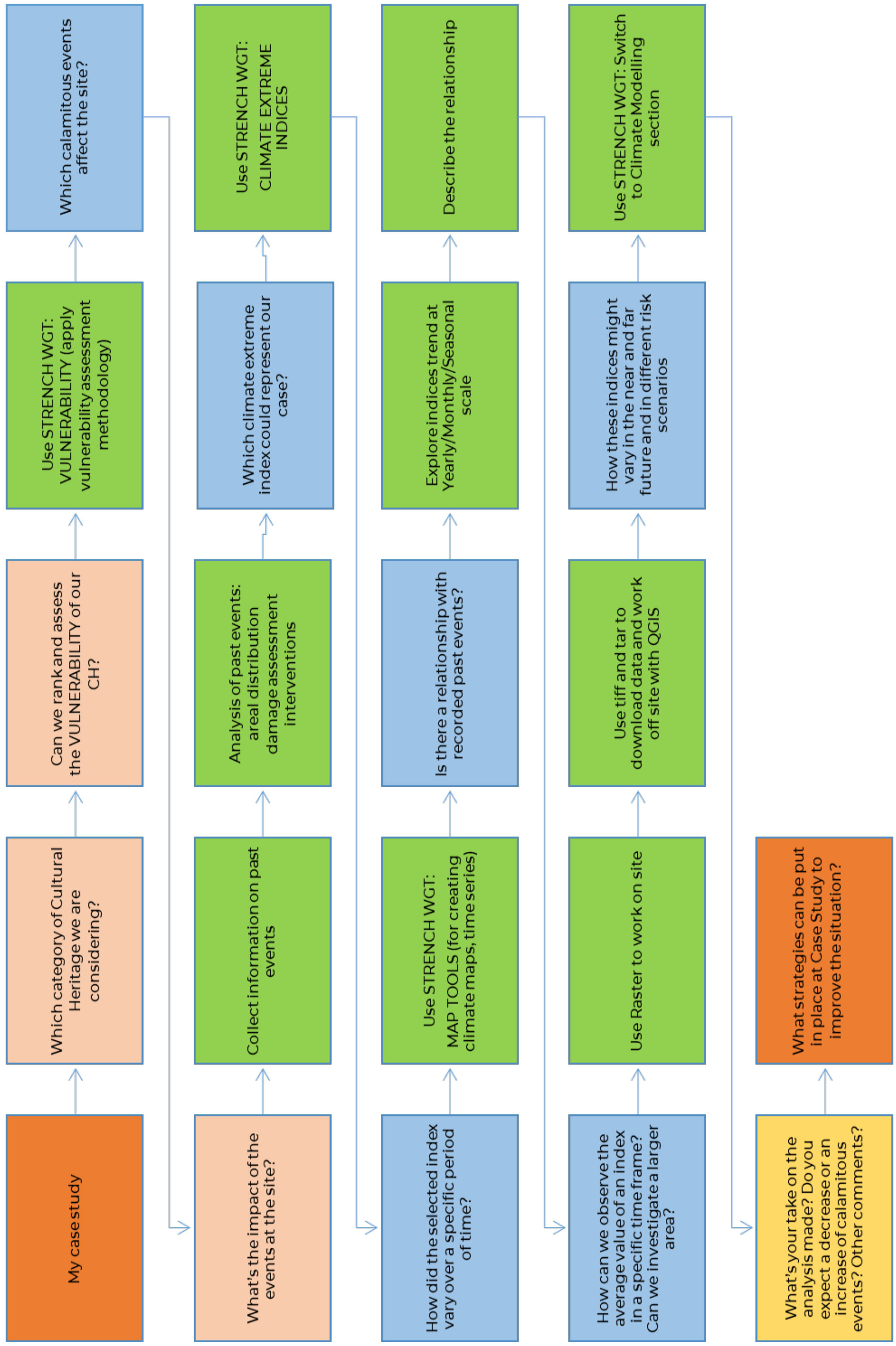
It is also important to underline that the following deliverables must be taken into consideration as being a fundamental part in the development of the methodology and tools integrated in the WGT:

- D.T1.1.2 "Exploring Copernicus programme for safeguarding Cultural Heritage at risk"
- D.T1.1.3 "Scenarios of impact of extreme climate conditions in Central Europe"
- D.T1.2.2 "Definition of a methodology for ranking vulnerability of cultural heritage (Manual)"
- D.T1.3.1 "Tailoring ProteCHt2save on line tool for further implementation"
- D.T1.3.2 "Finalization of the WebGIS tool for decision making in the management of heritage at risk"

The finalized web site of the Risk Mapping Tool for Cultural Heritage Protection is https://www.protecht2save-wgt.eu/.

2 Application of the WebGIS Tool

The methodological approach developed for testing the tools implemented in the "Risk Mapping Tool for Cultural Heritage Protection" is summarized in the following scheme:



3 Figure 1. Scheme of the proposed methodology for testing the WebGIS Tool

This methodological approach has been specifically setup to allow targeted users to exploit the different tools integrated in the WGT in any context ensuring its transferability in other geographical context and considering different cultural heritage categories.
The setup methodology foresees to perform a guided path for in-depth knowledge of the case study on which we need to work to put in place strategies and measure addressed to the protection of a specific cultural heritage category. Starting from a general introduction of the case study and providing an overview of its geographical location and main environmental features, we need to focus then on an in depth study and description of the cultural heritage category that we need to protect against one or more environmental hazard linked to climate change. After we have collected the key information on the cultural heritage asset under study, we can start to assess its vulnerability by applying the Vulnerability tool integrated in WGT. Then, we have to investigate about the main risk impacting the site and carry out a detailed research of the past calamitous events occurred at the site also considering protective and recovery measure put in place during and after the events. Following step by the step the methodological approach, we can apply now the different map tools integrated in the WGT to study and analyse past calamitous events occurred at the site and compare them with the variation of the most appropriate climate extreme indices elaborated in Map tools. Furthermore, we can investigate on how and where identified indices vary in the near and far future under different emission scenario. At the end we'll be able to know all the relevant aspect about our case study with the final aim to put in place all the measure for its protection against extreme events liked to climate change.

3 Case studies of landscape in STRENCH

Following the step by step process reported in the methodology described in Figure 1, PPs in charge for case studies started their work carrying out a detailed analysis of each case study providing a description of their geographical location and the main environmental features. Then, PPs focused on the detailed description of the existing cultural heritage assets present at the site also investigating the occurred past calamitous events and linked damage evaluation highlighting measure put in place during and after the events. PPs also provided all the other important information useful for the in depth knowledge of the site.

Results of these researches at the case studies representative for landscapes (Park of Villa Ghigi, Wachau, Lake Balaton, Vipava Valley) have been reported in the CASE STUDIES page of the WebGIS Tool where it is the possibility to visualize a synthetic description, along with a card containing a detailed description of each case study. These detailed descriptions are also reported as Annexes of the present Deliverable as follows:

- Annex 1 - CE1665 STRENCH D.T2.2.1 Case studies Villa Ghigi PP4 IT
- Annex 2 - CE1665 STRENCH D.T2.2.1 Case studies Wachau PP3 AT
- Annex 3 - CE1665 STRENCH D.T2.2.1 Case studies Lake Balaton PP6 HU
- Annex 4 - CE1665 STRENCH D.T2.2.1 Case studies Vipava Valley PP7 SI

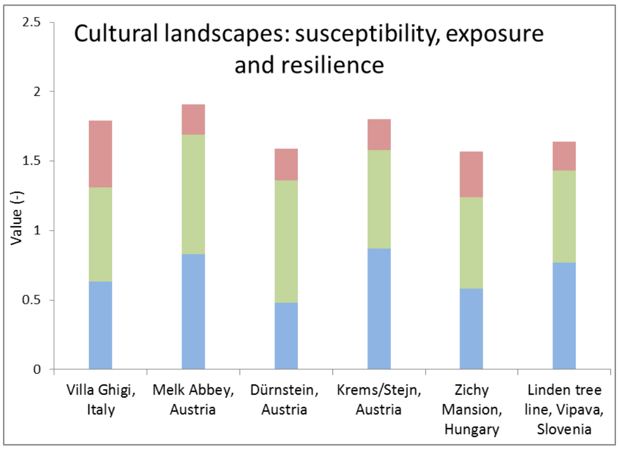
4 Assessing the vulnerability

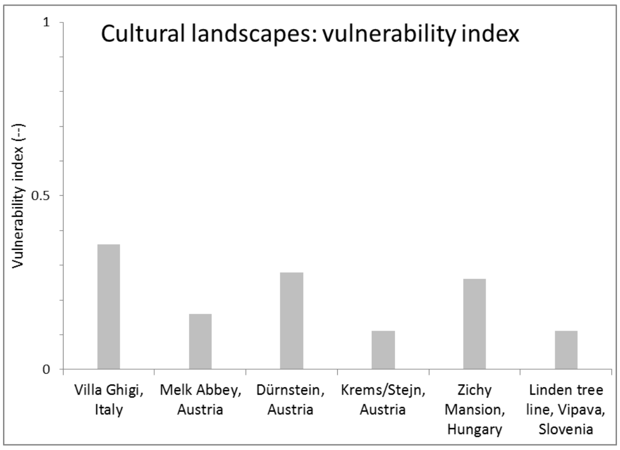
In this session is reported the work carried out by PPs for the assessment of the vulnerability at case studies as part of the Web GIS testing following the methodology developed in STRENCH (D.T1.2.2) and integrated in the WGT tools.

Risk is commonly intended a combination of probability and consequences. The main task of decision makers and managers is to determine how bad the consequences can be under particular scenarios. It is actually shown that not merely the magnitude of the event but rather the conditions within systems strongly determine whether these are likely to suffer major harm, loss or damage. Such conditions of the system are identified by its vulnerability. In the context of disasters, vulnerability has been defined as the degree to which a system, or part of a system, may react adversely during the occurrence of a hazardous event. As far as the physical vulnerability is concerned, vulnerability represents the degree of loss to a given element, or set of elements, within the area affected by a hazard.

In STRENCH, vulnerability is interpreted as the combination of three main factors of a cultural heritage system: 1) susceptibility, 2) exposure and 3) resilience. These represent the main elements that need to be characterised in order to provide an evaluation of vulnerability. The vulnerability index is computed as outlined in D.T1.2.2. For the pilot sites belonging to the cultural landscape typology.

	Type	***Susceptibility***	***Exposure***	***Resilience***	***Vulnerability index***
Villa Ghigi, Italy	Historic park	0.48	0.68	0.63	0.36
Melk Abbey, Austria	Cultural landscape	0.22	0.86	0.83	0.16
Dürnstein, Austria	Cultural landscape	0.23	0.88	0.48	0.28
Krems/Stejn, Austria	Cultural landscape	0.22	0.71	0.87	0.11
Zichy Mansion, Hungary	Historic park + mansion	0.33	0.66	0.58	0.26
Linden tree line, Vipava, Slovenia	Cultural landscape	0.21	0.66	0.77	0.11





In the VULNERABILITY page of the WebGIS Tool the users will find the general description of the developed methodology for the assessment of the vulnerability applied by PPs at case studies and there is also the possibility to visualize the preview of the values (as reported in the previous table) and to download the pdf card containing the detailed description of the evaluation for each case study. The vulnerability assessment gained for each pilot site representative of landscape under investigation is reported as Annexes of the present Deliverable as follows:

- Annex 5 - CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP4 IT Villa Ghigi
- Annex 6a -CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP3 AT Melk Abbay
- Annex 6b -CE1665 STRENCH_D.T2.2.1 Vulnerability ranking PP3 AT Dürnstein
- Annex 6c -CE1665 STRENCH_D.T2.2.1 Vulnerability ranking PP3 AT Krems_Stein
- Annex 7 - CE1665 STRENCH_D.T2.2.1 Vulnerability ranking PP6 HU Lake_Balaton
- Annex 8a - CE1665 STRENCH_D.T2.2.1 Vulnerability ranking PP7 SI Lanthieri_Manor
- Annex 8b -CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP7 SI Vipava House Miren 114
- Annex 8c - CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP7 SI Vipava House Miren 137
- Annex 8d CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP7 SI Vipava Linden tree line
- Annex 8e CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP7 SI Vipava Rence Church
- Annex 8f CE1665 STRENCH D.T2.2.1 Vulnerability ranking PP7 SI Vipava Rence School

The initial iterations of the methodology testing resulted in a validated version which has been digitalised in a simple decision support tool for vulnerability evaluation, in the form of a Excel worksheet.

In the next section testing of such tool is shown, presenting the evaluation of each of the cultural landscape case studies.

4.1 Villa Ghigi

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	N/A	0
	CR1.1b Use	N/A	0
	CR1.1c State of conservation	N/A	0
	CR1.1d Previous harming interventions	N/A	0
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	presence of elements of decoration	1
	CR1.2b Water features	presence of water feature	1
	CR1.2c Circulation features	presence of circulation features	1
	CR1.2d State of conservation	Fair	0.18
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Presence of species not tolerant to local natural and climate threats	0.3
	CR1.3a2 Age (Tree)	Prevalence of mature/veteran trees	1
	CR1.3a3 Slenderness ratio (Tree)	Presence of trees with h/d > 70	0.3
	CR1.3b Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0
	CR1.3c Use	Extensive land-use	1
	CR1.3d State of conservation	Fair	0.18
CR1.4 Topography		Unstable slopes with inclination of 15-30 degrees	1
CR1.5 Geosphere	*CR1.5a Bedrock*	presence of unstable bedrock	1
	CR1.5b Soil	fine-grained soil (silt, clay)	0.3
	CR1.5c Geomorphology	presence of unstable geological formation	1
CR1.6 Hydrosphere	*CR1.6a Groundwater*	water table prone to sudden fluctuations	1
	CR1.6b Surface water	close to permanent, seasonal and man-made water course	1
	CR1.6c Sea	far from sea	0

SUSCEPTIBILITY= 0.484

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	presence of built systems and features	1
	CR2.1b Natural systems and biodiversity	Presence of natural systems and features with high value for biodiversit	1
	CR2.1c Cultural traditions	presence of cultural traditions	1
	CR2.1d Cultural acknowledgements	Grade II	0.86
CR2.2Population		presence of fragile population	1
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		absence of relevant infrastructure	0

EXPOSURE= 0.683

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	regular maintenance	1
	CR3.1b Warning	absence of early warning systems	0
	CR3.1c Knowledge & awareness	knowledge and awareness ensured	1
	CR3.1d Information	partial, not up-to-date or incomplete information exist	0.3
	CR3.1e Policy &regulation	regulated CH protection	1
CR3.2Coping capacity	*CR3.2a Emergency resources*	Absence of emergency human and economic resources	0
	CR3.2b Mitigating systems/measures	Existence of mitigating system	1
	CR3.2c Physical strengthening/protection	Existence of physical protection	1
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	funds available but insufficient	0.3
	CR3.3b Social recovery	Existence of social recovery plan	1
	CR3.3c Physical recovery	risk management plan without specific emergency measures	0.3

RESILIENCE= 0.625

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.484) + (0.30x0.683) - (0.30x0.625) = 0.356

Vulnerability = 0.356

With 0≤V≤1 (low to high vulnerability).

4.2 Wachau

- Melk Abbey Landscape

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	Structurally sound constructions made of resistant materials	0
	CR1.1b Use	In continuous use	0.1
	CR1.1c State of conservation	Good	0
	CR1.1d Previous harming interventions	No interventions made	0
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	presence of elements of decoration	1
	CR1.2b Water features	presence of water feature	1
	CR1.2c Circulation features	presence of circulation features	1
	CR1.2d State of conservation	Good	0
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Presence of species tolerant to local natural and climate threats	0
	CR1.3a2 Age (Tree)	Presence of some mature/veteran trees	0.3
	CR1.3a3 Slenderness ratio (Tree)	Presence of trees with h/d > 70	0.3
	CR1.3b Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0
	CR1.3c Use	Intensive land-use with natural elements	0.3
	CR1.3d State of conservation	Good	0
CR1.4 Topography		Stable slopes with slope inclination higher than 30 degrees	0.3
CR1.5 Geosphere	*CR1.5a Bedrock*	presence of stable bedrock	0
	CR1.5b Soil	fine-grained soil (silt, clay)	0.3
	CR1.5c Geomorphology	presence of stable geological formation	0
CR1.6 Hydrosphere	*CR1.6a Groundwater*	stable water table	0
	CR1.6b Surface water	close to permanent, seasonal and man-made water course	1
	CR1.6c Sea	far from sea	0
		SUSCEPTIBILITY=	**0.219**

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	presence of built systems and features	1
	CR2.1b Natural systems and biodiversity	Presence of natural systems and features with high value for biodiversit	1
	CR2.1c Cultural traditions	presence of cultural traditions	1
	CR2.1d Cultural acknowledgements	Grade I	1
CR2.2Population		population but no fragility	0.3
CR2.3 Economic		presence of stable and ramified system with high economic value	1
CR2.4 Infrastructure		presence of relevant infrastructure	1
		EXPOSURE=	**0.86**

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	regular maintenance	1
	CR3.1b Warning	absence of early warning systems	0
	CR3.1c Knowledge & awareness	knowledge and awareness ensured	1
	CR3.1d Information	complete info is available	1
	CR3.1e Policy &regulation	regulated CH protection	1
CR3.2Coping capacity	*CR3.2a Emergency resources*	Existence of emergency human and economic resources	1
	CR3.2b Mitigating systems/measures	Existence of mitigating system	1
	CR3.2c Physical strengthening/protection	Existence of physical protection	1
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	funds available and accessible	1
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	risk management plan exists and up to date	1

RESILIENCE=	**0.825**

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.219) + (0.30x0.860) - (0.30x0.825) = 0.164

Vulnerability = 0.164

With 0≤V≤1 (low to high vulnerability).

- Dürnstein

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	Structurally sound constructions made of resistant materials	0
	CR1.1b Use	In continuous use	0.1
	CR1.1c State of conservation	Good	0
	CR1.1d Previous harming interventions	No interventions made	0
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	presence of elements of decoration	1
	CR1.2b Water features	presence of water feature	1
	CR1.2c Circulation features	presence of circulation features	1
	CR1.2d State of conservation	Good	0
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Presence of species not tolerant to local natural and climate threats	0.3
	CR1.3a2 Age (Tree)	Presence of some mature/veteran trees	0.3
	CR1.3a3 Slenderness ratio (Tree)	Presence of trees with h/d > 70	0.3
	CR1.3b Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0
	CR1.3c Use	Intensive land-use with natural elements	0.3
	CR1.3d State of conservation	Good	0
CR1.4 Topography		Stable slopes with slope inclination higher than 30 degrees	0.3
CR1.5 Geosphere	*CR1.5a Bedrock*	presence of stable bedrock	0
	CR1.5b Soil	fine-grained soil (silt, clay)	0.3
	CR1.5c Geomorphology	presence of stable geological formation	0
CR1.6 Hydrosphere	*CR1.6a Groundwater*	stable water table	0
	CR1.6b Surface water	close to permanent, seasonal and man-made water course	1
	CR1.6c Sea	far from sea	0

SUSCEPTIBILITY=	**0.23**

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	presence of built systems and features	1
	CR2.1b Natural systems and biodiversity	Presence of natural systems and features with high value for biodiversit	1
	CR2.1c Cultural traditions	presence of cultural traditions	1
	CR2.1d Cultural acknowledgements	Grade II	0.86
CR2.2Population		presence of fragile population	1
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		presence of relevant infrastructure	1

EXPOSURE=	**0.883**

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	regular maintenance	1
	CR3.1b Warning	absence of early warning systems	0
	CR3.1c Knowledge & awareness	knowledge and awareness ensured	1
	CR3.1d Information	complete info is available	1
	CR3.1e Policy &regulation	lack of regulations for CH	0
CR3.2Coping capacity	*CR3.2a Emergency resources*	Absence of emergency human and economic resources	0
	CR3.2b Mitigating systems/measures	Existence of mitigating system	1
	CR3.2c Physical strengthening/protection	Absence of physical protection	0
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	funds available and accessible	1
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	no risk management plan	0

RESILIENCE=	**0.475**

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.230) + (0.30x0.883) - (0.30x0.475) = 0.283

Vulnerability = 0.283

With 0≤V≤1 (low to high vulnerability).

- Krems/Stejn

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	Structurally sound constructions made of resistant materials	0
	CR1.1b Use	In continuous use	0.1
	CR1.1c State of conservation	Fair	0.18
	CR1.1d Previous harming interventions	No interventions made	0
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	presence of elements of decoration	1
	CR1.2b Water features	presence of water feature	1
	CR1.2c Circulation features	presence of circulation features	1
	CR1.2d State of conservation	Fair	0.18
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Presence of species tolerant to local natural and climate threats	0
	CR1.3a2 Age (Tree)	Presence of some mature/veteran trees	0.3
	CR1.3a3 Slenderness ratio (Tree)	Presence of trees with h/d > 70	0.3
	CR1.3b Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0
	CR1.3c Use	Intensive land-use with natural elements	0.3
	CR1.3d State of conservation	Fair	0.18
CR1.4 Topography		Stable slopes with inclination less than 15 degrees	0.15
CR1.5 Geosphere	*CR1.5a Bedrock*	presence of stable bedrock	0
	CR1.5b Soil	coarse-grained soil (sand, gravel)	0
	CR1.5c Geomorphology	presence of stable geological formation	0
CR1.6 Hydrosphere	*CR1.6a Groundwater*	stable water table	0
	CR1.6b Surface water	close to permanent, seasonal and man-made water course	1
	CR1.6c Sea	far from sea	0

SUSCEPTIBILITY= 0.223

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	presence of built systems and features	1
	CR2.1b Natural systems and biodiversity	Presence of natural systems and features with high value for biodiversit	1
	CR2.1c Cultural traditions	presence of cultural traditions	1
	CR2.1d Cultural acknowledgements	Grade III	0.61
CR2.2Population		population but no fragility	0.3
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		presence of relevant infrastructure	1

EXPOSURE= 0.713

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	regular maintenance	1
	CR3.1b Warning	presence of early warning systems	1
	CR3.1c Knowledge & awareness	knowledge and awareness ensured	1
	CR3.1d Information	complete info is available	1
	CR3.1e Policy &regulation	regulated CH protection	1
CR3.2Coping capacity	*CR3.2a Emergency resources*	Existence of emergency human and economic resources	1
	CR3.2b Mitigating systems/measures	Existence of mitigating system	1
	CR3.2c Physical strengthening/protection	Existence of physical protection	1
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	funds available but insufficient	0.3
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	risk management plan exists and up to date	1

RESILIENCE= 0.873

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.223) + (0.30x0.713) - (0.30x0.873) = 0.108

Vulnerability = 0.108

With 0≤V≤1 (low to high vulnerability).

4.3 Lake Balaton

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	Structurally sound constructions made of materials prone to degradation or impact damage	0.5
	CR1.1b Use	In continuous use	0.1
	CR1.1c State of conservation	Fair	0.18
	CR1.1d Previous harming interventions	Yes, previous interventions	1
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	presence of elements of decoration	1
	CR1.2b Water features	absence of water features	0
	CR1.2c Circulation features	presence of circulation features	1
	CR1.2d State of conservation	Fair	0.18
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Presence of species not tolerant to local natural and climate threats	0.3
	CR1.3a2 Age (Tree)	Presence of some mature/veteran trees	0.3
	CR1.3a3 Slenderness ratio (Tree)	Presence of trees with h/d > 70	0.3
	CR1.3b Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0
	CR1.3c Use	Extensive land-use	1
	CR1.3d State of conservation	Fair	0.18
CR1.4 Topography		Stable slopes with inclination less than 15 degrees	0.15
CR1.5 Geosphere	*CR1.5a Bedrock*	presence of stable bedrock	0
	CR1.5b Soil	fine-grained soil (silt, clay)	0.3
	CR1.5c Geomorphology	presence of stable geological formation	0
CR1.6 Hydrosphere	*CR1.6a Groundwater*	stable water table	0
	CR1.6b Surface water	far from permanent, seasonal and man-made water course	0
	CR1.6c Sea	far from sea	0

SUSCEPTIBILITY= 0.33

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	presence of built systems and features	1
	CR2.1b Natural systems and biodiversity	Presence of natural systems and features with low/medium value for biodiversity	0.5
	CR2.1c Cultural traditions	presence of cultural traditions	1
	CR2.1d Cultural acknowledgements	Grade III	0.61
CR2.2Population		population but no fragility	0.3
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		presence of relevant infrastructure	1

EXPOSURE= 0.663

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	irregular maintenance	0.5
	CR3.1b Warning	presence of early warning systems	1
	CR3.1c Knowledge & awareness	lack of awareness	0.8
	CR3.1d Information	partial, not up-to-date or incomplete information exist	0.3
	CR3.1e Policy &regulation	regulated CH protection	1
CR3.2Coping capacity	*CR3.2a Emergency resources*	Existence of emergency human and economic resources	1
	CR3.2b Mitigating systems/measures	Absence of mitigating systems	0
	CR3.2c Physical strengthening/protection	Existence of physical protection	1
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	funds available but insufficient	0.3
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	risk management plan without specific emergency measures	0.3

RESILIENCE= 0.58

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.330) + (0.30x0.663) - (0.30x0.580) = 0.256

Vulnerability = 0.256

With 0≤V≤1 (low to high vulnerability).

4.4 Vipava Valley

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	Structurally sound constructions made of resistant materials	0
	CR1.1b Use	In continuous use	0.1
	CR1.1c State of conservation	Good	0
	CR1.1d Previous harming interventions	No interventions made	0
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	presence of elements of decoration	1
	CR1.2b Water features	presence of water feature	1
	CR1.2c Circulation features	presence of circulation features	1
	CR1.2d State of conservation	Good	0
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Presence of species tolerant to local natural and climate threats	0
	CR1.3a2 Age (Tree)	Absence of mature/veteran trees	0
	CR1.3a3 Slenderness ratio (Tree)	h/d < 70	0
	CR1.3b Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0
	CR1.3c Use	Intensive land-use (incl. urban-sprawl, without natural elements	0
	CR1.3d State of conservation	Good	0
CR1.4 Topography		Stable slopes with slope inclination higher than 30 degrees	0.3
CR1.5 Geosphere	*CR1.5a Bedrock*	presence of stable bedrock	0
	CR1.5b Soil	fine-grained soil (silt, clay)	0.3
	CR1.5c Geomorphology	presence of stable geological formation	0
CR1.6 Hydrosphere	*CR1.6a Groundwater*	water table prone to sudden fluctuations	1
	CR1.6b Surface water	close to permanent, seasonal and man-made water course	1
	CR1.6c Sea	far from sea	0

SUSCEPTIBILITY= 0.207

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	presence of built systems and features	1
	CR2.1b Natural systems and biodiversity	Absence of natural systems and features	0
	CR2.1c Cultural traditions	presence of cultural traditions	1
	CR2.1d Cultural acknowledgements	Grade I	1
CR2.2Population		population but no fragility	0.3
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		presence of relevant infrastructure	1

EXPOSURE= 0.66

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	regular maintenance	1
	CR3.1b Warning	presence of early warning systems	1
	CR3.1c Knowledge & awareness	knowledge and awareness ensured	1
	CR3.1d Information	partial or complete info exist but not available	0.5
	CR3.1e Policy &regulation	regulated CH protection	1
CR3.2Coping capacity	*CR3.2a Emergency resources*	Existence of emergency human and economic resources	1
	CR3.2b Mitigating systems/measures	Existence of mitigating system	1
	CR3.2c Physical strengthening/protection	Existence of physical protection	1
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	funds available but insufficient	0.3
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	risk management plan without specific emergency measures	0.3

RESILIENCE= 0.765

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.207) + (0.30x0.660) - (0.30x0.765) = 0.113

Vulnerability = 0.113

With 0≤V≤1 (low to high vulnerability).

5 Results of the Web GIS tool at the pilot sites

The final results of the overall procedure carried out for the testing of the Risk Mapping Tool for Cultural Heritage Protection are reported in detail in the following annexes:

- Annex 9 - CE1665 STRENCH D.T2.2.1 WebGIS-Testing PP4_IT
- Annex 10 - CE1665 STRENCH D.T2.2.1 WebGIS-Testing PP3_AUT
- Annex 11 - CE1665 STRENCH D.T2.2.1 WebGIS-Testing PP6_HU
- Annex 12 - CE1665 STRENCH D.T2.2.1 WebGIS-Testing PP7_SI

The documents in the annexes also report final consideration of the PPs about the usability of the Risk Mapping Tool for Cultural Heritage Protection highlighting strengths and weaknesses for the application in the management of cultural heritage at risk due to climate change.

DELIVERABLE D.T2.2.1 (PP3)

Testing of the WebGIS tool for landscape protection, PP3 (AUT) Wachau Region

Inhalt

An introduction to the Wachau

The Cultural Landscape Wachau (UNESCO World Heritage Site) stretches between the towns Melk and Krems along the Danube River for approximately 36 km. The Wachau is described by the UNESCO as:

Figure 1 Typical Wachau landscape. ©Stefan Rotter

"(…) an outstanding example of a riverine landscape bordered by mountains in which material evidence of its long historical evolution has survived to a remarkable degree. Criterion (iv): The architecture, the human settlements, and the agricultural use of the land in the Wachau vividly illustrate a basically medieval landscape which has evolved organically and harmoniously over time".[1]

The Wachau cultural landscape is composed of an iconic mix of landscapes characterized by terraced viticulture, traditional small scale fruit cultivation, historic towns filled with a multitude of heritage sites most of which are built directly on the banks of the Danube River and backed against steep mountainous terrain.

This topography creates numerous risks for the cultural heritage of the region. The location of several historic towns (Melk, Duernstein, Stein/Krems) directly on the banks of river Danube and at the foot of the descending mountains of the valley, makes them vulnerable to Danube floods, landslides from the steeply ascending walls of the Danubian water gap and flash floods from tributary creeks and rivers.

The old towns of Melk, Duernstein, Krems and Stein are medieval in their structures. Bricks, stones and wood are the main building materials, with wood being especially in the roof constructions and first floors. This fact makes them very vulnerable to fire, especially since in the medieval cores of the towns the houses and roofs are built in a way in which the buildings neighbouring each other are directly joined, without gaps, which would hinder the spread of fire.

Severe hazards such as landslides, flash floods and rock fall threatening both the landscape itself and CH assets which are commonplace.

[1] https://whc.unesco.org/en/list/970 (accessed 20.12.2021)

Cultural Heritage at risk in the Wachau region

In December 2000 the "Wachau cultural Landscape" has been inscribed in the UNESCO List of World Heritage Sites and inhabits a broad spectrum of tangible and intangible cultural heritage.

Dry Stone Walls as tangible and intangible cultural heritage

Building and maintaining dry stone walls is considered its own craft and has been included by the UNESCO as an intangible cultural heritage for Austria just recently in 2021. Although similar constructions made of stone have been observed in Austria as being as old as 3.500 years the craft of building and maintain these has been widely forgotten in Austria except within the Wachau region where this tradition remains relevant due to its unique topography.

With the first literal evidence traced back to the 12th century A.D dry stone walls shape the cultural landscape of the Wachau region to this day. Dry stone walls have been used traditionally for agricultural purposes using locally available material for the creation of terraces for viticulture as well as for agricultural buildings, pathways and even in the construction of railroads, just to name a few.

Dry stone walls are an important aspect of the cultural landscape of the Wachau and are constructed by staking suitable locally available stones above each other with only dry earth being used in some instances as binding material. Structural integrity is achieved by carefully selecting the stones and then stacking them methodically and meticulously. This concept of construction reflects a resource-efficient use of locally available building material and has proven its value in creating acreage for vineyards in the steep terrain found within the Wachau region.

Traditionally the craft of creating dry stone walls was mainly passed on generation by generation as oral tradition and became increasingly forgotten with the increased mechanization of agricultural methods after the second world war in Austria. In the past decades however a revitalization of the craft has been observed and an increasing number of winemakers are returning to the use and restoration of dry-stone walls thanks to the efforts of many stakeholders and interest groups active in the field of heritage protection and winemaking.

Due to the local sourcing of building material and labour intense construction dry stone walls are deemed as especially sustainable method and contributes to an increase of biological diversity by creating small scale habitats and biotopes for various species. [2]

Figure 2 Dry-stone walls in the Wachau. ©Rainer Vogler

[2]https://www.unesco.at/kultur/immaterielles-kulturerbe/oesterreichisches-verzeichnis/detail/article/trockensteinmauern (accessed 22.12.2021)

Within the Wachau there are currently nearly three million square meters of vine-cultivation area which are directly placed on terraces carried by dry stone walls which translates to more than 40 percent of the total area used for viticulture in the region. Therefore, the craft and the existing dry-stone walls of the terraced viticulture of the Wachau represents an outstanding example on how intangible and tangible cultural heritage harmoniously complement each other as the upkeep and restoration of these unique and iconic terrasses would not be possible without the knowledge of the craft itself. [3] At this point Mr. Rainer Vogler must be named as a primary expert on this subject who is very active in the preservation and teaching of the craft. Unfortunately, a guided tour as part of a STRENCH working table in the Wachau which would have included this topic had to be cancelled due to Covid-19.

Castles, Palaces and Monasteries

The long history of settlement in the Wachau and unique landscape has "produced" numerous castles, ruins and monasteries within the area some of which are still in active use. From the well know ruins of Duernstein, the castles Aggstein & Gozzoburg to the lesser known but beautiful castle of Schönbühl (left picture) the Wachau is littered with cultural heritage sites. Fittingly two beautiful heritage sites the Melk Abbey and Göttweig Abbey, both of which contain numerous artistic treasures and antique libraries are located on the most western and eastern border of the Wachau.

Figure 3 Schloss Schönbühl. © Donau Niederösterreich/Lachlan Blair

It should be noted that although medieval and built heritage of later periods is commonplace in the Wachau the area was also an important region during the roman era. Being part of the roman province of Noricum the romans approximately settled in the Wachau more than 2000 years ago and made the Wachau river valley part of the Danubian Limes which became part of a 7,500-kilometre-long border of the roman empire. The roman presence is estimated to have lasted over 400 years and has given the area

Figure 4 Roman remains in Mautern. ©Eva Kuttner

[3] https://www.noe.gv.at/noe/Trockensteinmauern_auf_der_Liste_des_immateriellen_Kultur.html (accessed 22.12.2021)

additional cultural heritage sites such as seen in Mautern which was located on a strategic river crossing of the Danube being a major trade route north into the so called Barbaricum.[4]

Agriculture (apricot trees) & Viticulture

Originating from China the apricot is estimated to have been cultivated in Wachau since the mid-1st Century A.D. First written evidence of its cultivation in the Wachau has been found dating back to the year 1509. Today an estimated 100.000 apricot trees are cultivated in the Wachau and the name "Wachauer Marille" has become a kind of trademark and is reserved by the Austrian Federal Ministry for Agriculture only for apricots originating from the Wachau area. Aside from the produce the long tradition of cultivating apricots continues to preserve the cultural landscape of the Wachau and attracts tourists every year who wish to witness the blossoming of the trees. With regards to land use and contribution to the aesthetics of the Wachau viticulture is a very strong component taking up to 1.291 hectares of space and being a strong economic factor of the region.[5]

Figure 5 Cultural landscape Wachau. ©ÖWM/Robert Herbst

Artistic treasures

Aside from numerous built heritage sites containing artistic decoration a well as lavishly decorated churches the Wachau area contains several arts galleries and museums such as the State Gallery of Lower Austria, the Kunst Halle Krems and the Karikatur Museum and other notable treasures. Just to name one, the Venus of Willendorf: although the original 11cm tall statue is now exhibited in natural history museum Vienna located approx. 100 km away from the excavation site a small local museum and several art installations commemorate this extraordinary archaeological find which is estimated to being 29.500 years old. [6]

Figure 6 Venus of Willendorf. ©NHM

[4] https://www.donau-limes.at/besuchen/regionen/nibelungengau-wachau/ (accessed 22.12.2021)

[5] https://info.bmlrt.gv.at (accessed 22.12.2021)

[6] https://www.nhm-wien.ac.at/forschung/praehistorie/forschungen/venus-forschung (23.12.2021)

Historic medical city centres

Described by the UNESCO as a medieval landscape which harmoniously evolved over the centuries many towns in the Wachau contain historic city centres. Most notably the centres of Melk (including a famous abbey), Duernstein and Krems/Stein can be listed and are further elaborated and assessed upon in the following section.

Summary of Cultural Heritage Assets Wachau Region

In summary the cultural heritage assets considered for the Wachau region are:

- Historic (medieval) city centres
- Monasteries
- Castles
- Ruins
- Artistic treasures of all periods
- Various hamlets in the hinterland
- Terraced vineyards (dry stone walls) and apricot trees

Threats and Vulnerability (1): **Ranking the Vulnerability of the Wachau using the STRENCH vulnerability assessment methodology**

The Wachau itself is a region composed of a cultural landscape filled with towns and villages located along the Danube River. The STRENCH Vulnerability Assessment being somewhat more tailored towards single objects was applied to three specific sites deemed to be representative and were individually assessed.

1) Melk Abbey

Located at the western end of the Wachau Cultural Landscape the Melk Abbey is one of the highlights of the UNESCO world heritage site which encompasses the entire region. The Melk Abbey was founded in 1089 is a popular tourist destination attrackting roughly half a million visitors annually in the years prior to the Covid-19 pandemic. The Abbey itself is located on a hill close to the riverbanks of the Danube River and is filled with cultural heritage assesst dispersed throughout the abbies park, museum, historic libary as well as the church.[7]

Figure 7 Flooded old city of Melk, on the left the monastery. © ÖBH Kermer.

For the assesment of the Melk Abbey the saftey officer of the abbey Mr. Gerhard Scheiber was kind enough to give provide us with his input. It should be underlined that, for the sake of providing an example, the evaluation of only a few criteria/ sub-criteria is here presented. The remaining part of the assessment is therefore omitted.

[7] Weblink Abbey Melk: https://www.stiftmelk.at/de/ (accessed 16.01.2022)

Evaluation of SUSCEPTIBILTY (sub-)criteria: → **Susceptibility = 0.30625**

Although a large permanent water source namely the Danube River flows directly below the famous Melk Abbey, which is filled with cultural heritage treasures and as itself is a cultural heritage site, the structure of the building as well as other factors dampen its susceptibility.

Evaluation of EXPOSURE (sub-)criteria: → **Exposure = 0.76**

Nonetheless the location and significant of the site does lead to a high exposure rating.

Evaluation of RESILIENCE (sub-)criteria: → **Resilience = 0.825**

Regarding the resilience of the site the preparation measures in place as well as the work of the local security officer in conjunction with previous cooperation with the Centre for Cultural Heritage Protection at the Danube University Krems via various in STRENCH capitalized projects result in a stout resilience.

Vulnerability evaluation: **Vulnerability = 0.194875**

With 0≤V≤1 (low to high vulnerability).

2) Duernstein

Figure 8 Duernstein church seen from the castle ruin. © Kaiser

Dürnstein is a small municipality within the Wachau Region which is visited by roughly one million people per year (pre Covid-19). The old town and near by hamlet, in which the popular historic figure King Richard I of England was held hostage, are popular tourist destinations. Dürnstein is litered with cultural hertiage sites strongly contributing to the cultural landscape of the Wachau Region.[8]

For the assesment of Dürnstein Mr. Martin Jung a scientist at the AIT (Austrian Institute of Technology) who recently featured Dürnstein in the EU Interreg project CHEERS was kind enough to provide us with his input.

For the case study analysed:

Vulnerability evaluation: **Vulnerability = 0.351235**

With 0≤V≤1 (low to high vulnerability).

[8] Weblink: https://www.duernstein.at/ (accessed 16.01.2022)

3) Krems / Stein

Krems/Stein marks the east end of the Wachau Region. The Town is composed of two historic old towns (Krems & Stein) several museums including numerous cultural heritage objects attrackting a substantial amount of tourists with a quarter of a million overnight stays recorded in 2019. Other attractions include the Stein Prison which harbours Austrias most famous inmate Jofef Fritzl (visiting hours are Tue and Thu 08:00-11:00 &12:00-14:30, Fr & Sa from 08:00-11:00).

Figure 9 Stein an der Donau. © Kaiser

Vulnerability evaluation: **Vulnerability = 0.18242**

With 0≤V≤1 (low to high vulnerability).

Please note that for the sake of brevity a more detailed analysis of Duernstein & Krems/Stein was omitted and can be examined in detail in the STRENCH Deliverable D.T.1.2.2

Summary Melk, Duernstein, Krems/Stein:

One way possibly defining the vulnerability of the Wachau region may be in selecting some of the sites found withing and by assessing the region via the collective average. This train of thought however leaves many variables out of the equation and may result in a distorted picture regarding vulnerability therefore inviting a further evaluation via the WebGIS Tool.

Melk Abby	Vulnerability = 0.194875
Duernstein	Vulnerability = 0.351235
Krems/Stein	Vulnerability = 0.18242
Total Vulnerability	(0.194875+0.351235+0.18242) / 3 = **0.24284333**

Chart 1: With 0≤V≤1 (low to high vulnerability).

This argumentation becomes more relevant when taking a deeper look into the site Krems/Stein which has a historic town centre filled with cultural heritage sites and museums located directly on the riverbanks of the flood prone Danube River. Although effective flood protection measures such as mobile barriers and dams have proven valuable in more recent floods these protection measures were pushed to the limit during a flood event in 2013 during which the mobile flood protection had to be stacked up with the use of sandbags. Therefore, protection measures and evacuation plans for the sites and museums withing the flood zone remain vital for the security of the cultural heritage assets within and would benefit from prognostic data regarding the most prominent threats of the region. Thankfully these are provided by the WebGIS Tool.

Threats and Vulnerability (2): What Hazards threaten the cultural heritage of the Wachau region?

While the assessed sites (Melk, Duernstein, Krems/Stein) predominantly contain built heritage the question remains on the additional aspects of the UNESCO Wachau cultural heritage region namely the natural heritage including the famous apricot trees of the region. The natural heritage does however include built heritage elements such as the typical terraced landscape found within the Wachau region. When given regard to the various additional heritage assets such as the historic city centres, monasteries castles, ruins and hamlets in the hinterland, just to name a few, a wholistic precise assessment remains challenging.

However, most of the heritage assets of the Wachau share common, or indeed overlapping, threats which can be pinpointed using the WebGIS Tool. These major and most of the time omnipresent threats include:

Flood / Flash Flood (mainly from the Danube River and its tributaries)

With a large amount of cultural heritage sites, museums and art galleries located directly on the banks of Danube River and at the foot of the descending hills flooding and flash floods pose/s arguably the greatest risk to the plentiful cultural heritage sites within the Wachau.

Heavy Rain

Heavy rain can swamp and soak the steep vineyards of the Wachau valley and can cause strong erosion and landslides which may damage heritage sites as well as the iconic terraced landscape.

Landslides

A possible cause of heavy rain this hazard may be interlocked with it but can also appear on its own causing damage to cultural heritage sites and the iconic stone terraces which act as foundation for the still thriving viticulture in the Wachau.

Fire due to Draught

Fire is recognized as big risk to the old towns of Wachau, since the roofs of the buildings often are immediately connected, as well as for the natural (and cultural) landscapes, as the pastures and shrubs are often highly dried up due to long drought periods. An arguably more overlooked threat in Austria, fire due to draught has reached a new threat level due to the ongoing climate change and global warming. In October 2021 Austria experienced its largest forest fire in 60 years which appears to have been caused by an unusual low humidity, strong winds and a negligently extinguished campfire. This combination of environmental factors together with human error caused a prolonged and exhaustive firefighting effort lasting into November and resulting in an estimated 30 million EUR damage/cost.[9] Perhaps this destructive event will become common in Austria as it is well known in the Mediterranean area.

[9]https://boku.ac.at/wabo/waldbau/forschung/themen/bewirtschaftungskonzepte/waldbewirtschaftung-und-klimaaenderung/waldbrand/waldbrand-statistik (accessed 23.12.2021)

Examples of past calamities

When entering the Wachau it is easily observed that the dominating aspect of the landscape is the Danube River which has influenced the landscape and the human activity within arguably since the dawn of civilization. Although the human settlements may have benefited from the proximity of the Danube it is undeniably connected with the hazard of flooding which remains until this day the most likely and most severe hazard to cultural heritage in the region. As seen in the official flood-map of the federal state of Lower Austria the entire Wachau river valley is marked as high risk with several tributaries of the Danube having been identified as potentially hazardous as well.

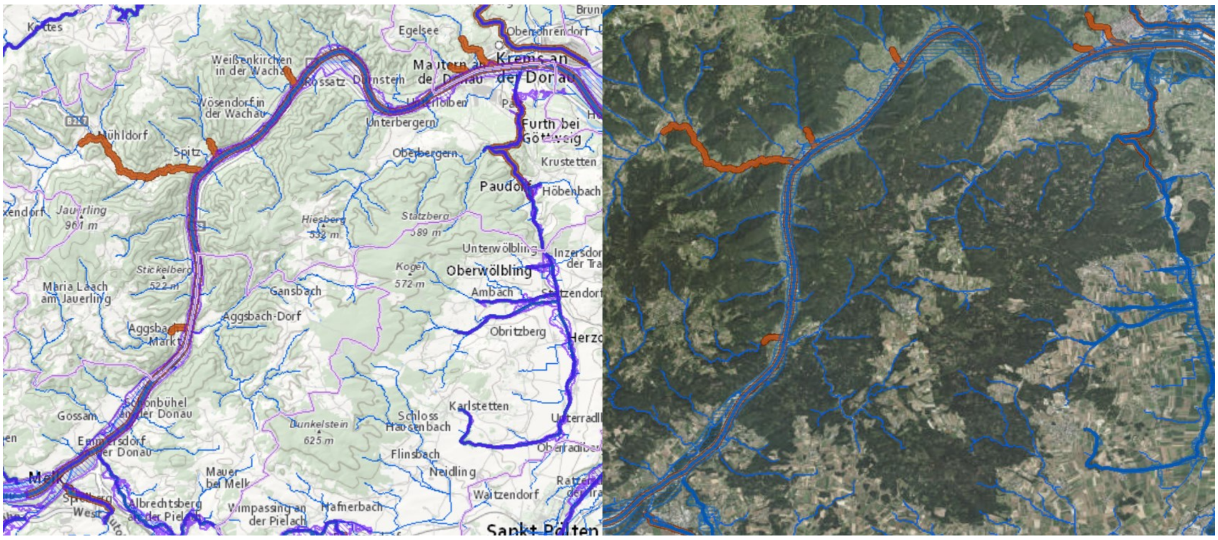


Figure 10: Screenshots of flood map of Lower Austria with the Wachau area[10]

Recent recorded flood incidences

Some of the more recent recorded flood incidences include:

- 13/07/1954, large scale river flood in Danube region being the most severe since 1899 submerging an estimated 100.000 hectares of land and requiring immediate rescue of approx. 40.000 people.[11]
- 02/07/1975, river flood in Danube region.
- 04/08/1991, river flood in Danube region.
- 14/08/2002, river flood in connection with heavy rain in Danube region
- 2008, flash flood/overflow of the tributary Grubbach (during the construction of the flood protection) in Weißenkrichen town (Wachau).

