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European Union European Regional Development Fund

STRENCH

DELIVERABLE D.T2.2.2

Testing of the WebGIS tool for hamlets 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 ruined hamlets 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:

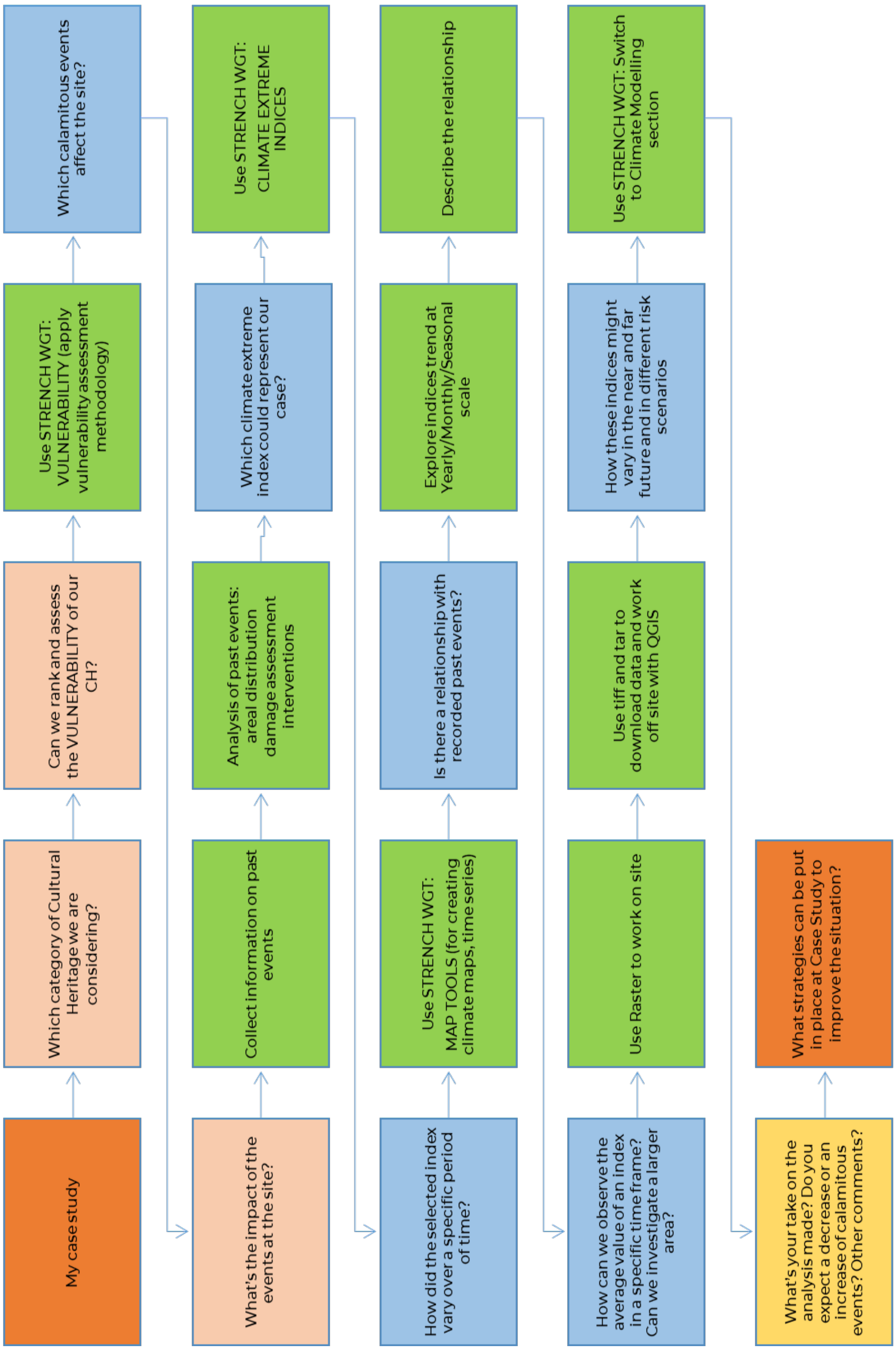


Figure 1. Scheme of the proposed methodology for testing the WebGIS Tool

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 ruined hamlets 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 ruined hamlets (Troja Château, Franconian Switzerland, Kolici) 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.T2.2.2 Case studies Troja PP2 CZ
- Annex 2 - CE1665 STRENCH D.T2.2.2 Case studies Franconian Switzerland PP8 DE
- Annex 3 - CE1665 STRENCH D.T2.2.2 Case studies Kolici PP9 HR

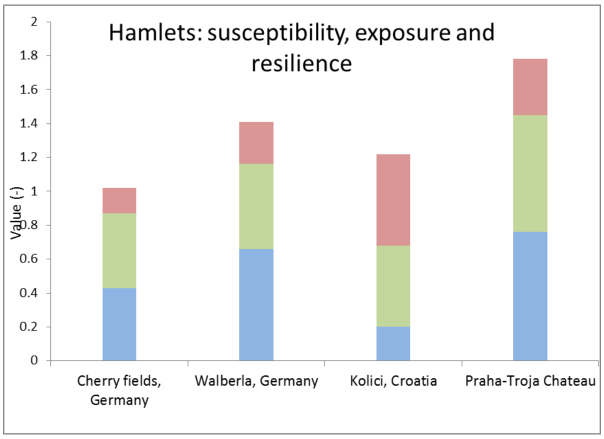
4 Assessing the vulnerability

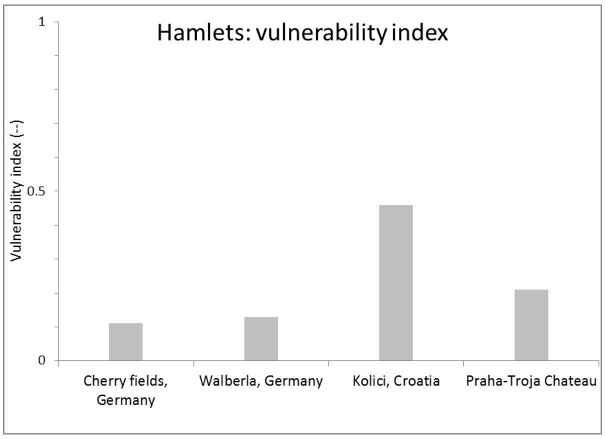
In this session is reported the work carried out by PPs for the assessment of the vulnerability at case studies as part of the Web GIS testing following the methodology developed in STRENCH (D.T1.2.2) and integrated in the WGT tools.

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 ruined (and not ruined) hamlets typology:

	Type	***Susceptibility***	***Exposure***	***Resilience***	***Vulnerability index***
Praha-Troja Chateau	Cultural landscape/hamlet/historic park	0.33	0.69	0.76	0.21
Cherry fields, Germany	Cultural landscape/ruins	0.16	0.44	0.43	0.11
Walberia, Germany	Cultural landscape/ruins	0.25	0.50	0.66	0.13
Kolici, Croatia	Ruined hamlet	0.54	0.48	0.20	0.46





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 ruined hamlet under investigation is reported as Annexes of the present Deliverable as follows:

Annex 4 - CE1665 STRENCH D.T2.2.2 Vulnerability ranking Troja PP2 CZ

Annex 5a - CE1665 STRENCH D.T2.2.2 Vulnerability ranking Cherry fields PP8 DE

Annex 5b - CE1665 STRENCH D.T2.2.2 Vulnerability ranking Walberla PP8 DE

Annex 6 - CE1665 STRENCH D.T2.2.2 Vulnerability ranking Kolici PP9 HR

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 ruined hamlet case studies.

4.1 Troja Château

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	Good	0
	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	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)	Absence of mature/veteran trees	0
	CR1.3a3 Slenderness ratio (Tree)	h/d < 70	0
	CR1.3b Grass/shrub cover	Presence of species not tolerant to local natural and climate threats	0.3
	CR1.3c Use	Intensive land-use with natural elements	0.3
	CR1.3d State of conservation	Good	0
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*	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= 0.33

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 II	0.86
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= 0.693

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	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 exists and up to date	1

RESILIENCE= 0.76

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.330) + (0.30x0.693) - (0.30x0.760) = 0.211

Vulnerability = 0.211

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

4.2 Forcheim District

- Cherry fields

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*	N/A	0
	CR1.2b Water features	N/A	0
	CR1.2c Circulation features	N/A	0
	CR1.2d State of conservation	N/A	0
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Prevalence of species not tolerant to local natural and climate threats	1
	CR1.3a2 Age (Tree)	Presence of some mature/veteran trees	0.3
	CR1.3a3 Slenderness ratio (Tree)	h/d < 70	0
	CR1.3b Grass/shrub cover	Presence of species not tolerant to local natural and climate threats	0.3
	CR1.3c Use	Intensive land-use with natural elements	0.3
	CR1.3d State of conservation	Good	0
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*	water table prone to sudden fluctuations	1
	CR1.6b Surface water	far from permanent, seasonal and man-made water course	0
	CR1.6c Sea	far from sea	0

SUSCEPTIBILITY=	**0.155**

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR2.1 Cultural significance	*CR2.1a Built systems and features*	absence of built systems and features	0
	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		population but no fragility	0.3
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		absence of relevant infrastructure	0

EXPOSURE=	**0.443**

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	lack of awareness	0.8
	CR3.1d Information	partial or complete info exist but not available	0.5
	CR3.1e Policy &regulation	ownership status issues	0.5
CR3.2Coping capacity	*CR3.2a Emergency resources*	Absence of emergency human and economic resources	0
	CR3.2b Mitigating systems/measures	Absence of mitigating systems	0
	CR3.2c Physical strengthening/protection	Absence of physical protection	0
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	no risk management plan	0

RESILIENCE=	**0.428**

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.155) + (0.30x0.443) - (0.30x0.428) = 0.113

Vulnerability = 0.113

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

- Walberia

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR1.1 Buildings	*CR1.1a Constructions & materials*	Structurally sound constructions made of resistant materials	0
	CR1.1b Use	Occasional use	0.4
	CR1.1c State of conservation	Good	0
	CR1.1d Previous harming interventions	Yes, previous interventions	1
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	N/A	0
	CR1.2b Water features	N/A	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 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	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 unstable bedrock	1
	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=	**0.252**

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		no population	0
CR2.3 Economic		livelihoods of local residents	0.5
CR2.4 Infrastructure		absence of relevant infrastructure	0

EXPOSURE= 0.5

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	lack of awareness	0.8
	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	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 not accessible	0.1
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	risk management plan without specific emergency measures	0.3

RESILIENCE= 0.655

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.252) + (0.30x0.500) - (0.30x0.655) = 0.130

Vulnerability = 0.130

With $0 \leq V \leq 1$ (low to high vulnerability).

4.3 Kolici

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	Abandoned	1
	CR1.1c State of conservation	Very bad	1
	CR1.1d Previous harming interventions	No interventions made	0
CR1.2Built/man-made features	*CR1.2a Built elements of decoration*	absence of elements of decoration	0
	CR1.2b Water features	absence of water features	0
	CR1.2c Circulation features	absence of circulation features	0
	CR1.2d State of conservation	Very bad	1
CR1.3 Vegetation	*CR1.3a1 Species (Tree)*	Prevalence of species not tolerant to local natural and climate threats	1
	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 not tolerant to local natural and climate threats	0.3
	CR1.3c Use	Extensive land-use	1
	CR1.3d State of conservation	Very bad	1
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	coarse-grained soil (sand, gravel)	0
	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= 0.54

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	None	0
CR2.2Population		no population	0
CR2.3 Economic		no economic value	0
CR2.4 Infrastructure		presence of relevant infrastructure	1

EXPOSURE= 0.48

CRITERIA	SUB-CRITERIA	VALUE MEANING	VALUE
CR3.1 Preparedness capacity	*CR3.1a Maintenance*	no maintenance	0
	CR3.1b Warning	absence of early warning systems	0
	CR3.1c Knowledge & awareness	lack of awareness	0.8
	CR3.1d Information	no info	0
	CR3.1e Policy &regulation	unclear responsibilities	0.3
CR3.2Coping capacity	*CR3.2a Emergency resources*	Absence of emergency human and economic resources	0
	CR3.2b Mitigating systems/measures	Absence of mitigating systems	0
	CR3.2c Physical strengthening/protection	Absence of physical protection	0
CR3.3 Restorative capacity	*CR3.3a Financial recovery*	no funds available	0
	CR3.3b Social recovery	Absence of social recovery plan	0
	CR3.3c Physical recovery	risk management plan exists and up to date	1

RESILIENCE= 0.203

Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.540) + (0.30x0.480) - (0.30x0.203) = 0.462

Vulnerability = 0.462

With $0 \leq V \leq 1$ (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 7 – CE1665 STRENCH D.T2.2.2 WebGIS-Testing Troja PP2 CZ

Annex 8 - CE1665 STRENCH D.T2.2.2 WebGIS-Testing Franconian Svitzerland PP8 DE

Annex 9 - CE1665 STRENCH D.T2.2.2 WebGIS-Testing Kolici PP9 HR

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.

STRENCH

STRENCH CASE STUDIES

ANNEX 1 - DELIVERABLE D.T2.2.2

TROJA HAMLET & DISTRICT

Version 1
03 2021

Name of PP(s): PP2 - ITAM
Ústav teoretické a aplikované Mechaniky Akademie věd České republiky
Institute of Theoretical and Applied Mechanics CAS

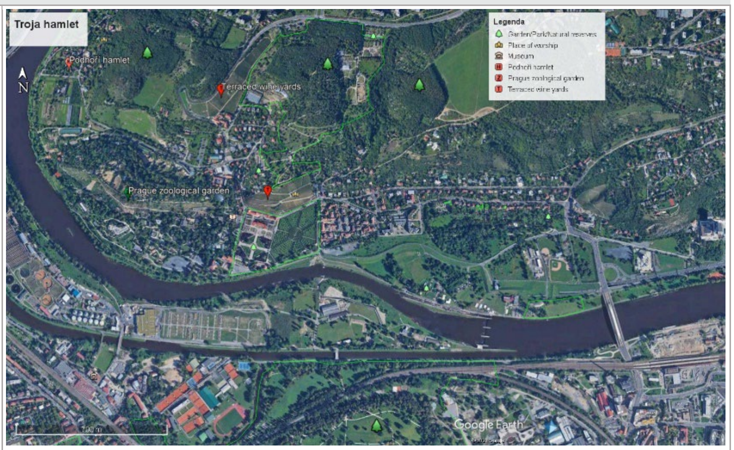
TROJA HAMLET

REGION	COUNTRY	EU ID	CITY	MUNICIPALITY
	Czech Republic	CZ	Prague	Troja

TYPOLOGY OF CULTURAL HERITAGE ASSETS	HAZARD TYPE
• Cultural landscapes (mainly terraced ones) • Hamlets in mountain areas • Historic parks	Flood Fire Windstorm

SITE LOCATION		
Geographical coordinates	Lat. 50.109666	Long. 14.408998

Troja hamlet is located in Prague's north-west borough and it lies in the proximity of the Vltava river.

Geographical positioning of the site (left) with delimitation of the area extension (right).

SITE DESCRIPTION

The Troja Valley features important natural and cultural heritage assets with millions of visitors yearly. One of the largest and oldest natural parks, "Stromovka" sprawls in the river meadow along with various Troja sport facilities mainly for wild water canoeing, football or softball fields, and with diverse public recreation amenities. The second largest historic complex in

Prague, the Baroque “Troja Château” with its gardens is situated in the vicinity of a protected hamlet of the historic fisherman village. The valley accommodates the Prague zoological and botanical gardens complemented with local art galleries. Steep slopes and cliffs skirt the valley. Some parts are cultivated with historic vineyards, some are covered with original herbs and plants and protected as natural reserves.

TYPOLOGY OF CULTURAL HERITAGE ASSETS

Cultural heritage assets include one of the most significant examples of the 17th century Bohemian palace in Baroque style surrounded by an extensive French garden decorated with terracotta vases, stucco prospects and orangeries with busts of imperators. Protected Cultural Heritage Monuments include Troja Mill, Troja Brewery, wine-yard homesteads, chateau farm, Vernacular Heritage Zone (Fisherman village). Besides the architectural heritage – the historic buildings, structures, walls and sculptures – moveable heritage in galleries as well as in private collections or in homes are also endangered. In regard to the landscape, the biological cover – mainly isolated trees – and exposed slopes are at risk.


Troja Chateau garden façade (left) and during wine harvest festival in 2019 (right)


Troja Mill and Troja Brewery in 1940 (left). Chateau farm after reconstruction in 2020 (right)

MAIN RISKS IMPACTING THE SITE

Proximity to the Vltava river.

Frequent high water level situations with major flooding are the main natural risks threatening the cultural heritage of the site along with the large numbers of visitors. Minor risks include local flash floods intensified with insufficient capacity of the rain drainage system, harsh weather situations with drought, strong winds and temperature fluctuations.

Historical constructions and their contents are mostly made of porous material with is highly susceptible to floods; building components as well as natural heritage is vulnerable to dynamic and static forces, flowing objects, moisture degradation of materials and biological colonisation.

Lack of specific management plan for cultural heritage risks in particular maintenance schemes.

Structural and architectonic elements typical of the Baroque period, in particular roofs and spires, are particularly prone to vibration included during windstorm.

Flash flood in August 2020 – transported stones from terraced slopes -

River flood in the year 2002 in the Chateau Troja garden (left), in the year 2021 in the Vltava valey.

RECORDED PAST EVENTS

Flood

- August 2002, Vltava and Labe (Elbe) rivers flood in Prague. Erosion, hydrostatic and debris actions were identified as principal flood actions on structures; in most cases combinations of the flood actions occurred. Main causes of structural damage included geotechnical aspects, inadequate structural properties, and insufficient communication among responsible authorities.

ADOPTED MEASURES

- Presence of a mobile flood barrier which protects only specific areas along the river.
- Creation of a flood warning system and local crisis management unit.

POINTS TO BE ADDRESSED AT LOCAL LEVEL

- Managerial issues such as planning, communication and awareness raising for local community.
- Implementation of local maintenace schemes to increase the resilience of cultural heritage assets with respect to flood, fire and wind hazards.

SUPPLEMENTARY MATERIAL

Regional/Local Strategies/Plans for the protection of Cultural Heritage

- Strategies for adaptation to climate change in the conditions of the Czech Republic: the document presents the national adaptation strategy of the Czech Republic, which, in addition to assessing the likely impacts of climate change, contains proposals for specific adaptation measures, legislative and partial economic analysis, etc. https://www.mzp.cz/cz/zmena_klimatu_adaptacni_strategie
- The concept of solving the problem of flood protection in the Czech Republic using technical and nature-friendly measures: the objective of the Concept is to assess and manage flood risks in accordance with Directive 2007/60 / EC and in accordance with the objectives of Directive 2000/60 / EC regarding the sustainable development of society and the interests of nature and landscape protection. http://eagri.cz/public/web/mze/ministerstvo-zemedelstvi/koncepce-a-strategie/koncepce-reseni-problematiky-ochrany.html
- Methodical instruction of the Ministry of Culture on fire risk assessment of monuments and determination of the minimum standard of fire protection for immovable monuments. https://www.mkcr.cz/doc/cms_library/metodicky-pokyn-ochrana-pamatek-4971.docx

Regional/Local Web GIS Platforms for Hazard/Risk assessment

- Flood risk map: map of flood danger and flood risks for the 2nd planning period 2021 - 2027 according to the European directive on the assessment and management of flood risks
  https://cds.mzp.cz/
- ELECTRONIC DIGITAL FLOOD PORTAL: focused on flood prevention, management and instructions for processing digital flood plans of individual municipalities, cities, ORP and regions, as well as a catalog of products and services focused on flood protection, expert articles and discussions about the issue.
  https://www.edpp.cz/online-povodnova-mapa-cr/

Regional/Local Maps for Hazard/Risk assessment including cultural/natural heritage

Online maps of inundation during various flood situations are available on the portal https://www.edpp.cz/online-povodnova-mapa-cr/ . The maps have layers for the flood danger of Q5, Q20 and Q100 equivalents. The map is related to the orthophoto maps in which the architectural heritage objects are presented. No specific hazard/risk map with cultural heritage description is available.

3D Models for risk management

Physical 3D model was elaborated to assess the flow of flood waters in the Troja basin.

3D model of the capital City of Prague - terrain and buildings is available at

http://en.iprpraha.cz/clanek/1437/explore-prague-with-a-new-3d-model-application

Videos/Virtual tour
n.a.
Photographic archives
Prague geographic data including for example Archive of Prague's Orthophotomaps available on https://www.geoportalpraha.cz/en More photographs of Troja District and from flood events available on the web site of the Municipal District Praha-Troja, www.mctroja.cz and in the Digital Archive at the Municipal District office
App
n.a.
Time Series
n.a.
Other
n.a.

STRENCH CASE STUDIES

ANNEX 2 – DELIVERABLE D.T2.2.2

FRANCONIAN SWITZERLAND

Version 1
05 2021

Name of PP(s): PP8 – LRA FO
Landkreis Forchheim
District Council Forchheim

FRANCONIAN SWITZERLAND

REGION	COUNTRY	EU ID	CITY	MUNICIPALITY
Bavaria	Germany	DE		

CULTURAL HERITAGE CATEGORY	HAZARD TYPE
• Cultural landscapes (fruit growing) • Hamlets	Flood Drought Temperature variation due to climate change

SITE LOCATION		
Centroid geographical coordinates (WGS84)	Lat. 49.719722	Long. 11.058056

The District of Forchheim (DoF) is located at the northern part of Bavaria, Germany, and is part of the Nuremberg metropolitan region. The DoF comprises parts of the scenic nature park "Fränkische Schweiz" (Franconian Switzerland) and has a long settlement history.

Geographical positioning of the site (left) with delimitation of the area extension (right).

SITE DESCRIPTION

The Forcheim district (northern Bavaria) comprises parts of the natural park Fränkische Schweiz (Franconian Switzerland), which is part of the low mountain range Fränkische Alp (Franconian Alp) and has a long settlement history. Franconian Switzerland is an upland in Upper Franconia, Bavaria and it comprises almost 30 municipalities with several hamlets and touristic areas. Consequently, the Franconian Switzerland covers cultural heritage and natural heritages such as a characteristic mountain and hilly cultural landscape with a high density of castles and ruins, striking rock formations and caves, deep valleys formed by rivers and old architectures. The cultural heritage assets include hamlets with half-timbered houses or mills at rural areas and natural, typical cultural landscapes with fruit growing areas in particular cherry plants.

TYPOLOGY OF CULTURAL HERITAGE ASSETS

Within the STRENCH project the DoF aims to strengthen the resilience of its unique cultural landscape with a special focus on fruit growing and hamlets in mountain areas. Thereby, the competences of the DoF lie in the regional planning and development.

Elements of the unique cultural landcape in the Forchheim district are for example ruins in mountainous areas (left) and fruit growing areas (right)

The “Walberla”, a characteristic mountain in the DoF, is a well-known cultural and natural heritage site with a settlement history from the Stone Age to the Middle Ages.

MAIN RISKS IMPACTING THE SITE

Natural and climate related hazards, particularly drought, heat, pluvial and flash floods, storm events, late frost events, fire and pests strongly affect the unique cultural landscape covering the District of Forchheim.

The cultural landscapes are facing more frequent and more unpredictable water floods especially in the valleys (river systems e.g., river Wiesent, Trubach, Leinleiter, Ehrenbach etc.) at mountain areas.

Agriculture, especially cherry cultivation, is facing water drought damage and temperature fluctuations.

Next to heat and drought, floods pose a major risk to the valleys in the district of Forchheim. The sceneric valleys (left) can turn into severely damaged floodplains (right).

RECORDED PAST EVENTS

Flood

- 1920s to 1960s, local flooding in Forchheim district with infrastructure and agriculture damages.
- 2007, heavy rain, thunder, flash flood in Forcheim district with infrastructure damages.

Drought

- 1930s to 1950s, drought in Forcheim district with harvest damages.

Low temperature

- 2000s, frost temperature in Forcheim district with harvest damages.

ADOPTED MEASURES

- Possible rivers re-naturalisation – building costs at reservoir pools.

- Physical resilience e.g., temperature at cherry growing plants: frost control, new water reservoir and distribution systems.

POINTS TO BE ADDRESSED AT LOCAL LEVEL

- Managerial weakness: NIMBY problem (not in my backyard/municipality).
- Better forecast and control system, better coordination of building and construction.

SUPPLEMENTARY MATERIAL

Regional/Local Strategies/Plans for the protection of Cultural Heritage

- Katastrophenschutzplan: management plan and coordination in case of natural or cultural catastrophe/emergency at the Forchheim district.

Regional/Local Web GIS Platforms for Hazard/Risk assessment

- FIN-Web: The Bavarian State Environmental Office provides various spatial environmental data. For certain user groups such as authorities, municipalities, landscape and nature conservation associations additional topics can be activated.
  https://www.lfu.bayern.de/natur/fis_natur/fin_web/index.htm
- CEDIM Risk Explorer Germany: maps that present the results of the CEDIM project "Riskmap Germany" including natural (winter storm, earthquake, flood) and man-made hazards, vulnerability, and risk as well as assets.
  http://cedim.gfz-potsdam.de/riskexplorer/#
- GIS ImmoRisk Naturgefahren: online GIS tool provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development. The map shows natural hazards at national level such as heavy rainfall, winter storms, forest fires, earthquakes, and heat as well as - depending on the availability of databases - a qualitative or quantitative assessment of climate risks.
  https://www.gisimmorisknaturgefahren.de/immorisk.html
- UmweltAtlas Bayern: the Bavarian State Environmental Office provides various spatial environmental data concerning different thematic areas (geological hazards, hydrology, protected areas, floods, past events etc.).
  https://www.lfu.bayern.de/umweltdaten/kartendienste/umweltatlas/index.htm
- BayernAtlas: maps concerning different thematic areas as environmental data and natural hazards.
  https://geoportal.bayern.de/bayernatlas/mobile.html?lang=de&topic=nage&bgLayer=atkis&catalogNodes=1&layers=5d4af972-fa72-48e0-a8c1-55d0782e540a,1ccf59af-de93-481b-ba48-f09a5f140fca&layers_visibility=false,false
- Hochwassernachrichtendienst Bayern: measure of river water for the prevention of floods.
  https://www.hnd.bayern.de/pegel/meldestufen
- Drought monitoring: map of drought index in Germany.
  https://www.ufz.de/index.php?de=37937
- Deutscher Wetterdienst: measure of climate indicators
  https://www.dwd.de/DE/wetter/warnungen_gemeinden/warnWetter_node.html

- Map of erosivity of rain events. https://hess.copernicus.org/articles/23/1819/2019/

Regional/Local Maps for Hazard/Risk assessment including cultural/natural heritage

- Denkmal-Atlas: The Bavarian Monument Atlas is the online version of the Bavarian Monument List - always up-to-date and accessible to everyone. Based on official maps and aerial photographs from the Bavarian survey authority, the atlas provides information on the current status of monuments, sites and ensembles throughout Bavaria. In combination with the above-mentioned Web-GIS platforms a hazard/risk assessment can be conducted. https://geoportal.bayern.de/denkmalatlas/

3D Models for risk management

Videos/Virtual tour

Photographic archives

App

Time Series

Other

STRENCH CASE STUDIES

ANNEX 3 – DELIVERABLE D.T2.2.2

KOLIĆI

Version 1
05 2021

Name of PP(s): PP9 - MoD
Općina Dugopolje
Municipality of Dugopolje

KOLIĆI

REGION	COUNTRY	EU ID	CITY	MUNICIPALITY
Split-Dalmatia	Croatia	HR		Dugopolje

CULTURAL HERITAGE CATEGORY	HAZARD TYPE
• Hamlet in mountain area	• Fire • Landslides

SITE LOCATION

Centroid geographical coordinates	Lat. 43.60301,	Long. 16.58136

Kolići is located on a hilly terrain in karst area on the northern side of the Mosor mountain. Vegetation is Mediterranean: maquis and garrigue. Geological structure is based on limestones and dolomites. Red soil and Mediterranean vegetation are the basis for agricultural production and livestock.

Geographical positioning of the site (left) with delimitation of the area extension (right): Opcina_Dugopolje (area delimited by red line) and Kolici Granica (area delimited by yellow line).

SITE DESCRIPTION

Kolići is a hamlet situated on the northeast side of the Mosor mountain, which represents a natural barrier to the Adriatic coast. There is evidence that proves that hamlet was populated in acient Roman times, which is seen in Roman pathways and Roman gardens (Grubuša). There is a great stagnation of population in Kolići recorded within the last century, following a tendency to reside in more developed areas, mostly in wider urban area of the city of Split. However, the traditional houses are still preserved and represent an excellent example of autochthonous Dalmatian architecture. Each summer the area is under a threat of devastating fires quick to get a great magnitude due to the impact of winds, droughts and vegetation that is easy to burn.

TYPOLOGY OF CULTURAL HERITAGE ASSETS

Kolići is a hamlet in mountainous area with an example of preserved traditional Dalmatian village mostly made of stone material. In its surrounding, local cultural heritage (prehistoric mounds along the ancient road as well as a ruined medieval settlement) are present. There are two antique pathways dating to 1st century AD, out of which one (Kolići-Podi) is registered as protected cultural heritage of the Republic of Croatia.

The photo shows traditionally built residential and commercial buildings that were used to engage in agricultural and livestock activities common to this area.

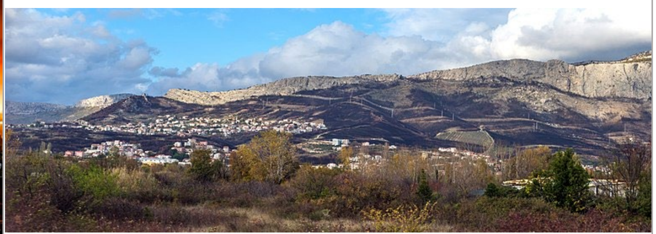
The buildings are built of lime-bound stone, while the stone fences are built using the drywall technique, which has been recognized and protected by UNESCO on the World Intangible

Heritage List. Due to poor housing conditions and underdevelopment, the environment around houses and outbuildings was often not paved.