[10] https://atlas.noe.gv.at/atlas/portal/noe-atlas/map/Wasser/Hochwasser (accessed 20.12.2022)

[11] https://www.wienerzeitung.at/nachrichten/chronik/oesterreich/181398_Juli-1954-Jahrhundertflut.html (accessed 12.01.2022)

- 04/07/2013, river flood in connection with heavy rain in Danube region during which water penetrated the churches of Mitterarnsdorf and Hofarnsdorf destroying the floor.
- 18/07/2021 river flood in conjunction with flooding of tributary rivers towards the Danube resulting in severe damage. A brief but powerful thunderstorm causes massive destruction by creating flooding along the tributaries of the Danube River resulting in a local state of emergency in some of the affected municipalities forcing federal authorities to deploy army engineers to aid in the disaster relief efforts.[12] [13] [14]

Figure 11 Austrian Army disaster relief

Figure 13 Austrian Army disaster relief

Figure 12 Clean-up efforts. © APA

[12] https://www.diepresse.com/6009844/hochwasser-mehrere-orte-zu-katastrophengebieten-erklaert (accessed 04.01.2022); https://www.meinbezirk.at/amstetten/c-lokales/glueck-im-unglueck-letzte-gewitterzelle-ging-nicht-in-amstetten-nieder-+video_a4772057?ref=curate#gallery=null (accessed 04.01.2022)

[13] https://www.bundesheer.at/cms/artikel.php?ID=10952 (accessed 04.01.2022)

[14] https://www.bundesheer.at/cms/artikel.php?ID=10952 (accessed 04.01.2022)

Hydrological details on four major floods in the Wachau area

The four major floods that hit the Wachau since 1828 are discussed in more detail, since the hydrological details, i.e., soil moisture and precipitation can be linked to predictions of the WebGIS tool, discussed below.

Floods in the Upper Danube Basin in Austria are produced by different processes, i.e., rain on snow, or frontal precipitation. The upper Danube Basin consists of two main sub catchments, the Bavarian Danube and the Inn, the latter draining large parts of the Austrian Alps; its southern tributaries stem from high rainfall areas in the Calcareous Alps, including the Traun, Enns and Ybbs. The northern tributaries joining the Danube in Austria come from tendentially lower rainfall areas with mainly granitic geology and include the Aist and Kamp. The typical floods can be classified into summer and winter floods. Summer floods usually have a strong contribution from the Alpine tributaries Iller, Lech, Isar, and Inn, induced by topographically enhanced precipitation at the northern fringe of the Alps. Winter floods on the other hand are usually caused by a warm front with snowmelt and rainfall on saturated or frozen soil, which lead to high discharges in the northern tributaries Naab and Regen.[15] Confluence of the Bavarian Danube and Inn at Passau – flood tends to travel faster if main water body comes from Alpine catchments, meaning the Inn, Traun and Enns.

All four major floods since 1828, in which the systematic observations started, were caused by immense precipitation in the summer. In addition to these major floods, small floods have increased in the 20th century, due to more precipitation in the summer and more river training.[16] The four major floods occurred in 1899, 1954, 2002, and 2013 and are marked in red in fig. 14 below. [17]

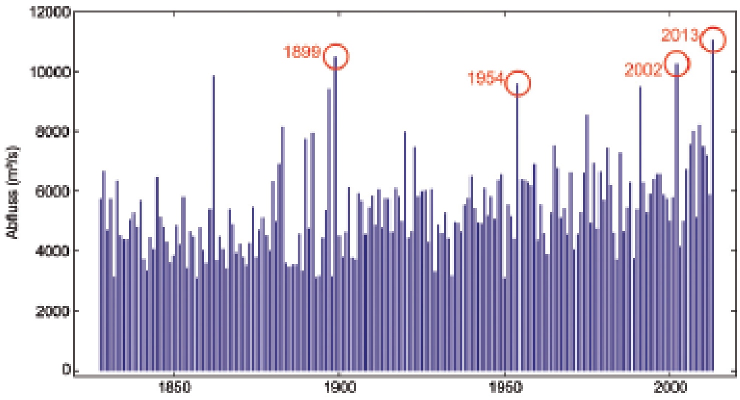


Figure 14 Annual floods of the Danube at Vienna since 1828

[15] Skublics, D. et al., Effect of river training on flood retention of the Bavarian Danube, in: Journal of Hydrology and Hydromechanics, 2016.

[16] Blöschl, G., Nester, T., Parajka, J., Komma, J. Hochwasserprognosen an der österreichischen Donau und Datenassimilation, in: HyWa 2014/2, pp. 64–72. DOI: 10.5675/HyWa_2014,2_1

[17] See note 14.

The June 2013 flood was one of the largest in the past two centuries. Prior to the flood the weather was extremely wet and cold than average for May; the immense precipitation leading to the flood fell on high soil moisture levels combined with high ground water levels. At the norther rim of the Alps the precipitation exceeded 300 mm over four days. The hydrological and meteorological circumstances resulted in a single peak, long-duration flood wave at the Inn and Danube, though snowfall at high altitudes in the Alps reduced the runoff volume.[18]

The August 2002 flood was a double event, with two rainfall peaks (August 7th and August 11th to 12th). The peaks were separated by four days rather than only a few hours, as was the case in 2013. In comparison to 2013, less precipitation came from the catchment of the Bavarian Danube, but significantly more from the northern tributaries at the Czech border, as the Kamp and the Aist.[19]

The three months preceding the 1954 flood were wetter than the mean. The flooding event consisted once again of two precipitation blocks, a minor event during July 1st to 2nd and a more extreme event during July 7th to 12th. The defining feature was the spatial distribution with an unusually high precipitation in the north of the Upper Danube, similar to, but exceeding that of the 2013 flood.[20]

The September 1899 flood on the other hand was quite different from the three other events, if seen from a hydrological point of view. The winter of 1898 and 1899 had been exceptionally dry, with very little snow fall and the summer of 1899 was unusually dry as well. The August precipitation was about one third lower than the long-term average, meaning that the precipitation of leading to the 1899 flood fell on soil that had much less moisture than the soil before the floods of 2013, 2002 and 1954. The precipitation, leading to flood, was enormous, with the 48-hour precipitation exceeding 200 mm over an area of 1,000 km^2. Weißbach recorded 515 mm in the period from September 8th to 14th.[21]

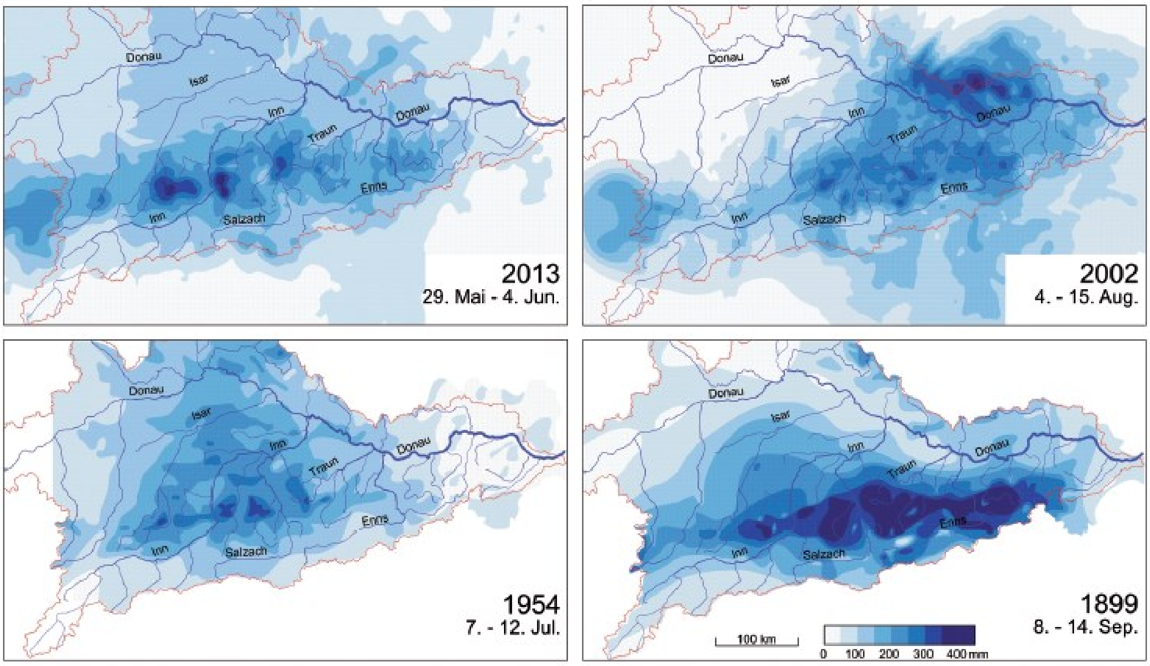
[18] Blöschl, G., Nester, T., Parajka, J., Komma, J. Hochwasserprognosen an der österreichischen Donau und Datenassimilation, in: HyWa 2014/2, pp. 64–72. DOI: 10.5675/HyWa_2014,2_1; Blöschl, G. et al., The June 2013 flood in the Upper Danube Basin, and comparisons with the 2002, 1954 and 1899 floods, in: Hydrology and Earth System Science 2013.

[19] See note 16.

[20] See note 16.

[21] See note 16.

Fig. 15 shows the event precipitation of the mentioned four large floods and chart 1 the summary of relevant hydrological and meteorological details.



[22]

Figure 15 Event precipitation of the four floods in the Danube catchment in the past two centuries

[22] Blöschl, G., Nester, T., Parajka, J., Komma, J. Hochwasserprognosen an der österreichischen Donau und Datenassimilation, in: HyWa 2014/2, pp. 64–72. DOI: 10.5675/HyWa_2014,2_1, fig. 2 p. 65.

Year	Discharge in Vienna	Weather	Precipitation	Peculiarity
2013	11.000 m^3/s	Stationary weather system in central Europe bringing moisture from the Atlantic and the Med Typical situation for Danube floods	> 300 mm	Soil moisture already very high, especially in catchment of Bavarian Danube, due to wet and cold spring North-south gradient with higher soil moisture in north, lower in south High ground water levels[1]
2002	10.300 m^3/s	Stationary weather system in central Europe bringing moisture from the Atlantic and the Med Typical situation for Danube floods	> 300 mm	
1954	9.600 m^3/s	Stationary weather system in central Europe bringing moisture from the Atlantic and the Med Typical situation for Danube floods	> 300 mm	
1899	10.500 m^3/s	Spacious low-pressure area/depression from North Africa to Balticum, Western Alps to Black Sea, bringing moisture from NW Europe, NE Europe and the whole Med in Danube catchment area	> 500 mm	Low soil moisture – therefore the discharge in Vienna is comparatively low considering the amount of precipitation

[23]

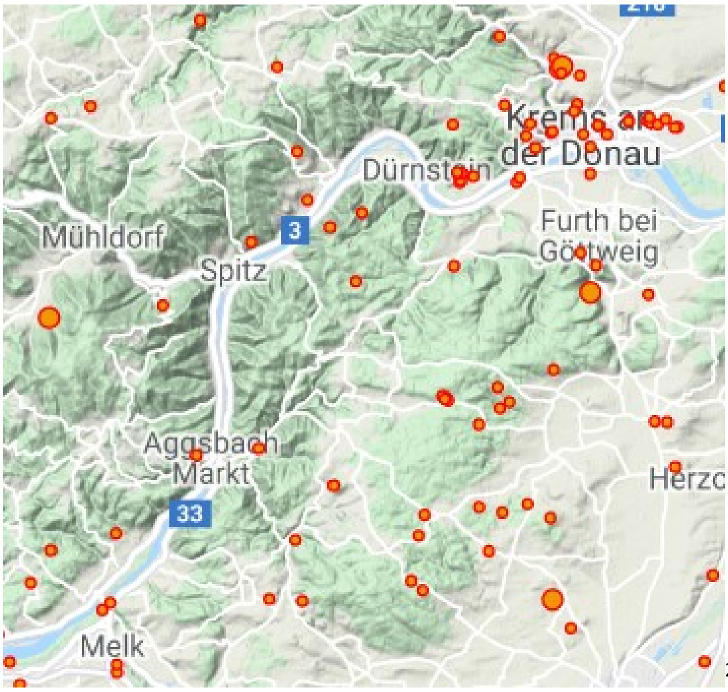
Figure 16 Summary of relevant hydrological and meteorological details, based on Blöschl et at, 2014

[23] See note 16.

Another prevalent threat inclined by the terrain surrounding the river Valley are landslides

- 14/08/2002 & 04/07/2021, heavy rain with consequent landslides in the whole Danube region: partial collapse and destruction of the characteristic dry-stone walls.

Wildfires are a known hazard and occur in the Wachau area as seen in the image below taken from the "Fire Database" of the University of Natural Resources and Life Sciences Vienna, which depicts recorded forest and other vegetation-based fires since the year 2000. However, firefighters in the area are preparing for an influx of wildfires due to anticipated prolonged durations of drought and a declining resilience of the tree population created by a combination of drought & pests and are already increasing their training efforts and seek to attain experience in combating wildfire abroad in order to enhance their competences.[24] The WebGIS tool could be a further asset in increasing the preparedness of emergency responders in this regard.



[25]

Figure 17 Forest & Vegetation Fires since the year 2000

[24] https://www.noen.at/krems/waldbrandgefahr-region-krems-heimische-wehren-ruesten-sich-bezirk-krems-feuerwehreinsatz-waldbrand-nordmazedonien-print-286194469 (accessed 04.01.2022)

[25] https://fire.boku.ac.at/firedb/de/ (accessed 23.12.2021)

Taking these threats/hazards into consideration the disaster likelihood and severity can be assessed as follows:

Likelihood	**Almost certain**					
	Likely				*Drought*	*Severe weather* *Heavy rain* *Flood* *Landslides*
	Possible			*Pests*	*Lack of maintenance / Deterioration*	*Fire* *Hail*
	Unlikely		*Pollutants*		*Earthquake*	
	Rare		*Vandalism* *Violence*			
		Insignificant	**Minor**	**Moderate**	**Major**	**Severe**
	Impact					

Risk matrix for the Wachau cultural landscape.[26]

[26] Linda Canesi, Presentation "Wachau Cultural Landscape" STRENCH Summer School 2021

Site evaluation using the WebGIS: Wachau Region

Location: Lat. 48.39018 – Long.15.47489

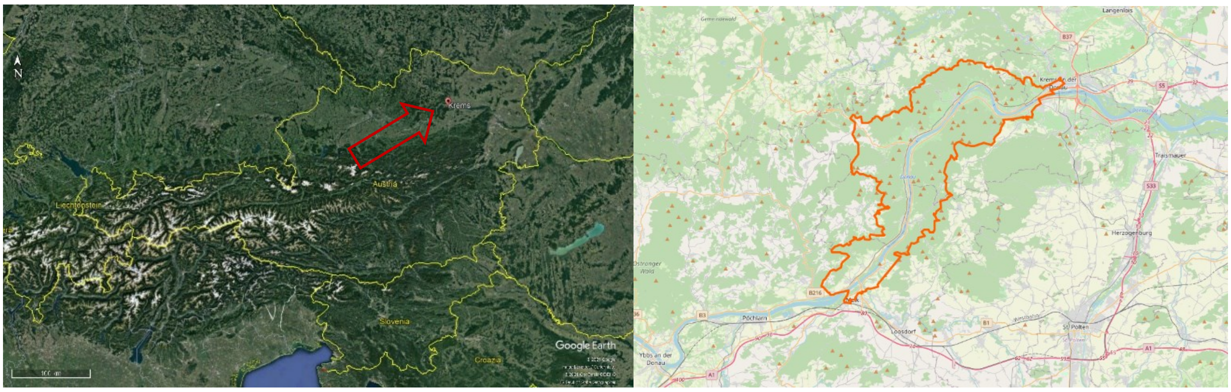


Figure 18 Google Earth screenhots showing the location of the Wachau.

Utilized WebGIS Indices & Climate Variables:

Extreme Event / Index	Description	Rationale for choice
(Heavy Rain) R20mm	**Very heavy precipitation days** Number of days in a year with precipitation larger or equal 20 mm/day.	Being a major factor for flooding within the Wachau area. In 2021 a brief but powerful thunderstorm caused massive destruction by creating flooding along the tributaries of the Danube River resulting in the declaration of a local state of emergency in some municipalities
(Heavy Rain) R95pTOT	**Precipitation due to extremely wet days** The total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days. A wet day is defined as having daily precipitation ≥ 1 mm/day. A threshold based on the 95th percentile selects	Another major factor when considering flooding, which may increase with the ongoing urbanization and sealing of land along the entire Danube possibly resulting in steeper rises of water levels after increased precipitation.

	only 5% of the most extreme wet days over a 30 year-long reference period.	
(Flooding) Rx5day	**Highest 5-day precipitation amount** Yearly maximum of cumulated precipitation over consecutive 5-day periods.	Flooding arguably remains the biggest threat to the UNESCO world heritage Site Wachau and requires further consideration in disaster preparedness and cultural heritage protection
(Drought) CDD	**Maximum number of consecutive dry days** Maximum length of a dry spell in a year, that is the maximum number in a year of consecutive dry days with daily precipitation smaller than 1 mm/day.	A possible indicator for wildfire which in turn can act as additional indicator for flash floods. In addition, increased drought may affect the cultural landscape created by viticulture and orchard farming should these be damaged.
(Extreme heating) Tx90p	**Extremely warm days** Percentage of days in a year when daily maximum temperature is greater than the 90th percentile. A threshold based on the 90th percentile selects only 10% of the warmest days over a 30 year-long reference period.	Indicator of increased threat for wildfire is also can indicate a weakening resilience of local forest towards such due to a combination of drought and pests.

WebGIS indices and climate variables used.

Regarding the usage of the WebGIS tool for decision making in cultural heritage protection future prognosis were deemed to be the most beneficial. Therefore, the extreme events as well as climate variables were observed for the near future (2021-2050) and the far future (2071-2100). Initially the model ensemble statistics, maximum, RCP 4.5 & RCP 8.5 were used for a numerical observation. When choosing the visual observation, the model ensemble statistics, maximum, RCP 4.5 was chosen. However, for the sake of visualization a baseline was seen as necessary in order to put the forecasted data into perspective. Therefore, when creating the visualized climate modelling in the WebGIS-Tool the historical observations were added as well.

Numerical observation

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			Near future RCP 4.5			Near future RCP 8.5			Far future RCP 4.5			Far future RCP 8.5		
2	Risk	Index	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
3	Heavy rain	R20mm (days)	-1	1-2	2-3	0	2	3	0-1	2	3-4	1-2	3-4	4-5
4		R95pTOT (mm)	-10-0	25-35	50-60	-20 - -10	30-35	50-70	0-10	40-50	70-80	20-30	50-70	90-100
5	Flooding	Rx5day (mm)	-6 - -4	4-6	15-20	-5 - -3	5-6	10-15	-3 - -2	6-7	18-22	-2-0	8-9	25-35
6	Extreme heating	Tx90p (%)	0-5	5-10	10-15	5-7	8-10	15-20	8-10	15-20	20-25	20-25	25-30	30-35
7	Drought	CCD (days)	-5 - -3	-1-1	2-3	-5 - -3	-1-1	2-4	-5 - -3	0-1	2-3	-4 - -3	0-1	3-4

Figure 19 Numerical observation graph taken from the WebGIS tool.

Upon brief inspectino one can observe that the chosen Extreme Events are forecasted to increse in the near and especially the far future.

However viewing output data from the WebGIS Tool in this fashion is arguably not presentable or pratical when communicating with decision makers and other stakeholders such as the broad public regarding cultural heritage protection. Fortunately the WebGIS Tool creates vivid images of these values.

Visualization of Extreme Event Indices

For this purpose, the model ensemble statistics, maximum, RCP 4.5 was chosen. For better illustration the option to show "*UNESCO world Heritage*" was enabled as it encapsulates the pilot site Wachau perfectly. For each extreme event a historical observation as well as a near future and far future map was created in the WebGIS.

Very Heavy Precipitation Days (R20mm)

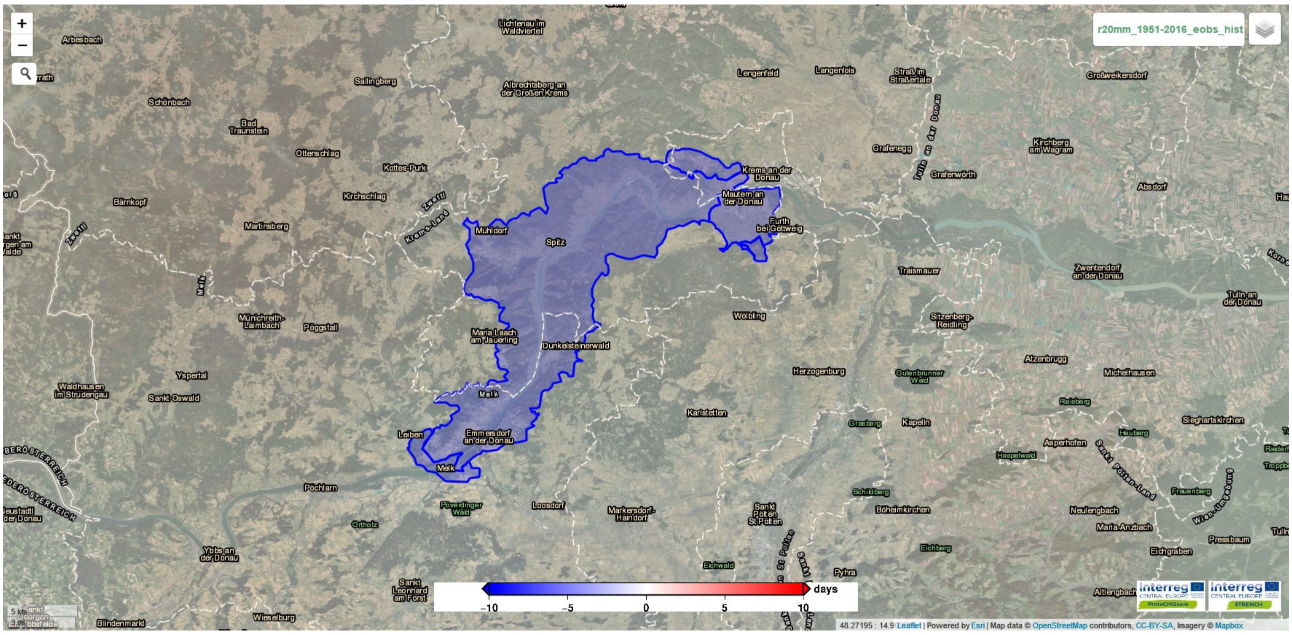


Figure 20 Historical Observation 1951 – 2016, WebGIS tool. (R20mm)

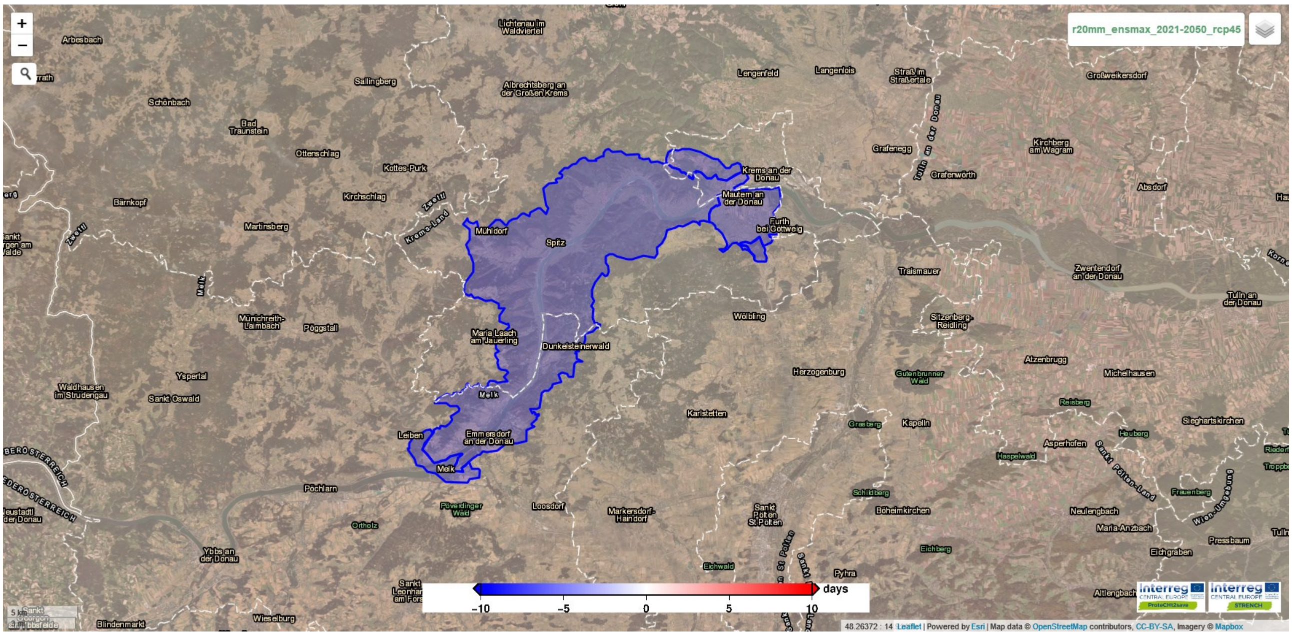


Figure 21 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (R20mm)

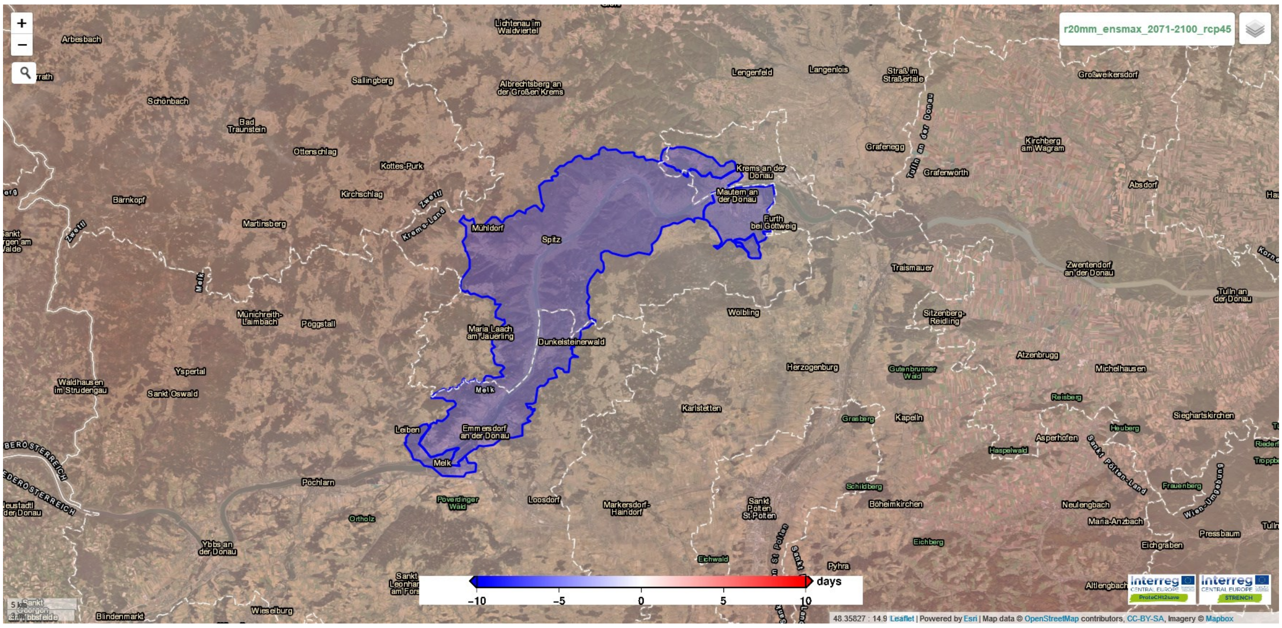


Figure 22 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool. (R20mm)

After observing the more or less neutral first image of the historic observations the increase in red colour indicating an increased amount of very heavy precipitation days becomes evident and is illustrated well.

Precipitation due to extremely wet days (R95pTOT)

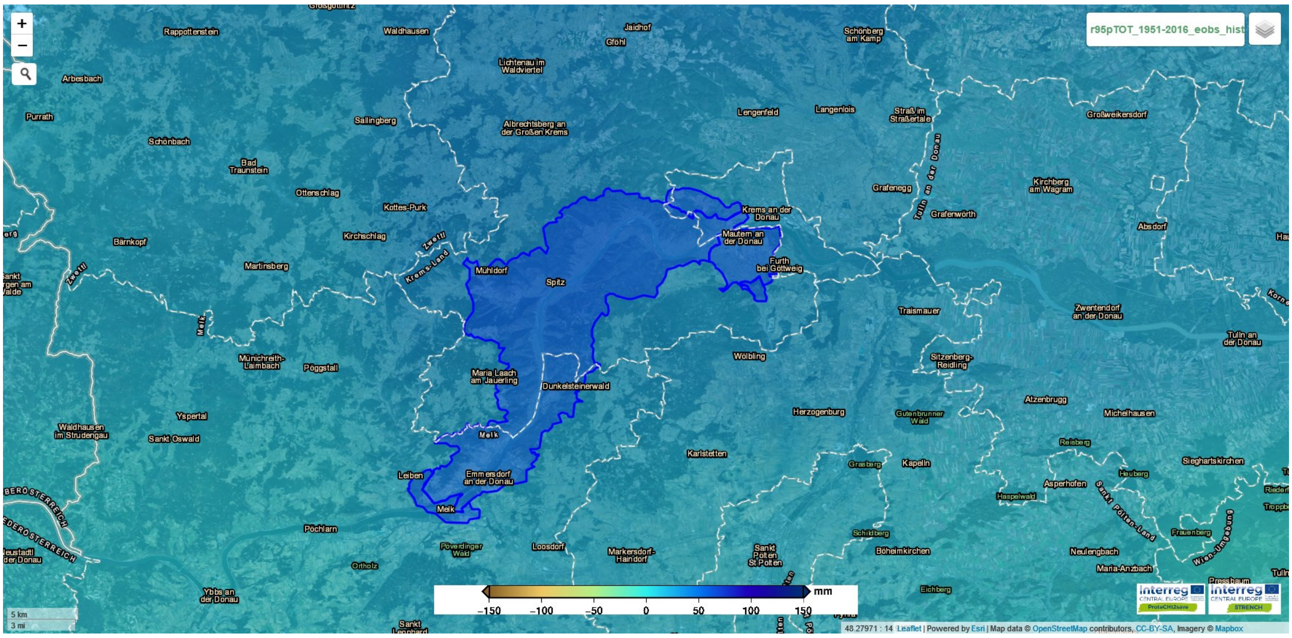


Figure 23 Historical Observation 1951 – 2016, WebGIS tool. (R95pTOT)

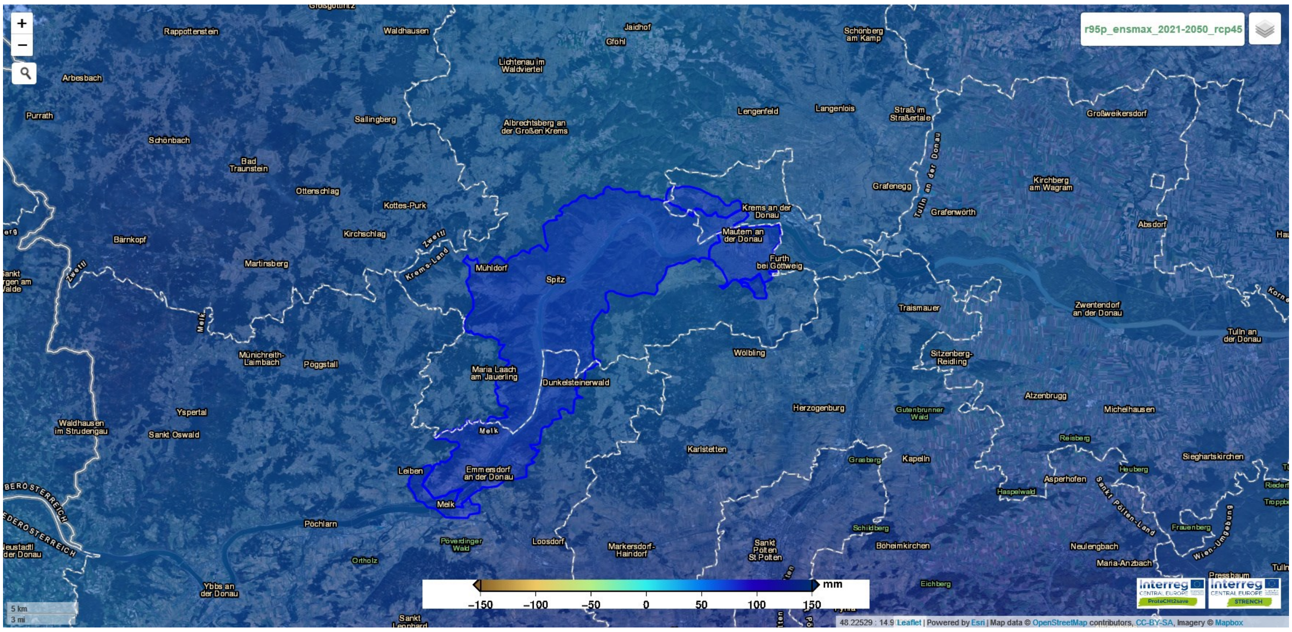


Figure 24 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (R95pTOT)

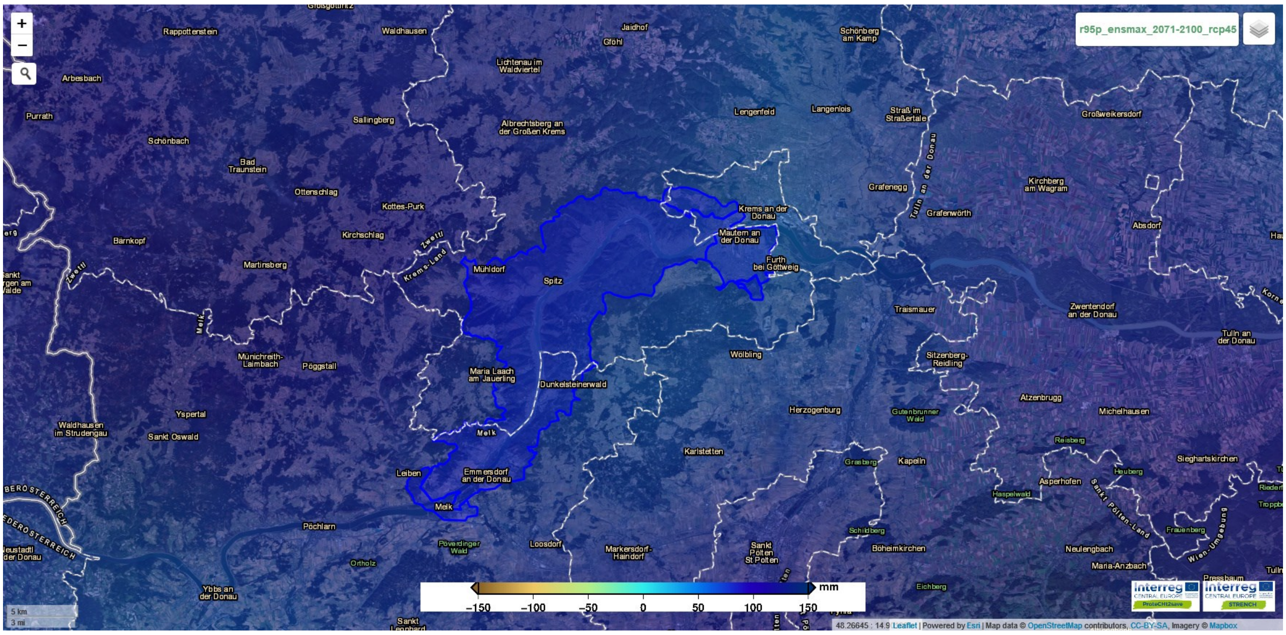


Figure 25 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool. (R95pTOT)

By merely increasing the map filter from 0.5 to 0.6 on all 3 maps the illustration of the darkening and thus increase in extremely wet days became more concise than with the previously observed R20mm. Showing these 3 maps in sequence illustrates well the forecasted increase in extremely wet days.

Highest 5-day precipitation amount (Rx5day)

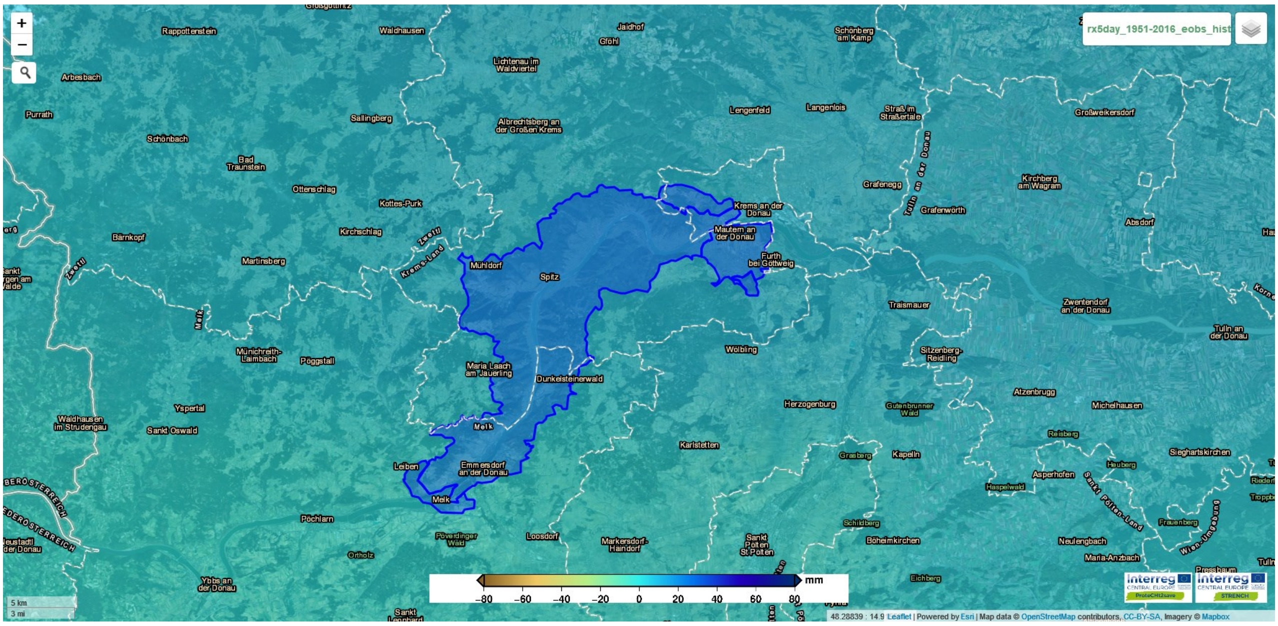


Figure 26 Historical Observation 1951 – 2016, WebGIS tool. (Rx5day)

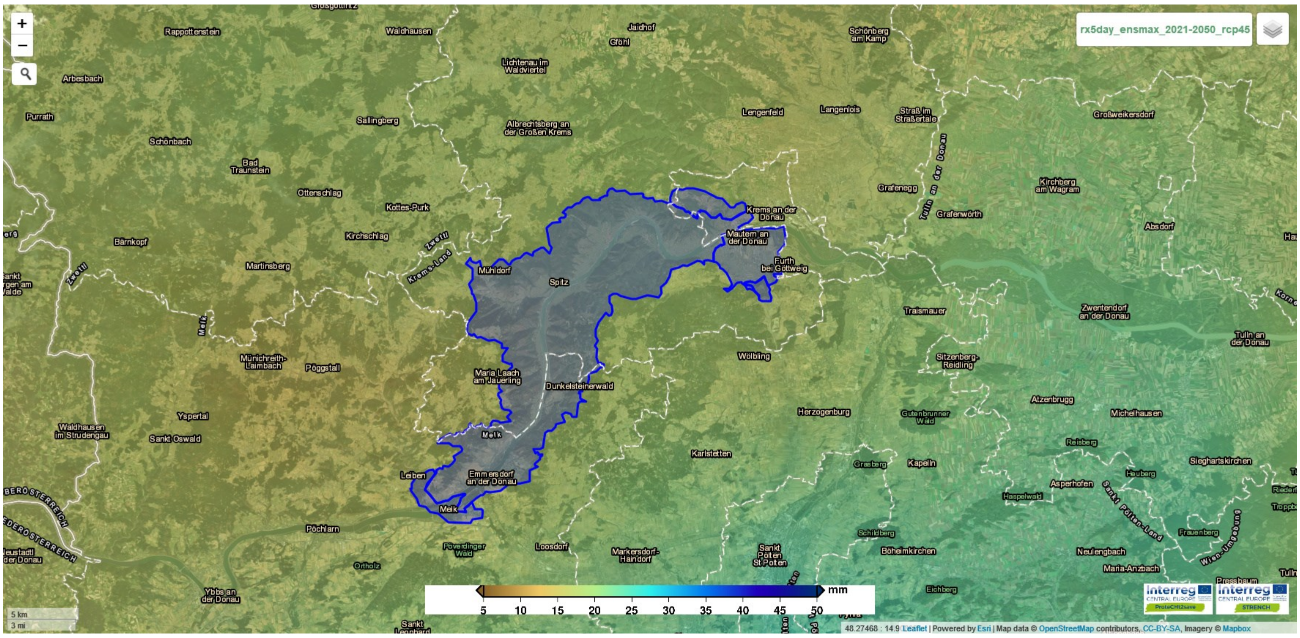


Figure 27 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (Rx5day)

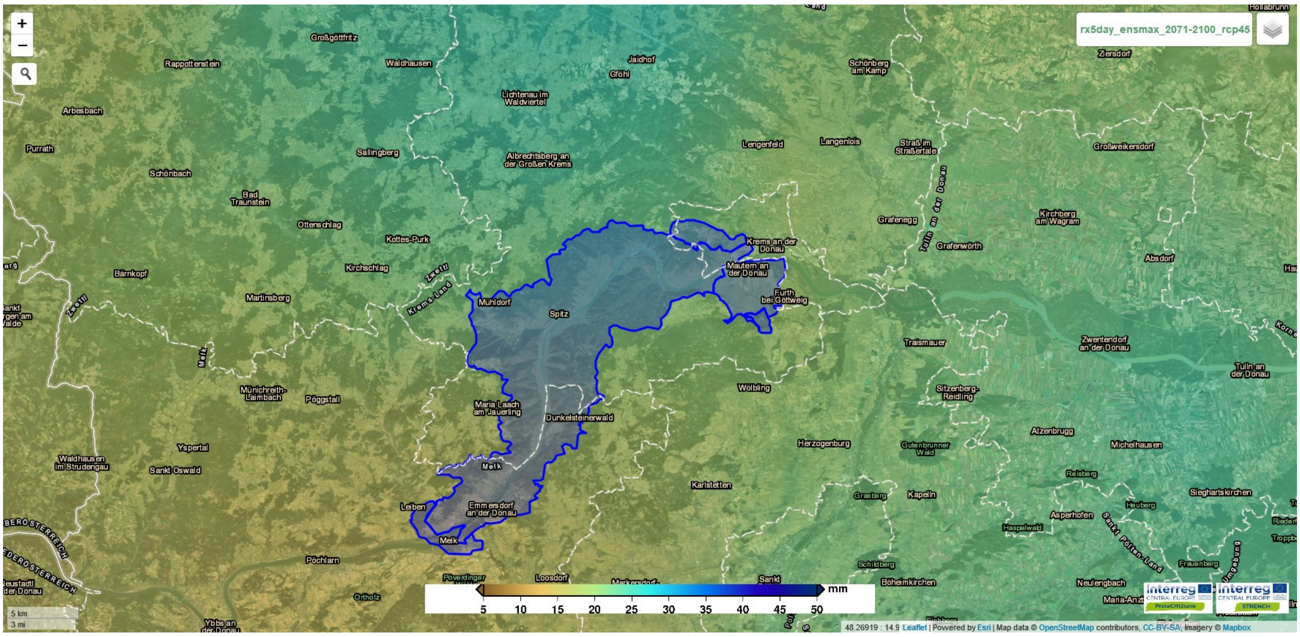


Figure 28 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool. (Rx5day)

While the number of days with heavy rain as well as extremely wet days increase the 5-day precipitation amount strongly decreases. This may lead to an increase in dry periods followed by an extreme amount of rain resulting in an increased hazard of flooding and landslides. Overall, when considering the indicators above an increase of such hazardous events may be likely.

Maximum number of consecutive dry days (CCD)

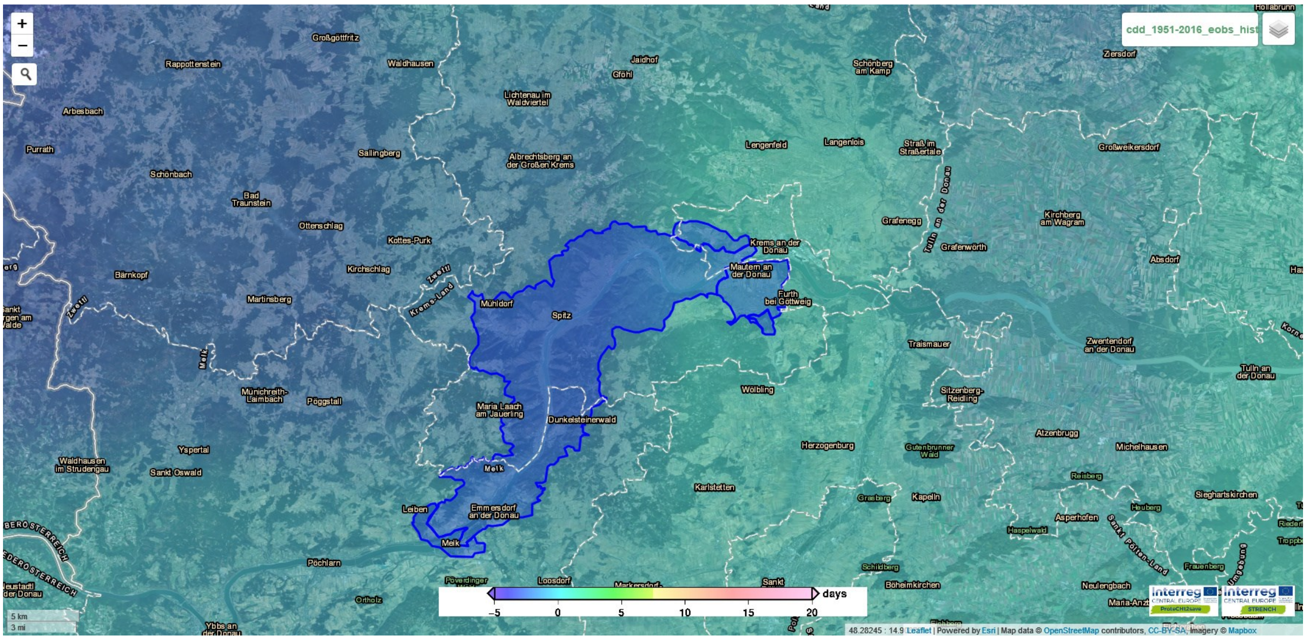


Figure 29 Historical Observation 1951 – 2016, WebGIS tool. (CCD)

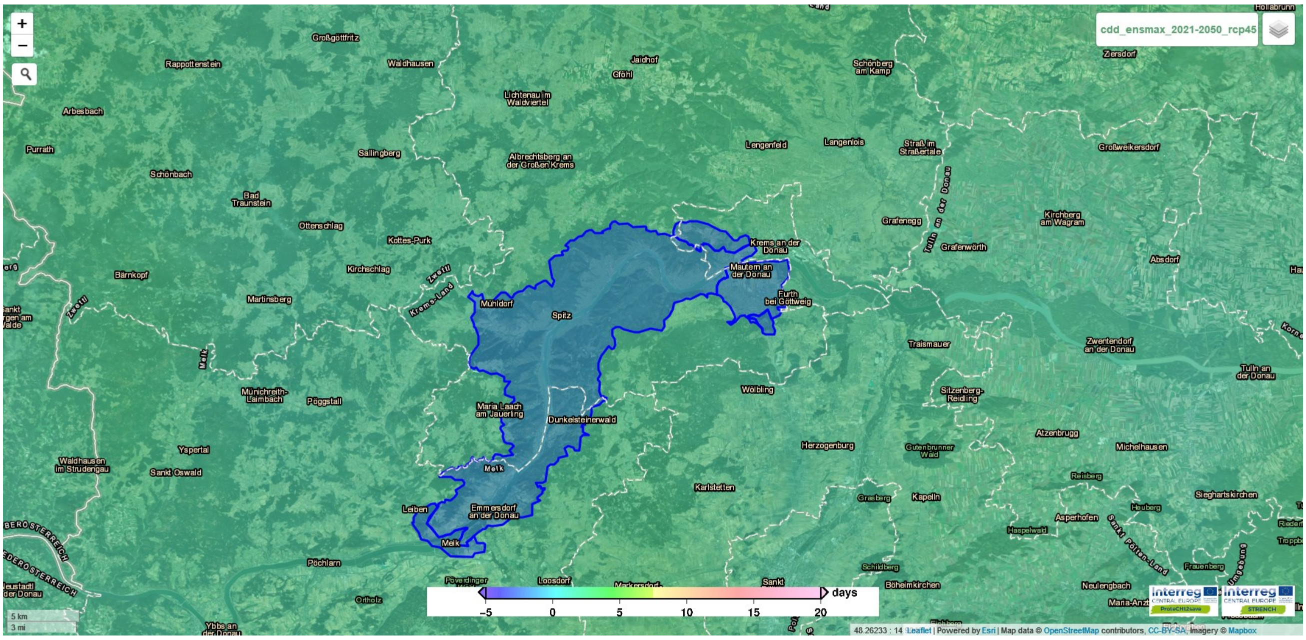


Figure 30 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (CCD)

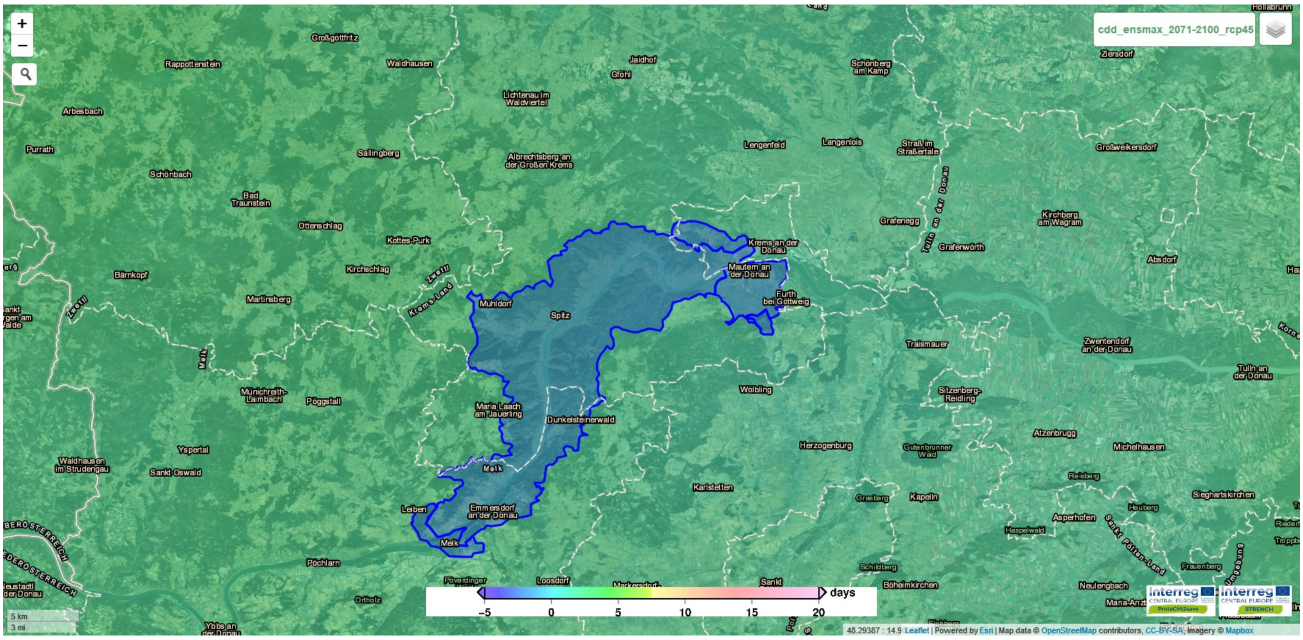


Figure 31 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool (CCD)

Similar as with the 5-day precipitation amount the consecutive dry days are predicted to strongly increase. This further hardens the fear that drought followed by heavy rain may become an all too familiar pattern increasing floods and landslides alike.

Extremely warm days / percentage of extremely warm days (Tx90p)

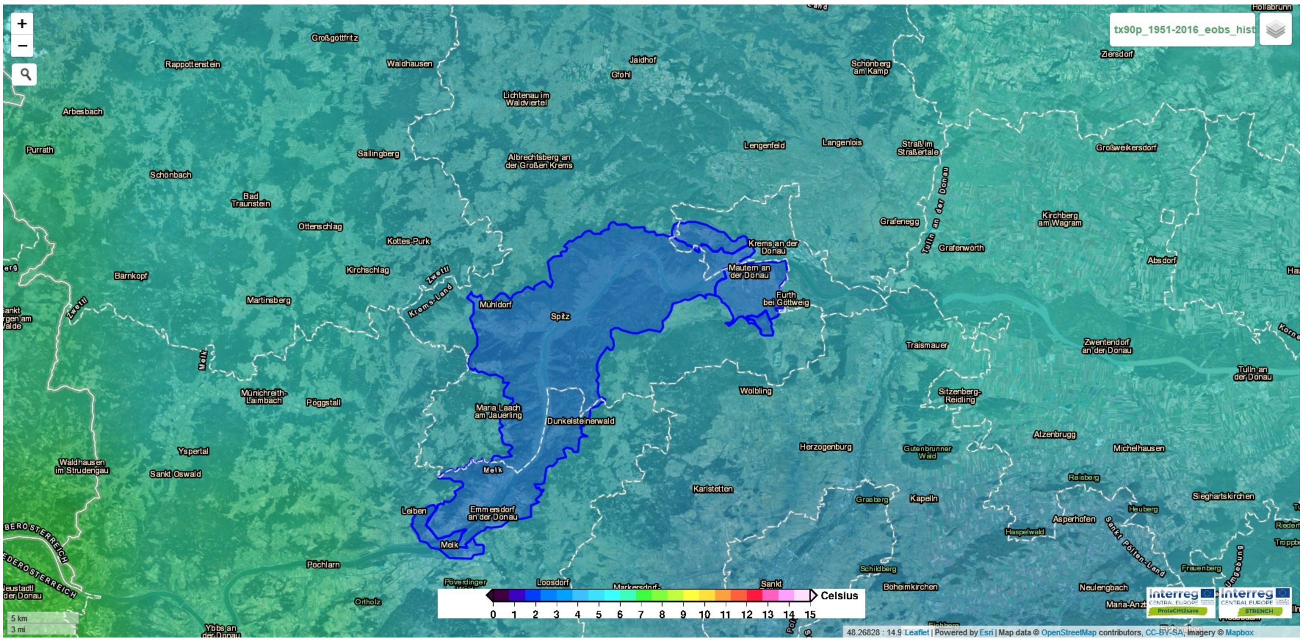


Figure 32 Historical Observation 1951 – 2016 in Celsius, WebGIS tool. (Tx90p)

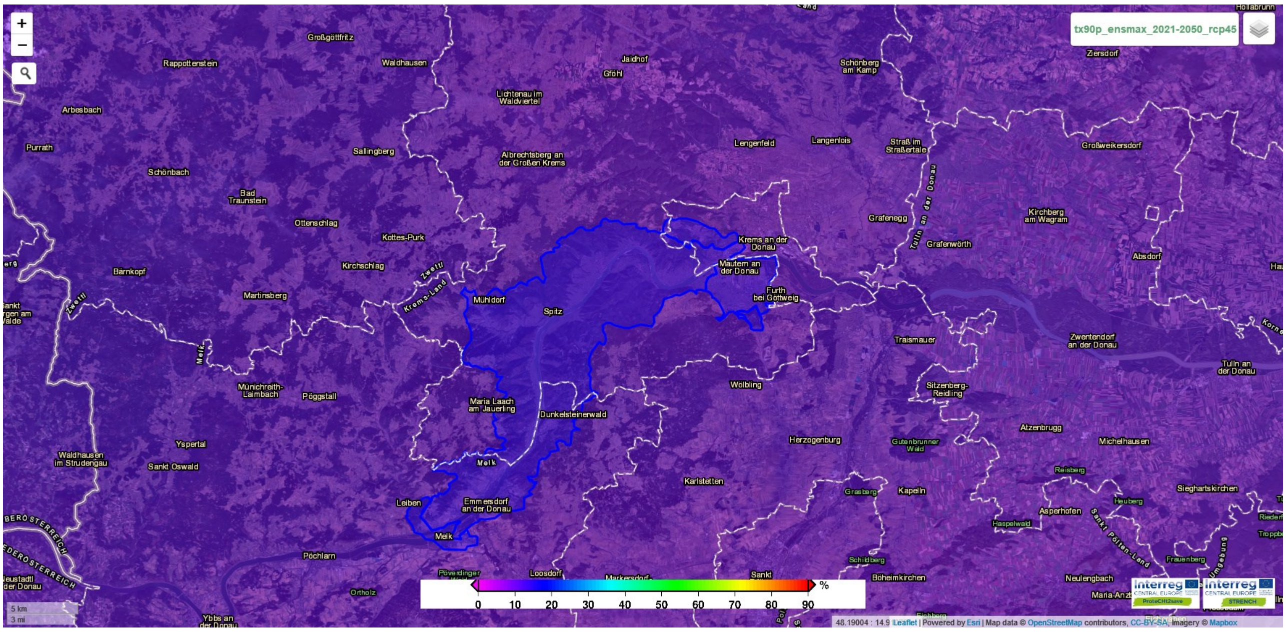


Figure 33 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050). Not in Celsius but in percentage, WebGIS tool. (Tx90p)

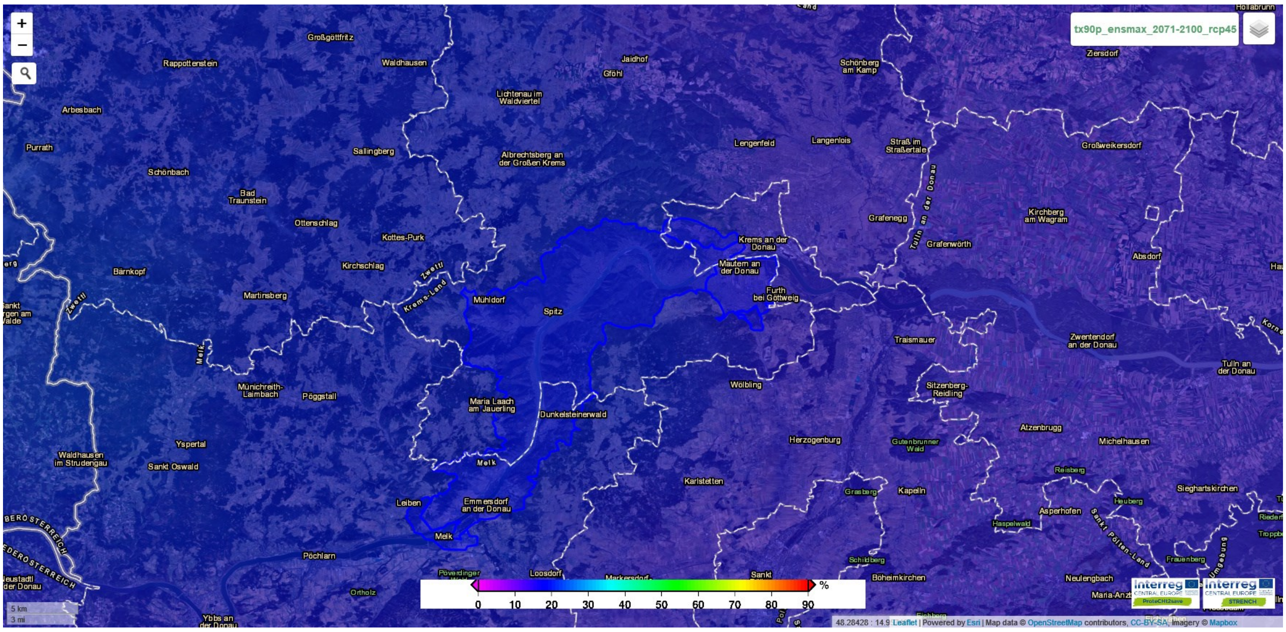


Figure 34 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100). Not in Celsius but in percentage, WebGIS tool. (Tx90p)

Before drawing any conclusions for Tx90p one must bear in mind that the historic observation is based on Celsius which appear to be an average. However, the forecast (near and far) both depict the percentage of days in a year when daily maximum temperature is greater than the 90th percentile. A threshold based on the 90th percentile selects only 10% of the warmest days over a 30 year-long reference period. Therefore, the historic observation can be discarded in this case. Nonetheless the comparison between the near and far forecasted future show that a very strong increase in extremely warm days is predicted. This again falls in line with the observed increase in extreme weather events as shown in the other observed incidences.

Observations and possible conclusions

Overall, a strong trend can be observed in which the Wachau region will experience less rainy days, increased hot days and drought, combined with probably infrequent but strong rainfall. This is a perfect receipt for increasing the likelihood of all current major hazards mentioned earlier such as flooding / flash floods, heavy rain, landslides and fire due to drought.

A precursor of this trend may have already been observed with the flooding and flash flood in July 2021 during which as brief but heavy rainfall caused massive destruction along the tributaries of the Danube River while the Danube itself was experiencing a flood. This resulted in a regional state of emergency within the affected municipalities going as far as to receive aid by the Austrian armed forces. In another instance during the flood of 2013 the modern mobile flood protection wall of the town Krems was too low to ward of the flood alone and had to be further heightened by piling sandbags on top of its aluminium stop logs.

While the flood protection along the Danube itself is highly sophisticated, small tributaries flowing either from the southern or the northern bank into the river, and thus cross the Wachau from north to south or vice versa, are not protected by flood protection measures and thus can become a major threat to people, infrastructure and the cultural landscape as a whole, as seen in July 2021.

The four major floods discussed in detail above show that a combination of factors is essential for understanding the magnitude of large, regional floods: the soil moisture, the shift / time between flood peaks from main tributaries and the time between possible rainfall blocks. The 2013 flood fell on high antecedent soil moisture, there was little time between the flood peaks at the confluence of the Bavarian Danube and the Inn, and rainfall blocks close together resulted in a single, large volume flood with a small peak attenuation.

One question that might be interesting for the future is what happens if a heavy rainfall like in 2013 or in 1899 happens as flash flood and falls on very dry soil, soil that in the moment of the downpour cannot accommodate the water, even if not saturated. This is a scenario that might become possible in the future, following the worst-case predictions of the WebGIS tool.

Thus, the illustrative maps and information generated by the WebGIS could be a valuable asset for further fostering awareness towards cultural heritage protection and the need for risk management measures caused by climate change. It is most certainly a helpful tool which will aid in tackling future challenges for cultural heritage protectors. Combined with information and pictures in the minds of people that are provided by recent major floods in the Wachau area, the WebGIS tool has huge potential to raise the awareness of policy and decision makers an all levels that action is necessary, also on the level of the cultural landscape in general, including cultural and natural heritage that makes the Wachau region so very special and is the Outstanding Universal Value for which it received the status of UNESCO World Heritage.

Cultural heritage and its protection in Austria

In Austria cultural heritage protection lies within different ministries. The Federal Monuments Protection Agency (Bundesdenkmalamt) is part of the Federal Chancellery. It is responsible for all matters of monuments protection and also defines cultural property according to the Hague Convention for the protection of cultural property in armed conflict from 1954. Responsibilities for UNESCO World Heritage in Austria rest with the Federal Chancellery and the Foreign Ministry. The Ministry of Defence is responsible for the protection of cultural property during armed conflict. On the very basic level the cultural institutions themselves are responsible for the protection of their heritage items; for preparation as well as during emergency situations they can draw on the expertise and support of the above-named entities, which are supported by different NGOs active in the field of cultural heritage protection in Austria.

On national level the responsibility for the protection of cultural heritage and UNESCO World Heritage lies basically with three ministries:

The Austrian Federal Chancellery has the two subordinate units Bundeskanzleramt and Bundesdenkmalamt. The Arts and Culture Division of the Federal Chancellery of Austria (Bundeskanzleramt) is responsible for monuments protection and preservation, UNESCO World Heritage, built and archaeological heritage, cultural landscapes, restitution of art, research on provenance, cultural objects displaced and looted during World War 2, art crimes and international transfer of cultural heritage. A subordinate entity is the Federal Monuments Protection Agency (Bundesdenkmalamt), which is responsible for restoration and catalogisation of heritage, including archaeological sites and historical gardens, as well as the export of cultural heritage from Austria. The Bundesdenkmalamt also places built heritage under monuments protection and defines which monuments are classified as cultural property protected by the Hague Convention of 1954. The president and the executive committee are located in Vienna and each of the other eight federal states of Austria has its own local branch on provincial level.

The Federal Ministry for Europe, Integration and Foreign Affairs is responsible for all the UNESCO agendas. Unit V.4.a is dedicated to the United Nations Educational, Scientific and Cultural Organization (UNESCO) agendas. This unit also functions as hub to the Austrian UNESCO Commission, which is based in Vienna as well.

The Ministry of Defence is responsible for cultural property protection in armed conflict, based on the 1954 Hague Convention for the protection of cultural property during armed conflict, which Austria ratified in 1964. The Austrian Directive for the Military Protection of Cultural Property and the Military Safeguarding of Cultural Heritage explicitly expands the responsibilities of the military.[27] The Austrian Army also needs to take cultural property protection into account during assistance operations for the civil government, thus not only during armed conflicts. The territorial military commands in every federal state of Austria have qualified personnel for cultural property protection, who also interact with the relevant civilian authorities and the curators of the cultural heritage institutions in order to prepare for emergency situations.

In the academic sector Danube University Krems plays a leading role in developing trainings and scenarios to enhance the cooperation between emergency units who might aid in the protection of cultural heritage and the curators and responsible personnel from the heritage institutions themselves. Danube University also acts as platform for transporting the knowledge of specialists from the above and below mentioned entities to everyone involved in the protection of cultural heritage, nationally and internationally.

The emergency responder most likely to deal with cultural heritage protection during a calamitous event is the fire brigade. Austria has a very well-developed system of voluntary fire fighters, who operate on the very local level and who are the ones who actually know the cultural heritage in their village best, from an emergency responder point of view. The fire brigades have a very clear priority for emergency operations– human lives come first, only after all people are saved, real values, like cultural heritage, may be taken into account.

Each federal state in Austria also has a so called Landeswarnzentrale, a coordination unit which is responsible for the provincial coordination of an emergency. During calamitous events it is the head of the federal state that has to announce the official catastrophic situation, which inter alia settles the question of who is going to pay for the assistance provided. Below the provincial government it is the head of a district or even the head of a municipality who can ask for assistance operations of the armed forces and who coordinate the cooperation of all the different emergency responders involved. In Austria the civil protection is not as well developed as in other Central European countries, its functions are taken over by the different emergency responders and if necessary, the Austrian Army during assistance operations to the civil government.

If the event affects more than one province or is no longer to be managed by the resources of one federal state, the national level takes over. The Ministry of the Interior steps in and coordinates the response. The national crisis and catastrophes management system (SKKM – Staatliches Krisen- und Katastrophenmanagement) involves emergency responders, authorities, academia, business, and the local population in order to best fight the circumstances. International assistance that might be necessary is also coordinated via the SKKM system.[28]

[27] BMLVS. Directive for the Military Protection of Cultural Property and the Military Safeguarding of Cultural Heritage. Vienna: 2009.

[28] BMI, Rechtliche und organisatorische Grundlagen des Staatlichen Krisen- und Katastrophenschutz-Managements (SKKM). Wien: 2010.

Crisis and emergency response units regularly train together on local and regional level. National exercises are scarcer, but equally important. The protection of cultural heritage assets does not play a role in these exercises until know, but the tendency goes in the direction of including cultural heritage protection into the exercises and also the coordination efforts on the level of the Ministry of Interior.

Since 2013 the Ministries for Finance, Interior and the NGO Blue Shield Austria cooperate in the fight against illicit trafficking of cultural heritage, but the cooperation has not been developed into other spheres of the protection of cultural heritage.[29] Based on the UNESCO Code of Ethics for Dealers in Cultural Property an Austrian version was developed.[30] Since 2016 the Austrian Kulturgüterrückgabegesetz (law for restitution of cultural heritage) is effective.[31]

The Austrian UNESCO Commission is based in Vienna and functions as link to the UNESCO in Paris. ICOM's National Committee of Austria provides a huge platform and immense knowledge on museums and the expertise of the International Council of Museums. The same goes for the Austrian National Committee of the Blue Shield and the Austrian Society for the Protection of Cultural Property, both based in Vienna as well.

On a more local level the Museumsmanagement of Lower Austria provides training and expertise for curators and museum personnel on provincial level and private initiatives like the Denkmalwerkstatt work together with private owners of large collection, archives, and heritage items in general and also built heritage.

The protection of cultural heritage from and during calamitous events is only a small part of the tasks of the above-mentioned entities and authorities. In the end the owners and curators of cultural heritage items or institutions are responsible for the emergency planning for their objects. Emergency plans for visitors and personnel are mandatory by law; there is however no liability to prepare emergency evacuation plans for cultural heritage, be it movable or immovable. Owners and curators can request support by the above-mentioned entities with knowledge in cultural heritage protection, and the different NGOs working the broad field of cultural heritage protection in Austria are also very supportive.

As a consequence, there is no general plan for the protection of cultural heritage in Austria, not even on regional or local level. The owners themselves are responsible and there is no liability to inform the authorities on existing plans. No national guideline for the development and implementation of such plans exists. One of the aims of the Danube University is to raise awareness for the necessity of cultural heritage protection both from man-made and natural

[29] A. Gach, Gegen illegalen Kulturhandel. Öffentliche Sicherheit. Das Magazin des Innenministeriums 5-6/17, 9-10.

[30] UNESCO, International Code of Ethics for Dealers in Cultural Property, adopted 1999, https://unesdoc.unesco.org/ark:/48223/pf0000121320 (accessed 17.04.2019); WKO Österreich, Ethikkodex für den Kunst- und Antiquitätenhandel. Verhaltensregeln für Händler in Österreich, 2018, https://www.wko.at/branchen/handel/juwelen-uhren-kunst-antiquitaeten-briefmarken/ethikkodex-fuer-den-kunst--und-antiquitaetenhandel.html (accessed 17.04.2019).

[31] BGBl I 19/2016.

disasters and to contribute to the development of guidelines for emergency preparedness plans for movable and immovable heritage. For the ten UNESCO World Heritage sites in Austria management plans do exist, which alas do not necessarily take issues of cultural heritage protection into account.

National, regional and local emergency plans aim at fighting different natural catastrophes. Concerning the threats water and fire, which are at the core of ProteCHt2save, national plans include the Flood Action Programme[32] and the Hochwasserrisikomanagementplan,[33] which also aim at reducing the threats of floods. A regional plan encompassing Lower Austria is the 1st DRB Flood Risk Management Plan which aims at the Danube River basin in general.[34] Local plans feature dams and mobile flood protections, like the one in the Wachau region, as described in deliverable D.T1.3.2 *Pilot Site Identification*. In Austria the voluntary fire brigades also fight floods and its consequences together with the local population. They also have firefighting plans and information on the most hazardous and vulnerable items in their area of responsibility concerning their eponymous threat, fire. In Krems-Stein, which has two medieval city centres with houses and roofs interconnected, the local fire brigades have developed a plan for what they call “Case Zulu”, fire in the old towns of Krems and Stein. In August 2017 a big fire happened in the outskirts of Krems, and the lessons learned are currently adopted into the modified firefighting plan.

Thus, the fire brigades are the ones on spot who already work for the protection of our cultural heritage and who can expand their possibilities for protecting cultural heritage together with the civilian owners of movable and immovable heritage, if training and education is made possible. Qualified personnel, material and equipment can be supplied by the Notfallverbund Österreichischer Museen und Bibliotheken, an initiative started by the Kunsthistorisches Museum Wien (the National Art Museum in Vienna). This Notfallverbund consists of different museums, archives and libraries all over Austria and pledges non-bureaucratic assistance to members in need.

Plans for the protection of movable and immovable heritage are not mandatory in Austria. Emergency plans for protecting people, communities, and real values in general also take care of cultural heritage, though cultural heritage is not mentioned and targeted explicitly by these plans. The protection of cultural heritage in most cases appears to be a side effect of the general emergency plans. Responsibilities for cultural heritage protection are split between different entities; a common platform is missing hitherto. In the end the owners and curators of cultural heritage and cultural heritage institutions are responsible for developing emergency

[32] https://www.icpdr.org/flowpaper/viewer/default/files/ICPDR_Flood%20_Action_Programme.pdf (accessed 03.06.2019)

[33] https://www.bmlfuw.gv.at/wasser/wisa/fachinformation/hochwasserrisiko/hochwasserrisikoplan.html (accessed 03.06.2019)

[34] https://www.icpdr.org/main/sites/default/files/nodes/documents/1stdfrmp-final.pdf (accessed 03.06.2019)

plans for their cultural heritage assets, but these plans are not mandatory. There are no official guidelines for their development or the collaboration with emergency responders like the fire brigades.

The biggest opportunities are to raise the public awareness for the necessity of cultural heritage protection and preparedness measures, to assist cultural heritage curators and owners in developing site-specific plans i.e., with guidelines and handbooks, and to include cultural heritage protection into the training of the fire brigades.

To summarize: The owners of cultural heritage sites themselves are responsible and there is no obligation to inform the authorities on existing plans. No national guideline for the development and implementation of such plans exists. The WebGIS Tool has illustrated its capability in being an asset for raising awareness for the necessity of cultural heritage protection both from man-made and natural disasters and to potentially aid in the development of guidelines for emergency preparedness plans for movable and immovable heritage.

EVALUATION AND ASSESSMENT

TESTING OF THE WEBGIS TOOL FOR LANDSCAPE PROTECTION

Villa Ghigi Park / Italy **December 2021**

VILLA GHIGI PARK

REGION	COUNTRY	EU ID	CITY	MUNICIPALITY
Emilia-Romagna	Italy	IT	Bologna	Bologna

CULTURAL HERITAGE CATEGORY	HAZARD TYPE
• Historic Park • Cultural landscapes • Natural heritage	Flood Landslide Heavy rain Windstorm Drought

SITE LOCATION		
Centroid geographical coordinates	Lat. 44.47610	Long. 11.32632

Geographical positioning of the site (left) and its location in relation to the city of Bologna (right).

1. Foreword

This document proposes a risk assessment for Villa Ghigi Park, a public green area owned by the Municipality of Bologna and located on the first hill in view of the city, at the edge of the city (2 km far from Piazza Maggiore).

The green area is located on a former agricultural estate and houses a 17th-century manor house and two farmhouses, one of which is the headquarters of the Villa Ghigi Foundation (which has been directly managing the park on behalf of the municipal administration since 2004). All the buildings are excluded from this assessment.

The park summarises the landscape and naturalistic characteristics and qualities of the Bologna hills, as well as the dynamics, vulnerabilities, and typical problems of the hill territory, which in recent times have become increasingly frequent and are often linked to extreme weather events.

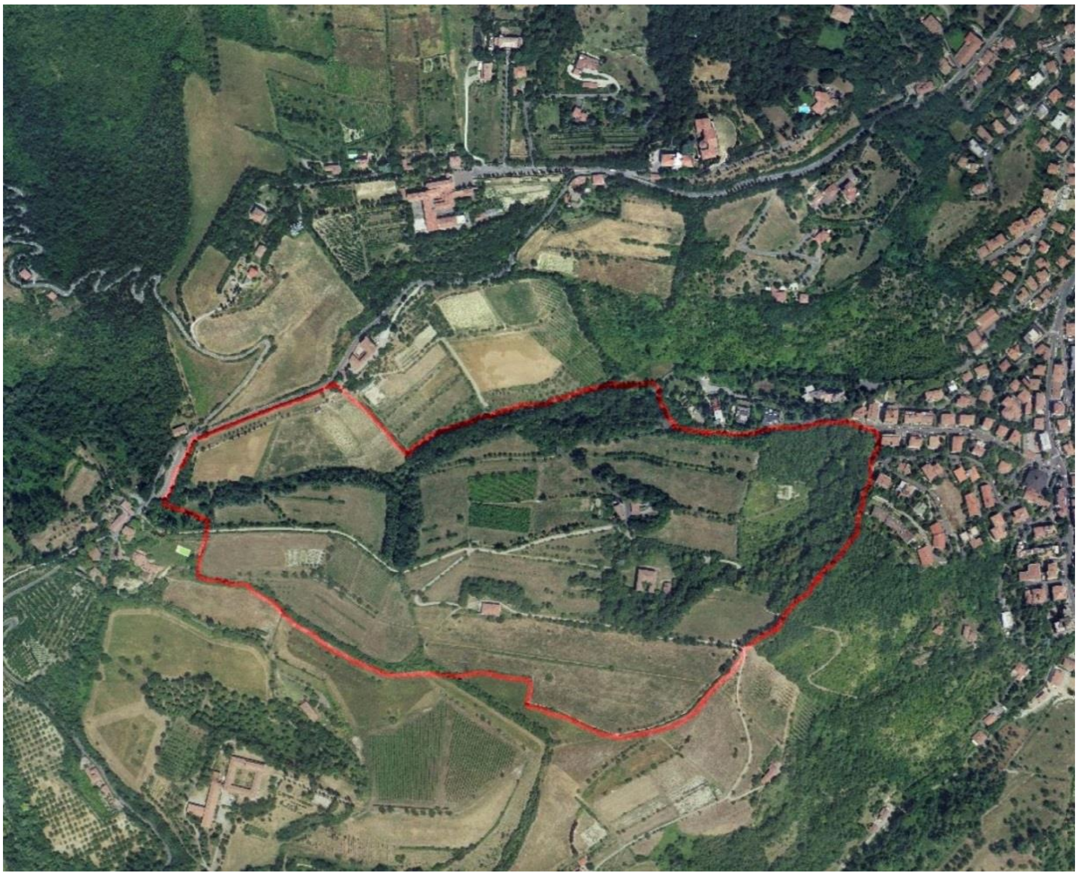
2. The site: framework and characteristics

The Villa Ghigi Park extends for 29 hectares on the first hills around Bologna, on the right side of the valley of the Rio Fontane, a tributary of the Aposa stream. The difference in height ranges from 104 meters at the bottom of the Rio Fontane valley to 243 meters at the highest point of the park, towards the top of the Ronzano hill. The slopes are medium to steep, mostly more than 20% with some stretches reaching 35%.

The park is characterised by a double level of protection: landscape (like most of the hills of Bologna, thanks to provisions dating back to the 1960s) and historical-cultural (regarding the 17th-century villa and the ornamental garden surrounding it). The park is also located in the territory of the “Paesaggio naturale e seminaturale protetto Colline di San Luca” (Protected natural and semi-natural landscape of the San Luca hills), included in the system of protected areas of the Emilia-Romagna Region. Finally, among the most valuable trees in the park, there is a specimen (Himalayan Cedar - Cedrus deodara) recently included in the list of monumental trees of Italy, according to art. 7 Law 10/2013.

From the point of view of vegetation cover, the park alternates between sectors of natural woodland, reforestation of native broadleaf trees, shrubland and permanent grassland; many rows of fruit trees and some old vineyards recall the past agricultural use of the site. The vegetation cover is continuous and there are no areas uncovered by vegetation (ploughed land, rock outcrops, etc.).

The park's tree heritage includes several mature and veteran trees belonging to both native and exotic species. As in any historical park, these trees are the most significant and characteristic elements of the green area, but by their nature they are also the most fragile elements, especially in relation to the extreme weather events of recent years, and attention and care must be focused on them to ensure their protection and at the same time the safety of those who use the green area.



Aerial photo of the foothills of Bologna showing the boundaries of the park.

The mosaic of environments that characterises the Villa Ghigi Park.


The great Himalayan cedar (*Cedrus deodara*) next to the building of Villa Ghigi, introduced in 1874 and recently included in the list of monumental trees in Italy (Ministerial Decree 5450 of 19.12.2017). The plant, about 30 years ago, was struck by lightning that cut off the top and left a long wound on the stem, triggering vegetative and phytosanitary problems. As part of the European HICAPS project, a wooden platform was created to welcome visitors, necessary to mitigate the negative effects of trampling under the tree.


The 17th-century building of Villa Ghigi, unfortunately abandoned (left) and the Palazzino farmhouse, home of the Villa Ghigi Foundation (right). The presence of the Foundation's headquarters in the park allows for direct, daily monitoring of the area, as well as a close relationship with its visitors and the teams of gardeners and workers who work there.

3. Weather related risks in the Villa Ghigi Park and in the Bologna's hill

In the context of the themes described in the STRENCH deliverable (D.T2.1.1 Criticalities of CH landscapes), attention is focused on the vulnerabilities that may have direct and important impact on the park territory, and more generally in the Bologna hills, in relation to the data and projections provided by the WebGIS tool "Risk Mapping Tool for Cultural Heritage Protection" (WGT). The themes considered concern: heavy rain and flash flood, landslide, windstorm, drought.

3.1 Heavy rain and flash floods

In the hills of Bologna, flooding due to heavy rainfall concentrated in a short period of time has become increasingly frequent in recent years, and is definitely confirmed by the weather projections provided by the WGT instrument.

For the park, in addition to the damage caused on dirt roads and paths and on the surface water regulation network, the intense rainfall concentrated in a short time is particularly critical for one of its entrances. This is due to the presence of a small watercourse often subject to overflows that also involve the public road and neighbouring houses and that in some cases have required the intervention of emergency management bodies (Civil Protection, Municipal Police, etc.). This type of hydraulic risk is common to the entire foothills of Bologna, as the watercourses that run through the hills at their entrance to the city have in the past been filled with hydraulic structures that are no longer adequate to receive the intense rainfall of recent years. In the light of current weather trends, the ordinary and extraordinary maintenance work provided for in the park's management plan is no longer sufficient to ensure the proper regulation of the water and the efficiency of the drainage network and to prevent or limit the damage caused by flooding. To solve this specific problem, it is necessary to plan a structural intervention, challenging also in economic terms, adapting the hydraulic structures to the current hydraulic flows and especially to those expected in the near future in relation to climate change, to be carried out in agreement with the competent municipal technical offices and with the bodies in charge of managing the covered hydrographic network of the city of Bologna.

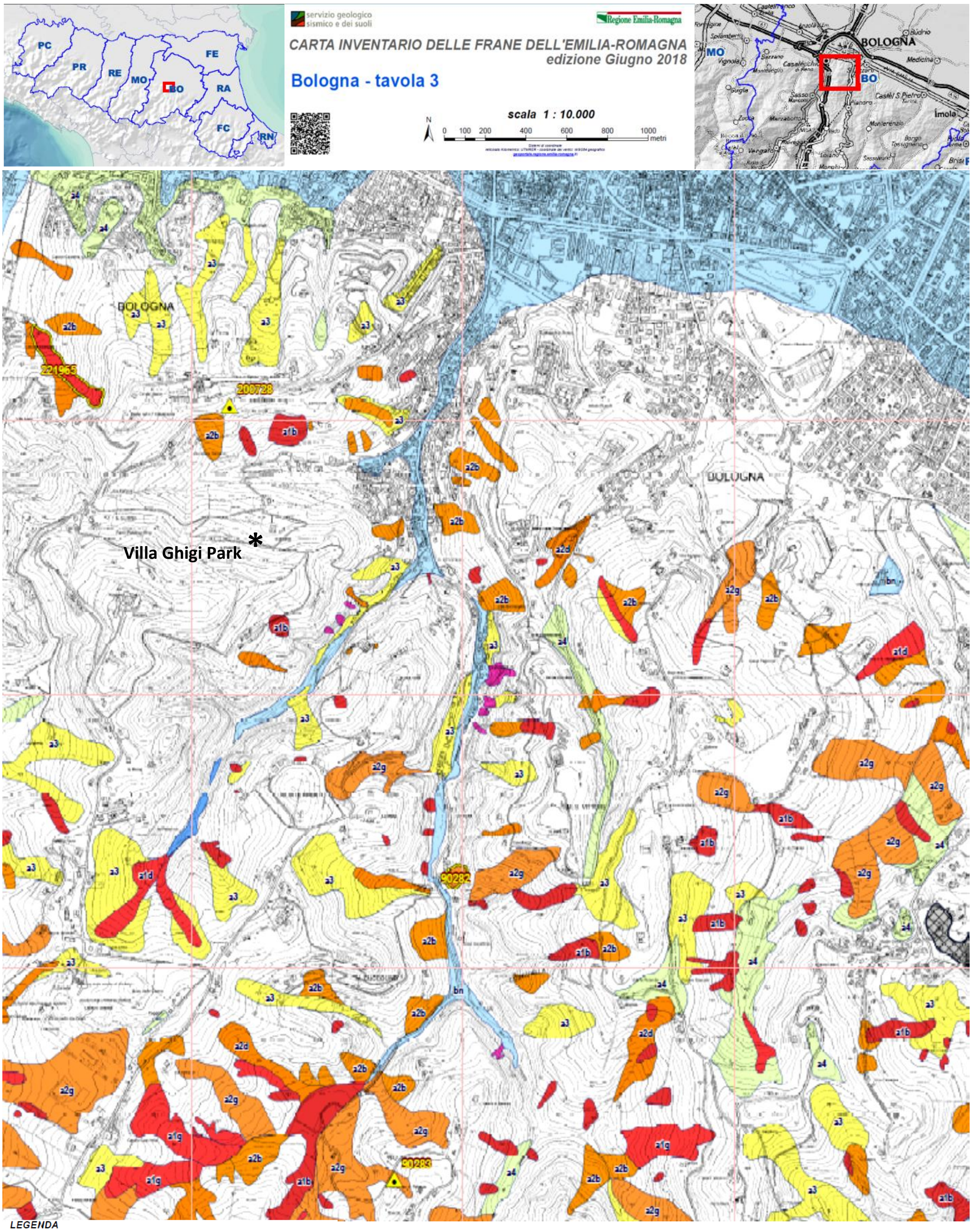
From an operational point of view, it is stressed that the constant monitoring of the green area, starting from the vulnerability map functional to highlight the most sensitive areas with respect to this specific issue (see page 14), is the basis of the programme of functional interventions to manage this specific aspect and that for the near future will have to be adapted in frequency and type to the new weather events foreshadowed by the climate projections returned by the WGT tool.

The more and more frequent and intense rains concentrated in a short time cause significant damage in the network of paths and in the regulation of surface water in parks and gardens. Some examples in the Park of Villa Ghigi in Bologna: one of the secondary entrances (upper picture) and two sections of the path network (lower pictures).

3.2 Landslides

Given the geological and geomorphological nature of the valley in which the park is located, and more generally of the Bologna hills, episodes of hydrogeological instability are widespread in the area, accompanied by more or less significant landslides, as the map on page 9 clearly shows. These episodes are partly attributable to the abandonment of farming, which has led to the cessation of the good practices of regulation and care of the land that were once carried out regularly by those who cultivated the land, and which included regular maintenance, cleaning and reshaping of ditches and drainage ditches, care of hydraulic structures and other functional works to maintain the efficiency of the drainage network and ensure the stability of the slopes. These preventive measures are currently carried out regularly in the park, as part of the management plan for the green area, thanks also to the specific vulnerability map (see page 14). Nevertheless, in recent years there have been episodes of instability, including a landslide movement of limited dimensions that also affected a section of the main road; the movement occurred in the spring of 2013 following a prolonged period of rainfall that most likely triggered the episode.

The landslide repair work took place in the park in the spring of 2013 following a prolonged period of rainfall. The restoration work, carried out promptly, has stopped the regularly monitored landslide movement for the time being.



LEGENDA

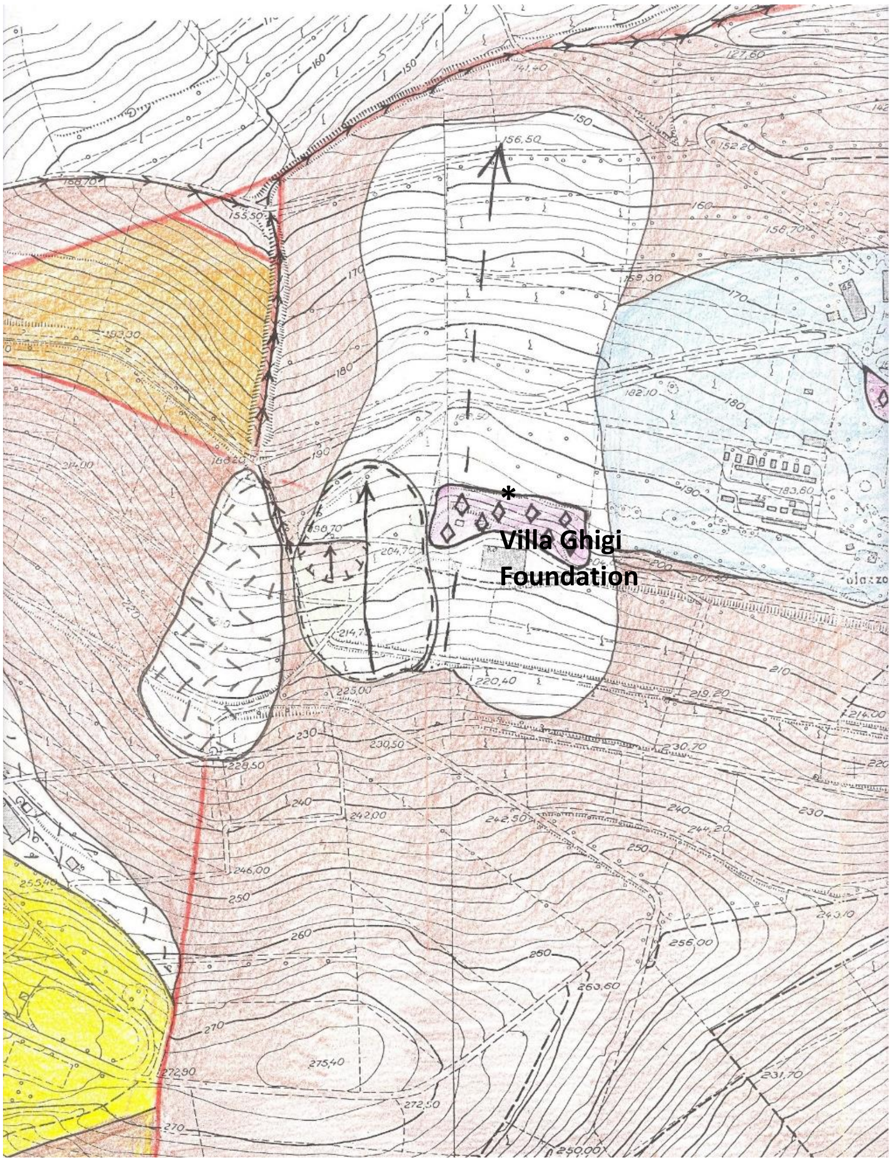
Depositi di frana

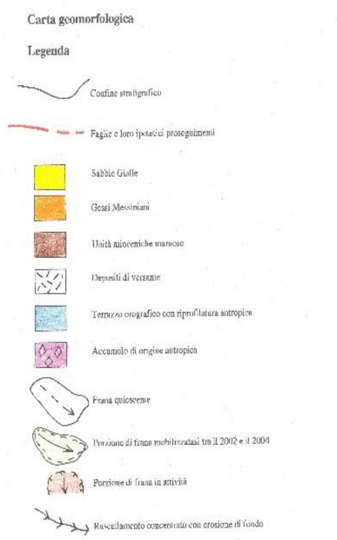
- a1a - Deposito di frana attiva per crollo e\o ribaltamento
- a1b - Deposito di frana attiva per scivolamento
- a1d - Deposito di frana attiva per colamento di fango
- a1e - Deposito di frana attiva per colamento detritico
- a1g - Deposito di frana attiva complessa
- a2b - Deposito di frana quiescente per scivolamento
- a2d - Deposito di frana quiescente per colamento di fango
- a2g - Deposito di frana quiescente complessa

Eventi di frana storicamente documentati

- Frana con eventi storicamente documentati di limitata estensione
- Frana con eventi storicamente documentati

The whole hill of Bologna, which includes the area of the pilot site, is characterised by a high risk of landslides as it is highlighted in the above map elaborated by the Emilia Romagna Region in which the active landslide areas (purple/red colour), the quiescent landslide areas (orange colour) and the landslide areas documented in the past (yellow colour) are reported.



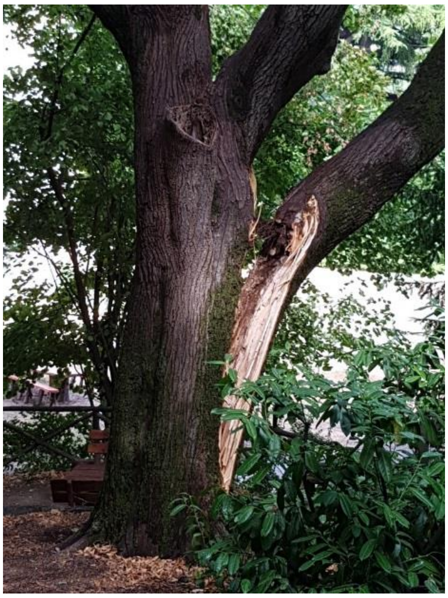


The specific geological survey carried out in Villa Ghigi Park showed the presence of active movements (highlighted by the arrow with a continuous line) and quiescent landslides (highlighted by the arrow with a dotted line) also inside the park. In the image to the side a detail of the geological map relating to the park with the sector close to the Villa Ghigi Foundation headquarters.