MAIN RISKS IMPACTING THE SITE

Due to its position in the Mediterranean area, Kolići hamlet is threatened by a high risk of drought and forest fires also increased by climate change; moreover, the site is surrounded by a particularly vulnerable and easily burning vegetation.

Geomorphologically, the site is located in a sensitive karst area. Being on a slope, it is also endangered by the slope processes as landslides.



One of the largest fires in Croatian history broke out on July 17, 2017 and with the extraordinary efforts of firefighters, the army and volunteers was brought under control two days later. The fire front was 10 kilometres long and 2 kilometres wide, and stretched on the southern slope of Mosor and Perun Hills, while the Kolići location is on the northern slope of Mosor. The combination of high temperature, wind and easily flammable vegetation resulted in the rapid spread of the fire.

At the beginning of December 2020, heavy rain caused floods in the area of Dugopolje, but also in the rest of the Dalmatia region. There is a lot of groundwater in this area, so during heavy rains, springs are activated that flood the fields. The average rainfall in central Dalmatia, where the project site is located, for the month of December is 100.6 mm per square meter, while in 24 hours on December 9, 2020, 306 liters of rain per square meter fell in Dugopolje. Tests have shown that water from this area affects the source of "Jadro", which is a source of drinking water that supplies almost all of central Dalmatia and the islands.

RECORDED PAST EVENTS

Fire

- 17/07/2017, fire in Split-Dalmatia country that covered an area of 4,500 ha in the vicinity of the city of Split in 2017, great material damage was recorded in the Split area. It was one of the biggest fires in Croatian history. The fire destroyed small villages on the slopes of Mount Perun, as well as large areas of the cultural landscape that includes dry stone walls, olive groves and vineyards that form typical Dalmatian landscape.

Floods

- 08/12/2020, heavy rainfall was caused by a Mediterranean cyclone. Low air pressure caused sea levels to rise, and southerly winds brought plenty of rain that fell non-stop for three days in a row. This caused flooding and activated landslides throughout Dalmatia. In addition, there has been an increase in the level of rivers in the region, especially the Neretva river, whose mouth is located in a low delta in which there are several settlements, which were flooded.

ADOPTED MEASURES

- Since Kolići hamlet is mainly made of stone material, it has a certain resistance to natural and human disasters. Historical sites located near the hamlet are recognized and protected by the Spatial plan of the Municipality of Dugopolje which represents the strength of the site in terms of management and protection.

POINTS TO BE ADDRESSED AT LOCAL LEVEL

The issue of conservation and management of cultural heritage is endangered by the consequences of climate change that are particularly expressed in the Mediterranean area. For this reason, it must be emphasized the importance of:

- setting up of monitoring and evaluation methodology of the risk management,

- the coordination of stakeholders involved in the decision making for cultural heritage protection,
- mapping and management of the pilot site in conditions of natural risks,
- strengthen the capacity of the public and private sectors in mitigating the impact of climate change and natural risks on cultural heritage,
- raising the level of awareness and knowledge about the process of cultural heritage protection.

SUPPLEMENTARY MATERIAL

Regional/Local Strategies/Plans for the protection of Cultural Heritage

- Disaster and major accident risk assessments for the Split-Dalmatia County: the document refers to the organization of civil protection as a system of organizing participants, operational forces, and citizens to achieve the protection and rescue of people, material and cultural goods and the environment at risk and under the influence of disasters (windstorm, fire due to drought, flash flood). https://webcache.googleusercontent.com/search?q=cache:Rjce8HIF8KoJ:https://www.dalmacija.hr/DesktopModules/EasyDNNNews/DocumentDownload.ashx%3Fportalid%3D0%26moduleid%3D1766%26articleid%3D21131%26documentid%3D6670+&cd=1&hl=en&ct=clnk&gl=hr

- Civil Protection Action Plan of the Municipality of Dugopolje: Civil Protection Action Plan of the Municipality of Dugopolje provides a description of the area of the Municipality of Dugopolje from the aspect of vulnerability to natural risks, as well as an action plan in a case of disasters. https://dugopolje.hr/dokumenti/sluzbeni-vjesnik-opcine-dugopolje-12-2019/

- Master plan for tourism development of Split-Dalmatia County (2017-2027) with strategic and operational plan: the main goal of the Master plan is to define the strategic and operational concept of tourism development according to the principles of sustainable development. The emphasis is on the development of cultural tourism which is enabled by wealth and diversity cultural heritage in the County. The need for effective cultural management is also emphasized, however, the strategy does not define the approach and manner of the management. https://www.dalmatia.hr/hr/priopcenja/glavni-plan-razvoja-turizma-splitsko-dalmatinske-zupanije

- Spatial plan of the municipality of Dugopolje: the spatial plan does not strictly define the cultural heritage management plan, but there are defined measures for the preservation, protection, arrangement and use of cultural property in the Municipality. It is stated that the cultural goods recorded in this plan must be included in a professionally acceptable manner in future development of the Municipality and the County. Although the cultural assets management plan itself is not defined by this document, the process of protection and preservation of cultural property is, as one segment of management, in detail prescribed by the spatial plan. https://dugopolje.hr/wp-content/uploads/2009/01/PPUO_-Dugopolje_prosinac_2004.pdf

Regional/Local Web GIS Platforms for Hazard/Risk assessment

- Interactive map of fire risks and vulnerability, regional scale (Kvarner, North and South Dalmatia): the map contains layers of fire risk and vulnerability, impact on transport infrastructure, proposed measures to reduce fire risk and control, land and vegetation characteristics, transport infrastructure, information relevant to the civil protection system. Source project: Copernicus.
- Interactive map of fire risks and vulnerabilities: the map contains layers of fire risk and vulnerability, impact on transport infrastructure, proposed measures to reduce fire risk and control, land and vegetation characteristics, transport infrastructure, information relevant to the civil protection system. https://hukm.maps.arcgis.com/apps/View/index.html?appid=b8905fa20a2a454c8d66c70537d26ed4

Regional/Local Maps for Hazard/Risk assessment including cultural/natural heritage

- Flood hazard map for low, medium, and high probability of occurrence, national scale: the maps show the possibility of developing three flood scenarios; they were prepared within the Flood Risk Management Plan in accordance with the provisions of Articles 111 and 112 of the Water Act of the Republic of Croatia. Paid service, source project: IPA 2010 Twinning.
- Preliminary erosion risk assessment: a preliminary erosion risk assessment was made in the framework of the Preliminary Flood Risk Assessment. The areas at risk of erosion are located in the Adriatic river basin district, to which the Municipality of Dugopolje belongs. About 40% of the territory of the Republic of Croatia is estimated to have a high and moderate risk of erosion, of which slightly more than 50% is located in the Adriatic river basin district. Paid service, source project: IPA 2010 Twinning.
- Extreme temperature, earthquake, forest fire, drought, landslide risk assessment: it was prepared in the framework of the Disaster Risk Assessment for the Republic of Croatia. https://civilna-zastita.gov.hr/UserDocsImages/CIVILNA%20ZA%C5%A0TITA/PDF_ZA%20WEB/Procjena_rizika%20od%20katastrofa_2019.pdf

3D Models for risk management

n.a.

Videos/Virtual tour

n.a.

Photographic archives

n.a.
App
n.a.
Time Series
n.a.
Other
n.a.

VULNERABILITY EVALUATION

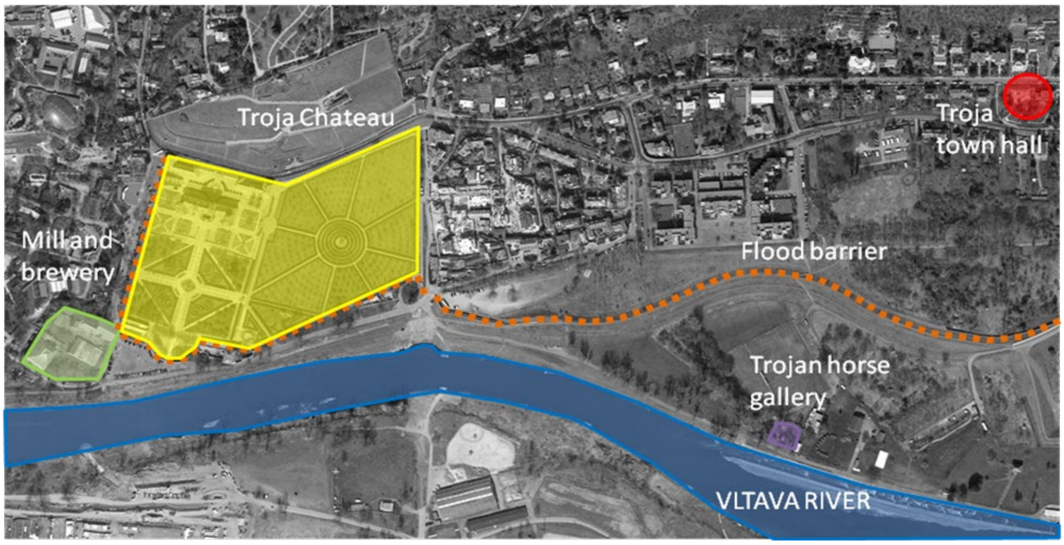
PRAHA-TROJA, CZECH REPUBLIC

Annex 4 - D.T2.2.2

Final
12 2021

Authors: Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences (PP2).

1. PRAHA-TROJA CHÂTEAU



1.1. Evaluation of susceptibility (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
		SUSCEPTIBILTY (RQ1)	
CR1.1a	Construction & materials	Structurally sound constructions made of materials prone to degradation or impact damage	0.50
CR1.1b	Use	In continuous use	0.10
CR1.1c	State of conservation	Good	0.00
CR1.1d	Previous harming interventions	Yes, previous interventions	1.00
CR1.2a	Built elements of decoration	Presence of elements of decoration	1.00
CR1.2b	Water features	Presence of water features	1.00
CR1.2c	Circulation features	Presence of circulation features	1.00
CR1.2d	State of conservation	Fair	0.18
CR1.3a1	Species	Presence of species tolerant to local natural and climate threats	0.00
CR1.3a2	Age	Absence of mature/veteran trees	0.00
CR1.3a3	Slenderness ratio	h/d < 70	0.00
CR1.3b	Grass/shrub cover	Presence of species not tolerant to local natural and climate threats	0.30
CR 1.3c	Use	Intensive land-use with natural elements	0.30
CR 1.3d	State of conservation	Good	0.00
CR1.4	Topography	Stable slopes with inclination less than 15 degrees	0.15
CR1.5a	Bedrock	Presence of stable bedrock	0.00
CR1.5b	Soil	Coarse-grained soil (sand, gravel)	0.00
CR1.5c	Geomorphology	Presence of stable geological formation	0.00
CR1.6a	Groundwater	Water table prone to sudden fluctuations	1.00
CR1.6b	Surface water	Close to permanent, seasonal and man-made water course	1.00
CR1.6c	Sea	Far from sea	0.00

From the weight assignment in section 7.1, it is known that:

Susceptibility= (0.20xBuildings) + (0.15x Built/manmade features) + (0.35 x Vegetation) + (0.10x Topography) + (0.10x Geosphere) + (0.10 x Hydrosphere)

→ **Susceptibility = 0.330**

1.2. Evaluation of exposure (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
EXPOSURE (RQ2)			
CR2.1a	Built systems and features	Presence of built systems and features	1.00
CR2.1b	Natural systems and biodiversity	Presence of natural systems and features with low/medium value for biodiversity	0.50
CR2.1c	Cultural traditions	Presence of cultural traditions	1.00
CR2.1d	Cultural acknowledgements	Grade II	0.86
CR2.2	Population	Population but no fragility	0.30
CR2.3	Economic	Livelihoods of local residents	0.50
CR2.4	Infrastructure	Presence of relevant infrastructure	1.00

From the weight assignment in section 7.1, it is known that:

Exposure= (0.40xCultural significance) + (0.20x Population) + (0.20x Economic) + (0.20x Infrastructure)

→ **Exposure = 0.693**

1.3. Evaluation of resilience (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
RESILIENCE (RQ3)			
CR3.1a	Maintenance	Irregular maintenance	0.50
CR3.1b	Warning	Presence of early warning systems	1.00
CR3.1c	Knowledge and awareness	Knowledge and awareness ensured	1.00
CR3.1d	Information	Partial or complete info exist but not available	0.50
CR3.1e	Policy and regulation	Regulated CH protection	1.00
CR3.2a	Emergency resources	Existence of emergency human and economic resources	1.00
CR3.2b	Mitigating systems/measures	Existence of mitigating system	1.00
CR3.2c	Physical strengthening/protection	Existence of physical protection	1.00
CR3.3a	Financial recovery	Funds available but insufficient	0.30
CR3.3b	Social recovery	Absence of social recovery plan	0.00
CR3.3c	Physical recovery	Risk management plan exists and up to date	1.00

From the weight assignment in section 7.1, it is known that:

Resilience= (0.50xPreparedness capacity) + (0.25xCoping capacity) + (0.25xRestorative capacity)

→ **Resilience = 0.760**

1.4. Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.330) + (0.30x0.693) - (0.30x0.760) = 0.211

For the case study analysed:

Vulnerability = 0.211

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

VULNERABILITY EVALUATION
FRANCONIAN SWITZERLAND, GERMANY

Annex 5a - D.T2.2.2 | **Final**
12 2020

Authors: District Council Forchheim (PP8)

1. CHERRY FIELDS

1. CHERRY FIELDS

Values are assigned to the lowest level in the requirement tree, i.e. either criteria or sub-criteria, whichever is available for a specific criterion analysed.