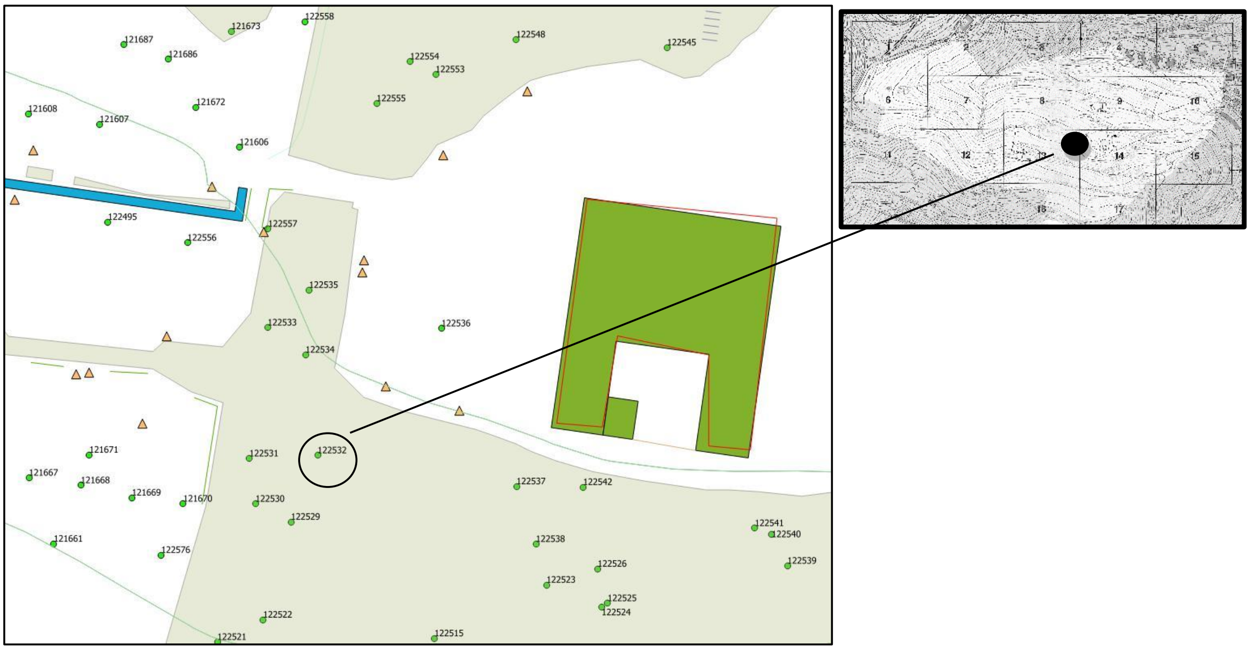
3.3 Windstorms and snow

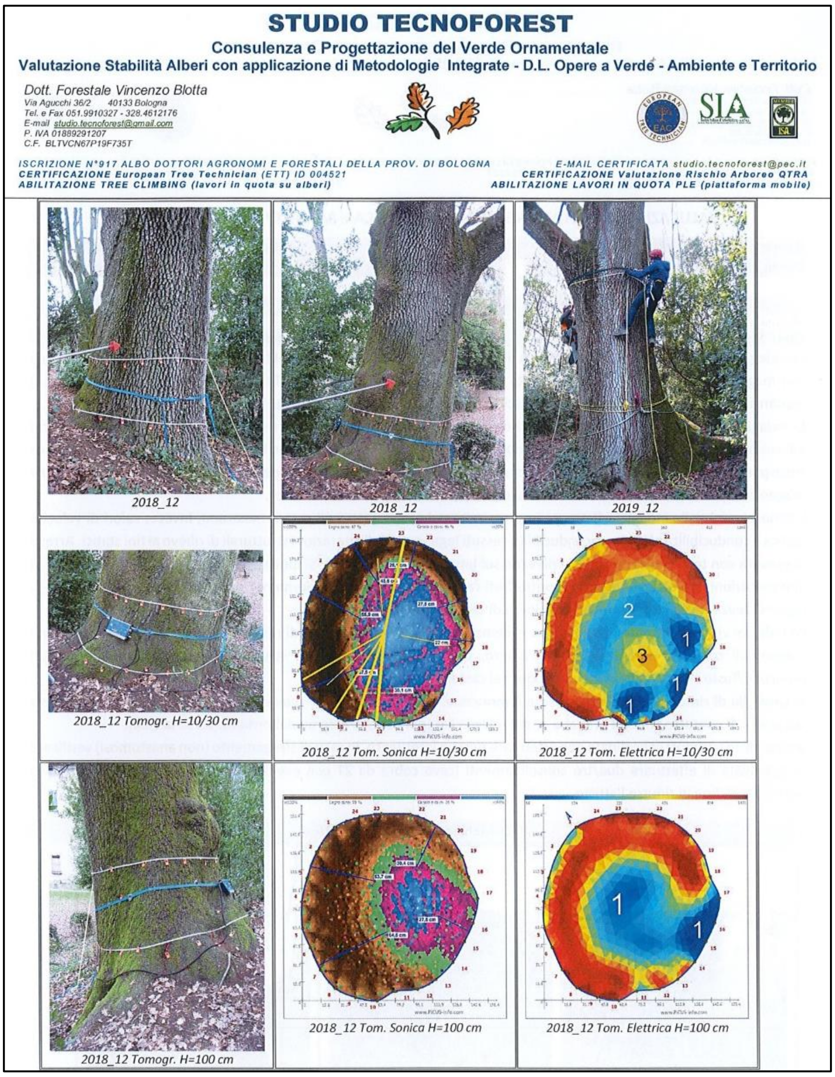
Storms associated with windstorms, which in the Bologna area are concentrated mainly in summer, can have a ruinous impact on the park's tree heritage, causing branches and twigs to snap off or entire specimens to collapse, thus posing a risk to people and property. Similar effects on the trees can also be caused by heavy snowfall, especially on evergreen tree species, or by unseasonal snowfall (concentrated in late autumn or early spring), which mainly affects deciduous species as the presence of foliage increases the static load on the plants.

The Park Management Plan includes the Tree Management Plan from a risk management perspective, aimed at risk assessment and management. The plan includes a geo-referenced census for the knowledge of the tree heritage (with a database and tree register), mapping of the territory (zoning) to identify the areas at greater risk with respect to the main vulnerabilities (see map on page 14), periodic checks of the trees thanks to selective cyclical monitoring and, lastly, a tree care plan through direct operations (felling, pruning, anchoring, etc.) and phytosanitary and stability assessments. This procedure makes it possible to define an intervention programme based on the real care needs of the trees and to establish clear and objective priority levels for intervention. Among the trees subjected to increased control are several centuries-old trees due to their special value in historic gardens, as they are particularly sensitive to storms associated with windstorms. Over the years, numerous static surveys (see page 12) have been carried out on these specimens by highly qualified personnel using sophisticated techniques.

A rest area near a large linden tree was closed after a branch of the tree collapsed during a summer storm (left). The crushed branch of the lime tree did not crash to the ground because it was held to the rest of the foliage by a system of cables; consolidation work was carried out following instrumental surveys that had revealed the plant's precarious structural condition.





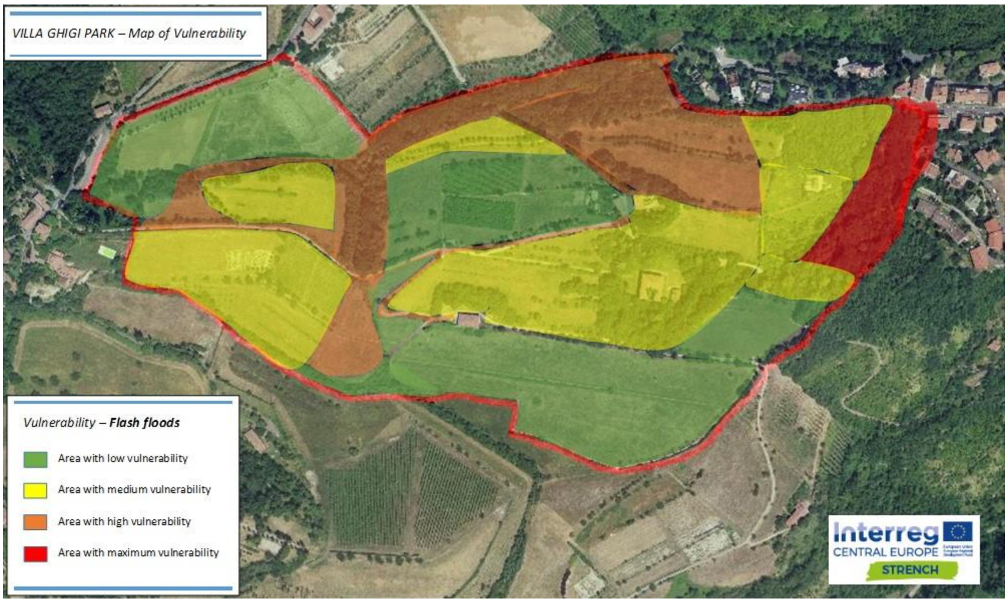
A centuries-old oak tree (Quercus pubescens) with a stem diameter of 160 cm, located in the centre of the historic garden near Villa Ghigi, is one of the plants included in the Census of the park's arboreal heritage (no. 122532) and has been the subject of constant monitoring and instrumental static surveys for many years in order to assess its condition and plan the cultivation work necessary for its conservation.

3.4 Long term increase of temperature and drought

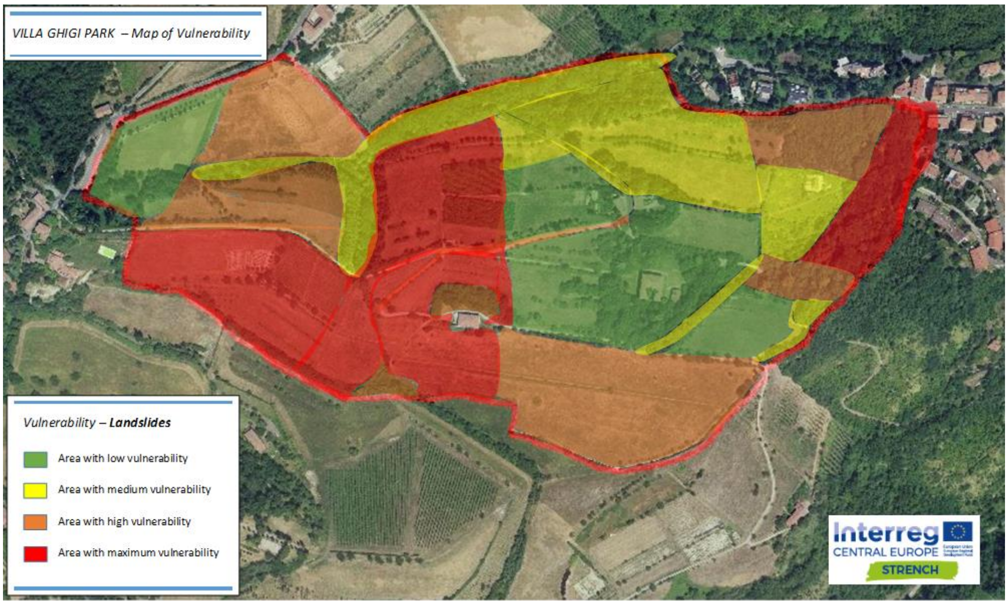
The damage to the vegetation due to the increase in drought periods and temperatures is now evident both in the whole Bologna area and in the park, and the climatic trends underway have been amply confirmed by the WGT data, both historical and projected for the future. Crossing the data extrapolated from the WGT with some important episodes of desiccation that have occurred in the last decade in the park, it has been possible to unequivocally confirm a correspondence between the decline in vegetation and the temperature peaks recorded in some years (as shown below on page 19).

The effects of prolonged drought and heat waves affect all vegetation components across the board, but are more pronounced on senescent trees (which see their decline accelerate) and on species that are more sensitive to drought (such as mesophilic species typical of other phytoclimatic belts).

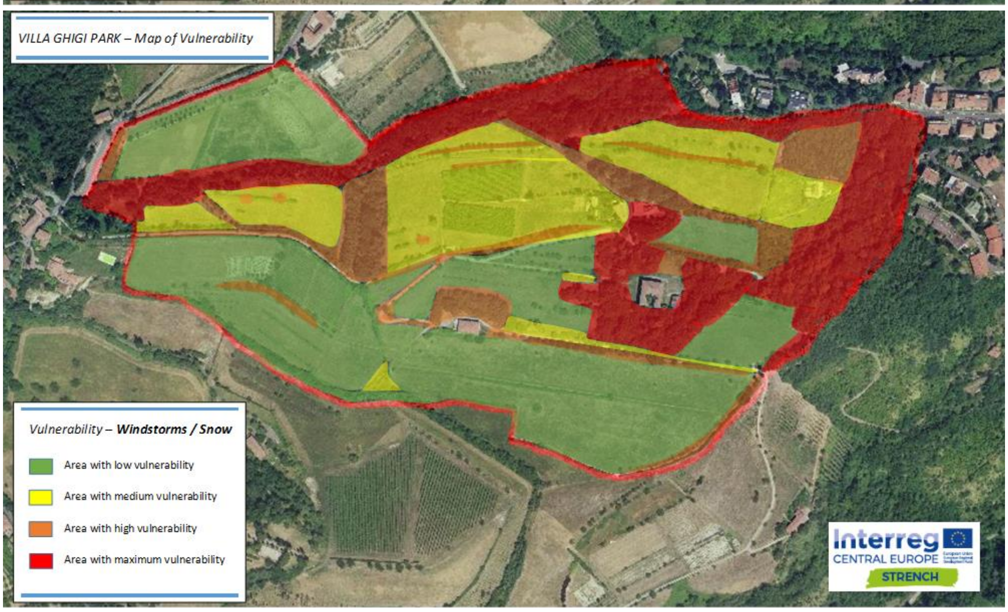
The majestic specimen of oak (Quercus pubescens) inside the Villa Ghigi Park subject to a progressive decline starting from 2011 that led to drying up; the decay phase of the plant lasted for about ten years but, despite the analyses and treatments undertaken, the oak dried up in 2018.



As part of the Park Management Plan, the area of the Villa Ghigi Park pilot site was zoned according to the main vulnerabilities identified in order to improve management and set up pre- and post-event contingency plans.

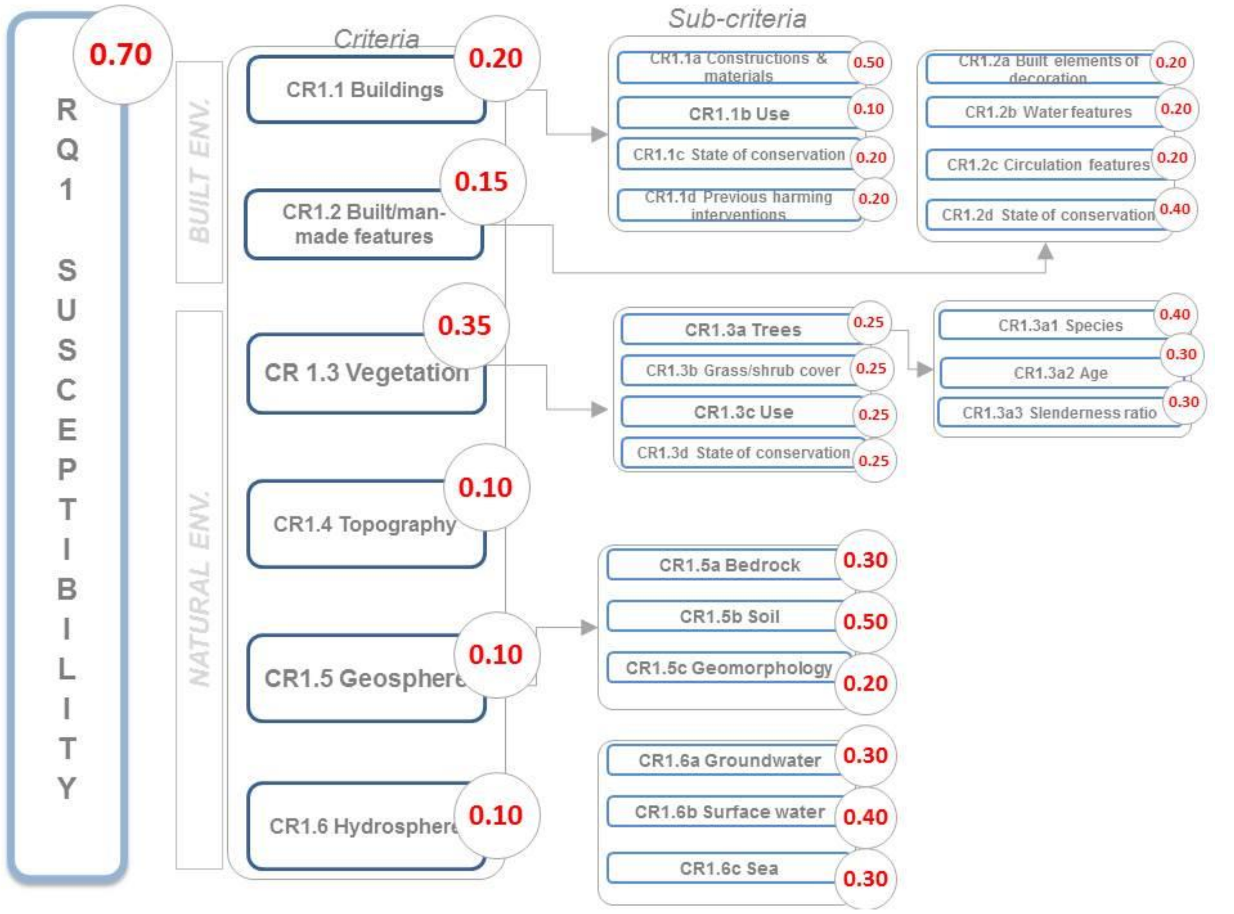


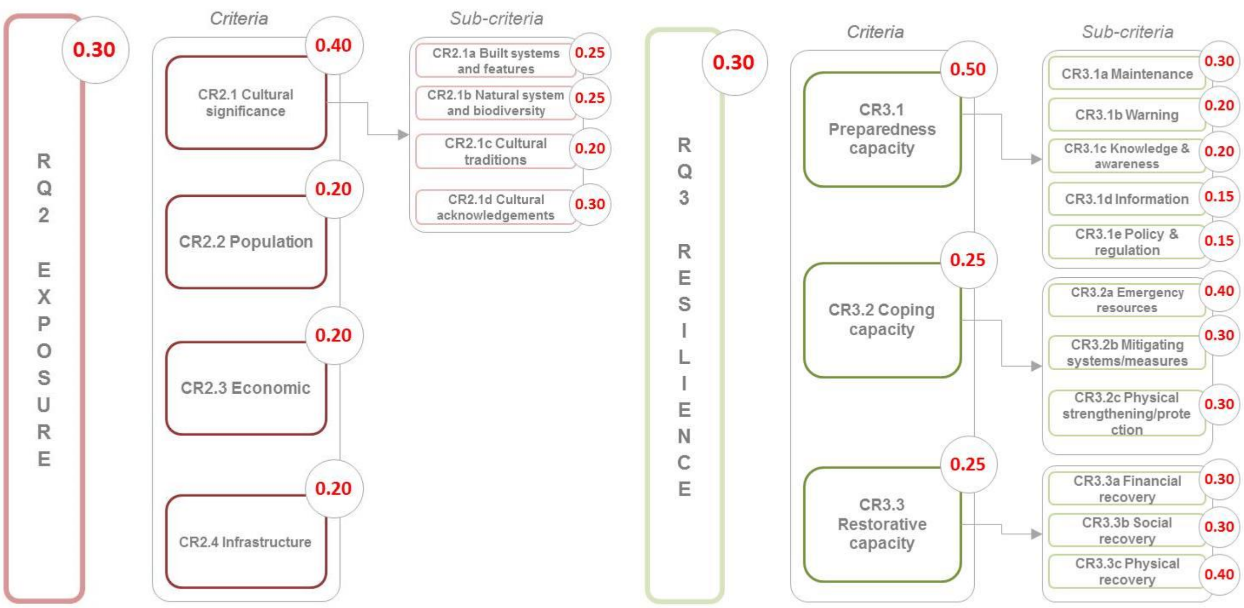
More attention has been paid to areas that may be subject to flash floods (top map), those at risk of landslides (side map) and areas of the park that may be subject to damage in the event of high winds or snowstorms (bottom map).



3.5 Methodology for ranking vulnerability of cultural heritage

At the end of the chapter, the vulnerability calculation for Villa Ghigi Park is presented using the methodology for ranking vulnerability of cultural heritage and the STRENCH guidelines for vulnerability evaluation (Annex D.T1.2.2).





Particular attention was given in the calculation to the sub-criteria related to the tree heritage (such as CR1.3a Trees), which represent for the pilot site Villa Ghigi Park one of the most important elements and more prone to damage in case of extreme events.

The vulnerability value for Villa Ghigi Park calculated is:

Vulnerability= 0.70 x Susceptibility + 0.30 x Exposure - 0.30 x Resilience
V = (0.70 x **0.48**) + (0.30 x **0.68**) - (0.30 x **0.55**) = 0.336 + 0.204 - 0.165 = **0.375**

Vulnerability = 0.375
With $0<V<1$ (low to high vulnerability)

4. Use of WebGIS "Risk Mapping Tool for Cultural Heritage Protection" - WGT

The WGT tool uses a series of extreme climate indices selected from the 27 standard indices defined by the Commission for Climatology/World Climate Research Programme/Technical Commission for Oceanography and Marine Meteorology (CCI/WCRP/JCOMM) Expert Team on Climate Change Detection Indices (ETCCDI).

The following table summarises the indices considered by the WGT with the reasons that make their analysis important for the Villa Ghigi Park pilot site.

Index	Definition / description	Reason
R20mm	**Very heavy precipitation days** Number of days in a year with precipitation larger or equal 20 mm/day.	Possible flash floods.
R95pTOT	**Precipitation due to extremely wet days** The total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days. A wet day is defined as havingdaily precipitation ≥ 1 mm/day. A threshold based on the 95th percentile selects only 5% of the most extreme wet days over a 30 year-long reference period.	Possible flash floods. Possibility of heavy erosion in the area, possibility of landslides.
Rx5day	**Highest 5-day precipitation amount** Yearly maximum of cumulated precipitation over consecutive 5-day periods.	Possibility of heavy erosion in the area, possibility of landslides, possible vegetation damage in case of snow.
CDD	**Maximum number of consecutive drydays** Maximum length of a dry spell in a year,that is the maximum number in a year of consecutive dry days with daily precipitation smaller than 1 mm/day.	Possible vegetation damage.
Tx90p	**Extremely warm days** Percentage of days in a year when daily maximum temperature is greater than the 90th percentile. A threshold based on the 90th percentile selects only 10% of the warmest days over a 30 year-long reference period.	Possible vegetation damage.

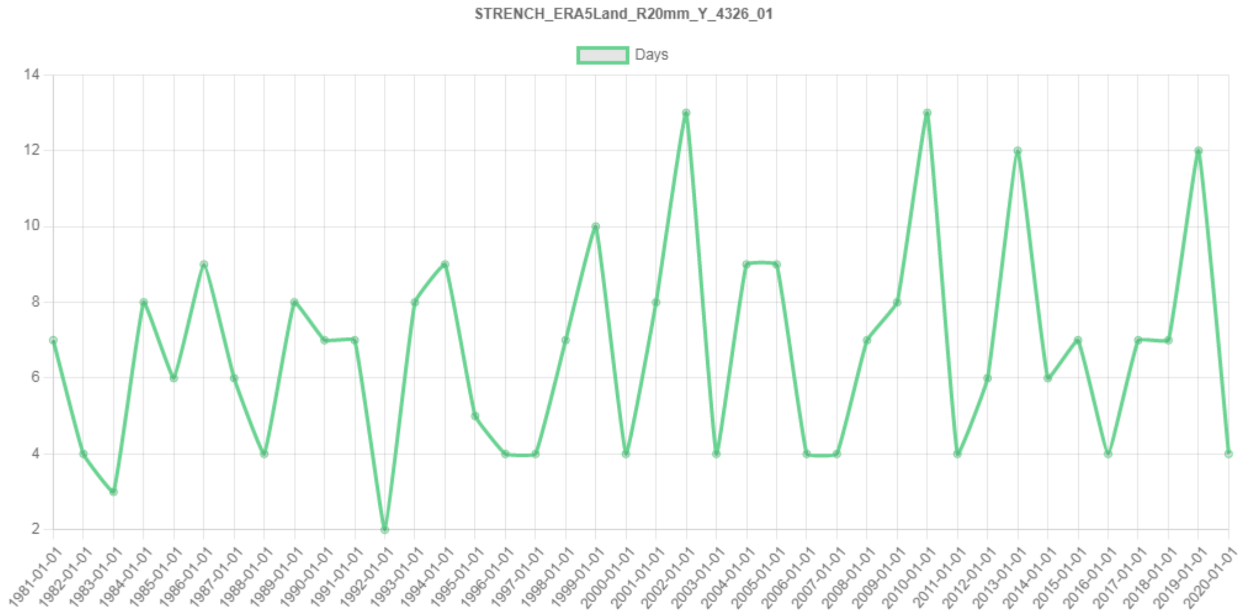
4.1 Use of WGT for investigation of past events

From the OPEN SEARCH section of the WGT it was possible to investigate past events concerning the pilot site area.

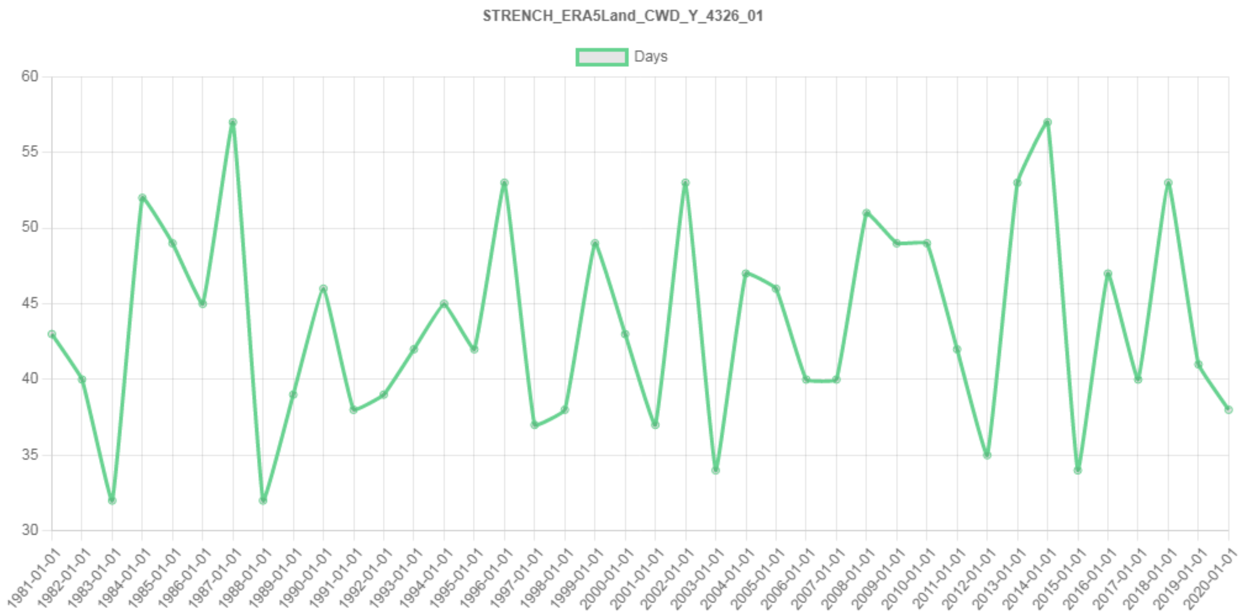
Among the various indices available, some provided by the Copernicus satellites were selected. They show particularly significant data for the pilot site because they are linked to important events that have affected the park in the past.

Of particular interest for the precipitation theme were the R20mm and CWD indices, which cover a 40-year period from 1981 to 2020. The CDD and TR index of tropical nights were of most interest for the tree stock.

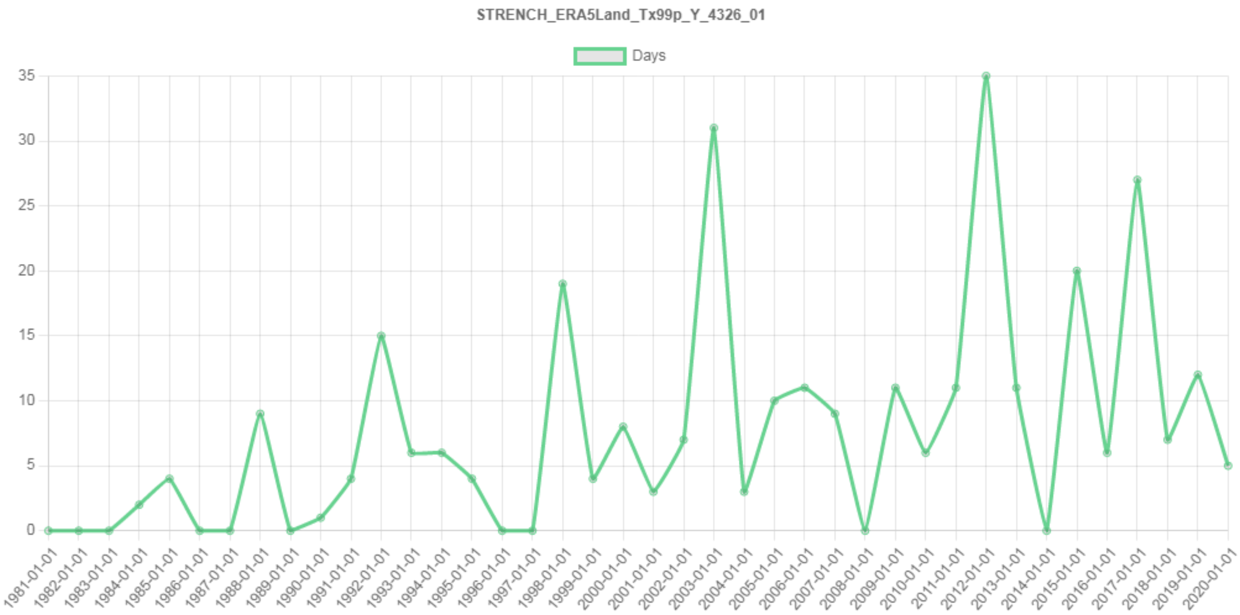
The following pages show the graphs related to the area in which the pilot site is located (Bologna hills), which have allowed us to discover or confirm in a documented way a couple of cause-effect links between some important events of various nature that occurred in the park and the climatic trends recorded by the Copernicus satellites.



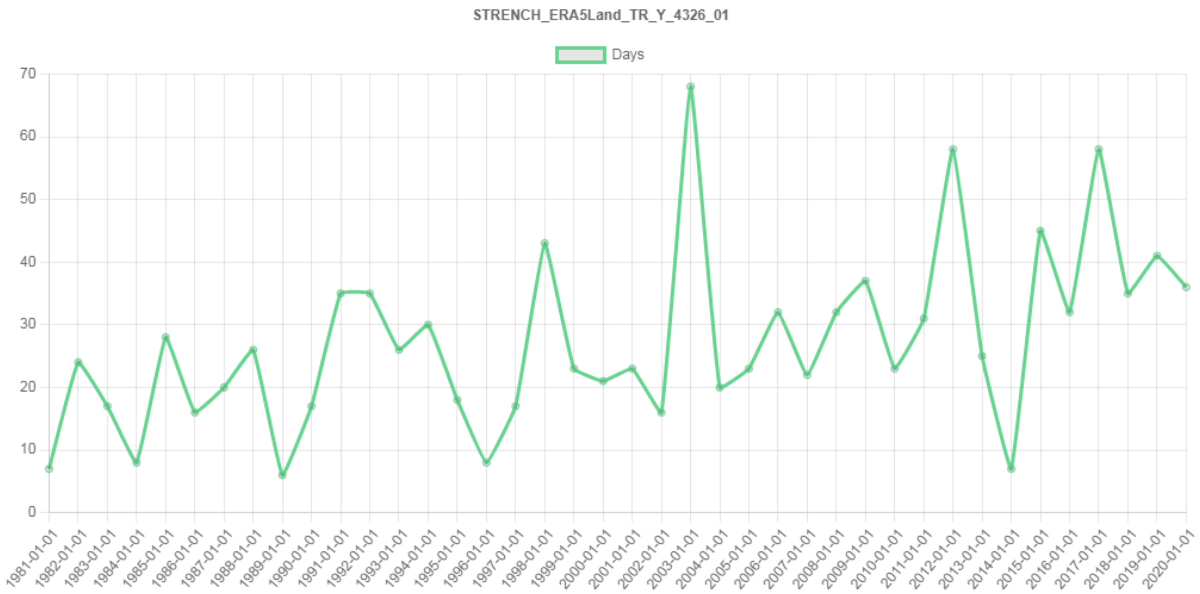
The index ***Very heavy precipitation days*** (***R20mm***) shows a significant difference between the period 1981/2000 and 2000/2020, with a marked increase in very heavy precipitation days in the latter period: there are four peaks of 12 days in two cases and 13 days in as many cases, compared with maximum values of 10 days in the former period.



The index showing the number of consecutive wet days (***CWD***) shows the highest peak coinciding with 2013, the year in which the last major landslide event occurred in the park (photo on page 8).



The graph of the ***Extremely warm days*** index (Tx99p) shows the highest peaks after 2000. Year 2011 was the one with the highest value of 35 days. In that year there was a long dry period with important consequences for the park's tree population: 2011 marks the beginning of the decline of one of the largest oaks (photo on page 13) and other old trees in the park. In the case of the oak, the death of the plant became apparent after the subsequent peak in 2017.



The ***Tropical nights (TR)*** index confirms the trend of the previous graph: there are five peaks corresponding to five years with more than 40 days concentrated in the most recent period (after 1998) and the year 2011 is among them; the peaks showing the years with the lowest number of tropical nights are mainly concentrated in the least recent period: before 1998 there are four years with less than 10 days compared to only one in the last twenty years.

5. Use WGT for creating climate maps

Once the current state of vulnerability of a historical garden has been ascertained, it is important to imagine what the future climatic variations might be in order to manage it correctly.

The ***WebGIS tool*** "***Risk Mapping Tool for Cultural Heritage Protection***" (***WGT***) allows the elaboration of forecast maps based on climate modelling, in order to check if the current strategies are suitable to face future climate scenarios and to understand which improvements might be necessary.

The approach was to collect maps of the area from the WebGIS application with past (1951- 2016), near future (2021-2050) and far future (2071-2100) projections (Model ensemble statistics / Maximum / RCP 4.5 and RCP 8.5).

Forecast maps for Villa Ghigi Park and Bologna Hills were created based on climate modelling for all five available climate indices and for each of them both future emission scenarios described in the latest IPCC (Intergovernmental Panel on Climate Change) were considered:

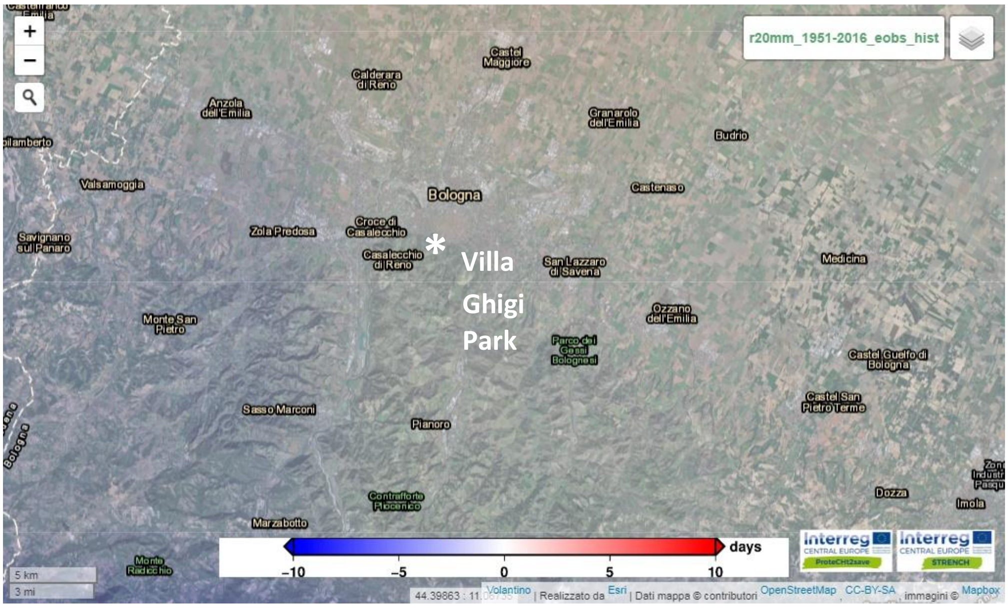
- RCP 4.5 greenhouse gas emission stabilisation scenario.
- RCP 8.5 high pathway scenario characterised by increasing GHG emissions over time.

The processing thus resulted in five comparable maps for each index. Each group of maps provided a series of interesting data on which some brief interpretation hypotheses were made, also considering the historical data available from the OPENSEARCH graphs.

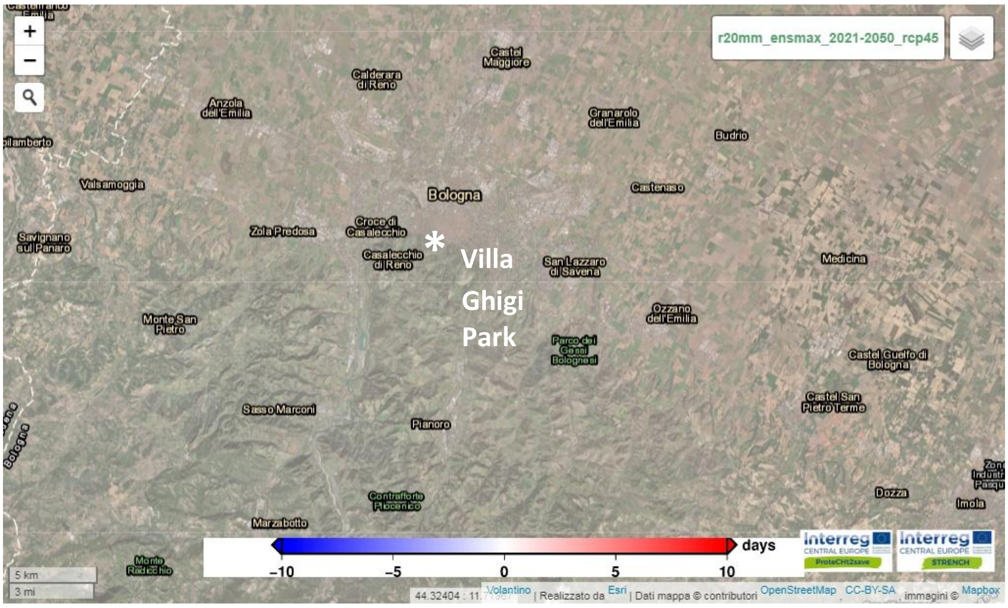
The table below summarises the values of the maps presented on the following pages.

	Near future RCP 4.5	**Far future RCP 4.5**	**Near future RCP 8.5**	**Far future RCP 8.5**
Index				
R20mm (days)	1-2	2-3	2-3	3
R95pTOT (mm)	60-70	70-80	70	120-130
Rx5day (mm)	30-35	20-25	25-30	40
CDD (days)	6-7	5	5-6	13-14
TX90p (%)	10	20	13	50

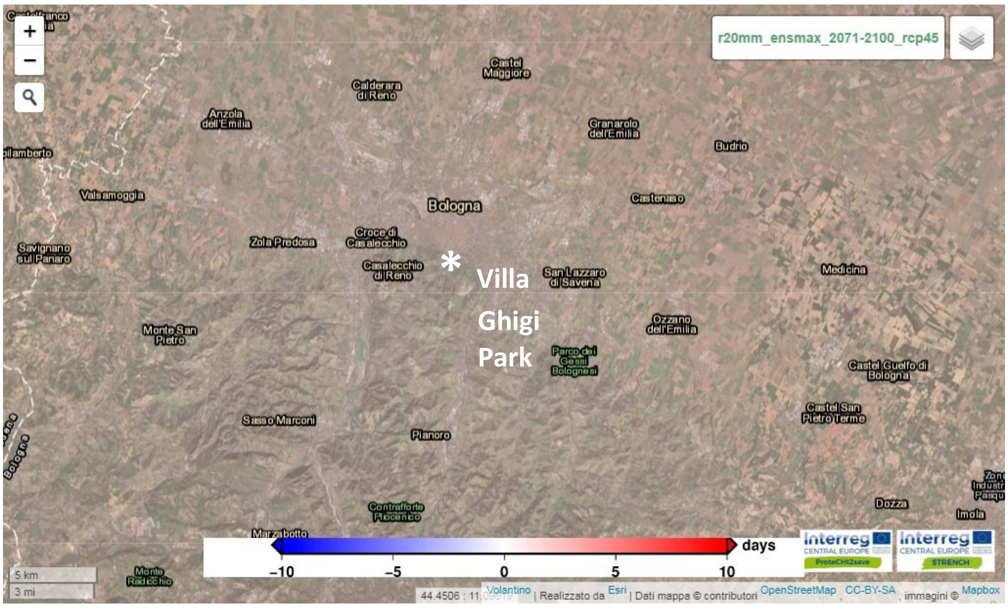
5.1 Very heavy precipitation days



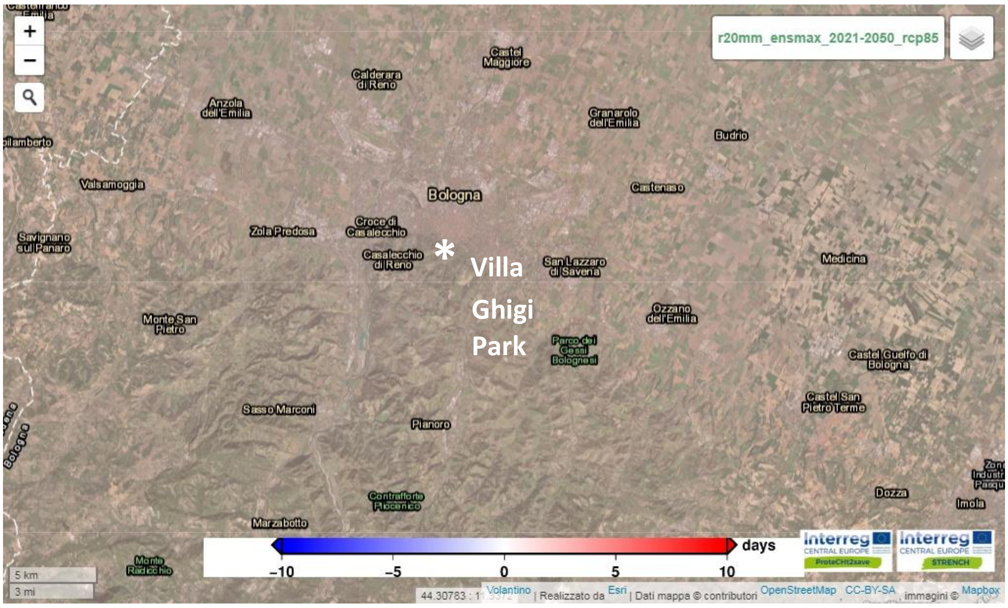
Map for the historic dataset on r20mm



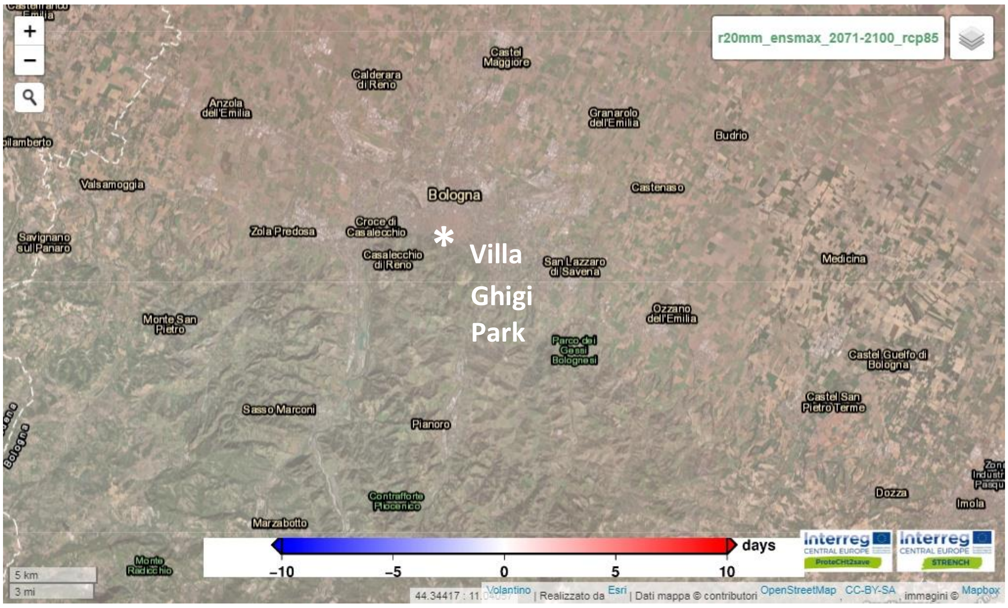
Map for the near future dataset on r20mm in the rcp45 scenario



Map for the far future dataset on r20mm in the rcp45 scenario



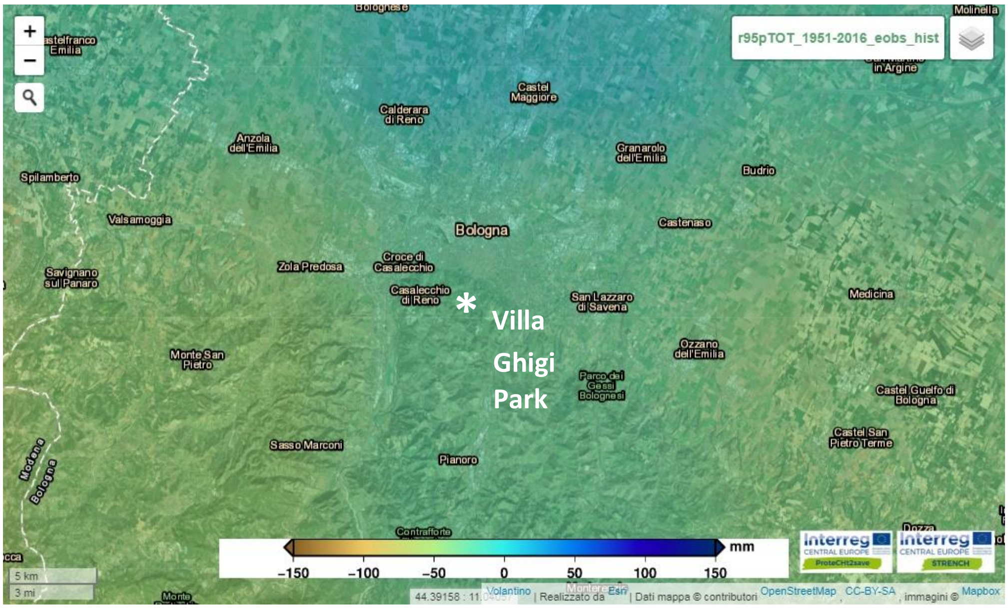
Map for the near future dataset on r20mm in the rcp85 scenario



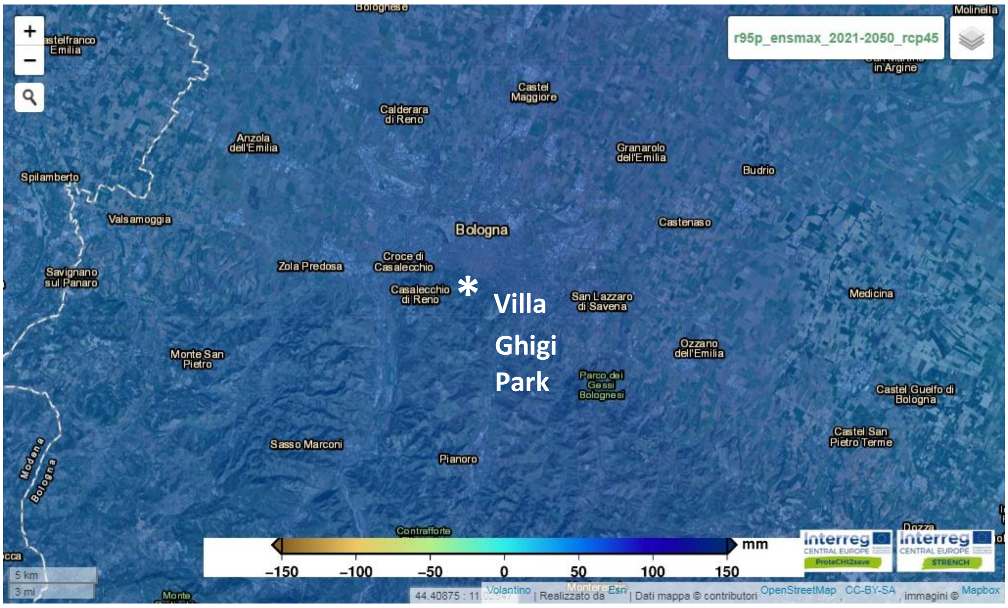
Map for the far future dataset on r20mm in the rcp85 scenario

The forecast maps show a slight increase in the number of days with the possibility of heavy rainfall in the RCP 4.5 scenario, especially in the far future; the change becomes slightly more pronounced in the RCP 8.5 scenario already in the near future, although the increase is always in the order of 2-3 days. On the basis of these projections, an increase in the number of rainy days can be expected with some probability, which in some cases could trigger flash floods.