1.1. Evaluation of susceptibility (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
SUSCEPTIBILTY (RQ1)			
CR1.3a1	Species	Prevalence of species not tolerant to local natural and climate threats	1.00
CR1.3a2	Age	Presence of some mature/veteran trees	0.30
CR1.3a3	Slenderness ratio	h/d < 70	0.00
CR1.3b	Grass/shrub cover	Presence of species not tolerant to local natural and climate threats	0.30
CR 1.3c	Use	Intensive land-use with natural elements	0.30
CR1.3d	State of conservation	Good	0.00
CR1.4	Topography	Stable slopes with inclination less than 15 degrees	0.15
CR1.5a	Bedrock	Presence of stable bedrock	0.00
CR1.5b	Soil	Fine-grained soil (silt, clay)	0.30
CR1.5c	Geomorphology	Presence of stable geological formation	0.00
CR1.6a	Groundwater	Water table prone to sudden fluctuations	1.00
CR1.6b	Surface water	Far from permanent, seasonal and man-made water course	0.00

From the weight assignment in section 7.1, it is known that:

Susceptibility= (0.20xBuilding and structures) + (0.15 x Built/man-made features) + (0.35xVegetation) + (0.10x Topography) + (0.10x Geosphere) + (0.10 x Hydrosphere)

→ **Susceptibility = 0.155**

1.2. Evaluation of exposure (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
EXPOSURE (RQ2)			
CR2.1a	Built systems and features	Absence of built systems and features	0.00
CR2.1b	Natural systems and biodiversity	Presence of natural systems and features with high value for biodiversity	1.00
CR2.1c	Cultural traditions	Presence of cultural traditions	1.00
CR2.1d	Cultural acknowledgements (to be adjusted according to the national adopted scale)	Grade II	0.86
CR2.2	Population	Population but no fragility	0.30
CR2.3	Economic	Livelihoods of local residents	0.50
CR2.4	Infrastructure	Absence of relevant infrastructure	0.00

From the weight assignment in section 7.1, it is known that:

Exposure= (0.40xCultural significance) + (0.20x Population) + (0.20x Economic) + (0.20x Infrastructure)

→ **Exposure = 0.443**

1.3. Evaluation of resilience (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
		RESILIENCE (RQ3)	
CR3.1a	Maintenance	Regular maintenance	1.00
CR3.1b	Warning	Presence of early warning systems	1.00
CR3.1c	Knowledge and awareness	Lack of awareness	0.80
CR3.1d	Information	Partial or complete info exist but not available	0.50
CR3.1e	Policy and regulation	Ownership status issues	0.50
CR3.2a	Emergency resources	Absence of emergency human and economic resources	0.00
CR3.2b	Mitigating systems/measures	Absence of mitigating systems	0.00
CR3.2c	Physical strengthening/protection	Absence of physical protection	0.00
CR3.3a	Financial recovery	Funds available but insufficient	0.30
CR3.3b	Social recovery	Absence of social recovery plan	0.00
CR3.3c	Physical recovery	No risk management plan	0.00

From the weight assignment in section 7.1, it is known that:

Resilience= (0.50xPreparedness capacity) + (0.25xCoping capacity) + (0.25xRestorative capacity)

→ **Resilience = 0.428**

1.4. Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.155) + (0.30x0.443) - (0.30x0.428) = 0.113

For the case study analysed:

Vulnerability = 0.113

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

VULNERABILITY EVALUATION
FRANCONIAN SWITZERLAND, GERMANY

Annex 5b - D.T2.2.2

Final
12 2021

Authors: District Council Forchheim (PP8)

2. WALBERLA

2. WALBERLA

Values are assigned to the lowest level in the requirement tree, i.e. either criteria or sub-criteria, whichever is available for a specific criterion analysed.

2.1. Evaluation of susceptibility (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
SUSCEPTIBILTY (RQ1)			
CR1.1a	Constructions & materials	Structurally sound constructions made of resistant materials	0.00
CR1.1b	Use	Occasional use	0.40
CR1.1c	State of conservation	Good	0.00
CR1.1d	Previous harming interventions	Yes, previous interventions	1.00
CR1.2c	Circulation features	Presence of circulation features	1.00
CR1.2d	State of conservation	Fair	0.18
CR1.3a1	Species	Presence of species tolerant to local natural and climate threats	0.00
CR1.3a2	Age	Absence of mature/veteran trees	0.00
CR1.3a3	Slenderness ratio	h/d < 70	0.00
CR1.3b	Grass/shrub cover	Presence of species tolerant to local natural and climate threats	0.00
CR 1.3c	Use	Extensive land-use	1.00
CR1.3d	State of conservation	Fair	0.18
CR1.4	Topography	Stable slopes with inclination less than 15 degrees	0.15
CR1.5a	Bedrock	Presence of unstable bedrock	1.00
CR1.5b	Soil	Fine-grained soil (silt, clay)	0.30
CR1.5c	Geomorphology	Presence of stable geological formation	0.00
CR1.6a	Groundwater	Stable water table	0.00
CR1.6b	Surface water	Far from permanent, seasonal and man-made water	0.00

From the weight assignment in section 7.1, it is known that:

Susceptibility= (0.20xBuilding and structures) + (0.15 x Built/man-made features) + (0.35xVegetation) + (0.10x Topography) + (0.10x Geosphere) + (0.10 x Hydrosphere)

→ **Susceptibility = 0.252**

2.2. Evaluation of exposure (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
EXPOSURE (RQ2)			
CR2.1a	Built systems and features	Presence of built systems and features	1.00
CR2.1b	Natural systems and biodiversity	Presence of natural systems and features with high value for biodiversity	1.00
CR2.1c	Cultural traditions	Presence of cultural traditions	1.00
CR2.1d	Cultural acknowledgements (to be adjusted according to the national adopted scale)	Grade I	1.00
CR2.2	Population	No population	0.00
CR2.3	Economic	Livelihoods of local residents	0.50
CR2.4	Infrastructure	Absence of relevant infrastructure	0.00

From the weight assignment in section 7.1, it is known that:

Exposure= (0.40xCultural significance) + (0.20x Population) + (0.20x Economic) + (0.20x Infrastructure)

→ **Exposure = 0.500**

2.3. Evaluation of resilience (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
		RESILIENCE (RQ3)	
CR3.1a	Maintenance	Regular maintenance	1.00
CR3.1b	Warning	Presence of early warning systems	1.00
CR3.1c	Knowledge and awareness	Lack of awareness	0.80
CR3.1d	Information	Partial or complete info exist but not available	0.50
CR3.1e	Policy and regulation	Regulated CH protection	1.00
CR3.2a	Emergency resources	Existence of emergency human and economic resources	1.00
CR3.2b	Mitigating systems/measures	Absence of mitigating system	0.00
CR3.2c	Physical strengthening/protection	Existence of physical protection	1.00
CR3.3a	Financial recovery	Funds available but not accessible	0.10
CR3.3b	Social recovery	Absence of social recovery plan	0.00
CR3.3c	Physical recovery	Risk management plan without specific emergency measures	0.30

From the weight assignment in section 7.1, it is known that:

Resilience= (0.50xPreparedness capacity) + (0.25xCoping capacity) + (0.25xRestorative capacity)

→ **Resilience = 0.655**

2.4. Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.252) + (0.30x0.500) - (0.30x0.655) = 0.17

For the case study analysed:

Vulnerability = 0.130

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

VULNERABILITY EVALUATION

KOLICI, CROATIA

Annex 6 - D.T2.2.2

12 2021

Authors: Municipality of Dugopolje (PP9)

1. KOLICI HAMLET

1.1. Evaluation of susceptibility (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
		SUSCEPTIBILTY (RQ1)	
CR1.1a	Constructions & materials	Structurally sound constructions made of materials prone to degradation or impact damage	0.50
CR1.1b	Use	Abandoned	1.00
CR1.1c	State of conservation	Very bad	1.00
CR1.1d	Previous harming interventions	No interventions made	0.00
CR1.2a	Built elements of decoration	Absence of elements of decoration	0.00
CR1.2b	Water features	Absence of water features	0.00
CR1.2c	Circulation features	Absence of circulation features	0.00
CR1.2d	State of conservation	Very bad	1.00
CR1.3a1	Species	Prevalence of species not tolerant to local natural and climate threats	1.00
CR1.3a2	Age	Prevalence of mature/veteran trees	1.00
CR1.3a3	Slenderness ratio	Presence of trees with h/d > 70	0.30
CR1.3b	Grass/shrub cover	Presence of species not tolerant to local natural and climate threats	0.30
CR 1.3c	Use	Extensive land-use	1.00
CR1.3d	State of conservation	Very bad	1.00
CR1.4	Topography	Stable slopes with slope inclination higher than 30 degrees	0.30
CR1.5a	Bedrock	Presence of stable bedrock	0.00
CR1.5b	Soil	Coarse-grained soil (sand, gravel)	0.00
CR1.5c	Geomorphology	Presence of stable geological formation	0.00
CR1.6a	Groundwater	Water table prone to sudden fluctuations	1.00
CR1.6b	Surface water	Close to permanent, seasonal and man-made water course	1.00
CR1.6c	Sea	Far from sea	0.00

From the weight assignment in section 7.1, it is known that:

Susceptibility= (0.20xBuilding and structures) + (0.25xBuilt/man-made structures) + (0.35xVegetation) + (0.10x Topography) + (0.10x Geosphere) + (0.10 x Hydrosphere)

→ **Susceptibility = 0.540**

1.2. Evaluation of exposure (sub-)criteria

Ref	**Criterion/sub-criterion**	**Value meaning**	**Value**
EXPOSURE (RQ2)			
CR2.1a	Built systems and features	Presence of built systems and features	1.00
CR2.1b	Natural systems and features	Natural systems and biodiversity	1.00
CR2.1c	Cultural traditions	Presence of cultural traditions	1.00
CR2.1d	Cultural acknowledgements (to be adjusted according to the national adopted scale)	None	0.00
CR2.2	Population	No population	0.00
CR2.3	Economic	No economic value	0.00
CR2.4	Infrastructure	Presence of relevant infrastructure	1.00

From the weight assignment in section 7.1, it is known that:

Exposure= (0.40xCultural significance) + (0.20x Population) + (0.20x Economic) + (0.20x Infrastructure)

→ **Exposure = 0.480**

1.3. Evaluation of resilience (sub-)criteria

Ref	Criterion/sub-criterion	Value meaning	Value
		RESILIENCE (RQ3)	
CR3.1a	Maintenance	No maintenance	0.00
CR3.1b	Warning	Absence of early warning systems	0.00
CR3.1c	Knowledge and awareness	Lack of awareness	0.80
CR3.1d	Information	No info	0.00
CR3.1e	Policy and regulation	Unclear responsibilities	0.30
CR3.2a	Emergency resources	Absence of emergency human and economic resources	0.00
CR3.2b	Mitigating systems/measures	Absence of mitigating systems	0.00
CR3.2c	Physical strengthening/protection	Absence of physical protection	0.00
CR3.3a	Financial recovery	No funds available	0.00
CR3.3b	Social recovery	Absence of social recovery plan	0.00
CR3.3c	Physical recovery	Risk management plan exists and up to date	1.00

From the weight assignment in section 7.1, it is known that:

Resilience= (0.50xPreparedness capacity) + (0.25xCoping capacity) + (0.25xRestorative capacity)

→ **Resilience = 0.203**

1.4. Vulnerability evaluation

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.540) + (0.30x0.480) - (0.30x0.203) = 0.462

For the case study analysed:

Vulnerability = 0.462

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

ANNEX 7 - DELIVERABLE D.T2.2.2

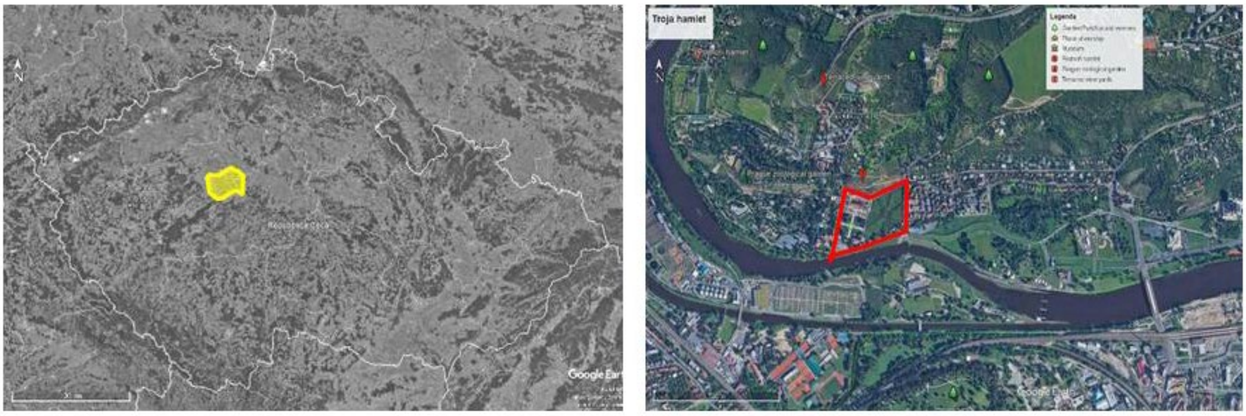
Testing of the WebGIS tool for ruined hamlets protection, Troja, Czech Republic

Version 1
12 2021

Authors: ITAM

1. Introduction

The Troja hamlet is located in Prague's north-west borough and it lies in the proximity of the Vltava river. The geographical coordinates are Lat. 50.109666 and Long. 14.408998.



Geographical positioning of the site (left) with delimitation of the area extension (right).

View from the Vltava river of the Troja hamlet in winter: Troja Chateau (left) and the hill with vineyards

Troja Chateau garden façade (left) and during wine harvest festival in 2019 (right)

The Troja Valley features important natural and cultural heritage assets with millions of visitors yearly. One of the largest and oldest natural parks, "Stromovka" sprawls in the river meadow along with various Troja sport facilities mainly for wild water canoeing, football or softball fields, and with diverse public recreation amenities. The second largest historic complex in Prague, the Baroque "Troja Château" with its gardens is situated in the vicinity of a protected hamlet of the historic fisherman village. The valley accommodates the Prague zoological and botanical gardens complemented with local art galleries. Steep slopes and cliffs skirt the valley. Some parts are cultivated with historic vineyards, some are covered with original herbs and plants and protected as natural reserves.

Troja Mill and Troja Brewery in 1940 (left). Chateau farm after reconstruction in 2020 (right)

Cultural heritage assets include one of the most significant examples of the 17th century Bohemian palace in Baroque style surrounded by an extensive French garden decorated with terracotta vases, stucco prospects and orangeries with busts of imperators. Protected Cultural Heritage Monuments include Troja Mill, Troja Brewery, wine-yard homesteads, chateau farm, Vernacular Heritage Zone (Fisherman village). Besides the architectural heritage – the historic buildings, structures, walls and sculptures –moveable heritage in galleries as well as in private collections or in homes are also endangered. In regard to the landscape, the biological cover – mainly isolated trees – and exposed slopes are at risk.

2. Hazards and vulnerability

The Troja hamlet is in proximity of the Vltava river. Frequent high water level situations with major flooding are the main natural hazard threatening the cultural heritage of the site along with the large numbers of visitors. Minor risks include local flash floods intensified with insufficient capacity of the rain drainage system, harsh weather situations with drought, strong winds and temperature fluctuations.

Flash flood in August 2020 – transported stones from terraced slopes

Historical constructions and their contents are mostly made of porous material with is highly susceptible to floods; building components as well as natural heritage is vulnerable to dynamic and static forces, flowing objects, moisture degradation of materials and biological colonisation. On site it is evidenced also the lack of specific management plan for cultural heritage risks in particular maintenance schemes. Structural and architectonic elements typical of the Baroque period, in particular roofs and spires, are particularly prone to vibration included during windstorm.

The STRENCH Vulnerability Assessment Methodology has been applied to the site for evaluation of its main criticalities. The results can be summarized as follows:

Susceptibility= (0.20xBuildings) + (0.15x Built/manmade features) + (0.35 x Vegetation) + (0.10x Topography) + (0.10x Geosphere) + (0.10 x Hydrosphere)

→ **Susceptibility = 0.330**

Exposure= (0.40xCultural significance) + (0.20x Population) + (0.20x Economic) + (0.20x Infrastructure)

→ **Exposure = 0.693**

Resilience= (0.50xPreparedness capacity) + (0.25xCoping capacity) + (0.25xRestorative capacity)

→ **Resilience** = **0.760**

Finally,

Vulnerability= 0.70xSusceptibility + 0.30xExposure -0.30xResilience

V = (0.70x0.330) + (0.30x0.693) - (0.30x0.760) = 0.211

For the case study analysed:

Vulnerability = 0.211 with 0≤V≤1 (low to high vulnerability).

The full details of the assessment are published in a different document, attached to the deliverable D.T2.2.1. The Troja hamlet presents a quite significant susceptibility to disasters due to its proximity to the river as well as to the presence of structures and building elements particularly prone to damage (plasters, wooden elements or slender components). Its exposure is also quite relevant, being a prime monument in the city of Prague and an important element for the local community's social and economic life. The resilience evaluated for the hamlet is significantly high with appropriate risk management measures in place. On the other hand, it can be highlighted the lack of continuous and regular maintenance as well as of plans for social and financial recovery in post disaster situations. The overall vulnerability scores in the low to medium range.

3. Relevant past events

Worth of notice is the most recent high impact flood in August 2002, the Vltava and Labe (Elbe) rivers flood in Prague. Erosion, hydrostatic and debris actions were identified as principal flood actions on structures; in most cases combinations of the flood actions occurred. Main causes of structural damage included geotechnical aspects, inadequate structural properties, and insufficient communication among responsible authorities.

River flood in the year 2002 in the Chateau Troja garden (left), in the year 2021 in the Vltava valley.

4. WebGIS "Risk Mapping Tool for Cultural Heritage Protection" testing

The WebGIS Tool (WGT) performs an analysis of changes in climate extremes, such as dry spells or intense precipitation, using indices to evaluate statistics of extreme events for temperature and precipitation and to compare them with observed extremes. Among the available climate indices, those considered for the Troja hamlet are outlined in the table below. These strongly relate to the types of extreme events observed at the site, in particular flooding, flash floods and partially fire.

Index	Description	Rationale for choice
R20mm	**Very heavy precipitation days** Number of days in a year with precipitation larger or equal 20 mm/day.	Major index governing flooding.
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.	Major factor governing flooding.
Rx5day	**Highest 5-day precipitation amount** Yearly maximum of cumulated precipitation over consecutive 5-day periods.	Major factor governing flooding.
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.	Climate index for determining potential drought as well as landslide hazard.
Tx90p	**Extremely warm days** Percentage of days in a year when daily	Indicator of increased threat for fire.

	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.	

4.1 Investigation of past climate data using the WGT

The Open Search Tool Box (OSTB) enables to discover, visualize, analyse and download climate data related to selected extreme climate indices based on change of temperature and precipitation and relate to heavy rain, flooding, drought and extreme heating.

In the perspective of investigating the development over the years of climate data at the pilot site, the time series of the Copernicus C3S ERA5 Land products (~9 km resolution, from 1981) are employed. These present the higher resolution and larger historical period covered among the options given. The indices considered (see table above) are the most significant for the case study as they are related to floods, flash floods, drought and landslides. The period investigated spans over almost 40 years, i.e. between 01/1981 and 01/2020. An annual frequency is used for the time series.

Climate index R20mm for the Troja hamlet over the period 1981-2020.

Climate index R95pTOT for the Troja hamlet over the period 1981-2020.

Climate index Rx5day for the Troja hamlet over the period 1981-2020.

Climate index CDD for the Troja hamlet over the period 1981-2020.

Climate index Tx90p for the Troja hamlet in days over the period 1981-2020.

From the graphs it is noticeable a significant correlation among the precipitation indexes R20mm, R95pTOT and Rx5day and the past events occurred at the site. In particular, the remarkable flood event of 2002 is clearly visible in the time series, where all the precipitation indices investigated score their maximum for the period considered: in 2002, R20mm equals to 7 days, same as for 2010 when other major floods occurred in the area; R95pTOT reaches over 50m of cumulative precipitation in 2002 (similar to 2010), the second highest value after that recorded in 1995 (above 55m); Rx5day is found to be equal to 0.025m in 2002, the second highest figure measured during the 40-year-long period.

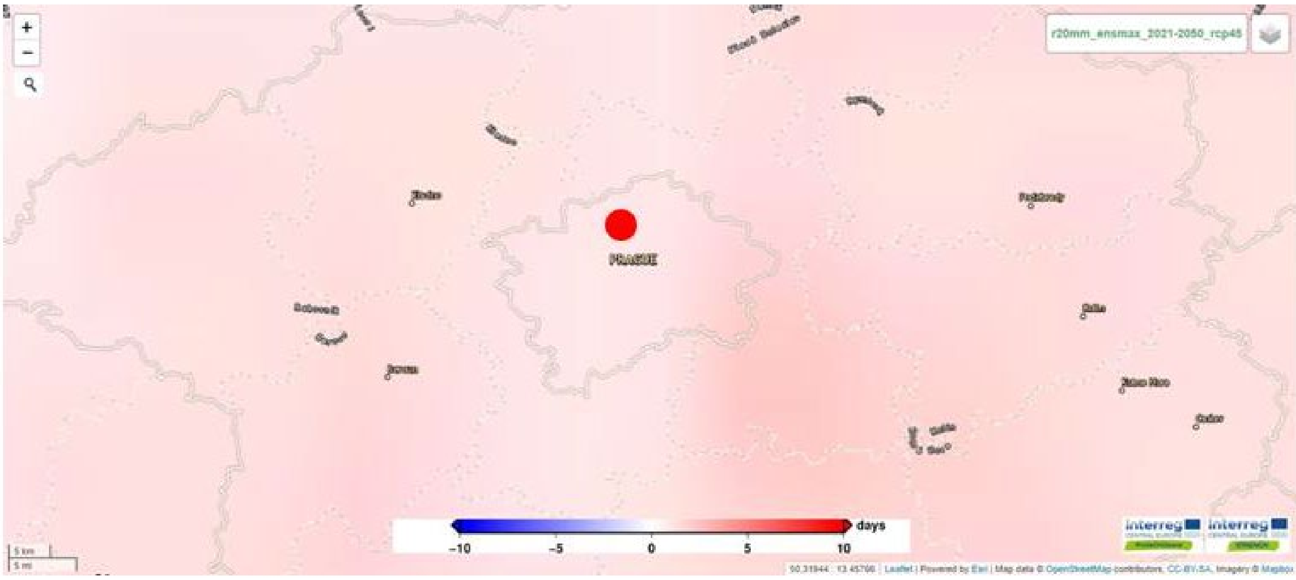
Concerning temperature variations, it is possible to observe the following from the climate data produced by the WGT: the number of consecutive dry days (CDD index) shows no clear trend with peaks in 1982 and 2003 (above 120 days) and minima in 1981 and 2009 (under 70 days); the index Tx90p (percentage of days in a year when daily maximum temperature is greater than the 90th percentile) shows instead how the daily maximum temperature increased especially when comparing the first 10 years of the reference period (1981-1991) to the last ten years (i.e. 2010-2020). In the first time frame Tx90p ranges between 0 and 5 days while in the second one it varies between 4 and 31 days. This shows also how the magnitude of temperature variation also exacerbated over time.

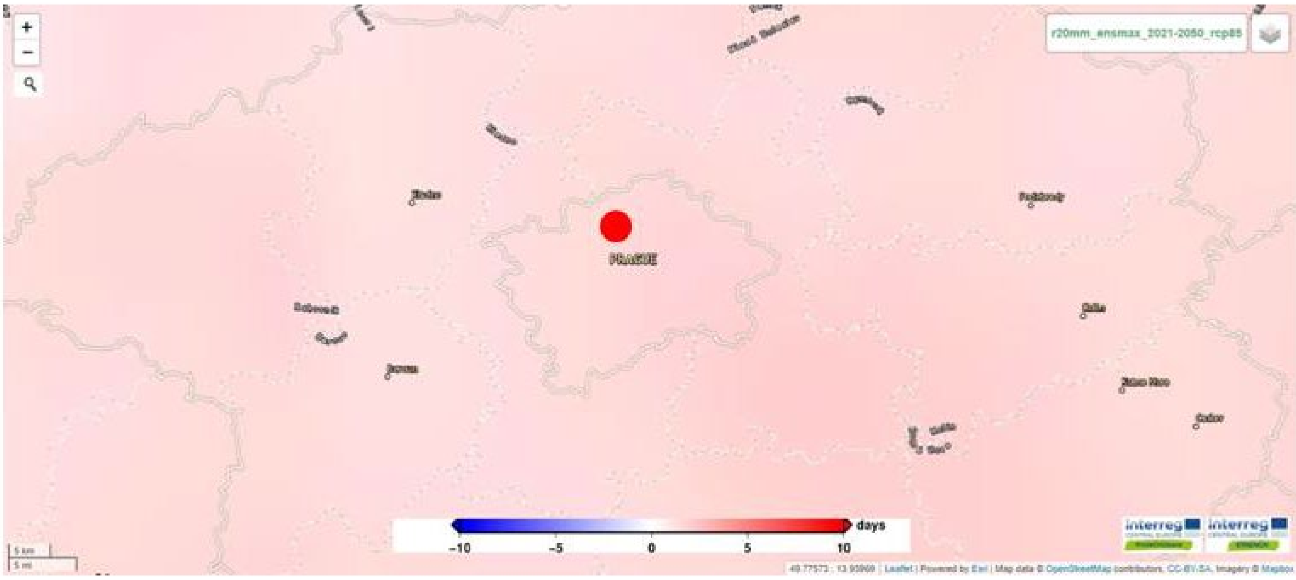
4.2 Climate projections using the WGT

Following the definition and analysis of the most relevant climate indices for the Troja hamlet, the WGT provides further insights on the hazard maps referring to heavy rain, flooding, drought, and extreme heat. The maps are elaborated covering the European and Mediterranean areas calculating climate extreme precipitation and temperature indices using data from the selected combination of models.

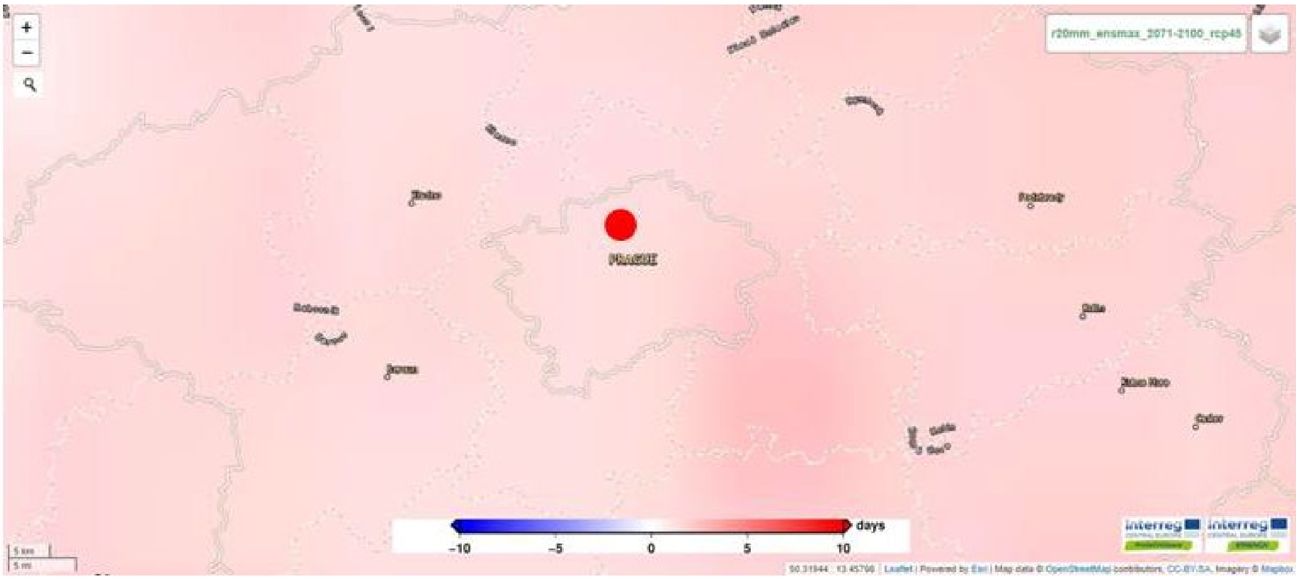
Different numerical climate model simulations have been analyzed to study the possible future evolution of the climate system. For the case study under investigation, the model ensemble statistics, maximum is used with near future (2021-2050) and far future (2071-2100) projections. Furthermore, two future emission scenarios, as described in detail in the latest IPCC , have been employed: RCP 4.5 is a stabilization scenario in which anthropogenic radiative forcing is stabilized at 4.5 W/m2 after year 2100, without overshooting the long-run radiative forcing target level; RCP 8.5 is a high pathway scenario characterized by increasing greenhouse gas emissions over time, for which anthropogenic radiative forcing reaches 8.5 W/m2 at year 2100 and continues to rise for some time. This is also known as the “business as usual” scenario.

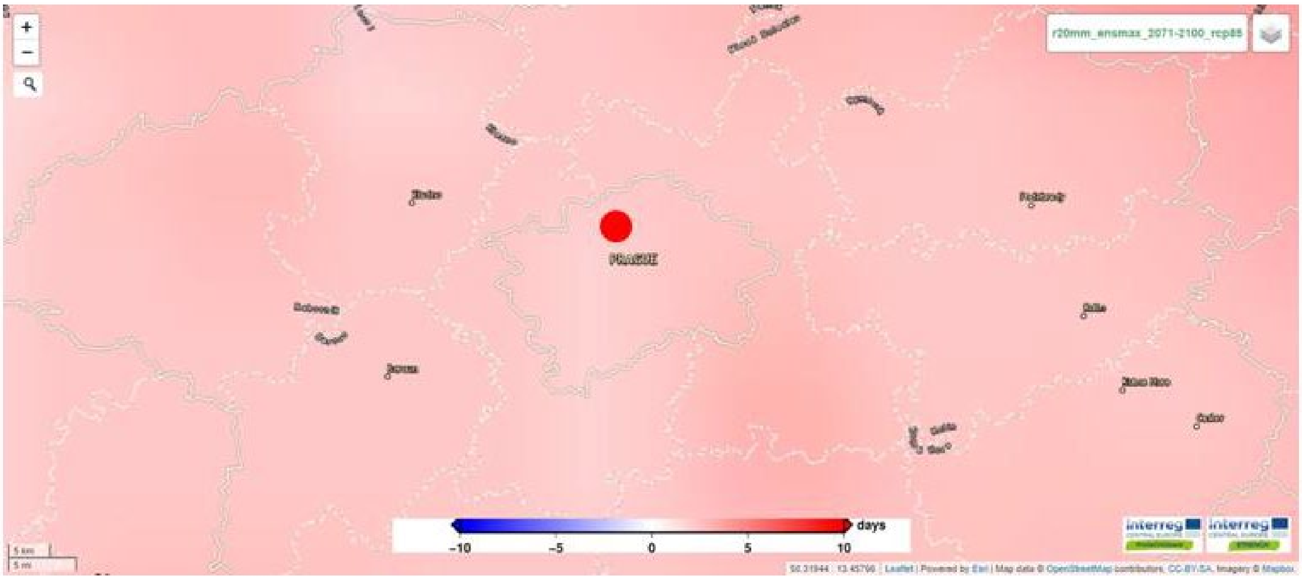
The maps below show, for the Troja hamlet, the projections for the selected climate indexes (see table above) and for the chosen scenarios (near/far future and RCP4.5/RCP8.5)