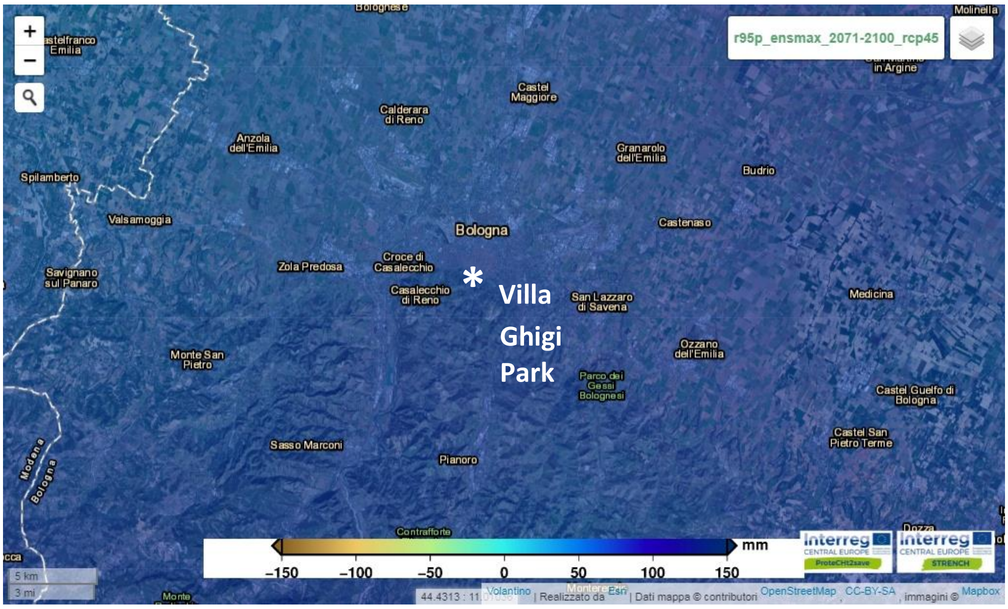
5.2 Precipitation due to extremely wet days



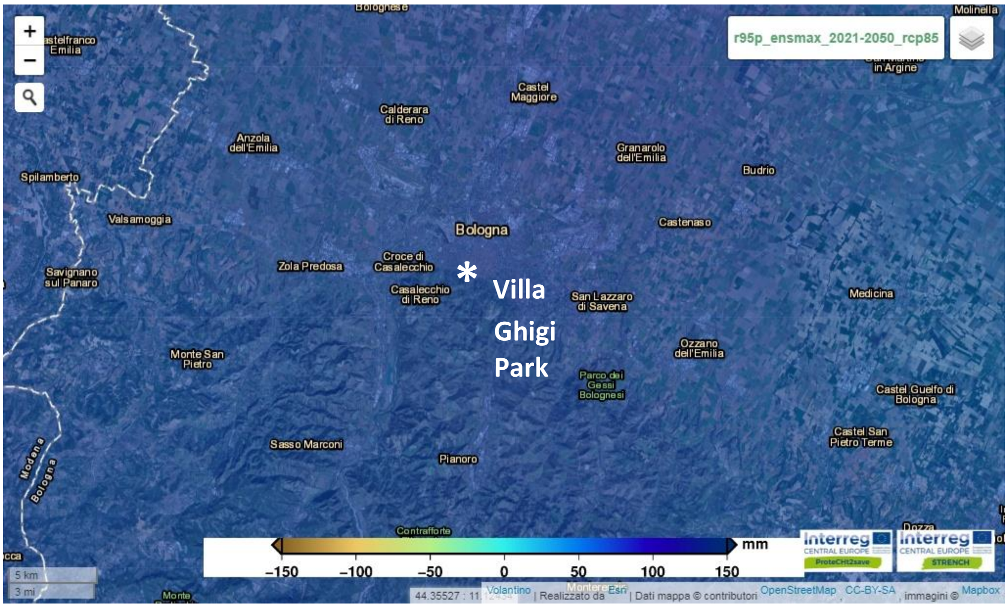
Map for the historic dataset on r95pTOT



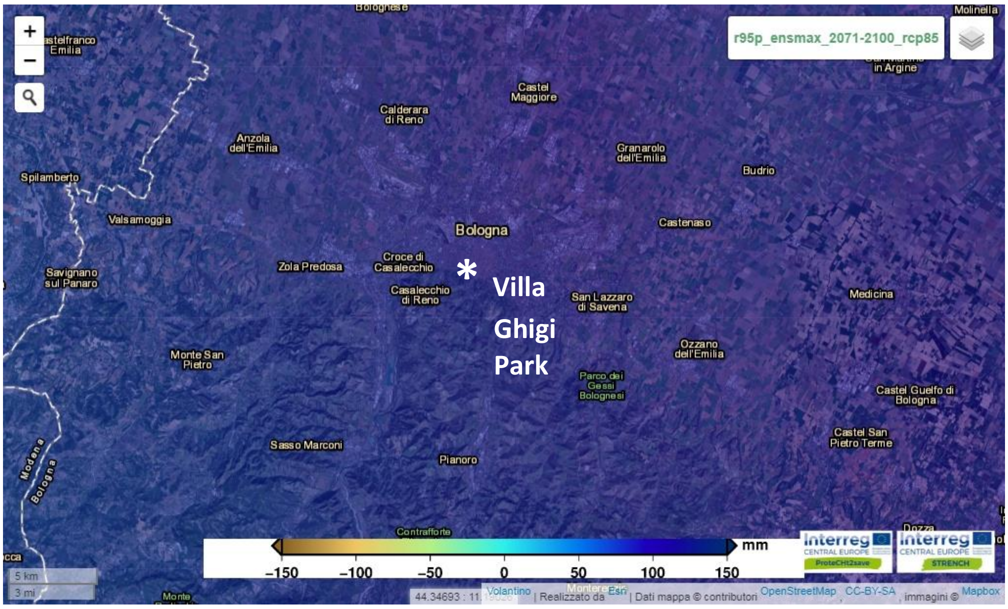
Map for the near future dataset on r95pTOT in the rcp45 scenario



Map for the far future dataset on r95pTOT in the rcp45 scenario



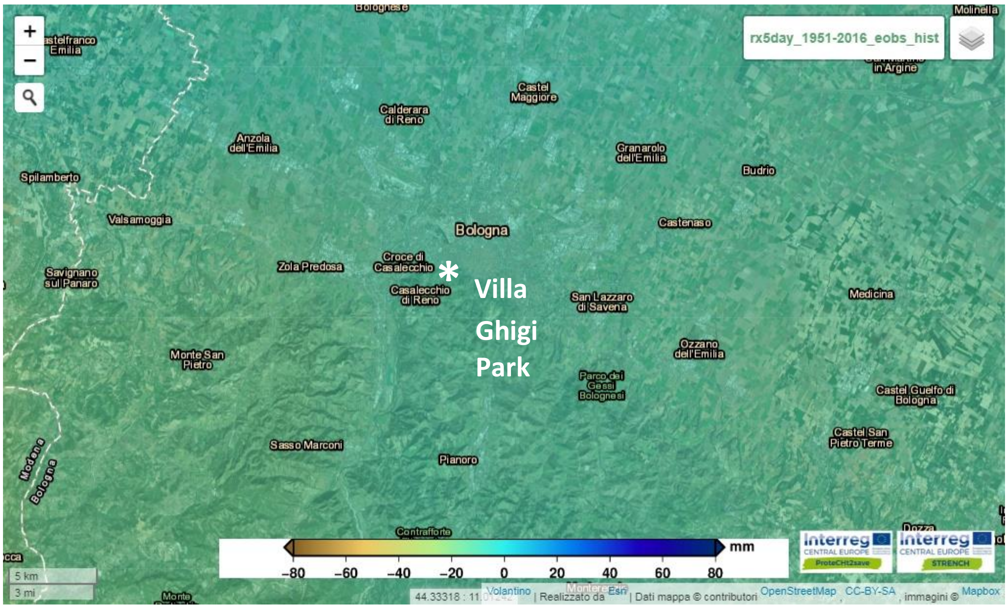
Map for the near future dataset on r95pTOT in the rcp85 scenario



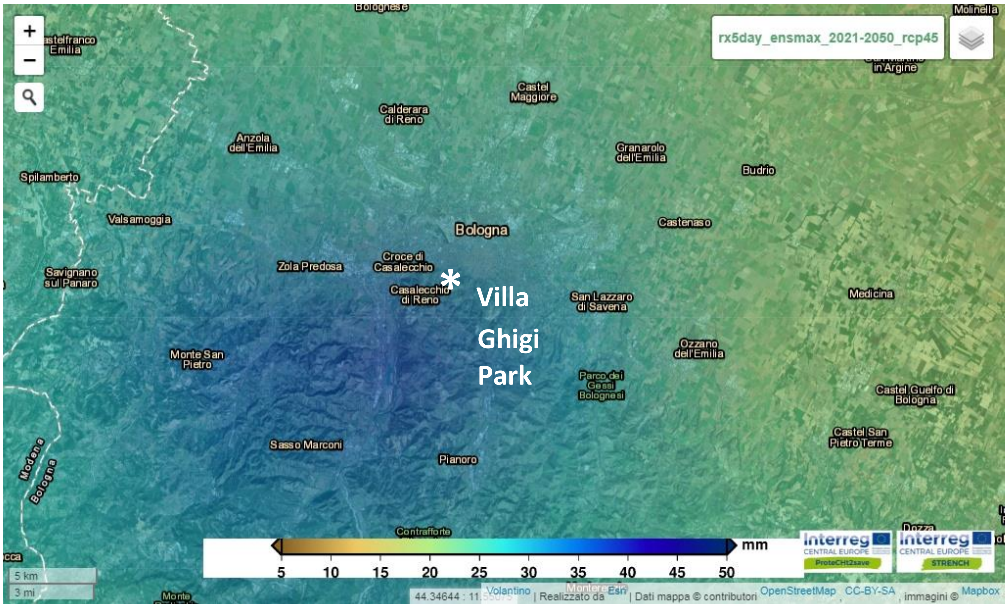
Map for the far future dataset on r95pTOT in the rcp85 scenario

Compared to available historical data, both scenarios show a significant increase in rainfall with increases in the order of at least 60-70 mm, reaching almost 120-130 mm in the future of RCP 8.5. These data can somehow confirm the hypothesis of an increased risk of flash foods episodes; a greater inflow of water to the ground can certainly increase surface erosion while the subsequent accumulation in the subsoil can also expose to the risk of landslides due to the reactivation of dormant landslides or the triggering of new landslides.

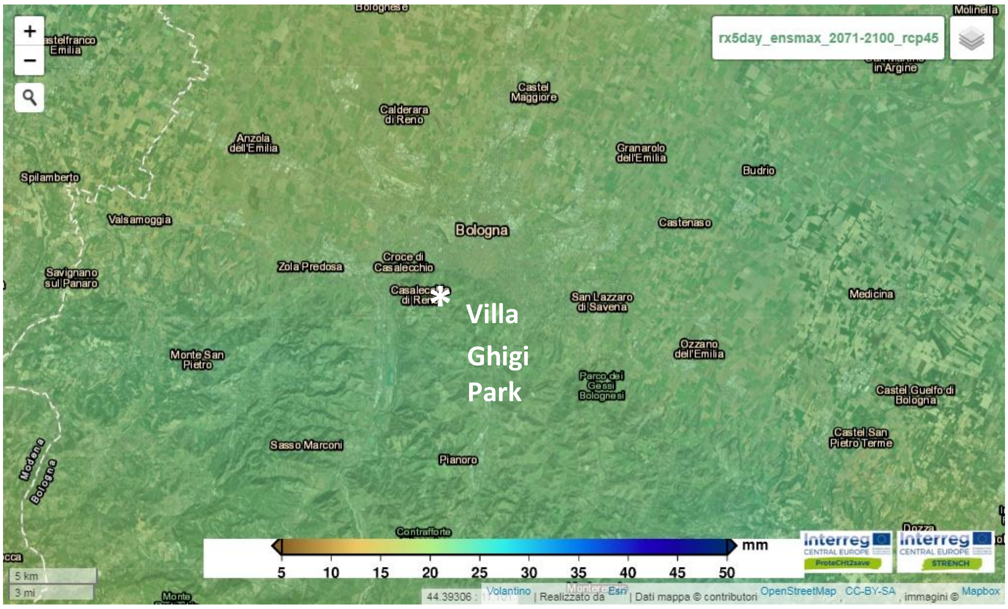
5.3 Highest 5-day precipitation amount



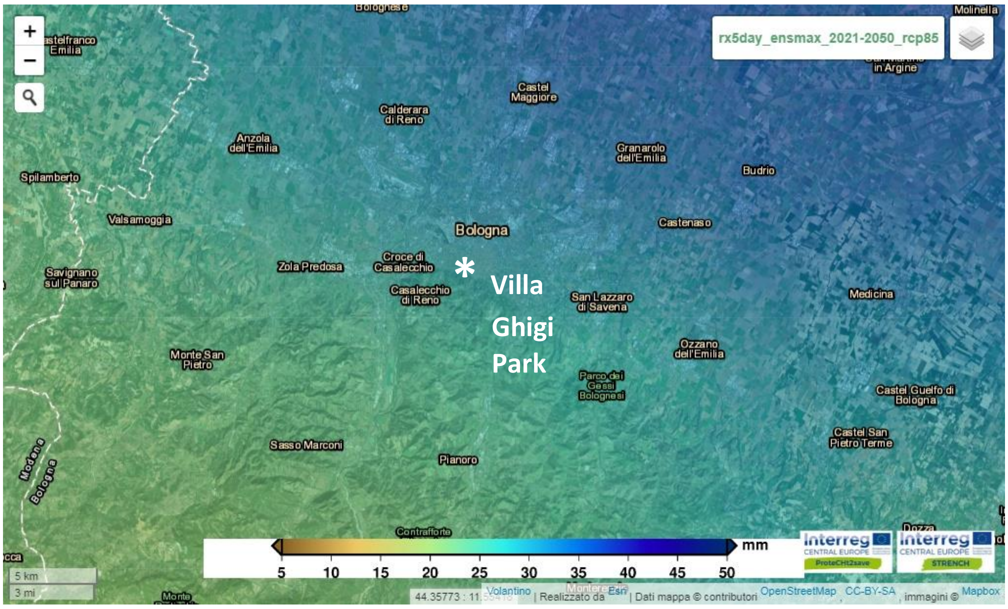
Map for the historic dataset on Rx5day



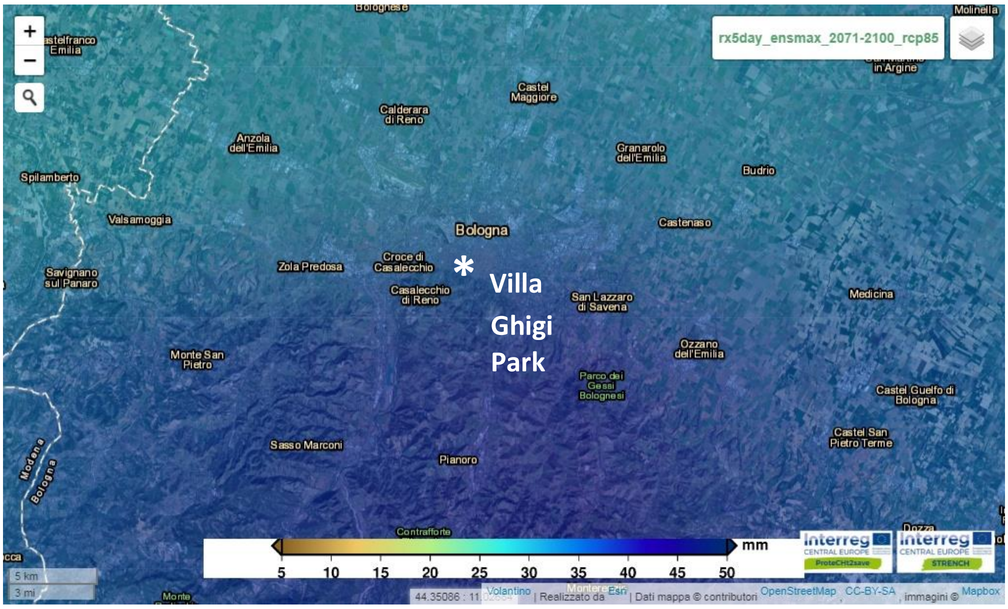
Map for the near future dataset on Rx5day in the rcp45 scenario



Map for the far future dataset on Rx5day in the rcp45 scenario



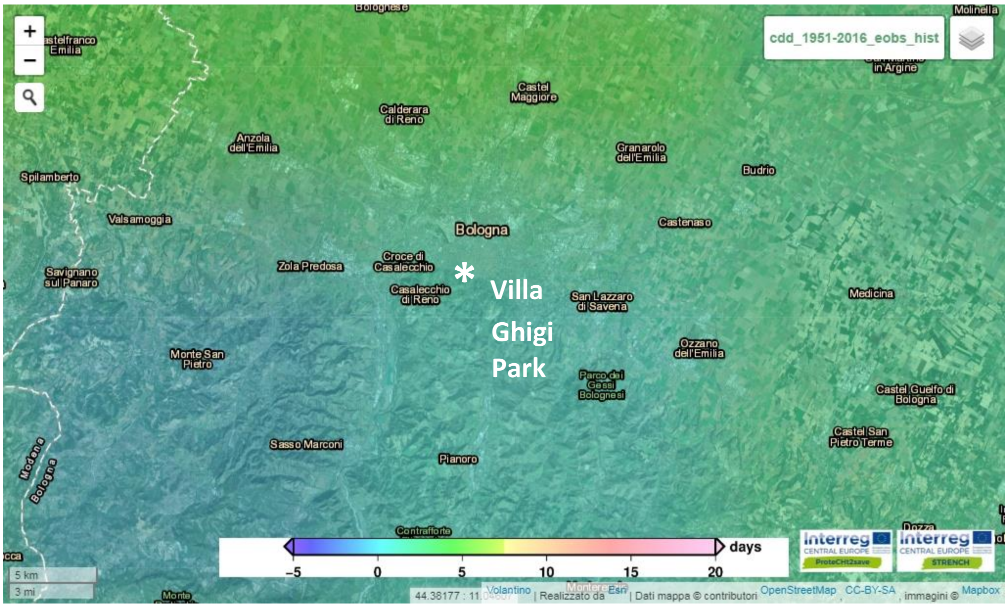
Map for the near future dataset on Rx5day in the rcp85 scenario



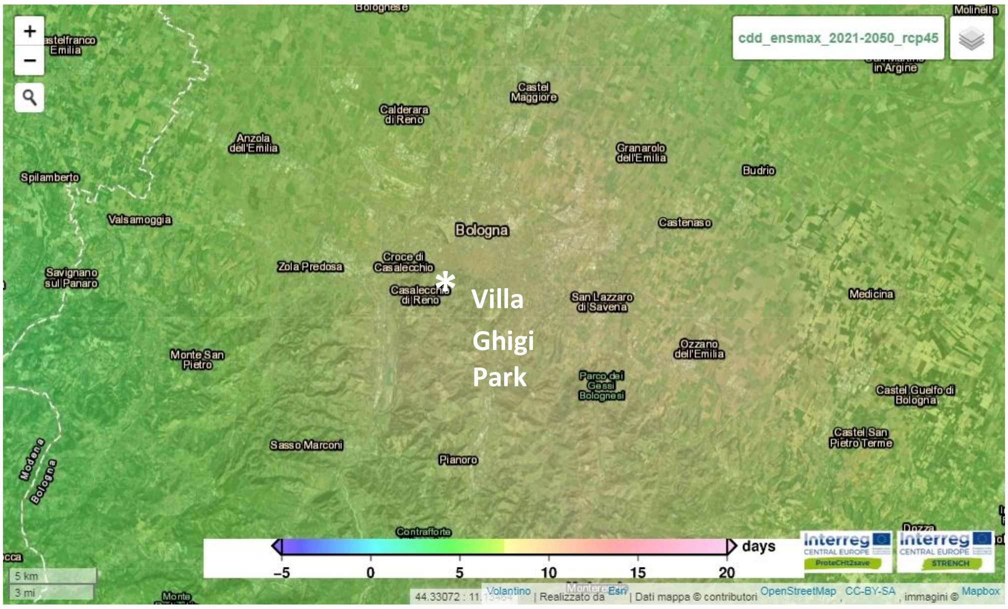
Map for the far future dataset on Rx5day in the rcp85 scenario

The figure for the maximum amount of precipitation in five days (Rx5day) is also increasing compared to the historical data available for both scenarios. Values vary between 20-30 mm increase up to about 30-40 mm. This index is particularly significant with regard to the risk of landslides in view of past events (graph on page 14), which have seen landslides trigger in the park precisely when there has been prolonged rainfall.

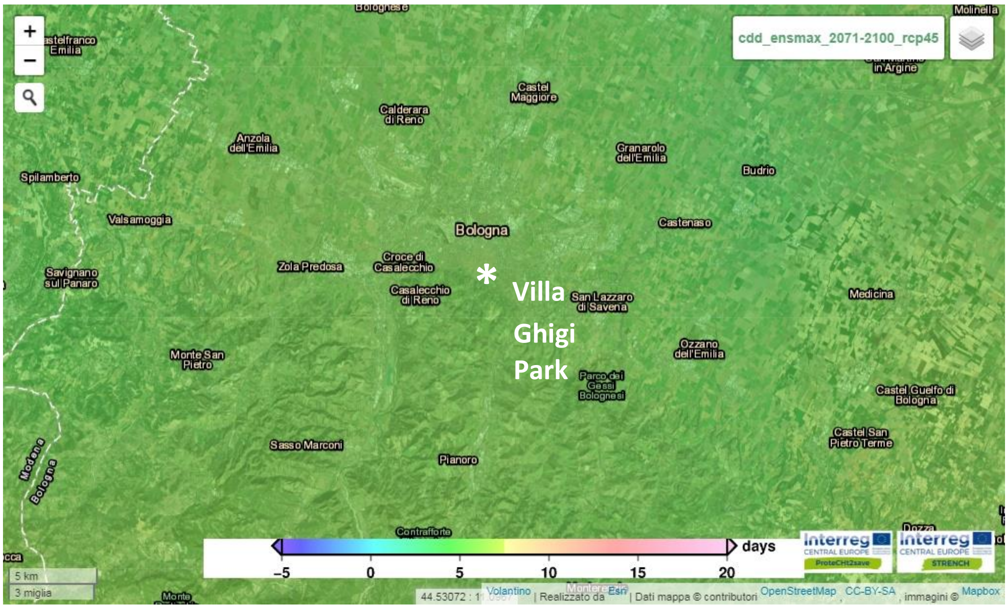
5.4 Maximum number of consecutive dry days



Map for the historic dataset on cdd

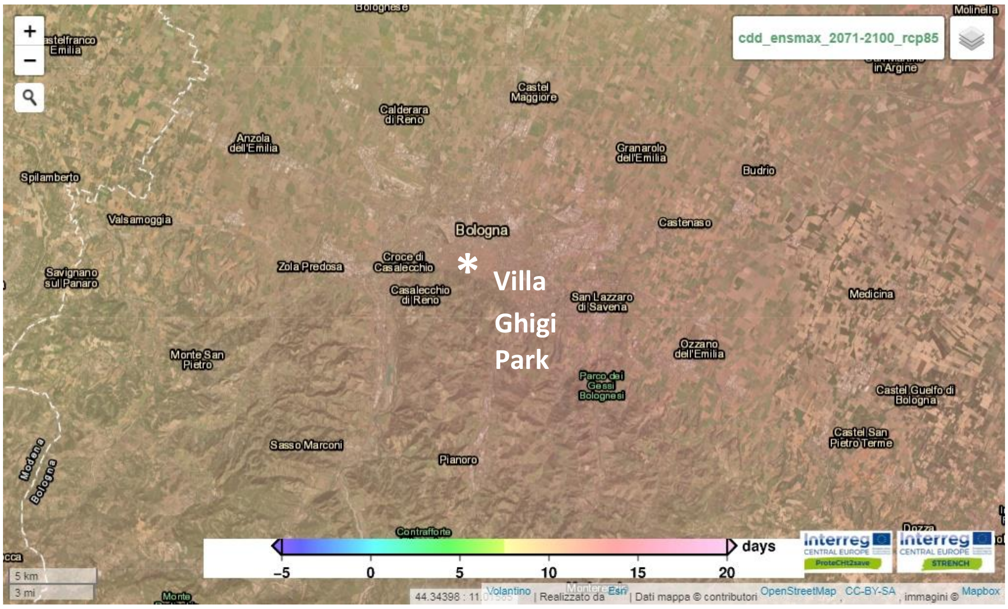


Map for the near future dataset on cdd in the rcp45 scenario



Map for the far future dataset on cdd in the rcp45 scenario

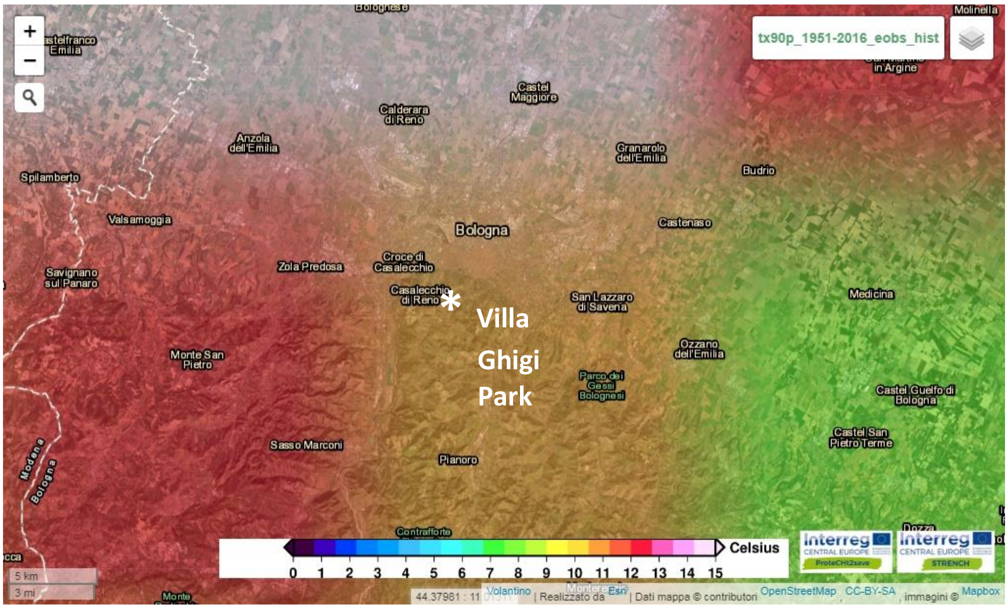
Map for the near future dataset on cdd in the rcp85 scenario



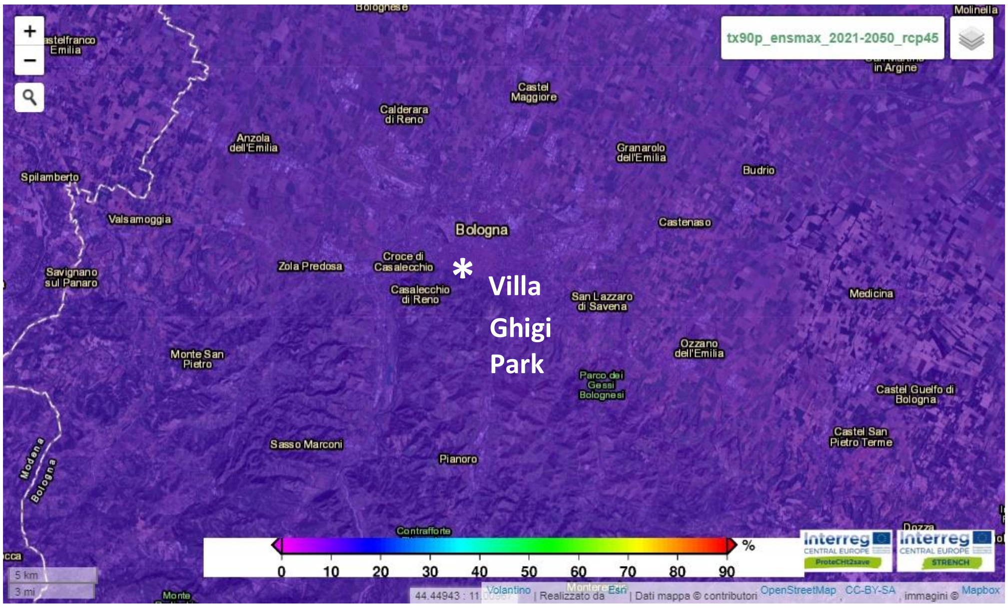
Map for the far future dataset on cdd in the rcp85 scenario

With regard to the Maximum number of consecutive dry days index, the forecast maps show a slight increase in the RCP 4.5 scenario in the near future, followed by a decrease in the far future, which can be justified by the stabilisation process considered for this scenario. In the RCP 8.5 scenario, after a slight increase in the near future (5-6) similar to the previous scenario, there is a marked increase in the far future, with a value that more than doubles (13-14). These projections are particularly worrying because of their possible repercussions on the tree heritage of a historical garden, especially on the oldest specimens or those affected by vegetative and phytosanitary problems.

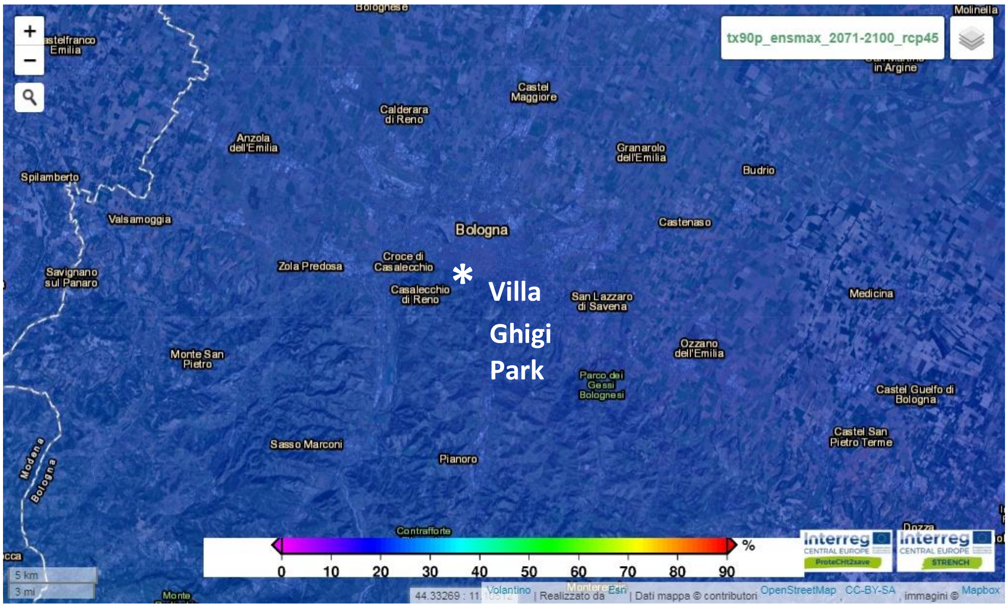
5.5 Extremely warm days



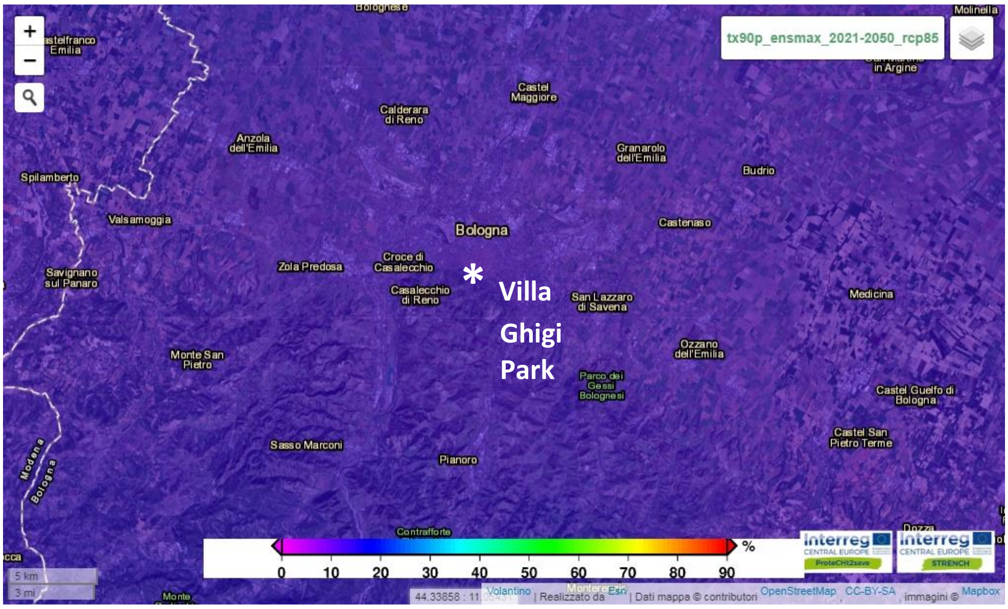
Map for the historic dataset on Tx90p



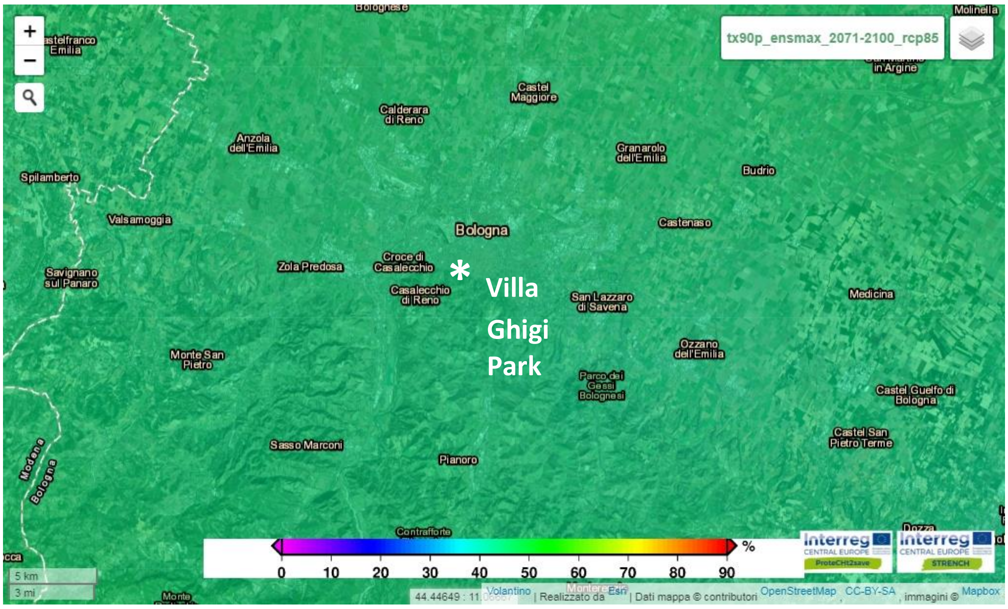
Map for the near future dataset on Tx90 in the rcp45 scenario



Map for the far future dataset on Tx90 in the rcp45 scenario



Map for the near future dataset on Tx90 in the rcp85 scenario



Map for the far future dataset on Tx90 in the rcp85 scenario

The forecast maps illustrating the future development of the number of extremely warm days show a decidedly upward trend for all scenarios and periods considered. In the RCP 4.5 scenario the percentage doubles (from 10 to 20), while in the RCP 8.5 scenario the increase is more than threefold, reaching a percentage figure of 50%. This index confirms the findings of the previous index and raises further concerns about the likelihood of damage to the plants, making it necessary to reflect on strategies to deal with this likely new condition and safeguard the park's tree heritage.

6. Conclusions and recommendations

The picture that seems to emerge in the future includes increases in all the indices investigated, although to different degrees depending on the index and the scenario considered. In particular, in the future of the RCP 8.5 scenario, the increases concerning both precipitation (R20mm, R95pTOT, R5xday) and drought (CDD, Tx90p) are very significant.

An increase in both precipitation-related indices and indices predicting longer dry periods and higher temperatures would seem to be in apparent contrast. One interpretation, which clearly needs much more detailed analysis and revision in the next period on the basis of the new climate data that will be collected, could be that of an increase in the concentration of phenomena, with alternating periods of drier weather and periods of heavy rainfall, in both cases with higher values than today's climate trend; in practice there is the possibility of more extreme phenomena, even if short-lived in terms of rainfall, in a framework of a trend towards a progressive increase in temperatures and in the duration of dry periods.

The projections show a clear climate change, some of which is probably already occurring if one looks at the historical data for the last forty years regarding the increase in tropical nights (TR) shown in the graph on page 15.

The ***WebGIS "Risk Mapping Tool for Cultural Heritage Protection***" application has a useful result in giving greater concreteness and highlighting trends on the subject of climate change that have been under discussion for some time. The use of maps offers a more immediate reading of possible future developments than other forms of data rendering (e.g., simple data or tables). WGT and climate modelling maps can be used to better guide the choice of strategies to address site-specific vulnerabilities. The scenarios derived from the maps allow the optimisation of resources to prevent risks and deal with emergencies and plan interventions according to actual priorities.

In the case of Villa Ghigi Park, the interpretation of the projections suggests strengthening the management strategies for all hazard types identified by adopting a series of measures both of a general nature (*general preparedness activity*) and specific to individual vulnerabilities, taking into account the gaps that exist today. In the light of the data and climate projections that emerged from the WGT tool and the likely increase in extreme weather episodes related to thunderstorms associated with windstorms, the Tree Management Plan, from a risk management perspective, will have to devote more energy and resources in the future to preserve the park's tree heritage and at the same time ensure the safety of places and visitors.

General preparedness activity

- Strengthen the network of contacts with local safety authorities (Civil Protection, Fire Fighters, Municipal Police, etc.) on the basis of the Municipal Civil Protection Plan that the city of Bologna has and systematically update the emergency numbers to activate the intervention procedures in case of need.
- Within the framework of the historical garden management plan, an indispensable basic tool for the correct management of the green area, strengthen the emergency plan, define pre- and post-event interventions to respond to the increased frequency and intensity of extreme weather events, designate a contact person to coordinate the first 24 hours or until the end of the event.
- Regularly review available sites producing weather forecasts for weather warnings.

- Strengthen the communication tools (website, social channels, information boards at the park entrances) with the users of the historic garden also for weather warnings (in accordance with the Municipal Civil Protection Plan of Bologna) and for further updates on any necessary post-event interventions.
- Constant monitoring of the green area with particular reference to the main vulnerabilities identified and reported in special zoning maps (such as those on page 11) attached to the management plan.
- Retain direct management of the historic garden and the presence of an operational office on site to facilitate constant monitoring of the area and coordinate the work to be carried out by qualified operational staff.
- Seeking more funding that could solve known problems that could recur in even greater severity during extreme events.

Heavy rain and flash floods

- Monitoring the condition of the surface water network and of the network linked to the road network (dirt roads, "cavedagne" and paths); routine maintenance work to clean ditches, drainage ditches and hydraulic structures (manholes, tanks, grates, pipes, "breaker" structures on the roadway, points of entry into the urban sewage system, etc.).
- Improvement of the surface water network. Construction of drains, hydraulic structures and other interventions also based on natural solutions (NBS-Nature-based solutions) to improve the reception of surface water and its passage into the city's underground network by adapting the new structures to the future hydraulic flows foreseen by the projections emerging from the climate modelling maps provided by the WGT.
- In the pre-event, additional cleaning of ditches, drains and hydraulic structures should be planned in anticipation of intense and/or prolonged rainfall. Interdiction of the most vulnerable areas.
- In the post event, carry out punctual inspections starting from the areas identified as most vulnerable. Interdiction of flooded areas, restoration of the efficiency of the hydrographic network and of the network of dirt roads and paths, cleaning of the riverbeds from vegetal materials and sediments carried by the water.

Landslides

- Strengthen the specialist monitoring of the site (geological, hydrogeological, geotechnical investigations) with particular attention to the evaluation of the conditions of slope stability and the dynamics of landslides.
- Strengthening the monitoring of the surface water network conditions and its integration where necessary through new drainage systems and other interventions to improve the reception of surface water in order to counteract erosion or instability phenomena by favouring naturalistic engineering techniques.
- Creation of new plantings with species with a high consolidating capacity in order to intercept rainwater and reduce the risk of slope instability.

Windstorms and snow

- Obtain information on prevailing winds, which is not currently available, on the basis of the data available for the area, past events that have affected the park and promote new specific research.
- Continue and intensify the current monitoring programme, included in the annual Villa Ghigi Park Management Plan, regarding the condition of the tree heritage, with particular regard to the sectors of the park that are most vulnerable to falling trees identified in the specific map and to the trees that are potentially more problematic included in the park's tree census (isolated specimens, with static and structural problems, senescent and/or monumental trees).
- Continue and intensify the annual programme of stability analyses (Visual Tree Assessment) and cultivation interventions (pruning, anchoring, static and dynamic consolidation) on the potentially most problematic trees included in the park's tree census.
- Use wind-resistant tree species for new plantings, especially in the most vulnerable areas.
- In the pre-event, provide for a plan for the temporary prohibition of stretches of roads considered most sensitive and vulnerable to the risk of branch breakage or falling trees.
- Improve in the post event, after the precise verification of the state of the elements (trees and buildings) of greatest vulnerability, the procedure for the execution of extraordinary interventions to make the park safe (starting from the temporary prohibition of areas with trees with dangerous branches and the timely removal of any crashed trees).

Long term increase of temperature and drought

- For new plantings in the historic garden, give preference to hardy tree and shrub species with low water requirements, which are more resistant to prolonged drought, heat waves and pathogenic organisms. When choosing species, consider species that are not only suitable for the current local climate, but also species (e.g., Mediterranean type) that are compatible with future climate change scenarios as predicted by the WGT forecast maps.
- Always apply good agronomic and arboriculture practices, including correct tree and shrub planting techniques using high water retention polymers, use of good quality nursery material, use of mulch, protection of trunks from excessive sunlight using shelters.
- Program cycles of emergency irrigation, especially for newly planted trees and shrubs, to ensure their rooting and development, and use low water consumption systems (drip irrigation) activated according to climatic conditions and actual needs. Intervene with additional emergency irrigation in the event of weather warnings regarding prolonged periods of drought.
- The tree monitoring plan should include an additional check on the vegetative and phytosanitary state to be carried out at the end of the summer, to be activated in the most critical years, with particular attention to veteran trees whose condition can be significantly worsened by water stress.

EVALUATION AND ASSESSMENT ZICHY MANSION

Lake Balation Region / Hungary December 2021

1. Foreword

This is a risk evaluation of Zichy Mansion which could be considered typical for the Lake Balaton area in the following terms:

- It is a cultural heritage site in medium condition (not at all critical, overlooked or completely abandoned, but the maintenance and protection could be improved in certain areas).
- It has the same typical weather related risks like many Lake Balaton areas. These are mainly high wind speeds, high amount of precipitation and associated flash floods, soil erosion and wildfires.

2. Evaluated site: Zichy Mansion

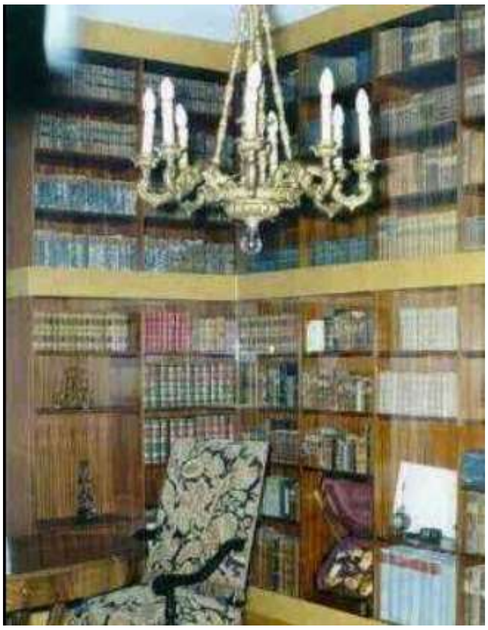
We intend to demonstrate in this evaluation how we intend to seamlessly integrate the WebGIS tool developed in the framework of the STRENCH project into the Hungarian disaster management practices concerning the protection of the greater Lake Balaton area. (Cultural heritage protection here being a part of disaster management in the sense of preventing and/or mitigating the effects of weather related incidents on both natural and human built environment.)