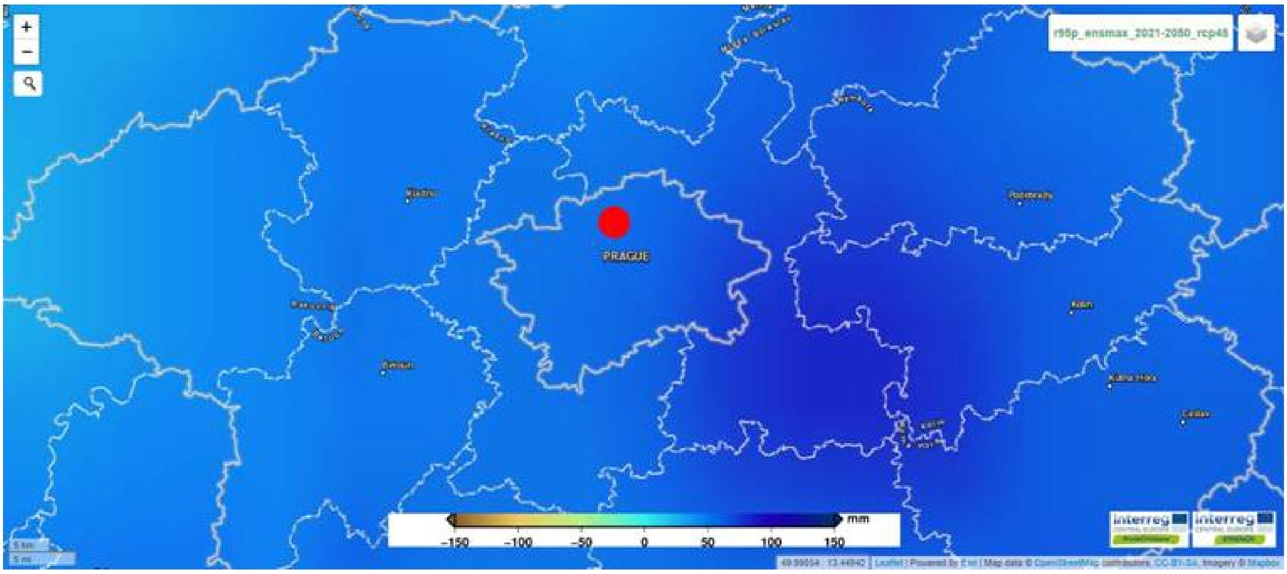


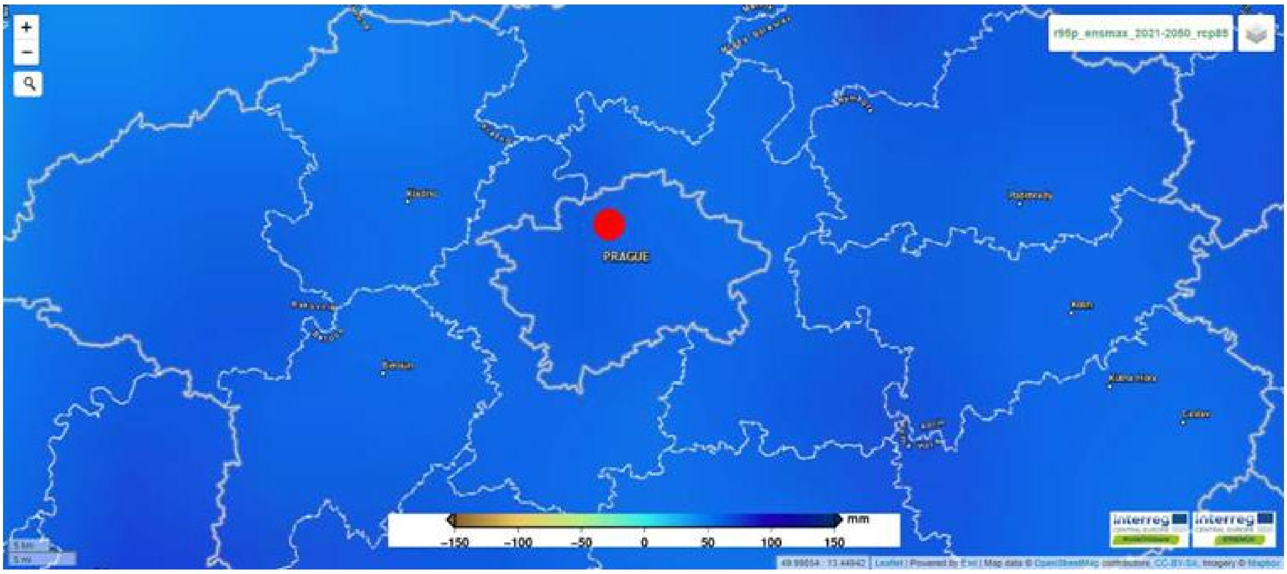
Near future (2021-2050) climate projections for Troja hamlet: R20mm RCP4.5 (above) and RCP8.5 (below).



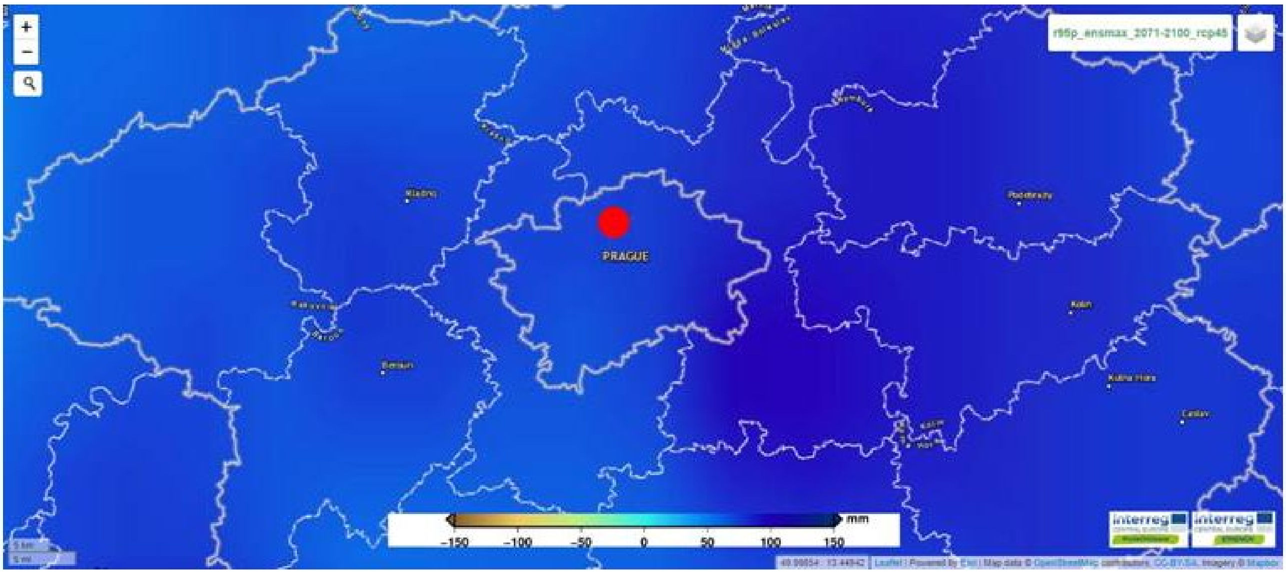


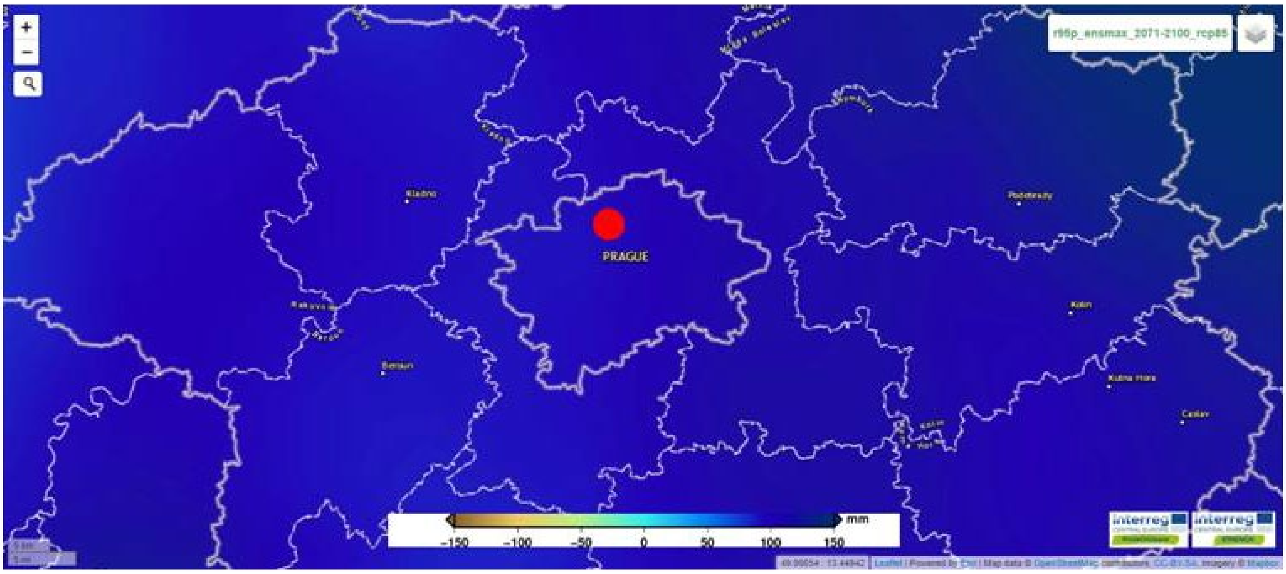
Far future (2071-2100) climate projections for Troja hamlet: R20mm RCP4.5 (above) and RCP8.5 (below).



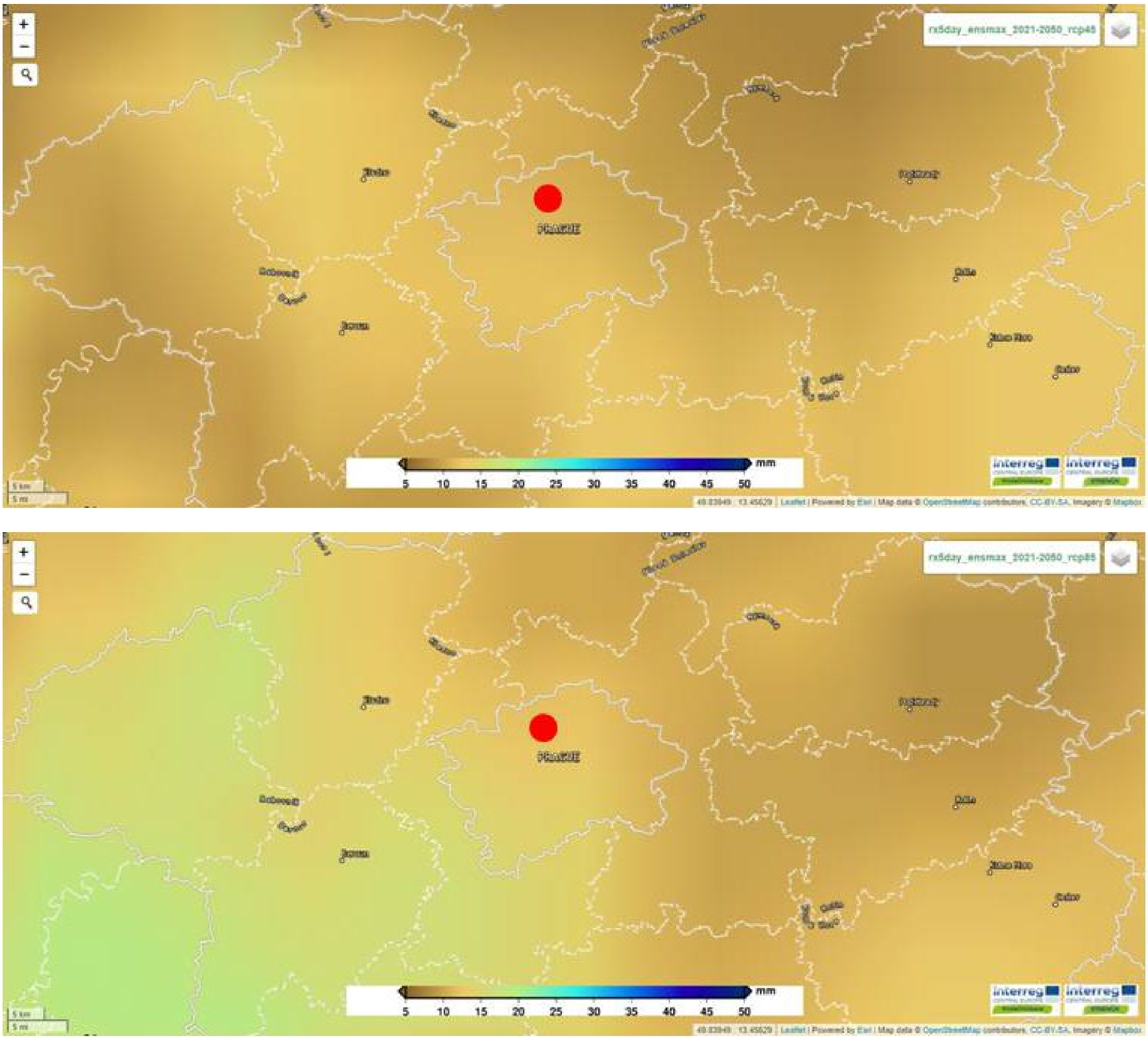


Near future (2021-2050) climate projections for Troja hamlet: R95p RCP4.5 (above) and RCP8.5 (below).