2.1. The Mansion and the surrounding area

The Zichy Mansion evaluated in this document is located in Hungary, in the greater Balaton region (in the village of Zala specifically). Famous painter Mihály Zichy was born in this mansion in 1827; the building itself today is operating as a museum which was founded in 1927, on the occasion of the centenary of the painter's birth by his granddaughter, Mária Alexandra Zichy and her husband István Csicsery-Rónay.

The exhibition was opened in 1979, then renovated and rearranged in 1992. The furniture in the exhibition is original and has been preserved by the Zichy family. The material of the exhibition can be viewed in eight halls, partly presenting the artist's paintings, drawings, as well as the objects, documents and collection of his life. Most of the 4,000-volume family library consists of German and Latin books.

The building is surrounded by a park broken into two segments, as can be seen in the picture below (the park segments are marked with red, the red dot represents the building itself). The park was planted around 1820. The park is a nature reserve with significant cultural and historical values. The 12-hectare park is divided by the village traffic road and the Zala stream. The mansion is surrounded by spruce trees in the upper park, and the lower park is surrounded by a row of horse chestnuts (Aesculus hippocastanum). There are nine protected tree species and 16 protected bird species in the park, which is under landscape protection, so *it is part of the cultural landscape at Lake Balaton.*



2.2. Zichy Mansion and park: the features

The Zichy Mansion itself is on stable slopes, with low inclination (less than 15 degrees), which makes it somewhat susceptible to heavy rainfall, flash floods.

The soil around the building and on the park area is fine-grained soil (high silt and loess content). Note that land segments in agricultural use surround the park itself (see the Google Map satellite view cutout below, the Mansion area marked red), so the potential heavy rainfall and/or flash floods have the effect of moving the loose soil into the lower part of the park itself.

The higher part of the park houses some 130 year trees but has little to no ground covering foliage. Because of this heavy rainfall and/or flash floods also have the ability to moderately or even heavily erode the ground itself, which weakens the grip of the tree roots in the ground and makes the trees themselves susceptible to heavy winds (which are prevalent in the area, see later).

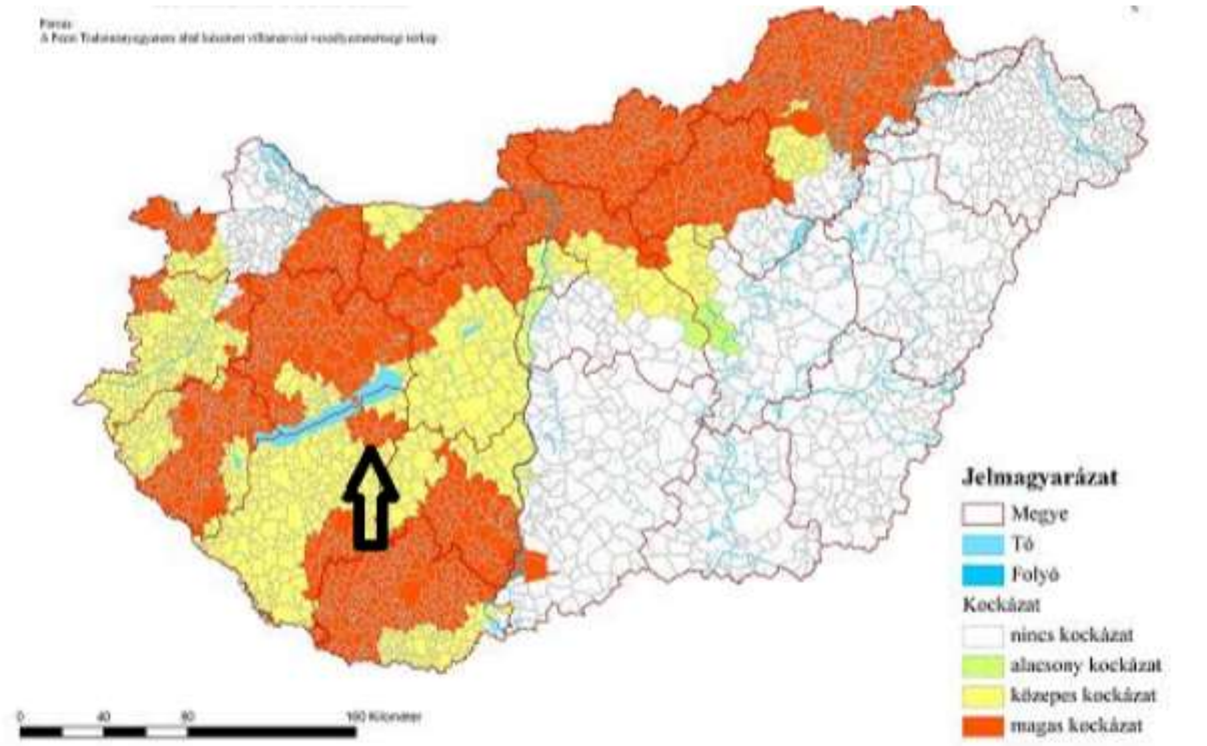
The building itself is in touristic use and in fair state of conservation, maintenance is done periodically, The main problem here is that it is heavily surrounded by trees hence the susceptibility to damage done by falling trees, branches etc. But beyond a certain speed heavy winds could also damage the roof structure itself, opening the building to rain damages.

3. Weather related risks in the Balaton region and around the mansion

Although it is beyond the scope of this document to evaluate the whole of the Lake Balaton area, we have to consider some characteristics of the area in which the Zichy Mansion is located in.

3.1. Flash flood (rainfall)

According to the disaster management evaluation of Hungary, a serious portion of Lake Balaton area is categorised as high flash flood risk. Zichy Mansion (the approximate location on the map below is shown with a black arrow) is located on the only portion of the South-Balaton area with high flash flood risk.

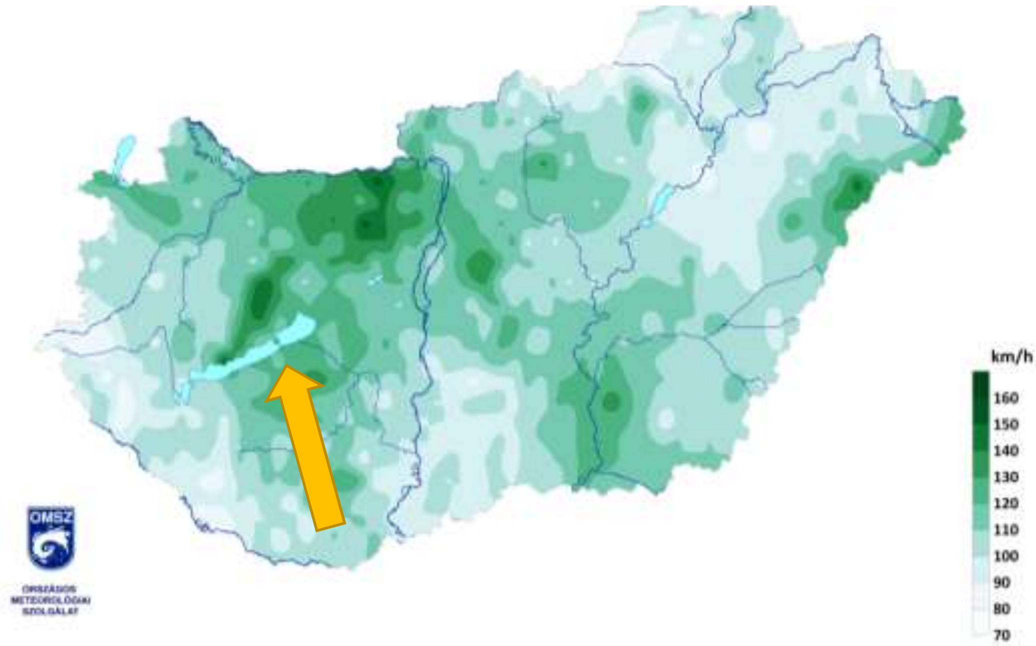


Flash flood risk map of Hungary. Legend: red = high risk, yellow = medium risk, green = low risk, white = no risk.

The problem with flash flood in connection with the park and the mansion building itself is that a) it could partially or wholly fill the upper area with sediment, b) the resulting erosion could damage the 130 year trees and to some extent even the building itself, c) it could damage roads in the area impeding the touristic use of the building/park.

3.2. Heavy winds (windspeed)

Heavy and damaging winds are a decade long problem in the greater Lake Balaton area. The effect of wind on the lake itself is especially interesting: strong wind gusts tend to „push" the water from one end of the lake from another. This so called „swing" could result in an increase/decrease of 10-20 cm water level (depending on the point of measure).



Maximum wind speeds in Hungary in a 30 year period (see legend in the bottom right corner for values). Note that the Zichy Mansion (marked with yellow arrow) is located in an area plagued by frequent high wind speeds (100–120 km/h winds are fairly frequent and pose a danger to infrastructure).

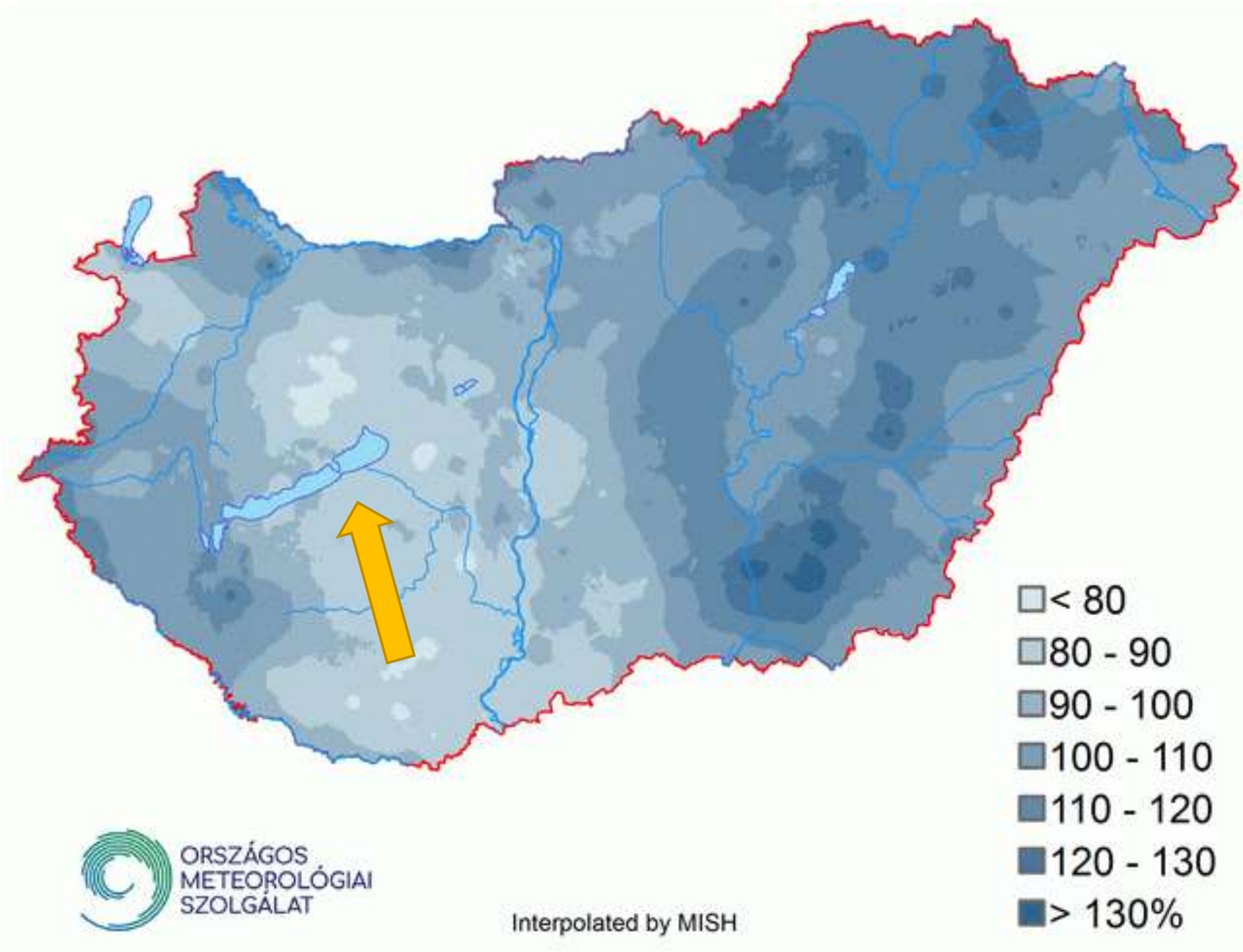
The Zichy site is located in an area with wind 90+ km/h wind speeds. The main problem is the constantly growing rate at which these wind speeds are happening. According to Hungarian meteorological research of the area, the following statements are true for the Lake Balaton area:

- In the first decade of the 21st century, there were **44 days** on which **90+ km/h** wind speeds were measured.
- In 2010–2020, there were **77 days** on which **90+ km/h** wind speeds were measured.
- In the first decade of the 21st century, there were **8 day**s on which **110+ km/h** wind speeds were measured.
- In 2010–2020, there were **27 days** on which **110+ km/h** wind speeds were measured.

The days with 90+ km/h wind speeds almost doubled, the days with 110+ km/h wind speeds tripled in the last 20 years. Strong wind gusts alone are enough of a threat but they are almost always coupled with heavy rainfall and storm activity, which increases the likelihood of flash floods, fallen trees, damages to infrastructure etc.

3.3. Heavy rainfall

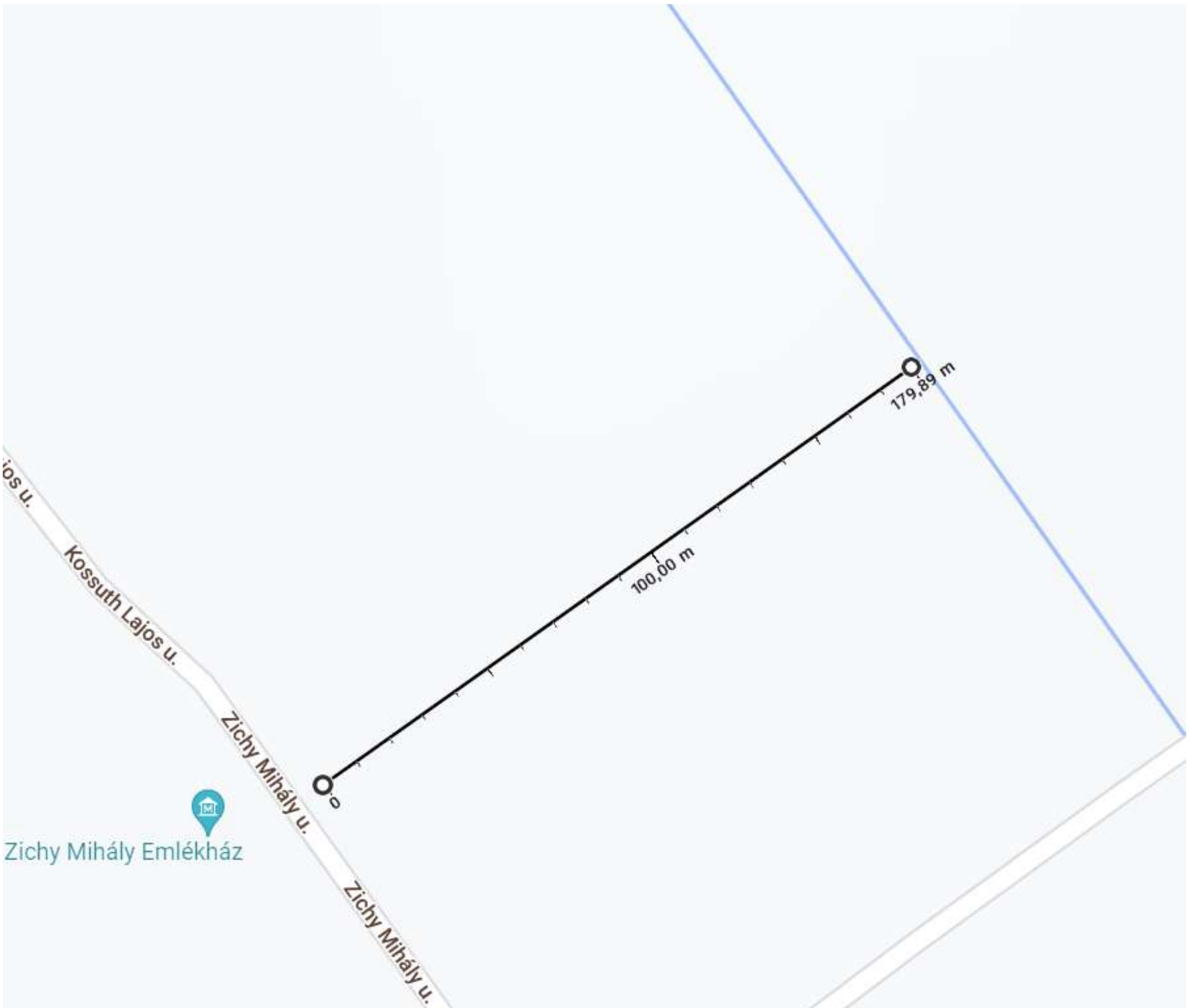
According to the Hungarian meteorological datasets, the yearly average rainfall was the same or less in the whole of Lake Balaton region. As can be clearly seen in the map below (the approximate location of the mansion is marked with a yellow arrow), the overall yearly precipitation decreased in the lower south-east Balaton area.



Precipitation amount for 2020 as percentage of yearly average for the 1981-2010 period (based on homogenised, interpolated data)

This lowers the risk posed by rain but in fact doesn't necessarily decrease the risk posed by flash floods.

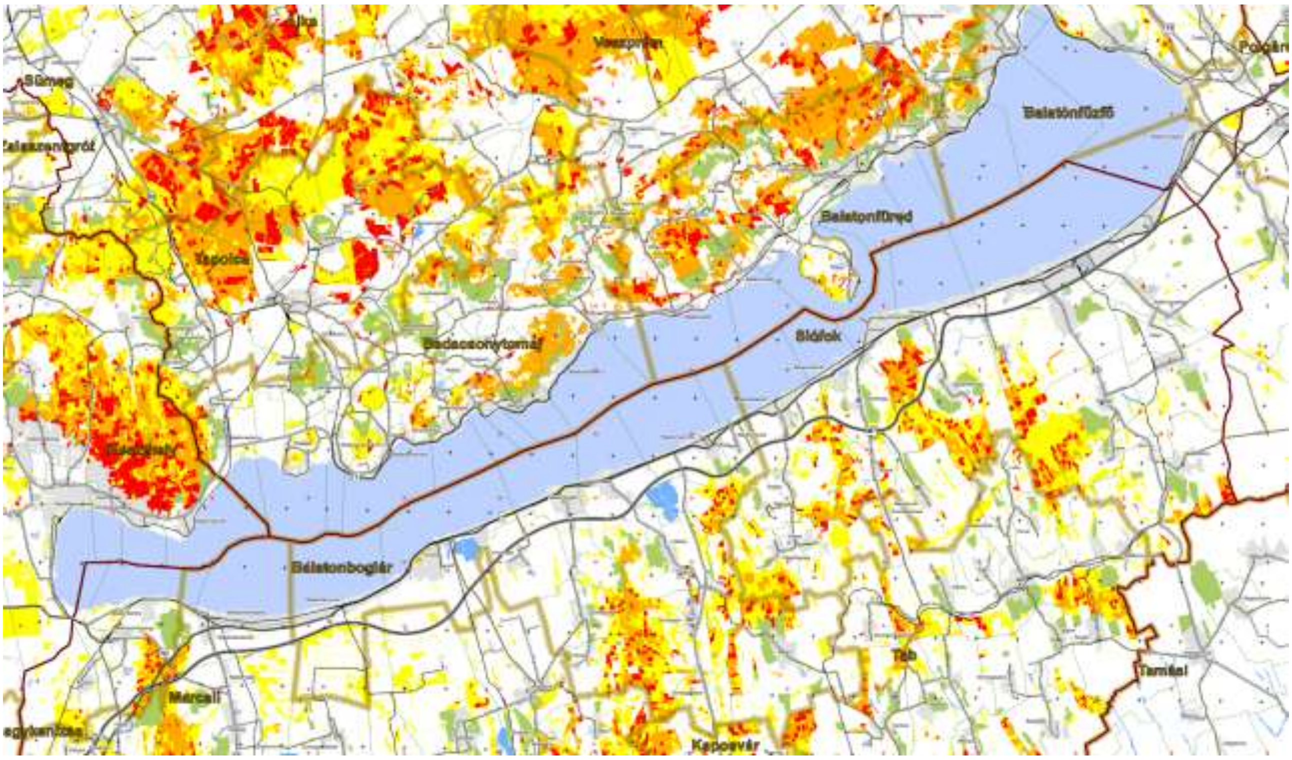
Additionally, there is a creek running only 180 meters from the Zichy Mansion (see picture below). This creek, being a tributary to a larger creek called Kis-Koppány (which was already overflooded in the past, eg. in 2014), could theoretically spill its creek bed and join in the forming of a larger flash flood, filling the upper part of the mansion area with debris.



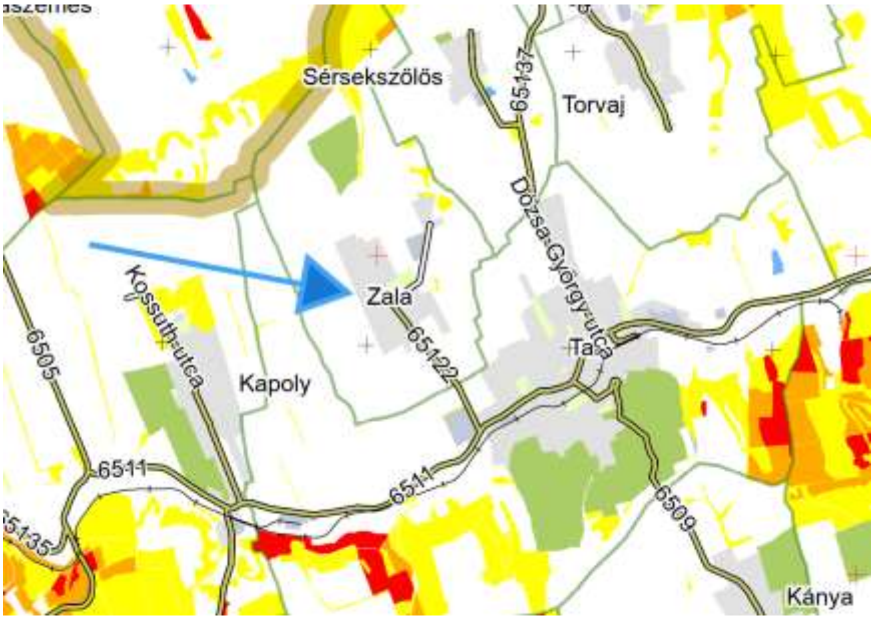
A Google Map cutout and distance measurement between the Zichy Mansion (on the picture marked with a blue icon and the title „Zichy Mihály Emlékház" and the Zala Creek (blue line). The creek itself is running parallel with the road (marked with the title „Zichy Mihály u."). When overflowing, the water and the debris could cross the road itself to the upper part of the mansion.

3.4. Fire risk

There are several high fire risk areas in the Lake Balaton region, particularly the northern territories.



Fire risk map of the Lake Balaton area. Legend: red = forestal areas with high fire risk, orange = forestal areas with moderate fire risk, yellow = forestal areas with no fire risk.

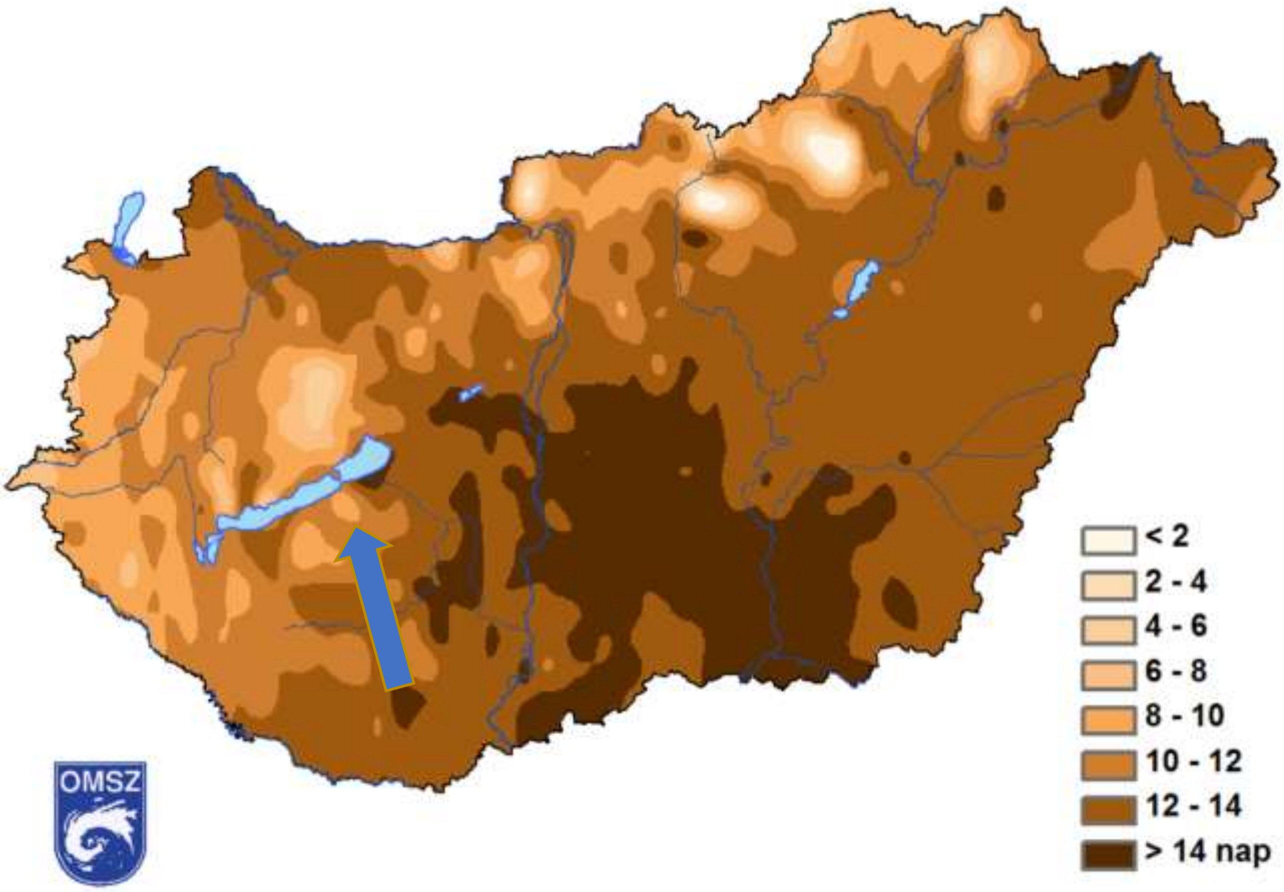


Cutout from the map above, Zichy Mansion marked with a blue arrow.

Although the mansion/park itself is not marked as a forest fire risk (mainly because the park is not large enough to be considered a forest), there are some high fire risk areas in the vicinity. (Note especially the red areas to the south and south-east in the first map. The second map shows a satellite image of roughly the same area, with one high fire risk area marked with red arrow.) In theory, these are far enough not to pose a direct threat, but if you consider the possibility of the fire accelerating effects of strong wind gusts, they are a risk to be calculated with.

Another (although lesser) problem is that in dry periods the surrounding agricultural land strips pose a threat. The use of agricultural machinery (tractors, harvesters etc.) is always a fire risk given the mix of overheated metal and dry harvested goods.

It is worth considering the temperature charasteristics of the area. The map below (the approximate location of the mansion is marked with a blue arrow) indicates how the days with a heatwave per year changed in Hungary in a 36-year period. The area surrounding the park suffered a moderate to heavy (8-12 days per year) increase. The problem is clear: more heatwaves and thus longer hot and dry periods with higher fire risk.

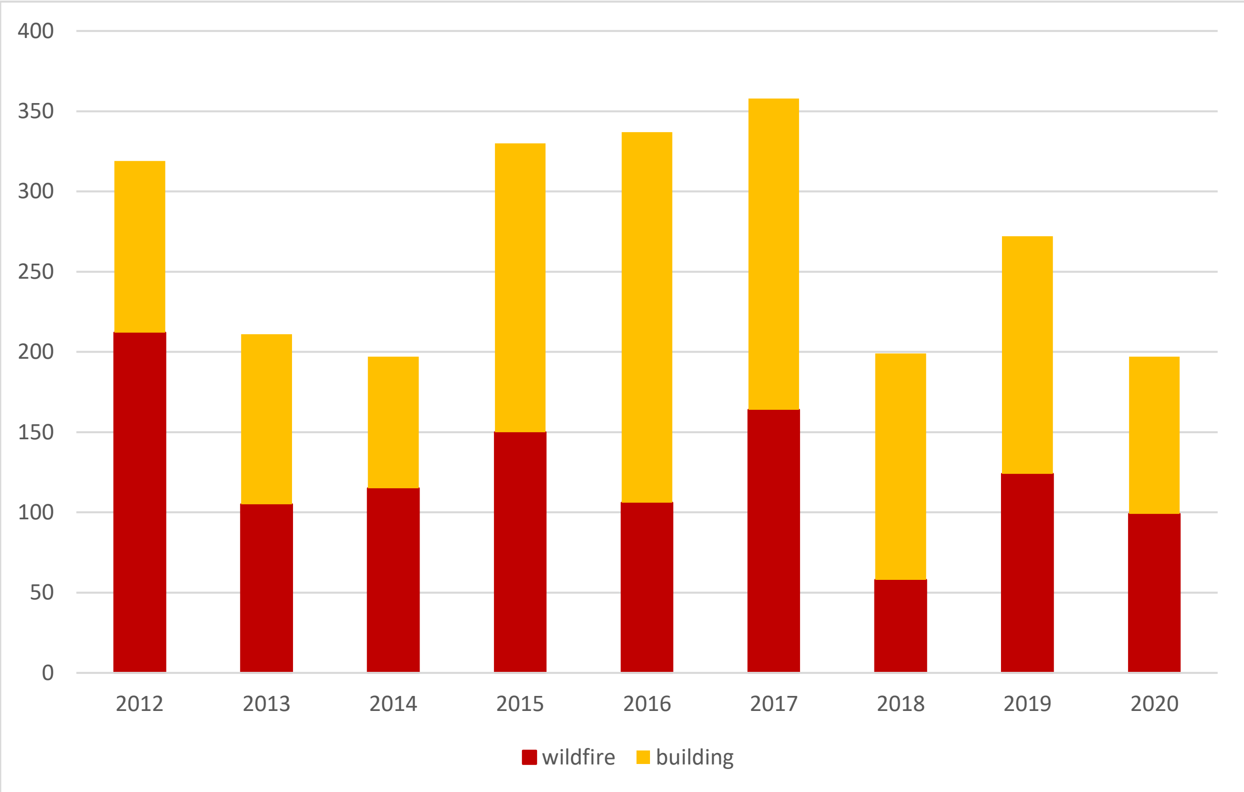


Days with a heatwave (daily avg. temp. 25+ °C) in a 36 years period in Hungary.

4. Risk matrix from a disaster management perspective

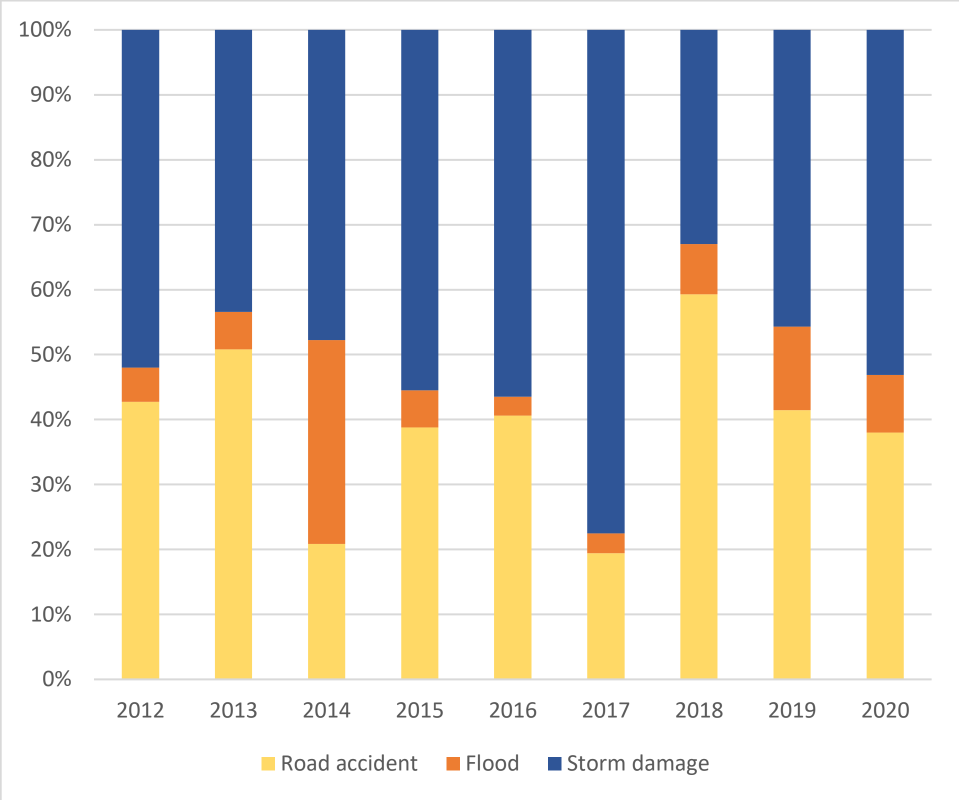
Considering all of the above it should be possible to establish a risk matrix for the mansion and the surrounding area, focusing on the disaster management aspects.

As to some disaster management background, see the diagrams below.



Fires in the larger South-Balaton area where the mansion itself is located. „Wildfire" means every incident where firefighters have to extinguish a fire affecting a natural environment (mainly forest, but also areas with foliage, agricultural areas with crop etc.). „Building" means every incident where firefighters have to extinguish a fire affecting a built environment (any type of building, infrastructure).

For the sake of this document the fires were divided into two categories. Wildfires (aside from a few years) are less common in this area, but overall they give a significant portion of firefighter's work.



The proportion of disaster management damage types in the larger South-Balaton area where the mansion itself is located. A„road accident" means an incident that involves some form of moving vehicle (eg. two cars crashing into each other, a car crashing in a tree etc.). A „flood" means an incident where water gets on/into built environment not meant to withstand large amounts of water (eg. basement, house) or where it impedes the normal use of that environment (eg. roads, railroads). „Storm damage" means every incident where firefighters have to mitigate damages done by the storm to natural and/or built environment which impede the normal use of that environment (eg. trees fallen to roads or seriously damaged roofs) or pose a threat to people (eg. loose bricks).

As can be seen from the diagram above, there are a lot of storm related damages in the southern Lake Balaton area. As we have already established, the Balaton region in general is plagued by high speed winds and heavy storms which of course take their toll on infrastructure. From the viewpoint of this document alone, road accidents are less relevant (although we should mention that certain trucks carrying hazardous material are a threat to the landscape itself). And finally, flood presents a small but significant portion of firefighters' work.

The disaster management risk matrix is made up of a likelihood and a threat level, which together give each weather related risk a threat index. This index is viewed in connection with the evaluation of Zichy Mansion and is only used in this document.

	minor threat (1)	moderate threat (2)	serious threat (3)	very serious threat (4)
low chance (A)	road accident			earthquake
moderate chance (B)			wildfire heavy rainfall	flash flood erosion
good chance (C)		heatwave drought		high wind speeds

Evaluation in case of Zichy Mansion:

- Category C4: high wind speeds
- Category B4: flash flood and erosion
- Category B3: wildfire and heavy rainfall

Other risks are either too low a chance to occur or else not serious enough to consider in the scope of this evaluation.

The vulnerability value for Zichy Mansion – calculated in the framework of the STRENCH project earlier – is 0.38.

The more prominent shortcomings in the vulnerability evaluation were:

- stocky constructions made of materials prone to degradation or impact damage
- large openings at ground floor
- fine-grained soil
- vegetation prone to serious damage
- financial recovery funds available but insufficient

To sum up the findings of this document so far, the criticalities in this area include:

- **High wind speeds.** Considered in connection with either heavy rainfall or wildfire. Although an uncontained wildfire is not a very high risk when looking at the mansion or the surrounding trees itself, there is a slight chance that a fire further away could „skip" some distances on a very windy day. Moreover, when coupled with heavy rainfall, wind speeds in the 120+ km/h range may be able to fall some of the 130-year old trees because of the soil getting too soft with rain and the trees losing their grip.
- **Erosion**. There are several spots in the Lake Balaton area in which erosion is a huge issue (eg. loess high cliffs near the shoreline or several other flat areas further away). The problem around Zichy Mansion is not as pronounced but nonetheless the silt-like soil is prone to small shifts and movements when exposed to large amount of sustained raining. This could affect the park and in very serious cases the building itself.
- **Heavy rainfall**. Interestingly, in itself, rain is not necessarily a prominent risk (but when coupled with wind it is, see above). The surface shape (mild slopes, agricultural areas

etc.) means however that if flash floods form, there could be medium to serious damages.

- **Wildfire**. Although only a moderate risk here, fires nonetheless form a caveat worth preparing for, maybe assessing future dry periods and calculating them into disaster management plans as well.

5. Evaluated site: Zichy Mansion

WebGIS indices used:

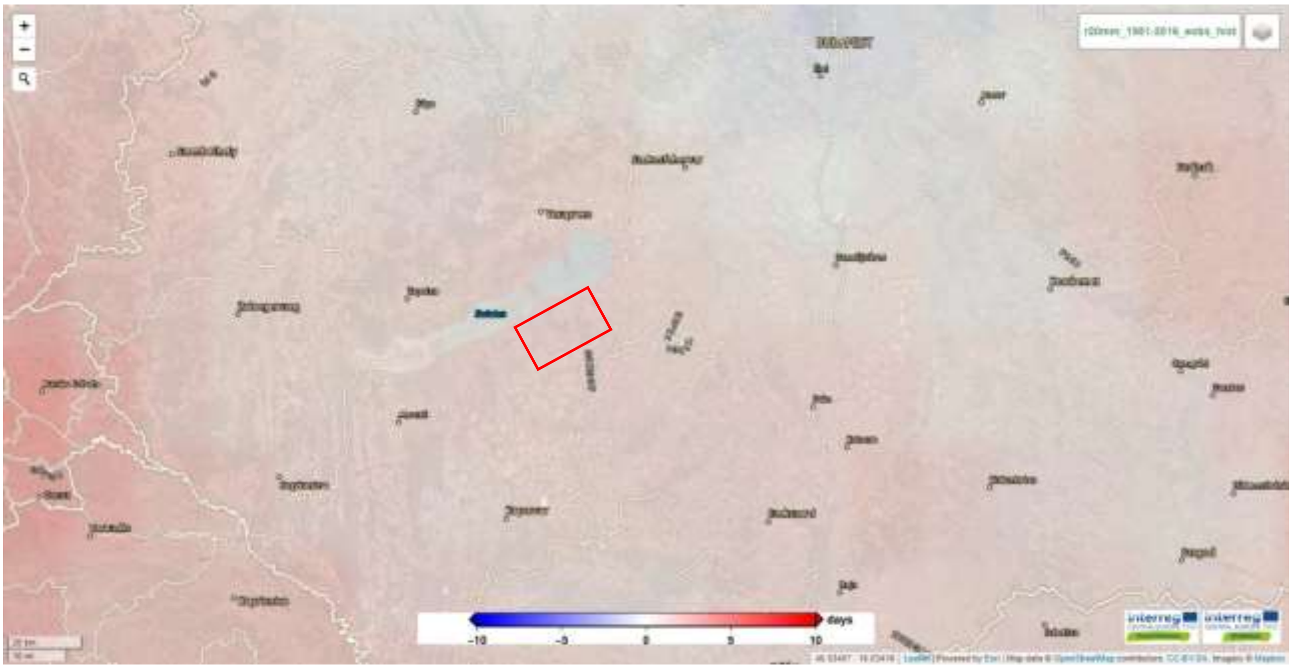
Index	**Definition / description**	**Reason**
R20mm	Very heavy precipitation days Number of days in a year with precipitation larger or equal 20 mm/day.	slow erosion, possible flash floods
R95pTOT	Precipitation due to extremely wet days The total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days. A wet day is defined as having daily precipitation ≥ 1 mm/day. A threshold based on the 95th percentile selects only 5% of the most extreme wet days over a 30 year-long reference period.	slow erosion, possible flash floods
Rx5day	Highest 5-day precipitation amount Yearly maximum of cumulated precipitation over consecutive 5 day periods.	possibility of heavy erosion in the area, possibility of flash floods
CDD	Maximum number of consecutive dry days Maximum length of a dry spell in a year, that is the maximum number in a year of consecutive dry days with daily precipitation smaller than 1 mm/day.	higher risk of wildfires

Tx90p	Extremely warm days Percentage of days in a year when daily maximum temperature is greater than the 90th percentile. A threshold based on the 90th percentile selects only 10% of the warmest days over a 30 year-long reference period.	possible vegetation damage

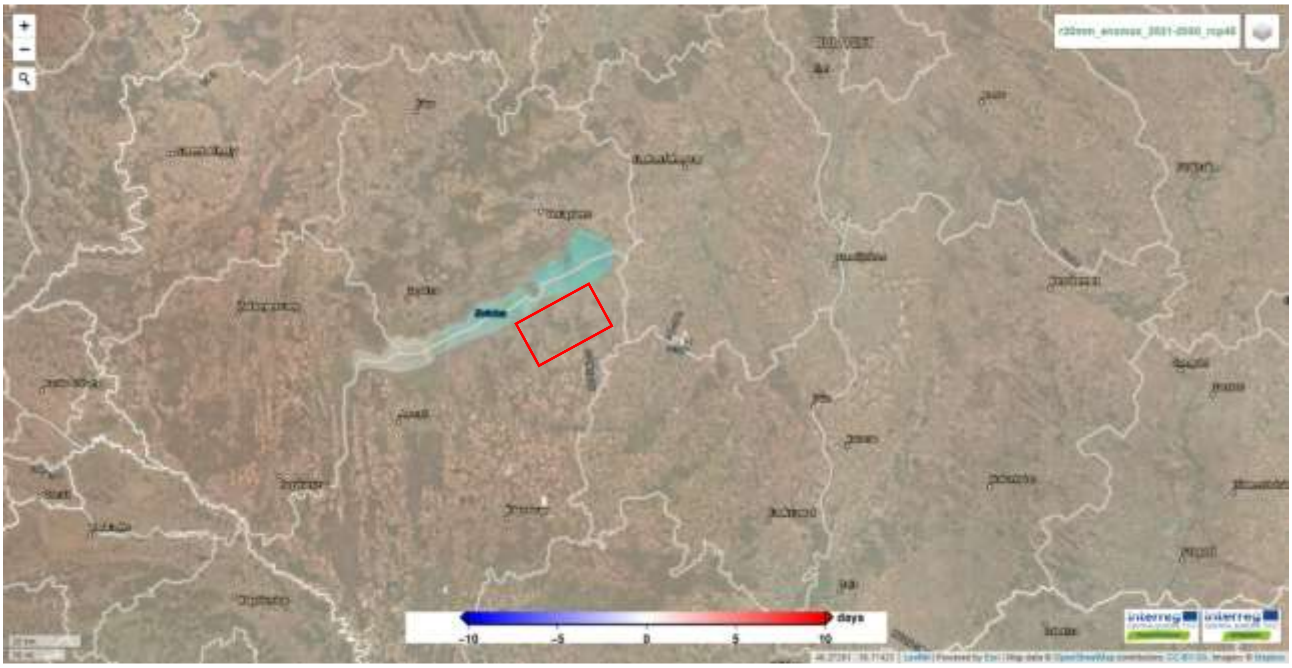
The approach was to collect maps of the area from the WebGIS application with past (1951–2016), near future (2021–2050) and far future (2071–2100) projections (Model ensemble statistics / Maximum / RCP 4.5). We found that the robust visualization tool of the WebGIS application is better suited for comparison (not to mention in case of decision preparation materials when the readers are laymen) than raw datasets. We divided this section in 5 segments, each dedicated to a weather index detailed above, and containing three maps with additional information and interpretation.

In the case of every map, an approximate smaller area was marked with a red/black (depending of the visibility) rectangle for comparison only. The idea was to get a general idea for the southern Balaton-area as the weather related phenomena and its consequences are not always constrained.

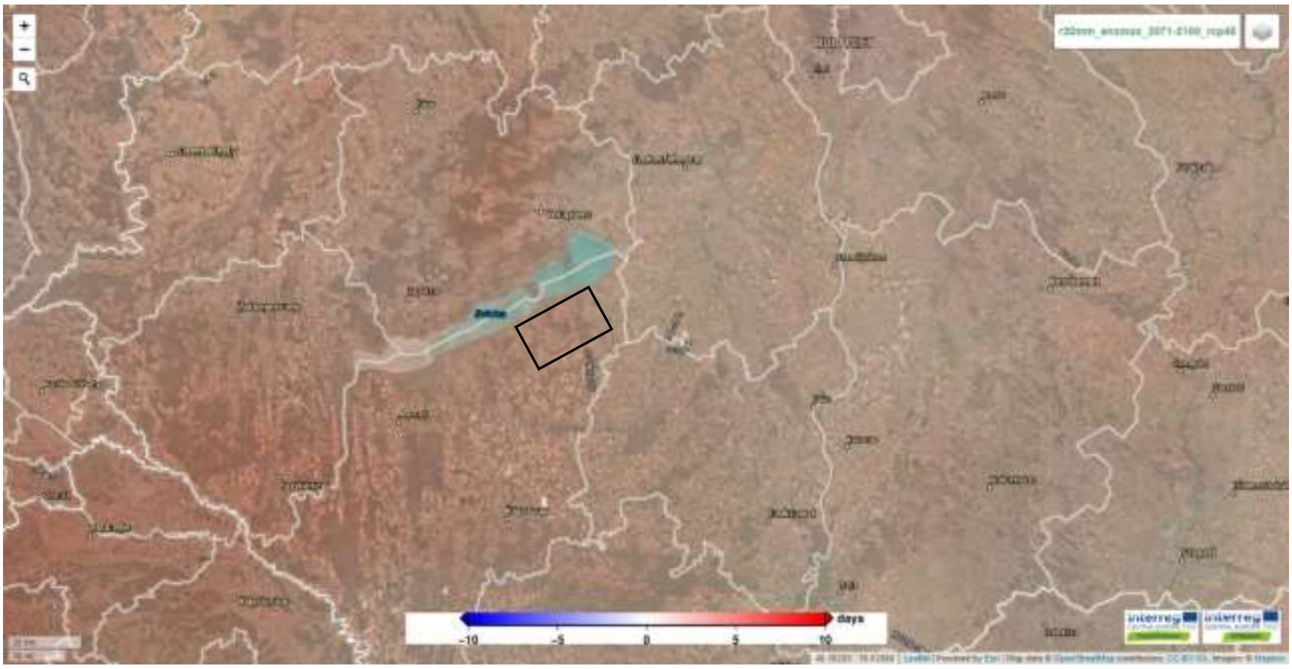
5.1. Very heavy precipitation days



Map for the past dataset on r20mm



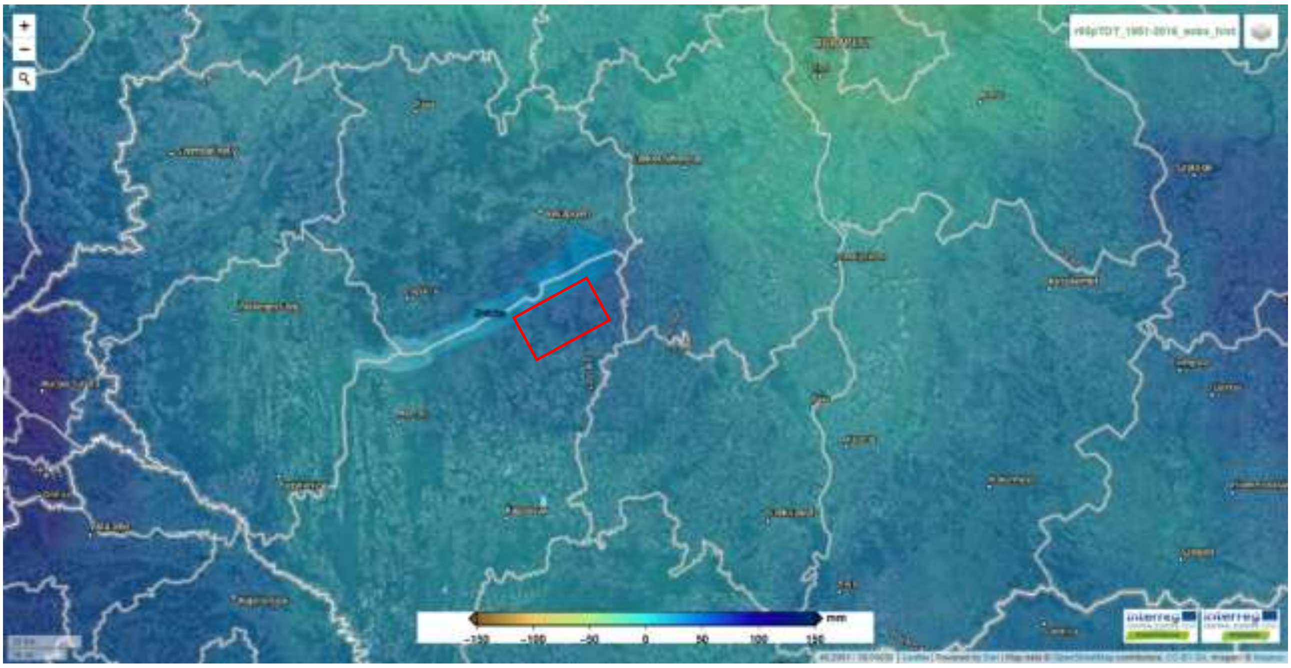
Map for the near future dataset on r20mm



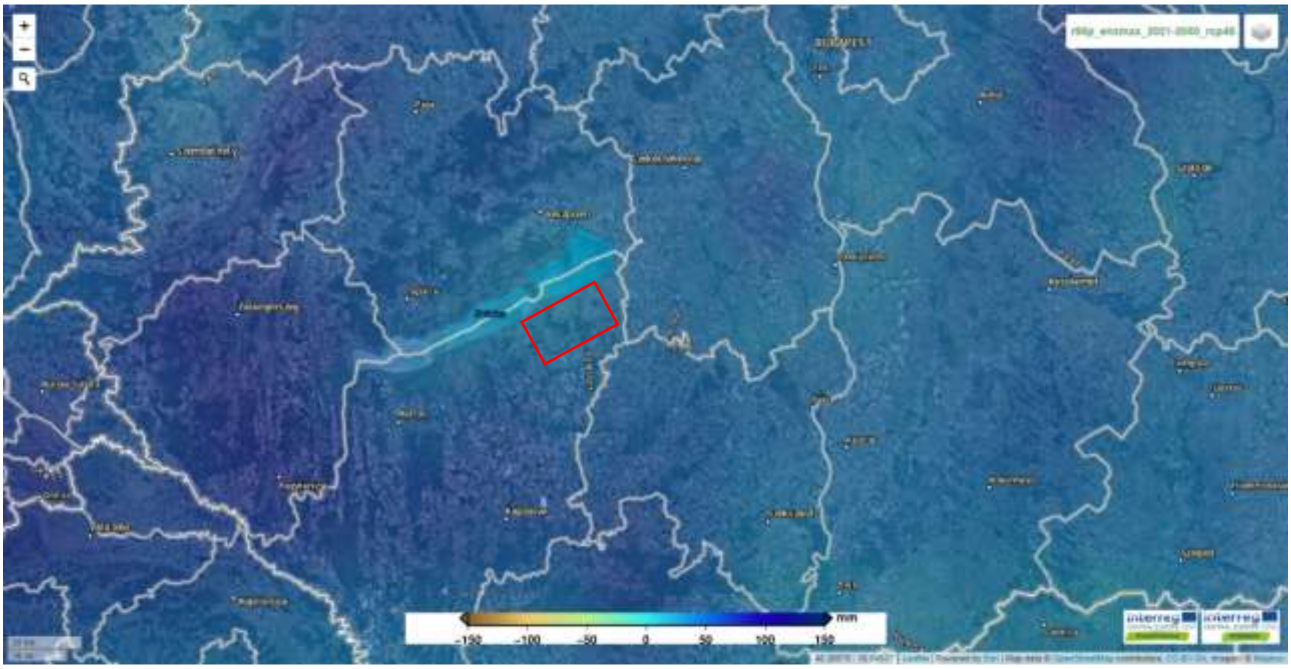
Map for the far future dataset on r20mm

The base for the evaluation is somewhere in the 0–1 days range as can be seen in the first map. The near future projections show a clear increase being in the 2–3 range but the far future projections have the real dramatic effect: it shows 4-5+ values.

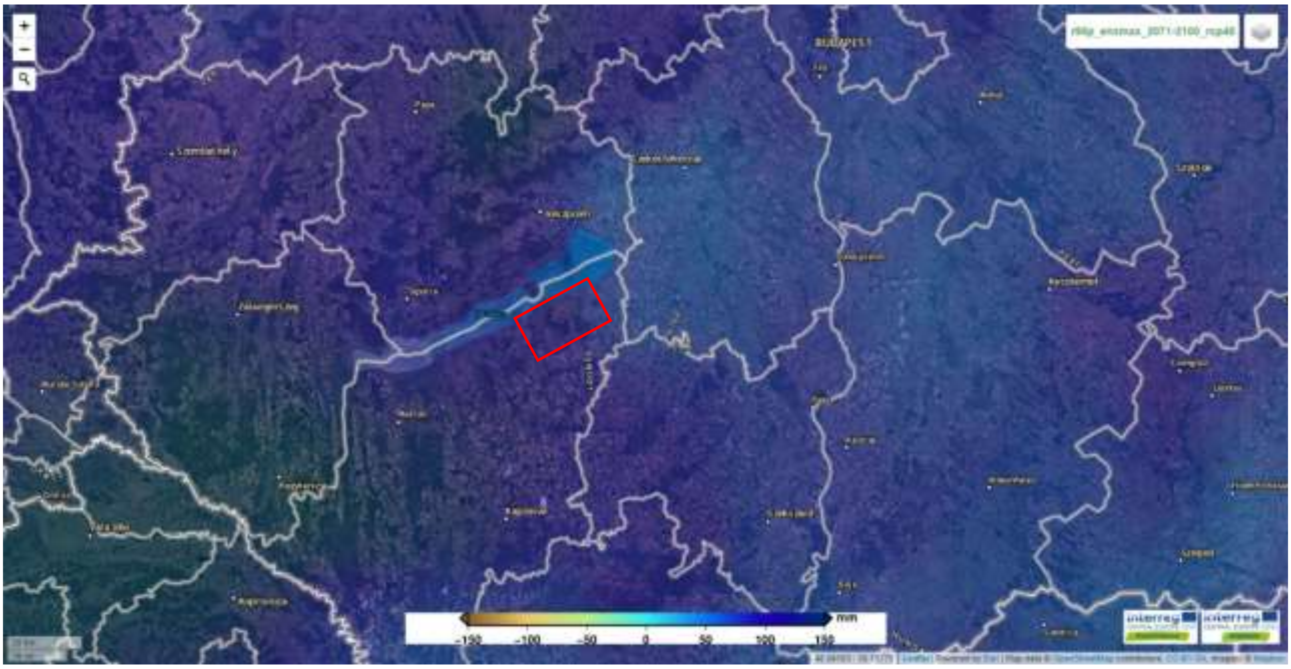
5.2. Precipitation due to extremely wet days



Map for the past dataset on R95pTOT



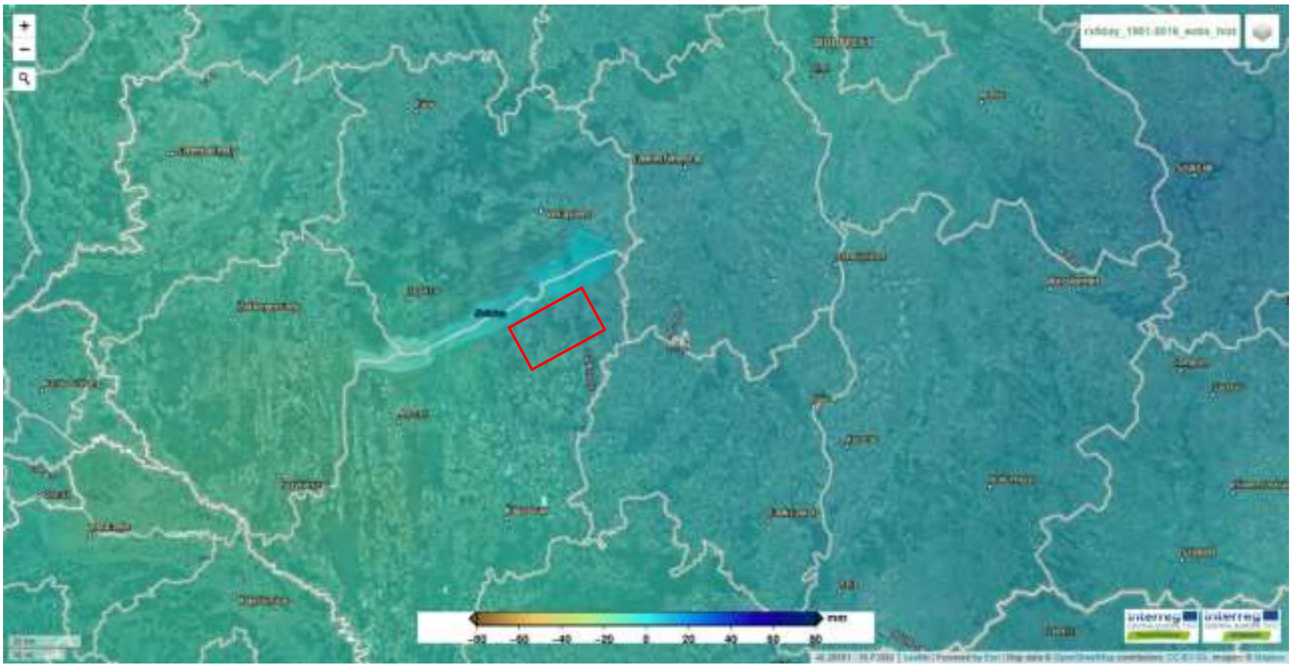
Map for the near future dataset on R95pTOT



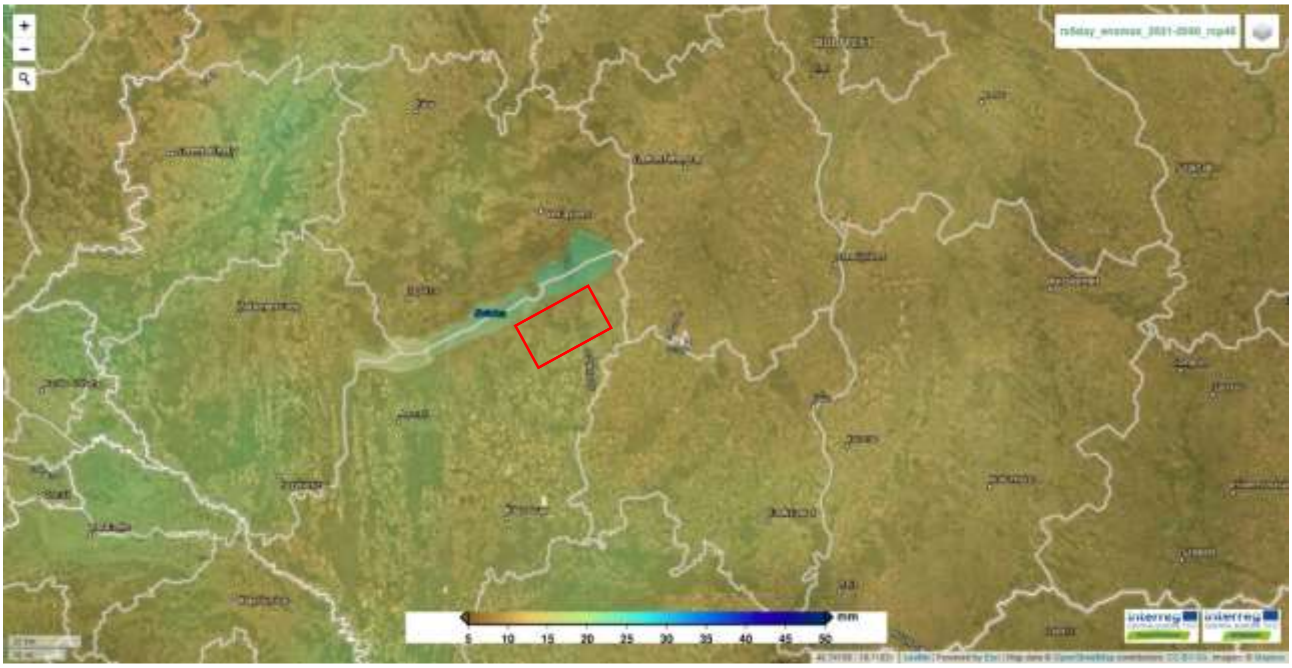
Map for the far future dataset on R95pTOT

The base for the evaluation is somewhere in the 40-50 mm range for the whole southern region. The near future projection increases this slightly in the 60-70 mm range, and the far future projections show a huge increase (100+ mm range).

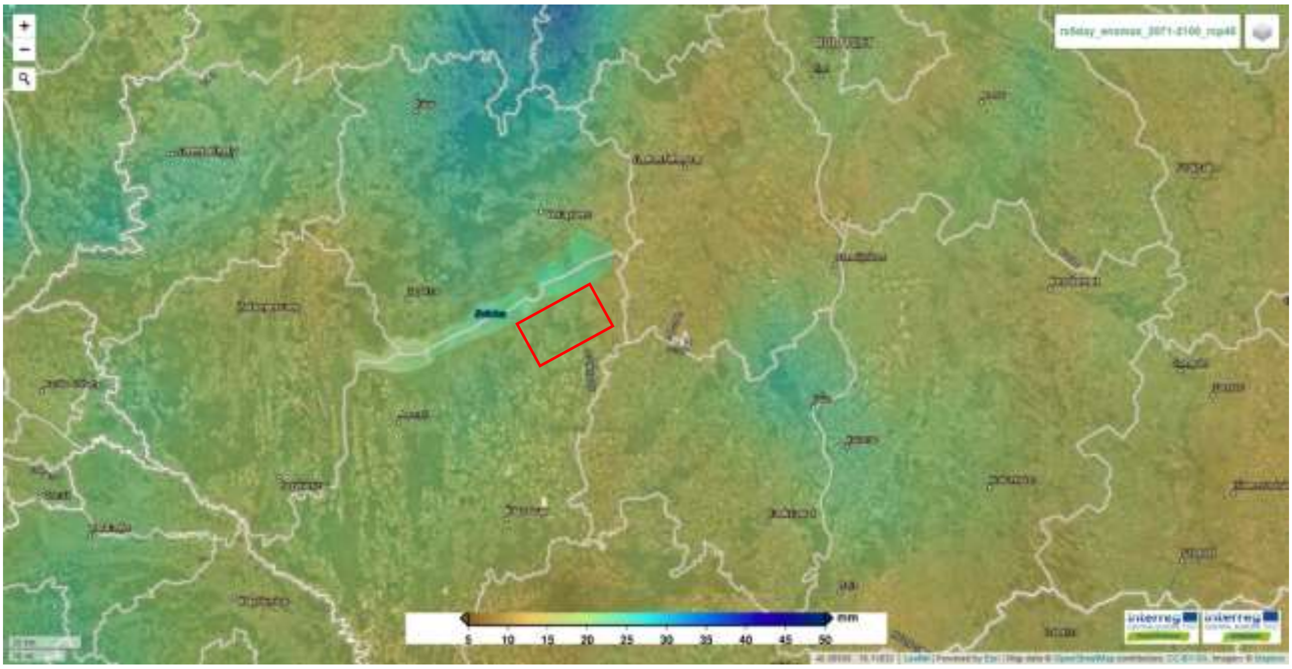
5.3. Highest 5-day precipitation amount



Map for the past dataset on Rx5day



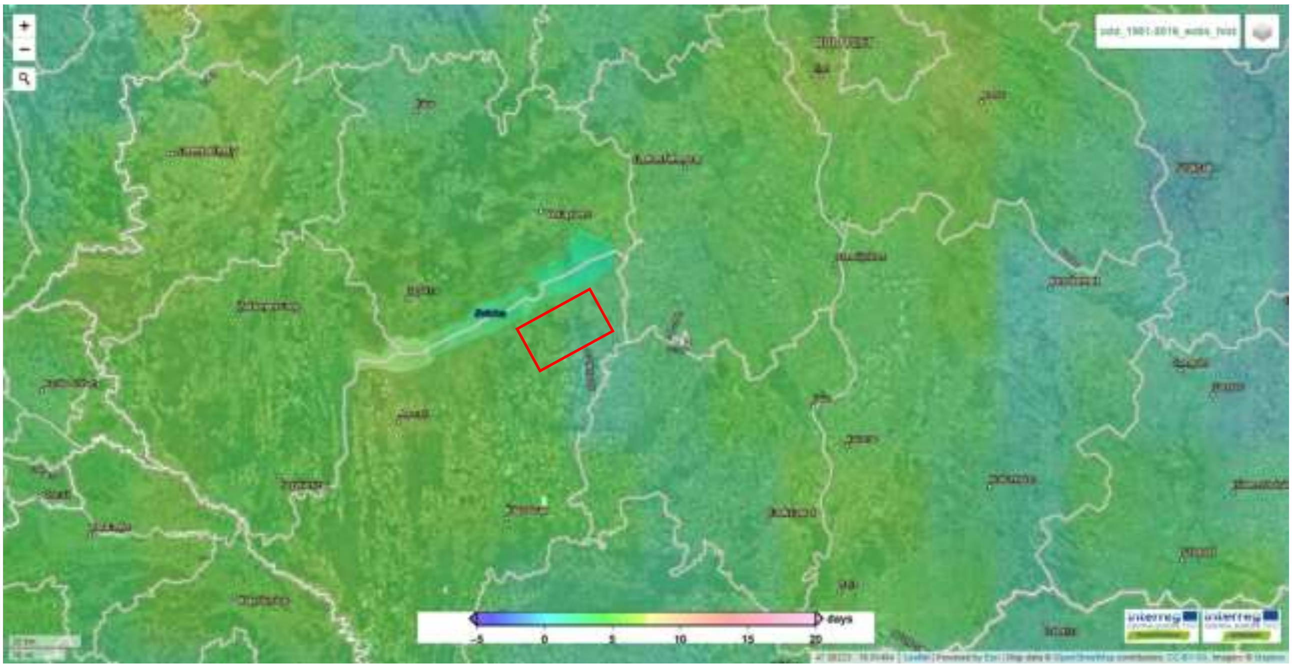
Map for the near future dataset on Rx5day



Map for the far future dataset on Rx5day

The two future projections show the southern Lake Balaton region being in the 12 and then the 20-25 mm range.

5.4. Maximum number of consecutive dry days



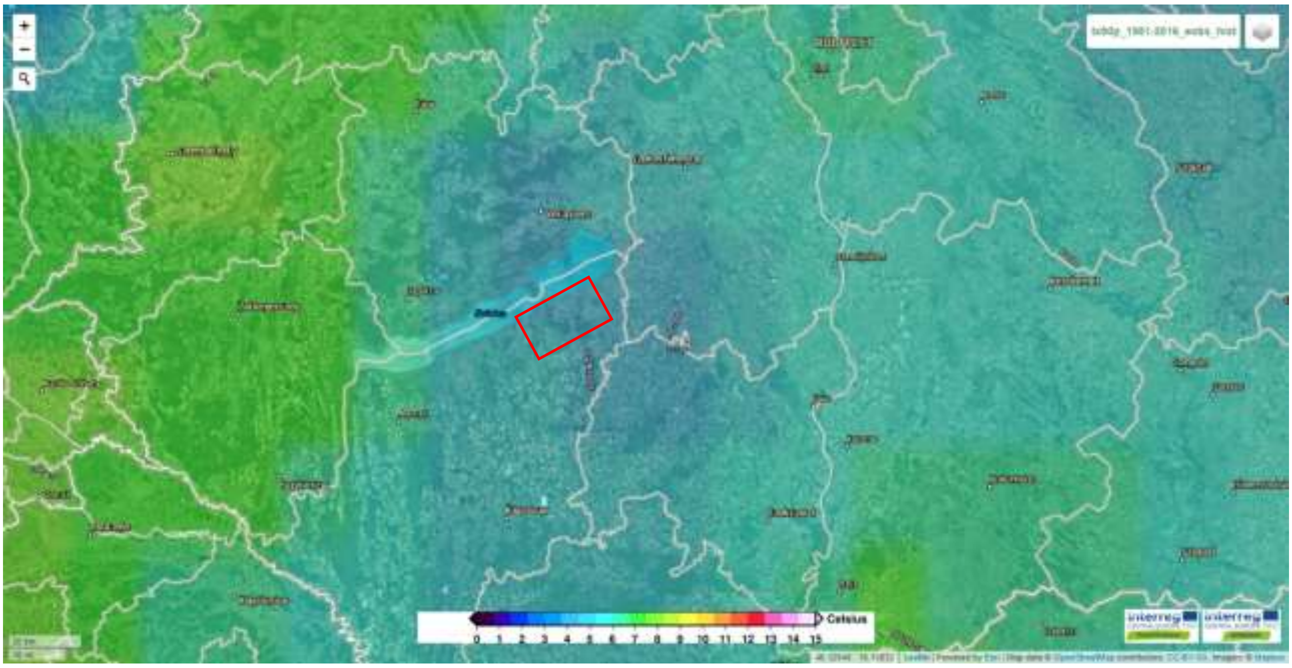
Map for the past dataset on CDD

Map for the near future dataset on CDD

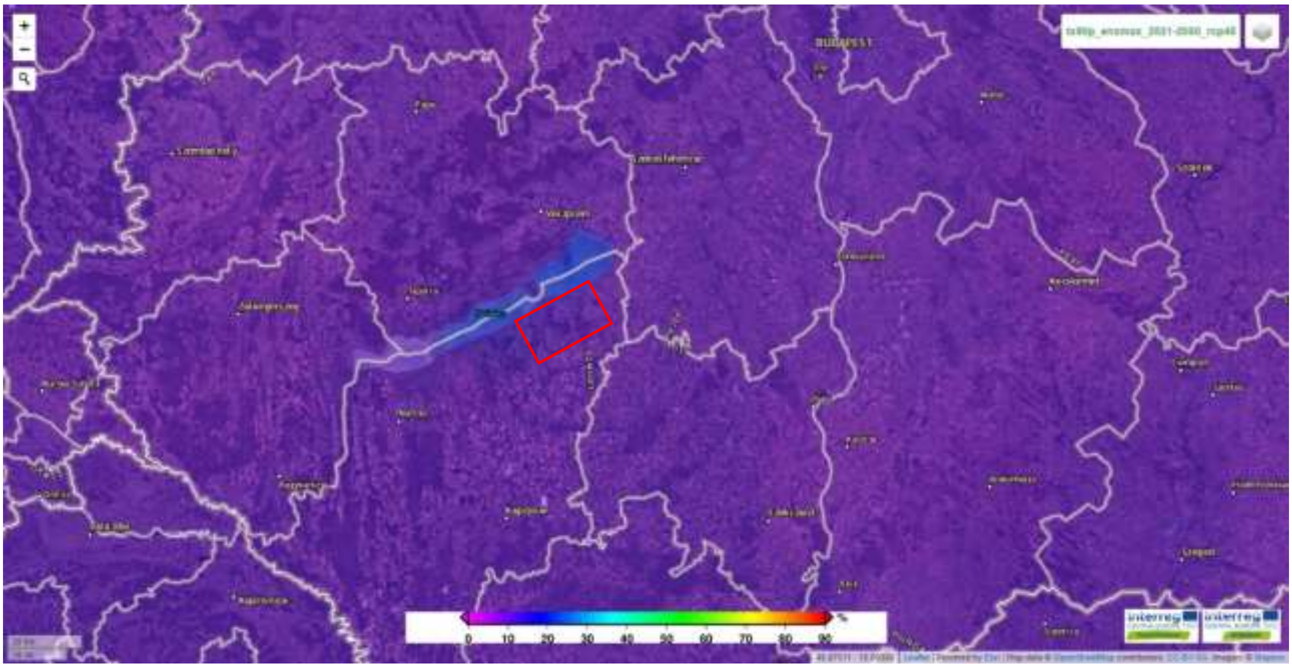
Map for the far future dataset on CDD

Interestingly there is no significant increase in an 80 years timespan. In this instance, judging from the visual representation, the risk stays more or less the same, so we must plan accordingly (more on that later, see Chapter 6).

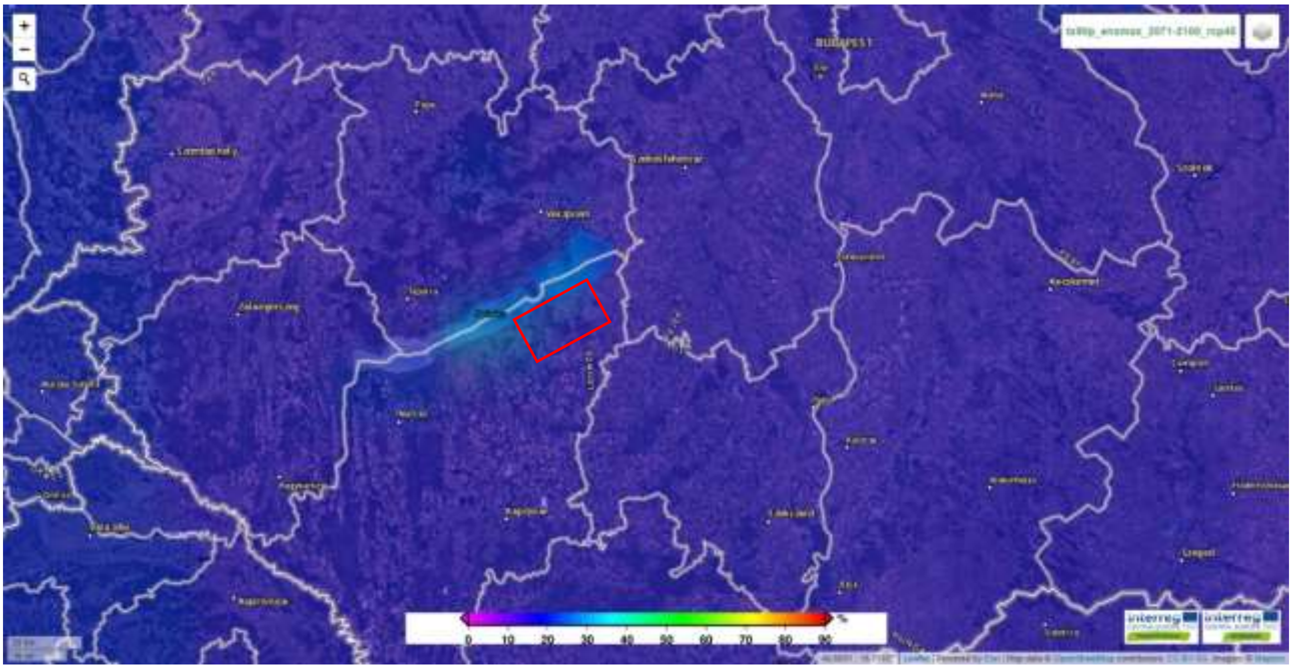
5.5. Extremely warm days



Map for the past dataset on Tx90p



Map for the near future dataset on Tx90p



Map for the far future dataset on Tx90p

A 8-10 percentage value in an almost 30 years timespan, and then an increase in the 18-20 percentage range 50 years after that. According to the visual representation, the amount of extremely warm days will be much higher in the future, increasing the likelihood of damage done to the plants (more on that later, see Chapter 6).

6. Conclusions and suggestions

The projections have provided the following conclusions:

- Heavy rainfall is going to be the main problem in the area. The maps on *very heavy precipitation days* and *precipitation due to extremely wet days* show a distinct increase of precipitation in general. This means that in the future the loose, silt-like soil is going to be a more emphasized risk factor and the likelihood of erosion is going to increase. Just the same with flash floods: although the connection with rain tends to be more complex than „*the more rain the more floods*", it is very much possible that flooding, especially in the creek area, is going to be an issue too. Also, with the increase of the *highest 5-day precipitation amount* landslides may very well be forming on the otherwise mild slopes of the area.
- Heat indices were somewhat of a mixed bag. Severe drought may not be a greater threat than it is now (which does not mean that it is to be taken lightly). On the other hand, the increase of extremely warm days could be the foreshadowing of possible vegetation damage in tha park, which could speed up erosion (the mix of damaged and already missing foliage means fewer roots to contain slow erosion and quick landlsides). Extreme heat could also lead to fire risks although it is not certain to which extent.

Calculating these factors in the planning for the future, the following suggestions can be made in the preservation of Zichy Mansion and the landscape elements (mainly the arboretum and especially the 130-year old trees).

Heavy rainfall, flash floods, erosion. At the moment there are some weaknesses that need to be addressed, even more so in the face of the projetctions. Rain is going to be an emphasized problem, and although we had no chance to test storm related indices, it should be a good rule of thumb to link heavy rainfall with storm (and so wind speeds), thus making the prognosis of steadily increasing windy days aswell. This makes the following suggestions feasible.

- First and foremost: volunteer firefighter associations play a great role in the Hungarian disaster management system, yet they are not included the cultural heritage protection planning, their use is ad hoc in this regard, and is usually limited to general damage mitigation. The local assets should be contacted and used in case of emergencies like flash floods. Local volunteer firefighters often have the capacity to conduct defense alone, without the help of professional (state) firefighters. The use of defensive measures (sandbags, ditches etc.) is practically impossible without the help of the local workforce.
- Careful planting in the park area, replacing the missing foliage should be a priority. The absence of adequate small plant covering means that the area is more prone to erosion damage, maybe even landslide. A firm rooting can keep the silt-like soil in place. The

plant planning should really be careful as the temperature indices suggest an increase in heat load on the foliage (see the next segment).

- A survey of the large trees in the park. Especially the 130-year trees could be a serious damage factor if the soil loosened by the sustained raining is resulting in trees falling over. There should be some form of cataloging of trees (according to size, location and/or possible weaknesses).
- Re-thinking the current agricultural and/or land use regulation in the Zichy Mansion area. Agricultural vegetation and the one sided land use decreases plants with the ability to „hold soil” (i.e. firmer roots going deeper, resisting erosion or larger landslides).
- Further regulation of the Kis-Koppány tributaries in the region may be desirable, especially so in the case of Zala creek. The creek itself may not be a problem now, but with the increasing rainfall this could change.
- The draining is going to become more important in the future. A careful re-thinking and planning of draining ditches is needed.

High windspeeds. Based on the projections it would be wise to anticipate an increase in storms (both quantity and „quality”, i.e. more severe storms). There already is a complex storm warning system in place around Lake Balaton, but this mainly focuses on the lake itself (meaning: it warns sailing boats, ships and people in the water and on the shores).

- The details about volunteer firefighter associations mentioned above is also true here.
- A secondary storm warning system of sorts would be of great help to CH sites. Of course this would be the focus of an entire project but in this case Zichy Mansion could benefit from direct storm warnings filtering out only the events which could be really harmful to the site itself.
- It is advisable to evaluate and in case strengthen the roof structure of Zichy Mansion. Currently there are no greater issues but the possibility of increasing heavy wind speeds (120+ km/h) mean more wind load to the roof structure.
- The park survey mentioned above could also prove beneficial in this case. Mapping weak trees should be useful.

Wildfires. Fires are not an emphasized issue now. The reach of hungarian disaster management units is adequate (i.e. how fast they are on the scene in case of a fire). There are only some general advices to consider:

- Agricultural work should be monitored and, if necessary, regulated.
- Fire ban periods (i.e. hot and dry periods in which it is forbidden to light any open fires outdoors) should be strictly enforced.
- Fire warning systems of the mansion should be checked regularly.

Rescue / salvage of cultural assets in case of emergency. In general, a more detailed and comprehensive emergency planning is needed. Suggestions:

- Comprehensive mapping of cultural assets in and around the mansion. This includes the categorization of assets by value, size, weight, handling needs etc. Bearing these attributes in mind, it should be possible to lay out an emergency plan which contains what to do if there is an emergency, what should be moved first, what can't be moved, how and where things should be stored etc.
- Volunteer firefighter organizations should be included in the planning and executions of the cultural asset rescue in some form. Volunteer firefighters represent an ever growing part of the Hungarian disaster management system: they are recognized, supported through monetary contributions, and, in some cases they can be deployed alone, without the support of state firefighters. Because of these reasons it would be a waste not to count on them – but to do this, they need to trained aswell. CH rescue courses, trainings could prove very useful, but at the very least they should be made aware of the problems.

7. Addendum

We feel that the WebGIS application has a place in the Hungarian disaster / cultural heritage management practice. The robust visualization tool of the WebGIS application is suitable for disaster management planning and short but catchy decision preparation materials as instead of raw numbers it produces easy to understand visual maps of the area in question. Moreover, the possibility to compare past datasets with near and far future projections the change is easily grasped and because of the dramatic contrast, also better suited for presentations.

TESTING OF THE WEBGIS TOOL FOR DELIVERABLE D.T2.2.1

VIPAVA VALLEY / SLOVENIA

Version 1
01 2021

Name of PP(s): PP7 – UIRS
Urbanistični inštitut Republike Slovenije
Urban Planning Institute of the Republic of Slovenia

Content

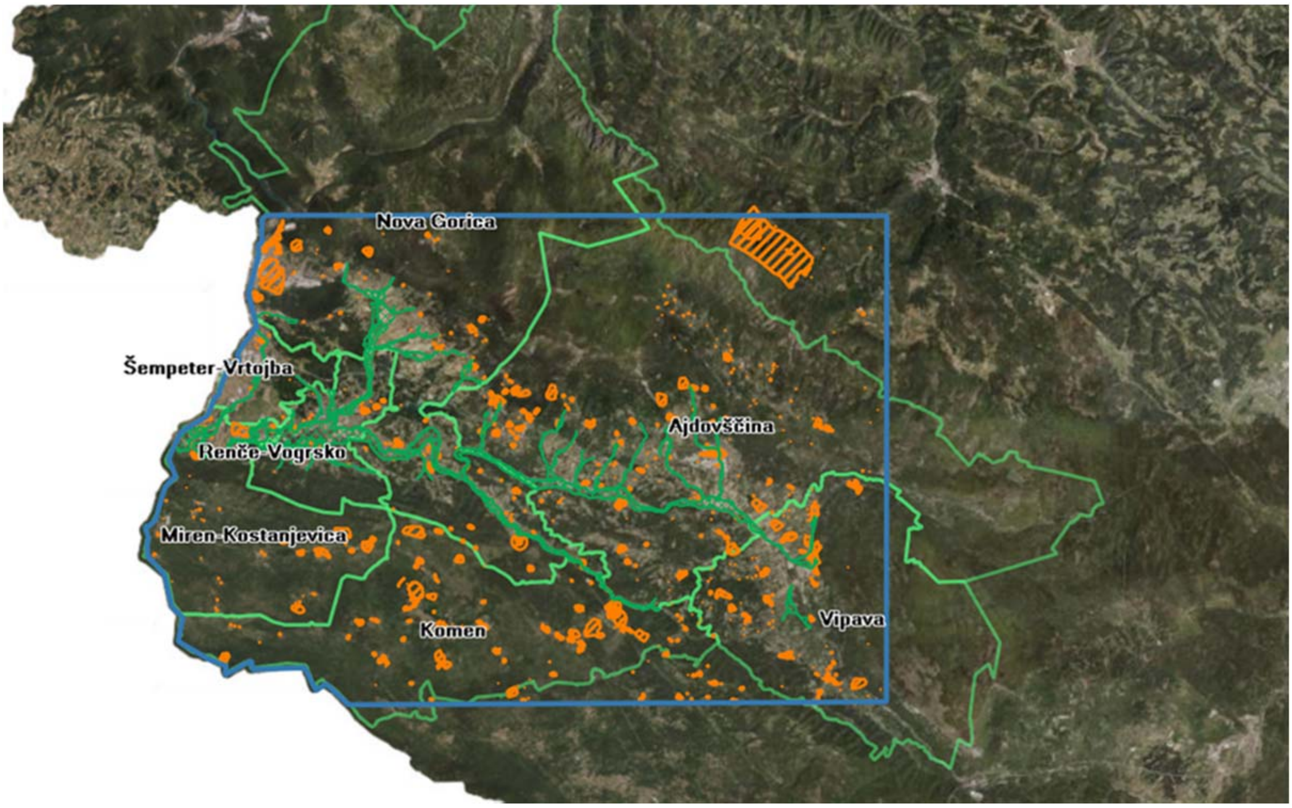
1. Introduction

UIRS evaluated the STRENCH WEBGIS tool for Vipava Valley - the pilot area in Slovenia. The main risks in the pilot area are floods and windstorms. The evaluation followed WGT content and focused on floods.

The goal of evaluation was to get an overview of the potential risk of floods on cultural heritage in Vipava Valley.

2. Site location

The Vipava Valley is located in the south-western part of Slovenia. The valley is surrounded by the mountains Trnovski gozd, Hrušica and Nanos and by the Vipava Hills merging with the Karst.



3. Site description

The Vipava Valley is rich in cultural landscape and cultural heritage: sacred monuments, mostly churches from the Gothic period, and castles constitute an important national heritage from Roman period to the 17th century. The Vipava Valley reflects the history as it has been a passageway between Italy and Danube region for millennia.

4. Tipology of cultural heritage assets

Through the Vipava Valley, there are more than 1200 cultural heritage sites, also with a status of national or local importance. As mentioned above, there are different types of cultural heritage from prehistorical archaeological sites, monuments from the Antique, Gothic, Baroque periods, and other objects from the 19th century.

Vipava Valley landscape

Lanthieri Manor, Vipava (left). Renče dam with mill (right).

5. Main risks impacting the site

The Vipava Valley and its cultural heritage are affected by natural disasters due to geographical, hydrological, and climatic characteristics. Locals are tackling bora wind, floods, and landslides for centuries. Floods, landslides, and the bora wind affected architecture, agriculture, economic activities, and the population. Landslides are common on the steep slopes during heavy rainfall events in the north of the Vipava Valley.

The main risks impacting the Vipava Valley area are floods and windstorms.

Bora wind comes down from the mountain peaks to the valley with high speed and poses a hazard for building structures - roofs and facades, throughout history, this influenced the design of dwellings.

In the Vipava river basin, there are five significant flood risk areas concerning cultural heritage, human health, environment, and economic activity. According to the preliminary Slovenian hazard indication map, there is a likelihood of rare floods. The upper stream of the Vipava River and its tributaries were already regulated in the past. Flood protection is an issue in the lower part of the basin, where floods have become more frequent and several severe floods occurred in past years. These floods are a result of changes in the precipitation regime as a consequence of climate change. Let us also mention the landslides as a potential risk to cultural heritage areas.

5.1. Recorded past events

Floods:

- October 1898, in the 2nd half of October, Vipava was flooded (water up to half a meter high).
- 16-19/10/1992, floods in Vipava lower stream.
- 3-7/12/1992, Vipava near Ajdovščina flooded.
- 28/10/1994, Vipava near Žablje overflowed due to heavy rainfall.
- December 1995, Vipava lower stream flooded at the end of December.
- 2/04/1996, Heavy rainfall caused minor flooding of the Vipava river.
- 29-31/03/2009, the water caused the most damage in the Vipava and Goriška regions. Extensive agricultural areas, fields, vineyards, orchards, as well as dozens of residential and other buildings were flooded.
- 23-27/12/2009, the warning flows on the Vipava in Dolenja and its tributaries, especially the Hubelj flood of the Vipava upstream, were exceeded.
- 17-21/09/2010, extensive floods covered the Vipava.
- 06-10/12/2010, the river Vipava flooded harder. Vipava upper and lower part of the Vipava valley heavier floods.

* 23-27/12/2010, Vipava floods to a lesser extent.
* 27/10/2012, Vipava started flooding to a lesser extent in the morning.
* 05-20/11/2014, three more intense flood events occurred: 6 -11 November, 11-13 November, 18-20 November.
* 14/10/2015, Vipava floods in usual places in the lower part, increased flows in Hubelj, Branica and Lijak floods.
* 01/10/2016, Vipava was the first to rise and spilled to a lesser extent in the areas of frequent floods.
* 08-16/02/2017, with the onset of precipitation, flows began to increase.
* 27-28/04/2017, the first river overflows began on the morning of the 28 of April and in the central flood Vipava spilled along the watercourse.

Windstorm:

* 03-07/02/2015, very strong bora wind: the highest half-hour average wind speed was 54 km/h caused road closures.
* 19-23/05/2015, very strong bora wind: the highest half-hour average wind speed was 78 km/h.
* 11/01/2016, bora wind: the highest half-hour average wind speed was 10,5 km/h.
* 05-07/11/2016, bora wind: the highest half-hour average wind speed was 9,2 km/h.
* 16-19/01/2017, strong bora wind: the highest half-hour average wind speed was 17,7 km/h.
* 14-20/09/2017, strong bora wind: the highest half-hour average wind speed was 19,1 km/h.
* 22-23/10/2017, bora wind: the highest half-hour average wind speed was 10 km/h.
* 12-15/11/2017, bora wind: the highest half-hour average wind speed was 13,9 km/h.
* 03/02/2018, bora wind: the highest half-hour average wind speed was 14,5 km/h.
* 22/02/2017, bora wind: the highest half-hour average wind speed was 13,9 km/h.
* 27-30/10/2018, strong bora wind: the highest half-hour average wind speed was 18,7 km/h.
* 02/01/2019, bora wind: the highest half-hour average wind speed was 12,55 km/h.
* 02/02/2019, bora wind: the highest half-hour average wind speed was 9,1 km/h.
* 03/11/2019, bora wind: the highest half-hour average wind speed was 7,6 km/h.
* 21/10/2019, bora wind: the highest half-hour average wind speed was 10,5 km/h.


Vipava, linden avenue, floods in June 2020 (left).

Velike žablje, Vipava flooding in June 2020 (right).

5.2. Adopted measures

In Slovenia, the majority of responsibilities for immovable heritage protection are divided between the Ministry of Culture, municipalities, and the Institute for the Protection of Cultural Heritage of Slovenia. Public and private owners are fully responsible for the maintenance, management, and strategic development of cultural assets.

Cultural Heritage Protection Act requires that cultural heritage is taken into consideration in the preparation of all spatial plans and that spatial plans must include heritage protection measures. That means that monuments of local and of national importance registered archaeological sites and heritage protection areas are included and taken into consideration as obligatory components of spatial (zoning) plans at the national and local levels.

The Environmental Protection Act sets a strategic environmental impact assessment procedure. An assessment of the impact on the heritage of the potential development is an important part of the SEIA. SEIA is prepared for all categories: monuments, registered archaeological sites, and heritage protection areas. A strategic impact assessment on heritage is also mandatory for interventions to areas without heritage if such interventions could have a direct or indirect impact on heritage.

The protection of Slovenian cultural heritage is also regulated by the Act on Protection Against Natural and Other Disasters. This act defines the general framework for the prevention and elimination of threats to cultural heritage and establishes principles for other heritage protection regulations, acts, and guidelines. The system of protection against natural and other disasters includes the protection of cultural heritage, with a view of reducing the number of disasters and preventing or reducing the number of casualties and other consequences of such disasters. Legislation on emergency preparedness is strict; however, these regulations do not apply specifically to cultural heritage.

Natural disasters as floods and wind are present in Vipava Valley for centuries hence are well tackled in national and local documents. The Vipava river basin is managed with the Vipava River Basin Management Plan and its Program of Measures according to the EU Water Framework Directive that has been completely integrated into Slovenian legislation through the Waters Act. There are also other sectorial strategic plans related to water management, as The Flood Risk Management Plan, Natura 2000 Management Programme, and other sectorial documents in agriculture and forestry.

6. WEBGIS tool evaluation for Vipava Valley

The main risks affecting the Vipava Valley area are floods and windstorms. We evaluated 2 extreme events: heavy rain and flooding. Furthermore, we also evaluated all Climate variables.

In the evaluation of the WGT tool, we collected maps of the area with past (1951–2016), near future (2021–2050), and far future (2071–2100) projections (Model ensemble statistics / Maximum / RCP 4.5). Due to the scale available in the Web GIS tool, UIRS evaluated the whole Vipava Valley.

We found that the robust visualization tool of the WGT tool is better suited for comparison of past with future scenarios than raw datasets.

The goal of this evaluation was to get an overview of the potential risk of floods and hot weather on cultural heritage in Vipava Valley.

Extreme events	Indexes	Description
Heavy rain	Very heavy precipitation days (R20mm)	Number of days in a year with precipitation larger or equal 20 mm/day.
Heavy rain	Precipitation due to extremely wet days (R95pTOT)	The total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days. A wet day is defined as having daily precipitation ≥ 1 mm/day. A threshold based on the 95th percentile selects only 5% of the most extreme wet days over a 30 year-long reference period.
Flooding	Highest 5-day precipitation amount (Rx5day)	Yearly maximum of cumulated precipitation over consecutive 5 day periods.
Flooding	Consecutive wet days (CWD)[1]	Seasonal maximum number of consecutive days with RR>=1mm.

[1] During evaluating STRENCH WGT fture simulations were not available.