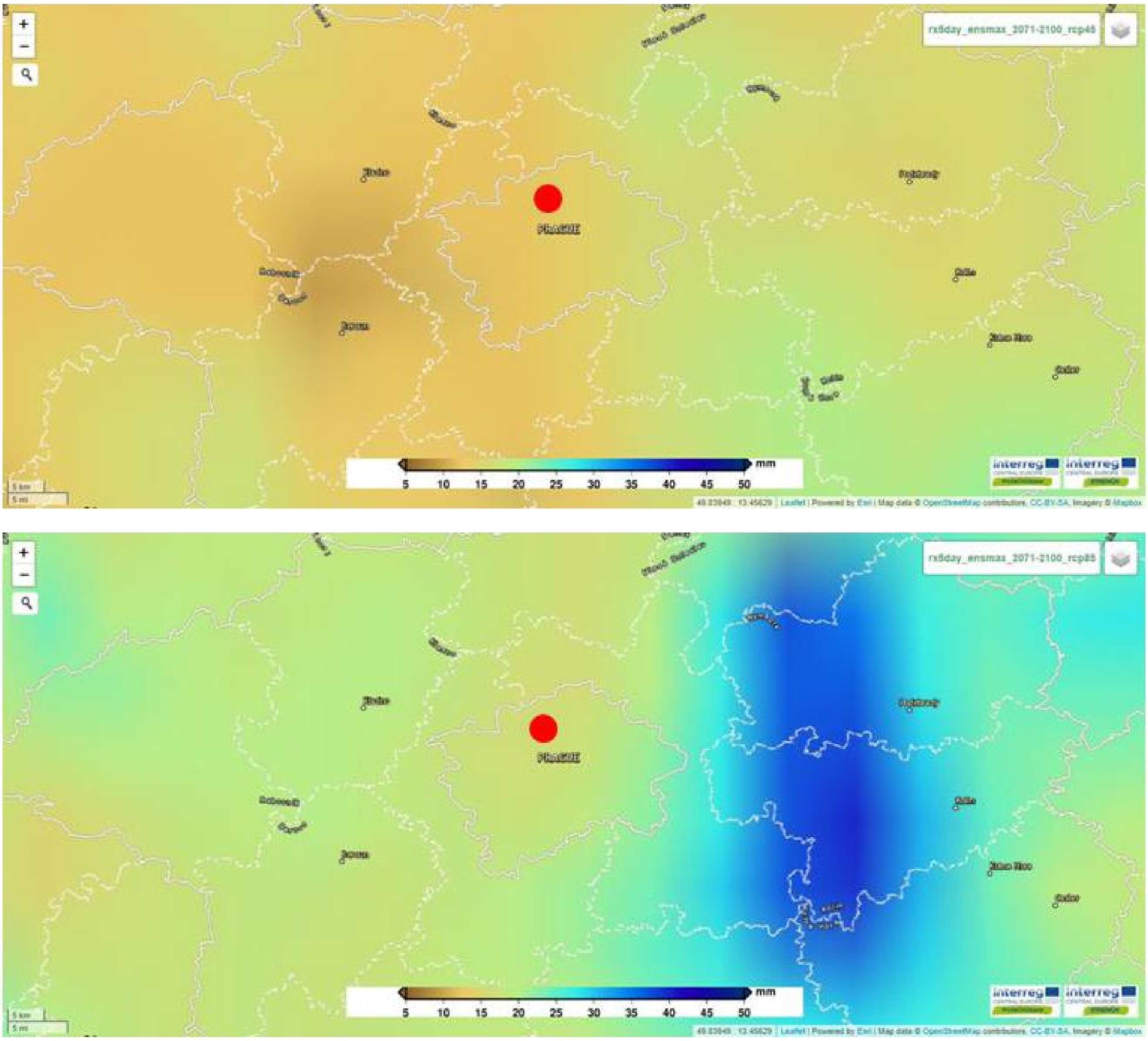




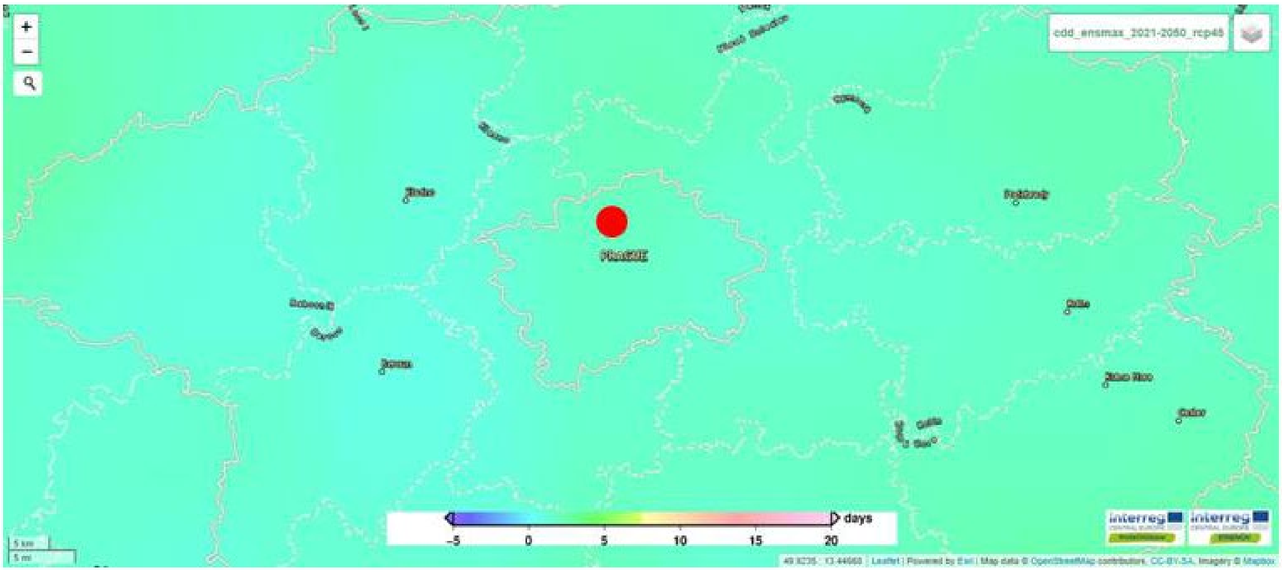
Far future (2071-2100) climate projections for Troja hamlet: R95p RCP4.5 (above) and RCP8.5 (below).

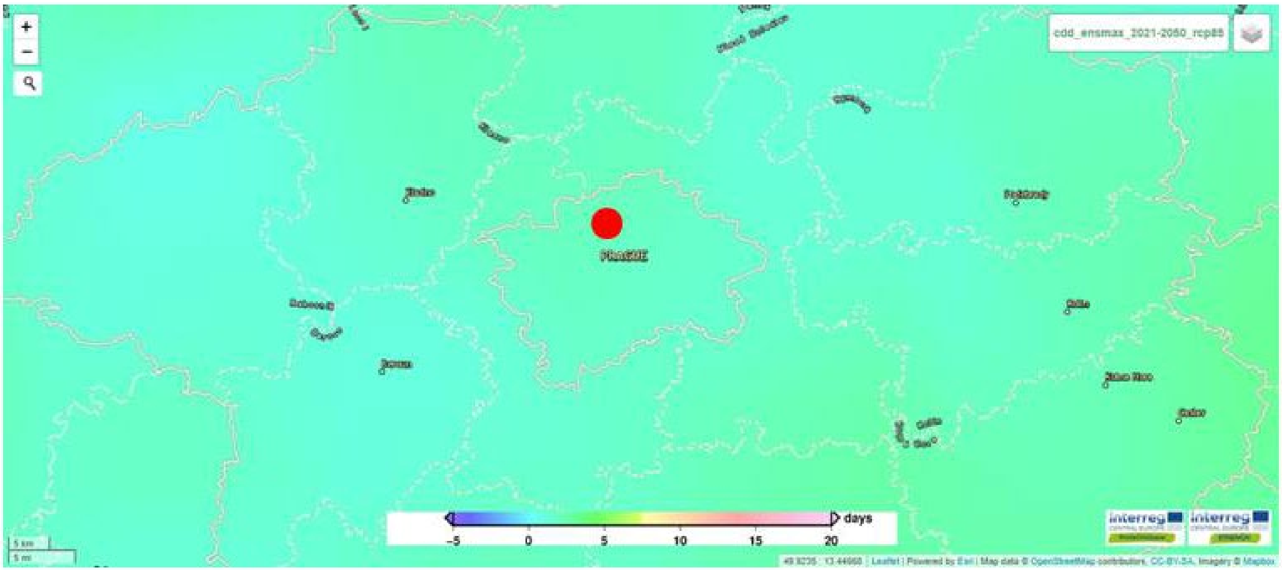


Near future (2021-2050) climate projections for Troja hamlet: Rx5day RCP4.5 (above) and RCP8.5 (below).

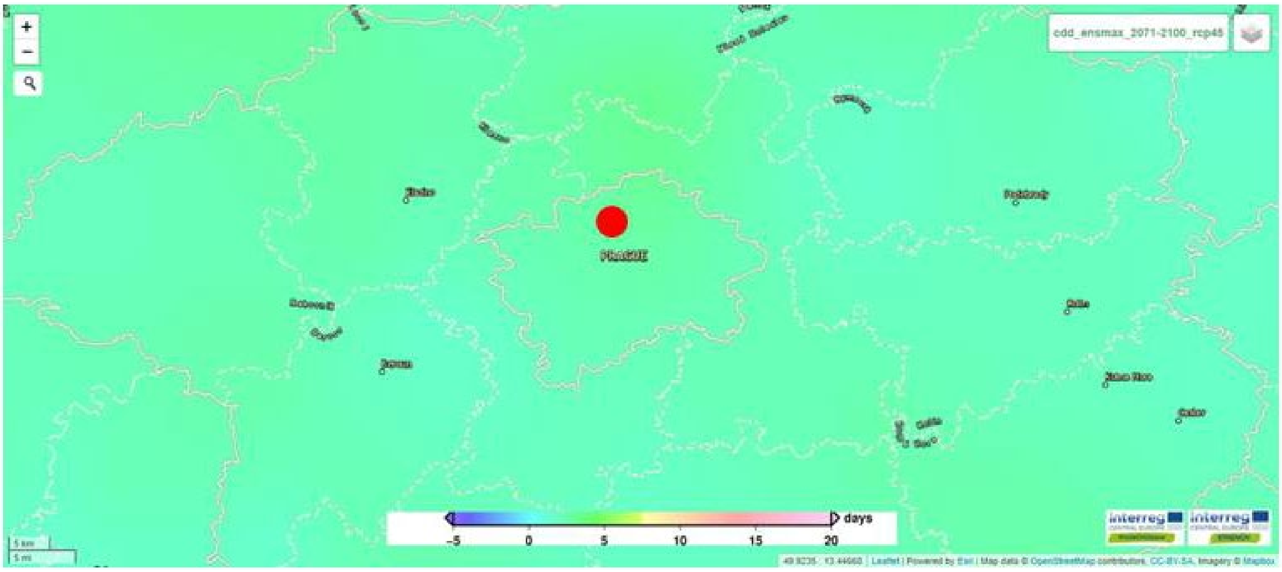


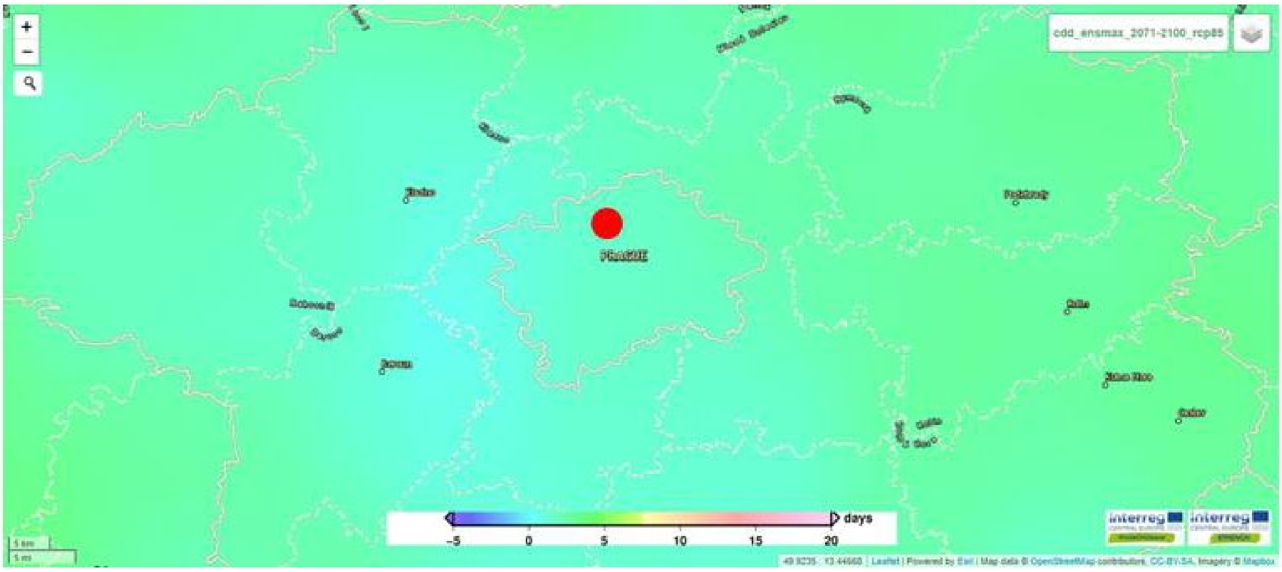
Far future (2071-2100) climate projections for Troja hamlet: Rx5day RCP4.5 (above) and RCP8.5 (below).



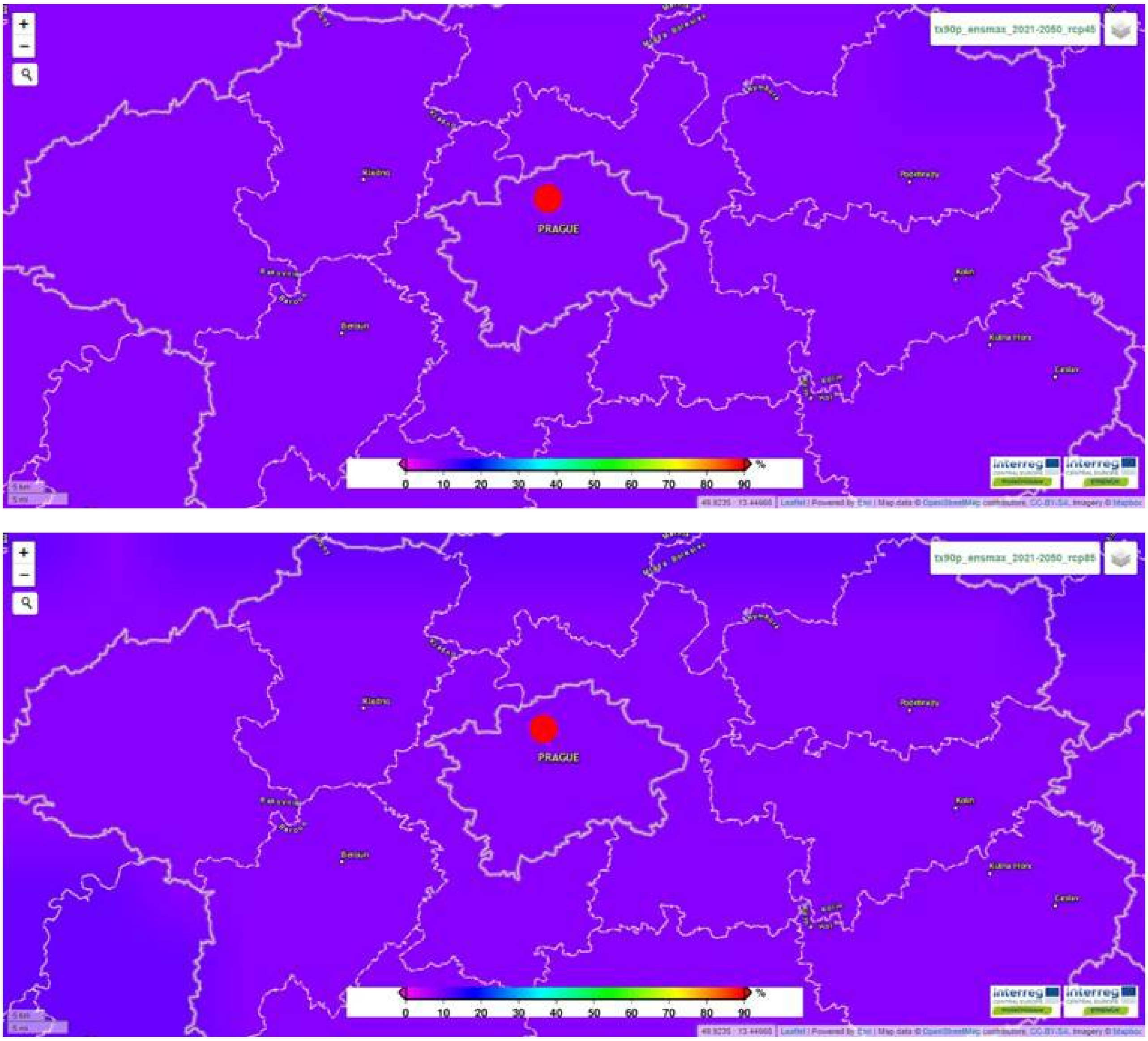


Near future (2021-2050) climate projections for Troja hamlet: CDD RCP4.5 (above) and RCP8.5 (below).