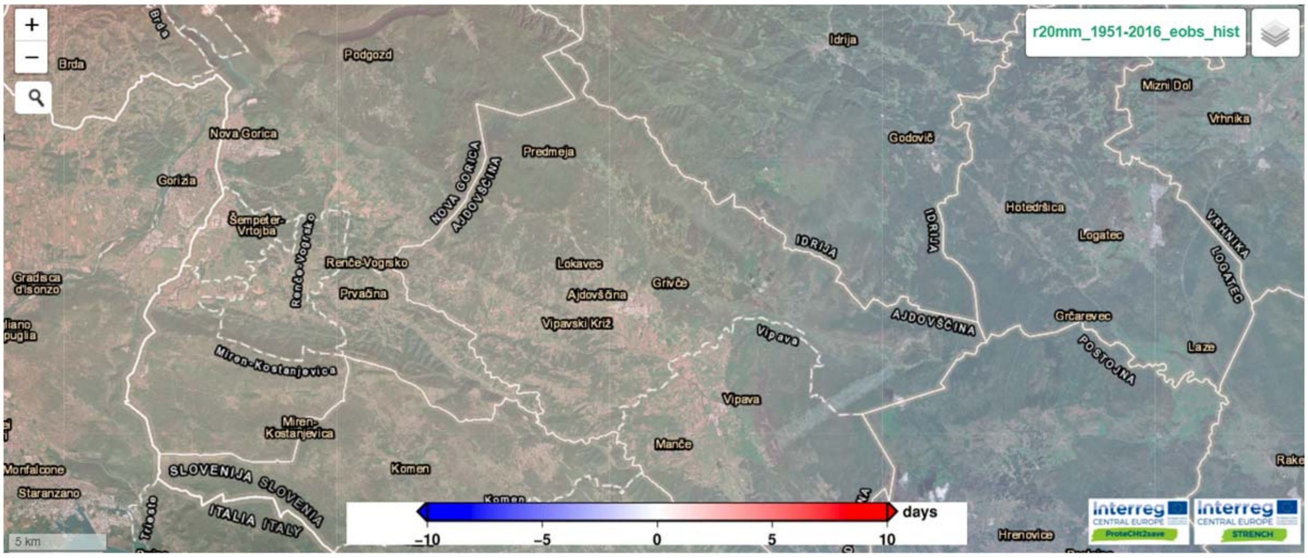
Extreme event: Heavy rain

Very heavy precipitation days

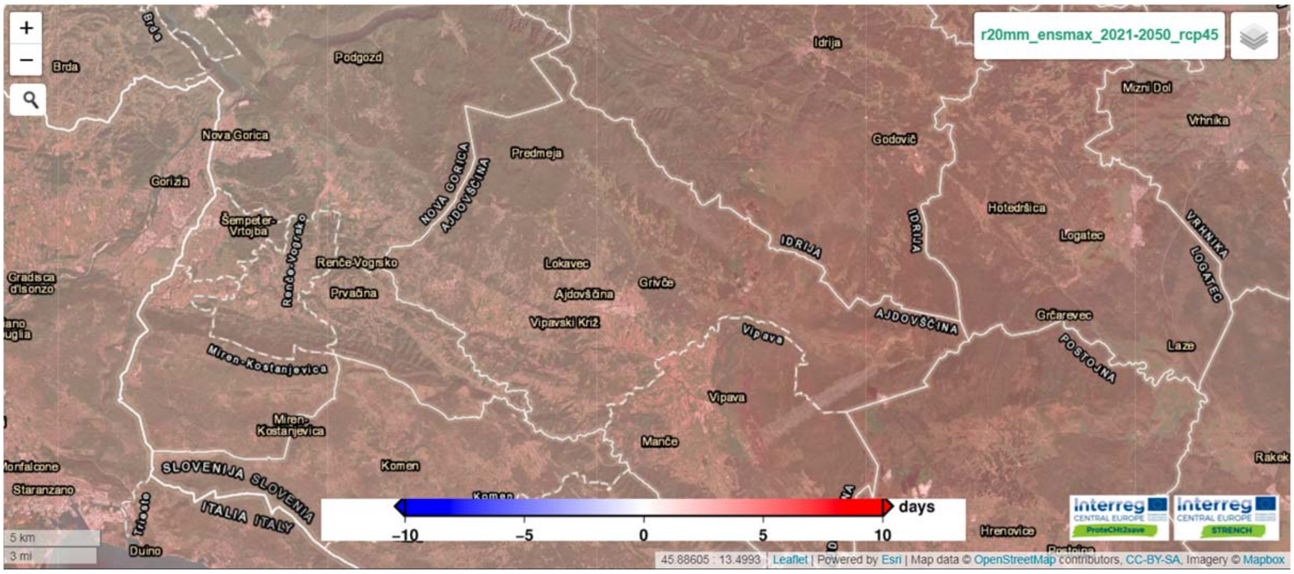
Index: R20mm

Number of days in a year with precipitation larger or equal 20 mm/day.

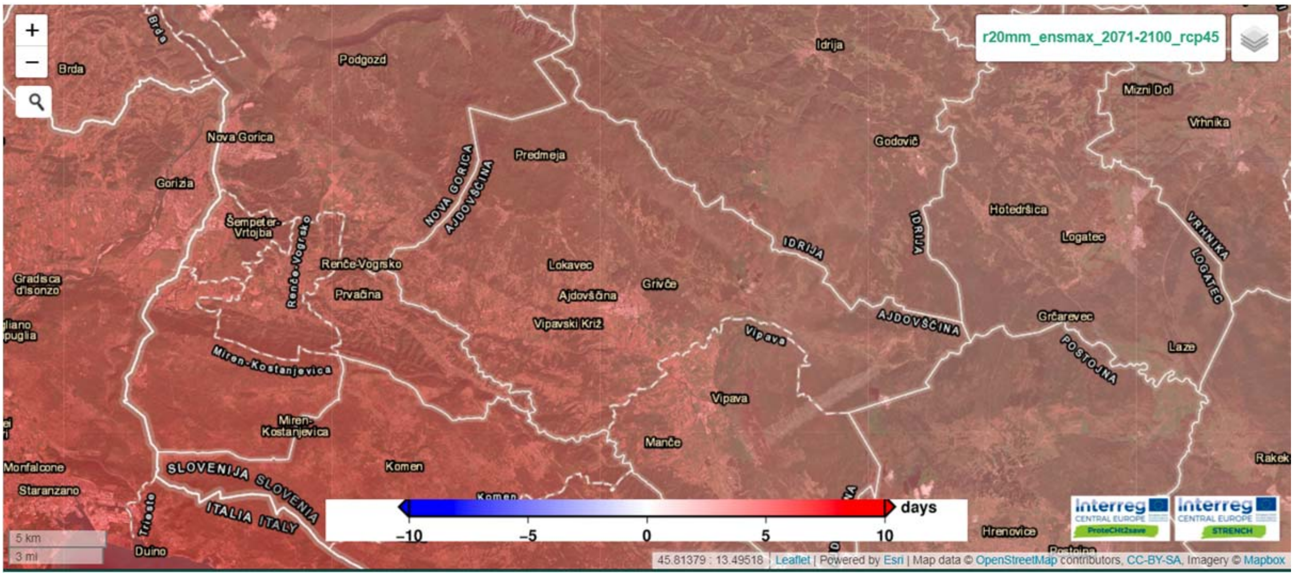
Map: Historical observations: r20mm_1951-2016_eobs_hist



Map: Model ensemble statistics: Mean / near future / RCP 4.5: r20mm_ensmax_2021-2050_rcp45



Map: Model ensemble statistics: Mean / far future / RCP 4.5: r20mm_ensmean_2071-2100_rcp45



The near and far future projections show an increase in the number of days in a year with precipitation larger or equal to 20 mm/day.

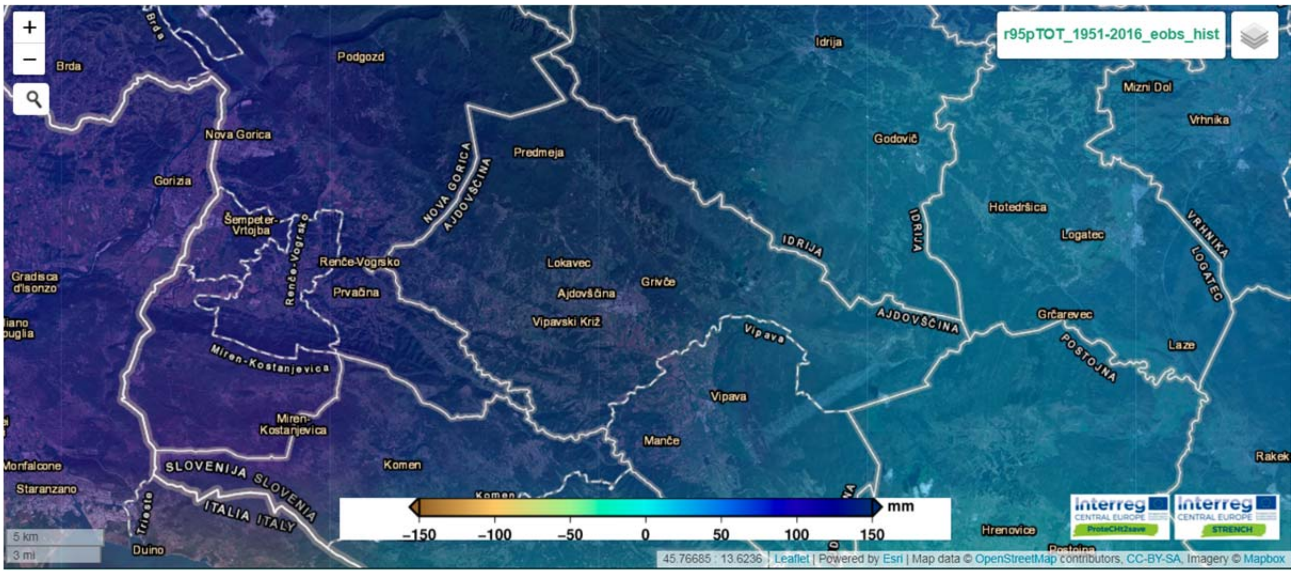
Extreme event: Heavy rain

Precipitation due to extremely wet days

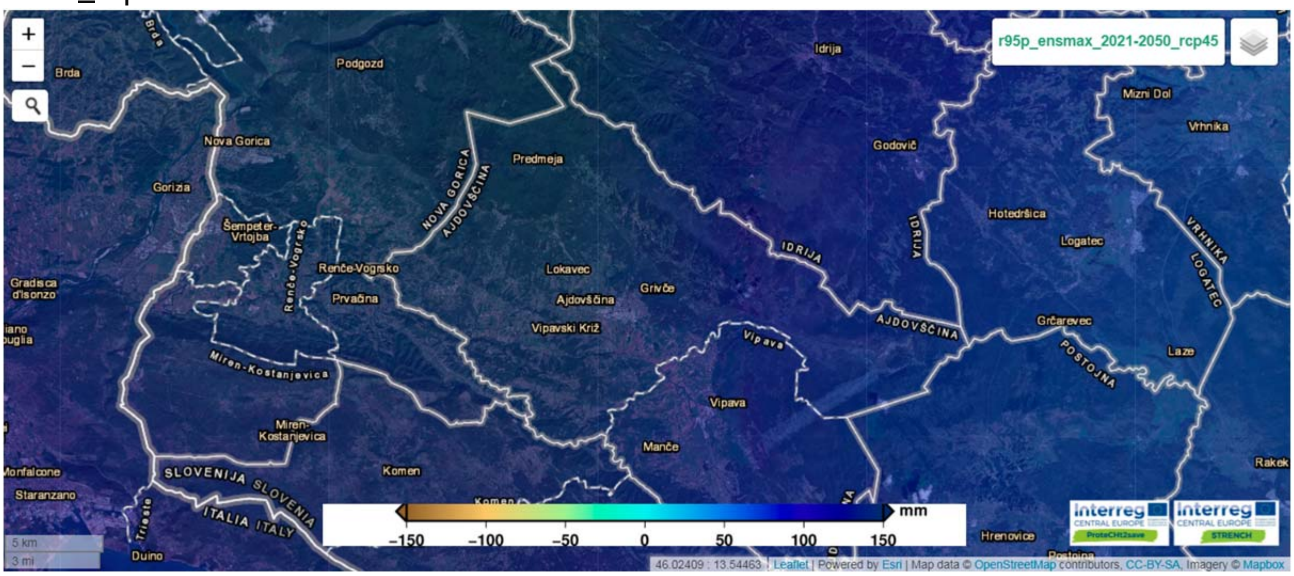
Index: R95pTOT

The total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days. A wet day is defined as having daily precipitation ≥ 1 mm/day. A threshold based on the 95th percentile selects only 5% of the most extreme wet days over a 30 year-long reference period.

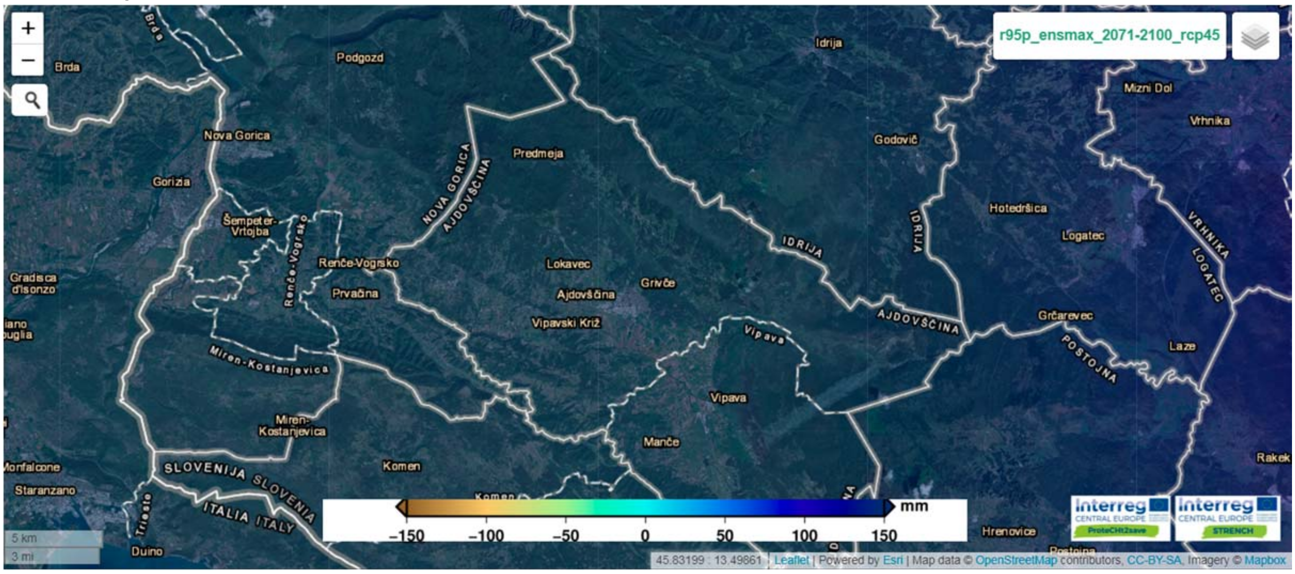
Map: Historical observations: r95pTOT_1951-2016_eobs_hist



Map: Model ensemble statistics: Mean / near future / RCP 4.5: r95p_ensmax_2021-2050_rcp45



Map: Model ensemble statistics: Mean / far future / RCP 4.5: r95p_ensmax_2071-2100_rcp45



The near and far future simulations show an increase of total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days.

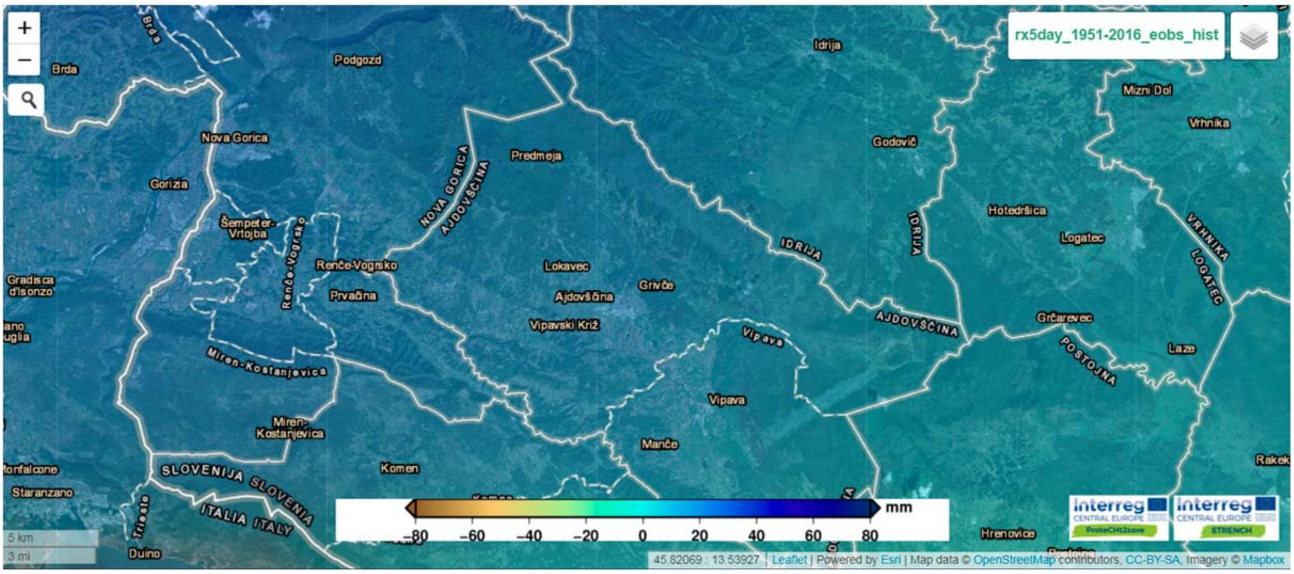
Extreme event: Flooding

Highest 5-day precipitation amount

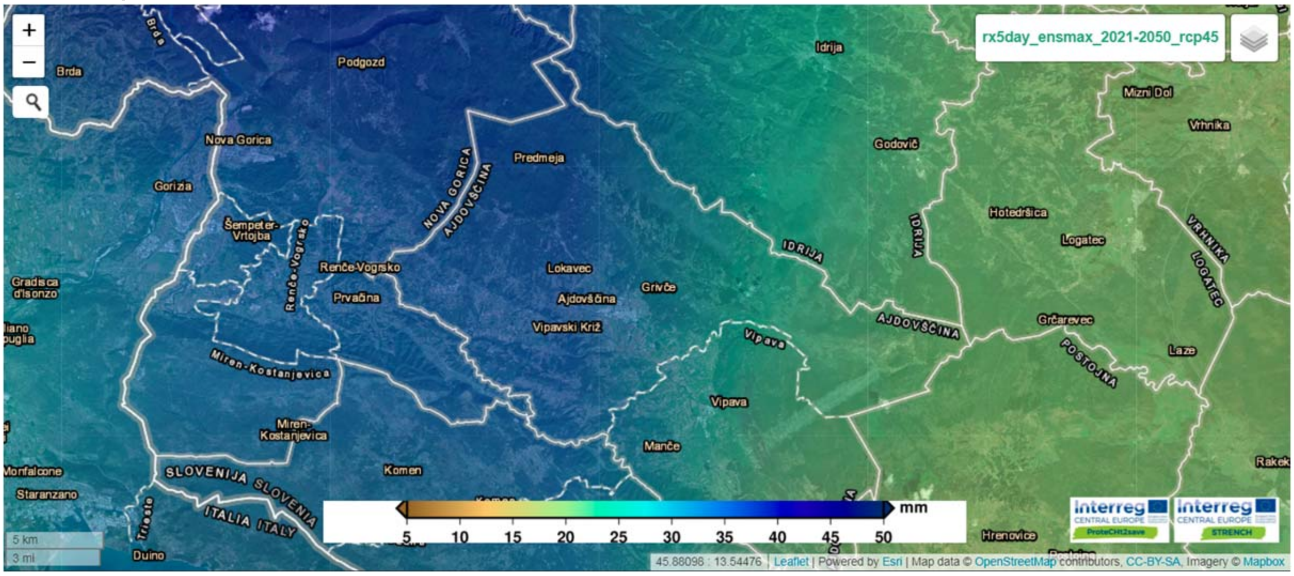
Index: Rx5day

Yearly maximum of cumulated precipitation over consecutive 5 day periods.

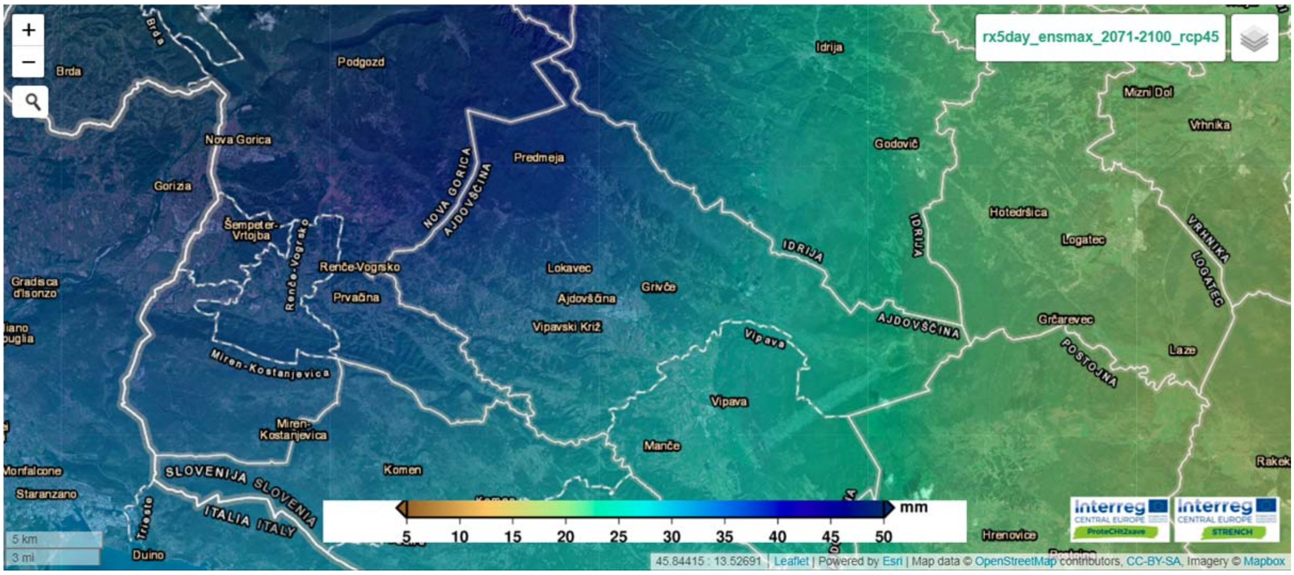
Map: Historical observations: rx5day_1951-2016_eobs_hist



Map: Model ensemble statistics: Mean / near future / RCP 4.5: rx5day_ensmax_2021-2050_rcp45



Map: Model ensemble statistics: Mean / far future / RCP 4.5: rx5day_ensmax_2071-2100_rcp45



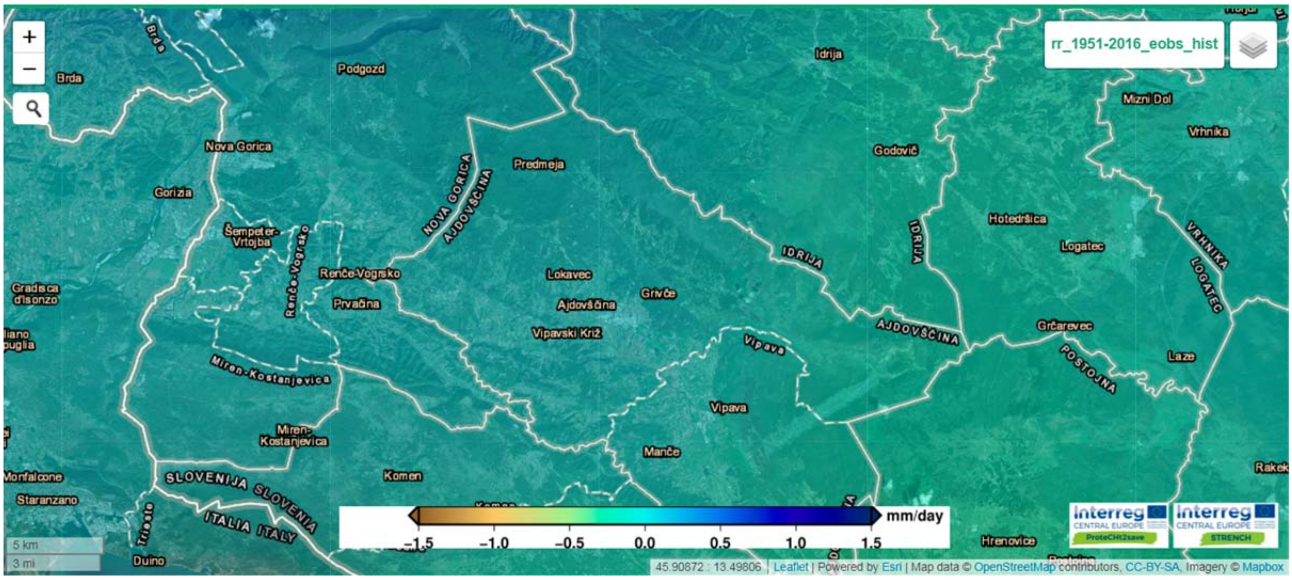
The near and far future projections show a decrease of a yearly maximum of cumulated precipitation over consecutive 5 day periods.

Evaluation of climate variables

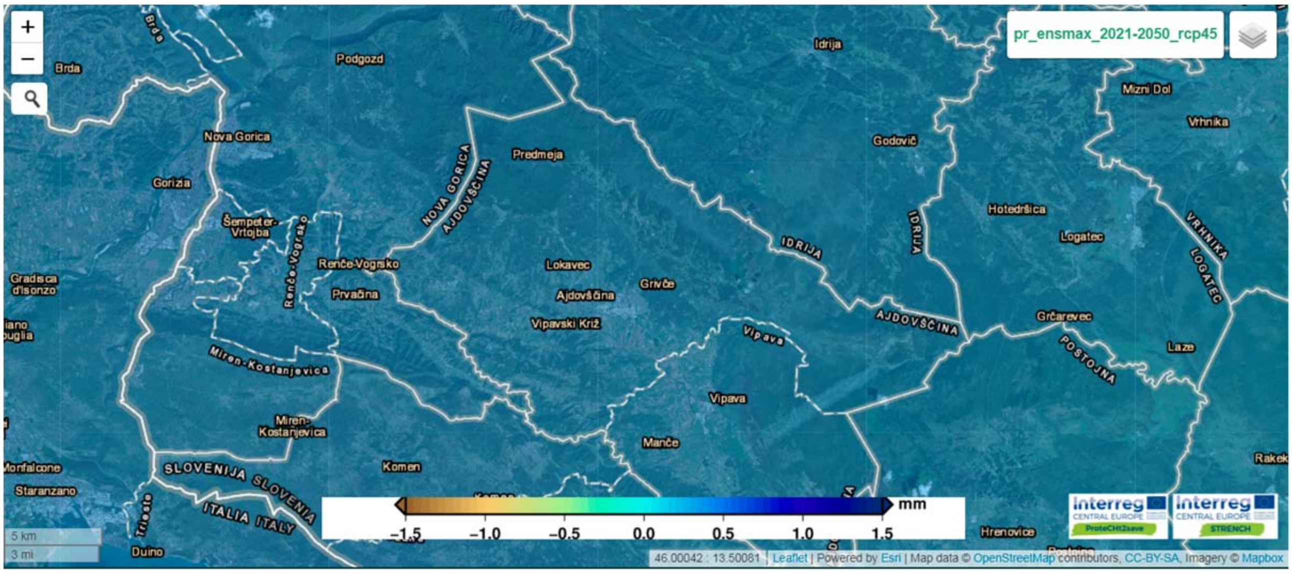
Precipitation	RR	daily cumulated precipitation
Tmax	Tx	daily maximum temperature
Tmin	Tn	daily minimum temperature

Precipitation: RR: daily cumulated precipitation

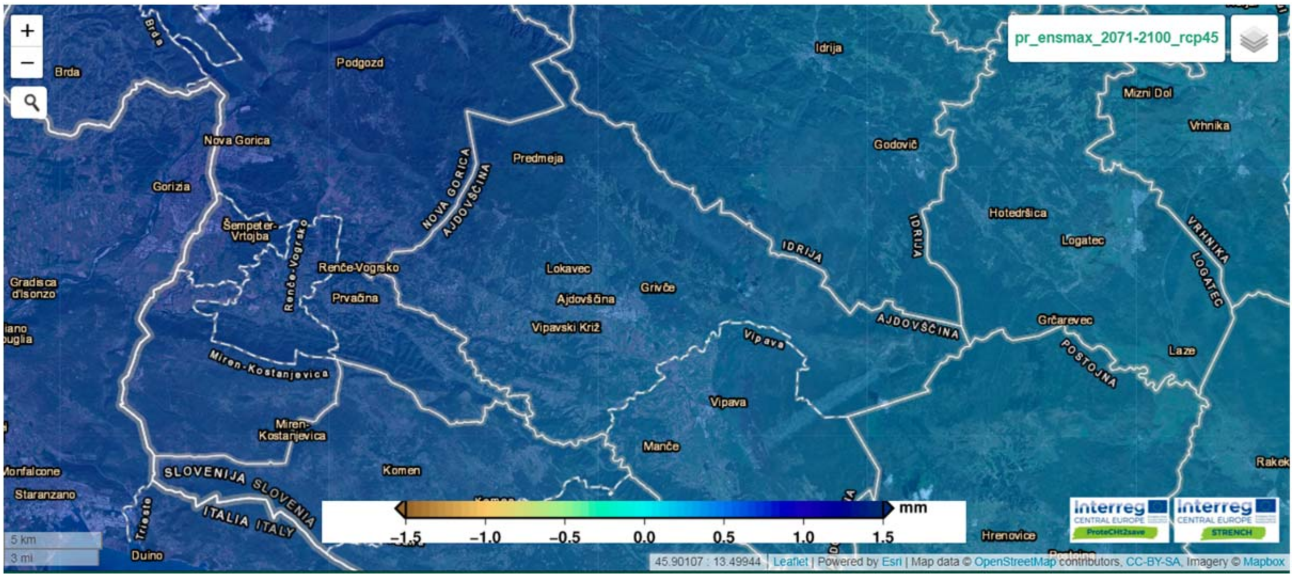
Map: Historical observations: rr_1951-2016_eobs_hist



Map: Model ensemble statistics: Mean / near future / RCP 4.5: pr_ensmax_2021-2050_rcp45



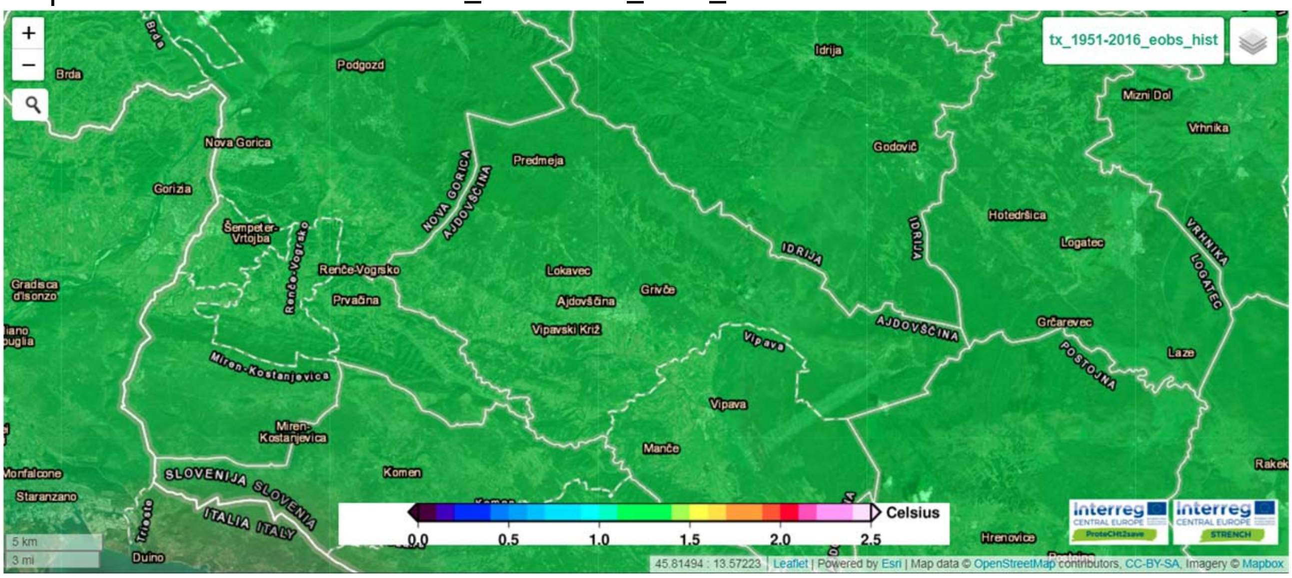
Map: Model ensemble statistics: Mean / far future / RCP 4.5: pr_ensmax_2071-2100_rcp45



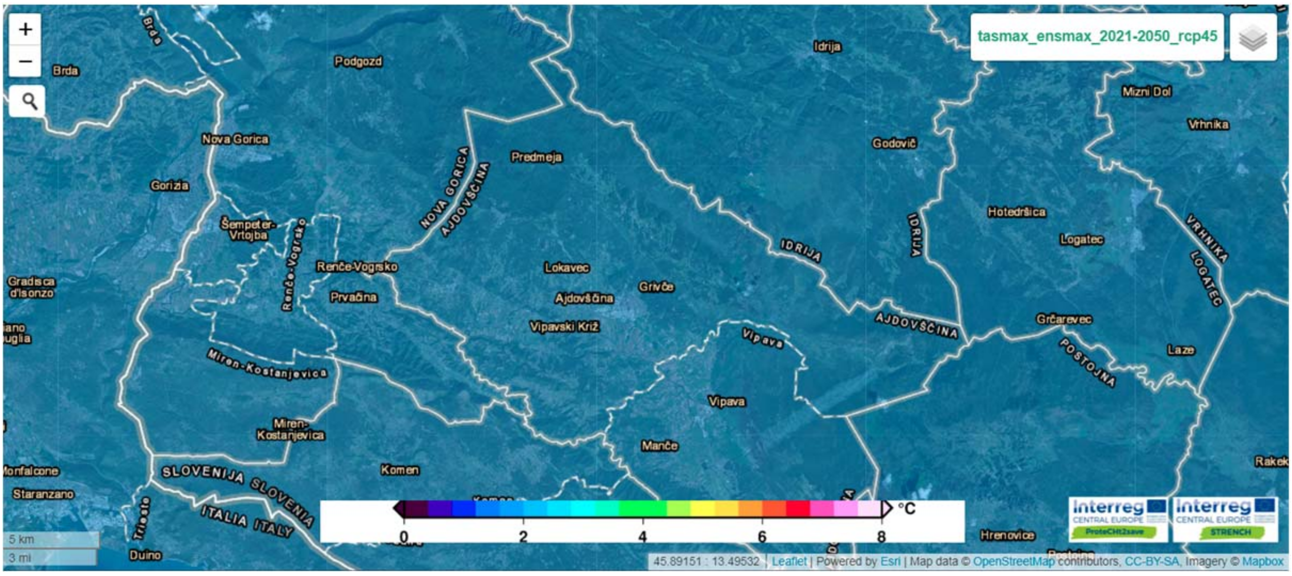
The future projections show an increase in daily cumulated precipitation in Vipava Valley in the near and far future.

Tmax: tx: daily maximum temperature

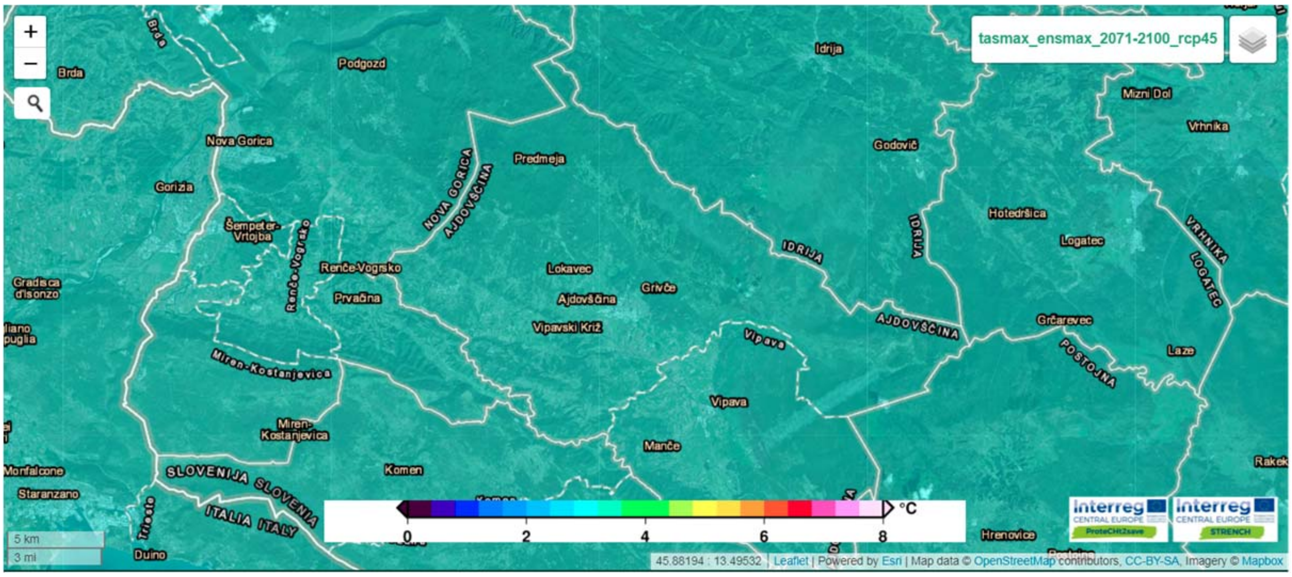
Map: Historical observations: tx_1951-2016_eobs_hist



Map: Model ensemble statistics: Mean / near future / RCP 4.5: tasmax_ensmax_2021-2050_rcp45



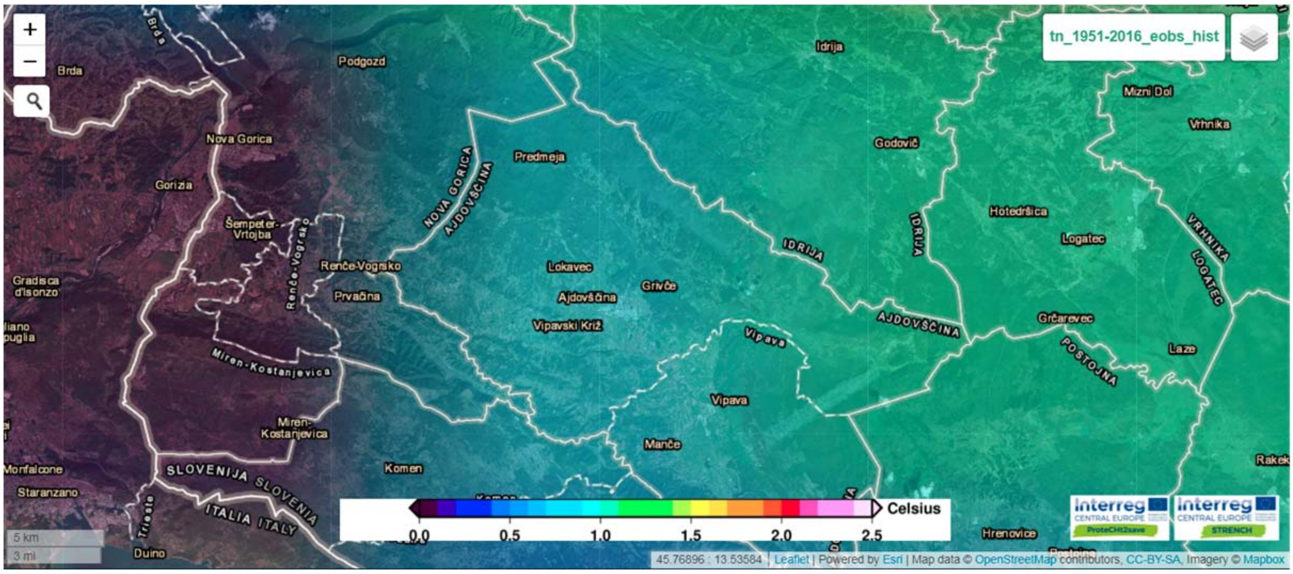
Map: Model ensemble statistics: Mean / far future / RCP 4.5: tasmax_ensmax_2071-2100_rcp45



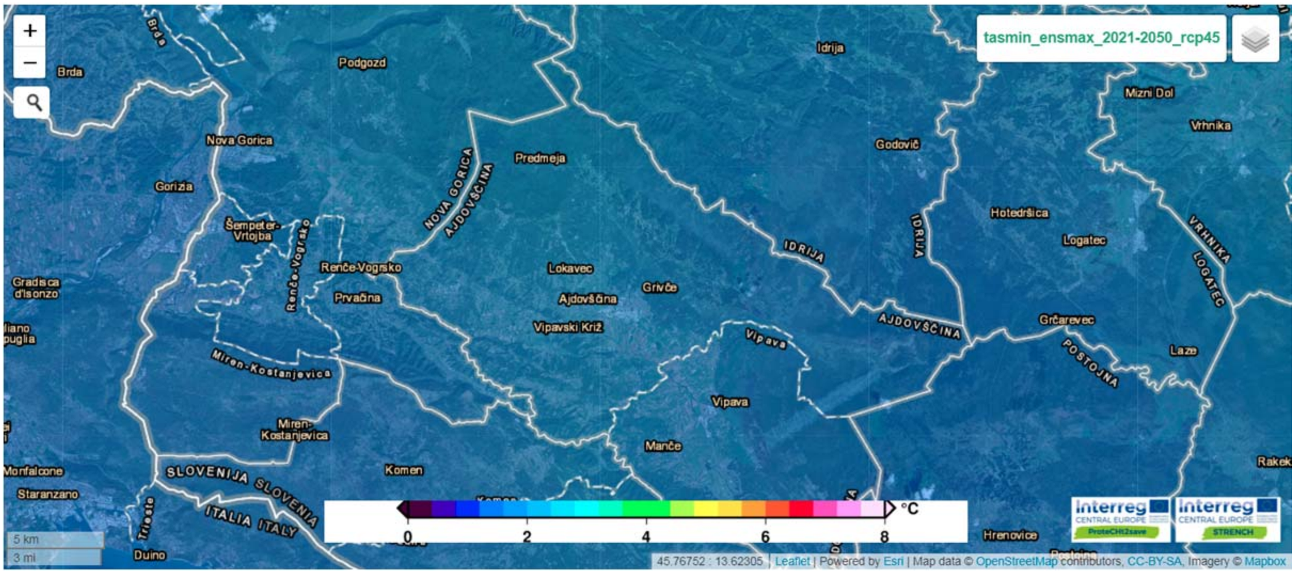
The near and far future projections show a decrease in a daily maximum temperature in Vipava Valley.

Tmin: Tn: daily minimum temperature

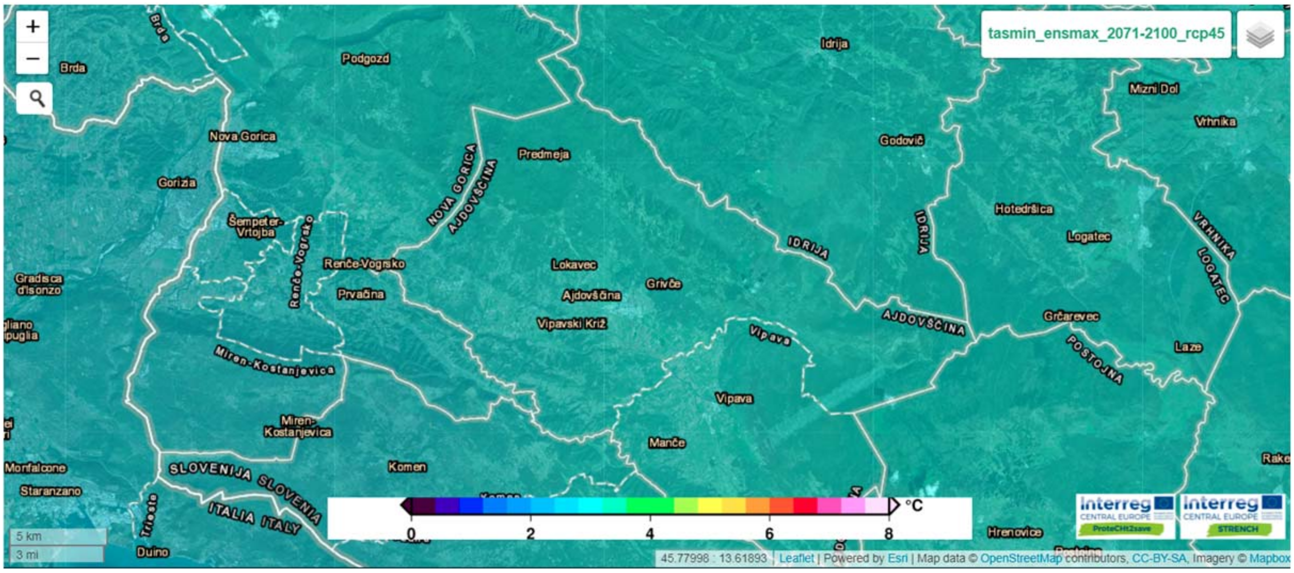
Map: Historical observations: tn_1951-2016_eobs_hist



Map: Model ensemble statistics: Mean / near future / RCP 4.5: tasmin_ensmax_2021-2050_rcp45



Map: Model ensemble statistics: Mean / far future / RCP 4.5: tasmin_ensmax_2071-2100_rcp45



The future projections show a decrease in daily minimum temperature in Vipava Valley in the near and far future.

7. Conclusions

Evaluation of STRENCH Web GIS tool focused on topics tackled in Vipavska Valley pilot site. Due to the scale available in the Web GIS tool, UIRS evaluated the whole Vipava Valley. Evaluation considered extreme events heavy rain, flooding, and climate change variables. In the evaluation of the WGT tool, we collected maps of the area with past (1951–2016), near future (2021–2050), and far future (2071–2100) projections (Model ensemble statistics / Maximum / RCP 4.5).

We found that the robust visualization tool of the WGT tool is better suited for comparison of past with future scenarios than raw datasets.

The goal of this evaluation was to get an overview of the potential risk of floods on cultural heritage in Vipava Valley.

- Heavy rain will remain to be a problem for the protection of cultural heritage sites. The projection for index R20mm shows that the number of days in a year with precipitation larger or equal to 20 mm/day will increase. That means a potential of flash floods, erosion, etc. Near and far future projections show an increase for index R95pTOT values. That also calls for attention regarding the protection of cultural heritage.

- Flooding is an issue for Vipavska Valley for centuries, hence quite well tackled in strategies and on the field. It was interesting to evaluate STRENCH future projections. The near and far future projections for index Rx5day show a slight decrease of a yearly maximum of cumulated precipitation over consecutive 5 day periods.

- Climate variables daily minimum and maximum temperature and daily-cumulated precipitation were also evaluated. The future projections show an increase of daily-cumulated precipitation in Vipava Valley in the near and far future. The future projections show a decrease of daily maximum and minimum temperature in the near and far future.

Results of The STRENCH WebGIS tool evaluation showed that it can be interesting for analysing climate change effects on cultural heritage.