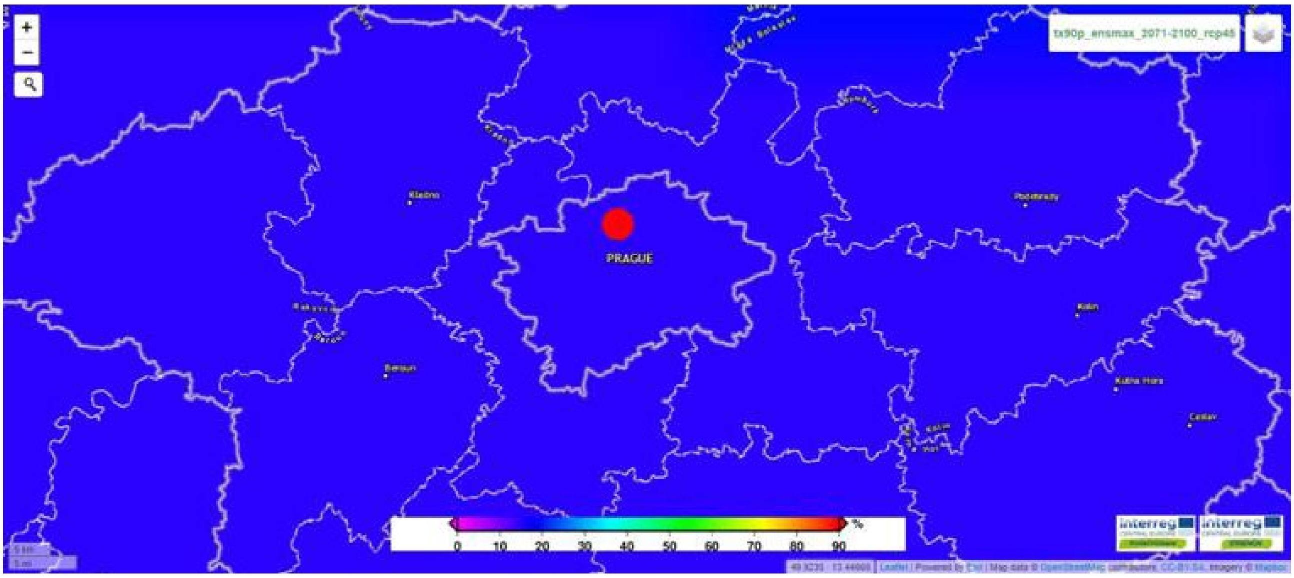


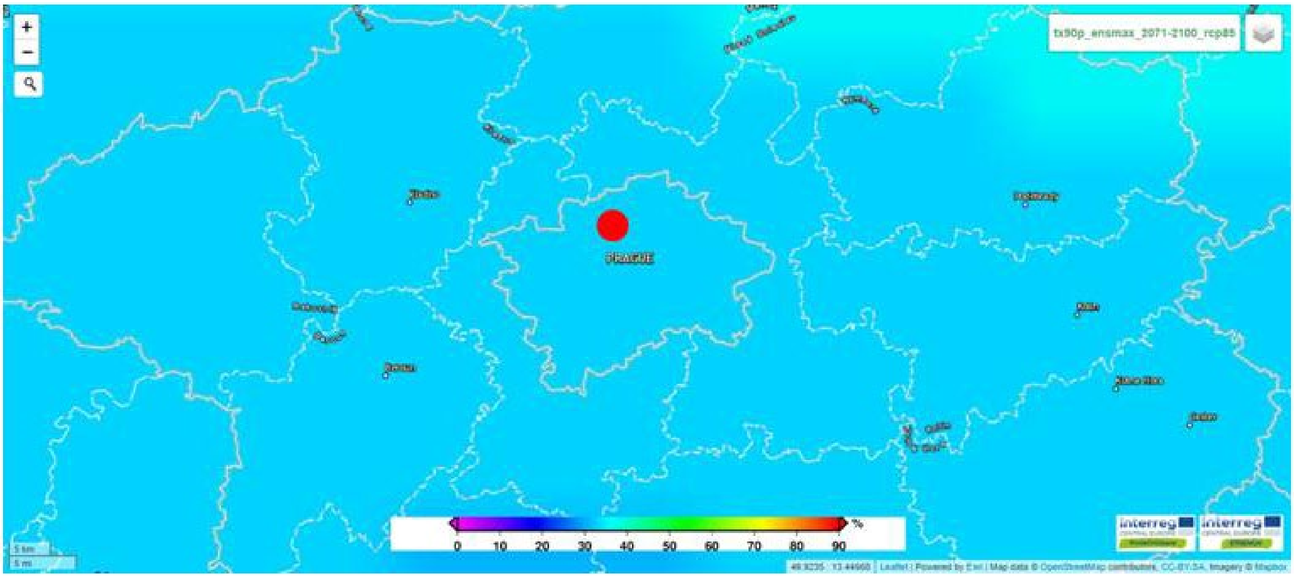


Far future (2071-2100) climate projections for Troja hamlet: CDD RCP4.5 (above) and RCP8.5 (below).



Near future (2021-2050) climate projections for Troja hamlet: Tx90p RCP4.5 (above) and RCP8.5 (below).





Far future (2071-2100) climate projections for Troja hamlet: Tx90p RCP4.5 (above) and RCP8.5 (below).

The results from the climatic projections are summarised in the table below.

	Near future/RCP4.5	***Near future/RCP8.5***	***Far future/RCP4.5***	***Far future/RCP8.5***
R20mm (days)	1	2	2	3
R95pTOT (mm)	40	50	50	80
Rx5day (mm)	10	15	15	20
CDD (days)	1	2	3	4
Tx90p (%)	5	10	20	40

Future changes are calculated as the difference between the period 2021–2050 and the period 1976–2005 (near future projection) and as the difference between the period 2071–2100 and the period 1976–2005 (far future projection), under both RCP 4.5 and 8.5 scenarios (spatial resolution 12 × 12 Km).

The near future projection (2021-2050) for the Troja hamlet yields the following results:

-stabilisation scenario (4.5RCP): the precipitation indices show a mild increase with R20mm recording a change of plus 1 day, R95pTOT plus 40 mm and Rx5day plus 10 mm with respect to the reference period (1976-2005). Similarly, the temperature indexes vary moderately, namely plus 1 day CDD and 5% Tx90p.

-pessimistic scenario (8.5 RCP): a slightly more significant change is observed for this scenario, where R20mm increases by 2 days, R95pTOT by 50 mm and Rx5day by 15 mm; on the other end the temperature indexes vary by plus 2 days (CDD) and plus 10% (Tx90p).

For the far future projection (2071-2100) for the Troja hamlet it is possible to outline the following:

-stabilisation scenario (4.5RCP): the precipitation indices show moderate changes increase with R20mm plus 2 days, R95pTOT plus 50 mm and Rx5day plus 15 mm with respect to the reference period (1976-2005). Temperature indexes present a rather marked change, namely plus 3 days for CDD and plus 20% Tx90p.

-pessimistic scenario (8.5 RCP): a rather significant change is observed for this scenario, where R20mm increases by 3 days, R95pTOT by 80 mm and Rx5day by 20 mm; also relevant increases are observed for the temperature indexes, with plus 4 days (CDD) and plus 40% (Tx90p).

5. Conlcusions

The WGT provides useful insights on the hazards for the chosen site, enabling decison makers and cultural heritage managers to better investigate the potentially threatening scenarios and prioritise the measures to be taken in order to mitigate risk.

From the climate mapping, it is evidenced that the Troja hamlet will experience with time increasing rainfall as well as dry spells. This will impact the site possibly triggering soil erosion, speeding up the degradation of materials and influencing the conservation of the vegetation and other natural systems present on-site.

Under the stabilisation scenario (4.5RCP), both near and far future projection show a mild increase of precipitation and temperature indices. This translates in a significantly greater risk of flash floods for the site due to the intensification of rainfall. Remarkable climate changes are instead observed under the pessimistic scenario (8.5RCP). The far future projection, predicting strong changes to precipitation and temperature at the site, is of particular concern. This scenario would lead to a remarkable risk situation for flood and flash flood. Also the variation in soil moisture content due to extreme wet and dry cycles may induce larger volumetric changes (in particular for soils with lager clay content) and thus imposing movements to the overlying structures.

In the perspective of evaluating the applicability and efficacy of the WGT, it is interesting to underline some of the strengths and opportunities for risk management in cultural heritage protection as well as some of the limitations. The Open Search Tool Box (OSTB) enables to discover, visualize and download climate data related to selected extreme climate indices and successfully allows to tailor the climate mapping in order to provide relevant insights on heavy rain, flooding, drought and extreme heating. This proves to be a very useful tool for hazard determination as well as for risk assessment when coupled with vulnerability data. On the other hand, it should be underlined the possibility of reading errors for the mapping mainly due to their limited resolution and the impossibility to adjust the scale to the ranged of value observed. Both resolution and scale rigidity limit the granularity of information. This would affect for example the analysis at building or site scale and the comparison among different locations within an area of only a few square kilometers (common for cities or hamlets).

ANNEX 8 - DELIVERABLE D.T2.2.2

Testing of the WebGIS tool for ruined hamlets protection, Franconian Switzerland, German

Version 1
12 2021

Project Partner: District Council Forchheim

Author: Sebastian Maier, Andreas Rösch

1. Introduction of the District of Forchheim

The District of Forchheim (DoF) is located at the northern part of Bavaria, Germany, and is part of the Nuremberg metropolitan region (Figure 1).

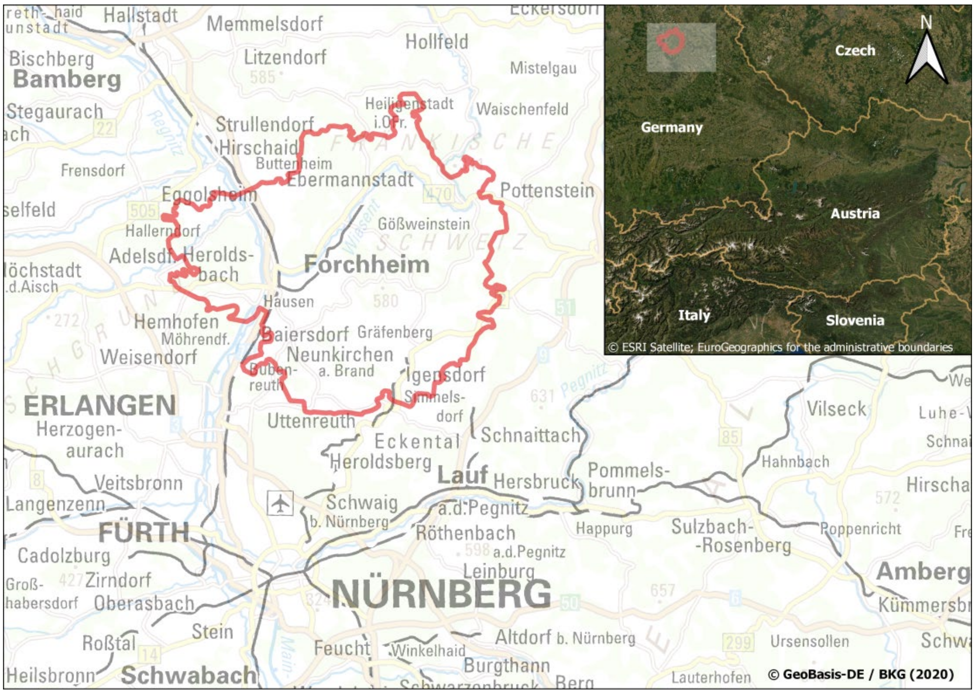


Figure 1: The location of the District of Forchheim (red line).

The DoF comprises parts of the nature park “Fränkische Schweiz” (Franconian Switzerland), which is part of the low mountain range “Fränkische Alp” (Franconian Alp) and which has a long settlement history. Consequently, the Franconian Switzerland covers cultural (CH) and natural heritages (NH) such as a characteristic mountain and hilly cultural landscape with a high density of castles and ruins, striking rock formations and caves, deep valleys formed by rivers and old architecture. Furthermore, because of its climatic- and site conditions, meadow orchards and fruit tree plantations contribute to a beautiful and inspiring cultural landscape, which attracts tourists and serves as recreation area. Inhabitants and tourists particularly enjoy climbing, biking and hiking, canoeing, exploring caves and visiting cultural sites in the DoF.

However, due to its site conditions, the DoF with its CH and NH is particularly susceptible to floods, landslides, drought, harvest failure due to frost events, rock fall etc. Thus, it is of great importance to i) understand whether climate change affects the frequency and magnitude of climatic and environmental hazards in the DoF and ii) to analyse in how far the DoF is vulnerable to climate change. So far, climatic changes have not been assessed for the DoF, why the District Council Forchheim is pleased to be part of the Interreg Central Europe project STRENCH.

The DoF aims to elaborate a climate adaption and mitigation strategy in collaboration with the project partners of STRENCH and regional stakeholders. Since the climate adaption and mitigation strategy is intended to be fact-based, climatic trends and changes were assessed for the District of Forchheim and then compared to results obtained from the Web-GIS tool.

2. Case Studies

At the STRENCH project the Assessment of Vulnerability at Case Studies (D.T1.2.2) has been done at three different case studies / pilot sites in DoF. These three case studies are **representatives** at cultural heritage (CH) or cultural landscape at DoF. The cultural landscape is result of a

- Diverse (cherry growing, brewery, mills, …)
- Site-adapted (cherry plantations, watered grasslands, sandstone buildings/ half-timered houses, …) and
- Low-intensive land-use that evolved since the Medieval.

The CH is crucial for providing identity, tourism and nature conservation. In order to representate DoF cultural landscape following case studies have been selected all near to or illustrate hamlets at mountain region:

Site 1:

Cherry Orchard Hiltpoltstein 49°39‘53“N 11°19’28“E

Site 2:
Ruined hamlet Neideck
49°48‘41“N 11°14‘00“E

Site 3:
Behringersmühle
49°46‘54“N 11°19‘59“E

Site 1 and site 3 have a local climate station / data. All these three sites are in DoF at a distance between around 15 to 20 km. Therefore climate data analyses showed that at Web GIS tool e.g. the Copernicus data at 12x12km grid explained no significant difference at local/regional level. Hence we took a middle range/average of all data representing very well DoF and Franconian Switzerland. Nevertheless at specific sites – very local phenomena e.g. late sudden frost at cherry orchards or local heavy rain at small rivers can damage CH severely. The challenge is now to identify on the one hand very short weather conditions at local / regional level but on the other hand long term climate change at a wider regional / European or even global level.

3. Climatic chances in the Distric of Forchheim

In the following a few results obtained from the analysis of climatic changes in the DoF are described. These examples shall illustrate that climatic changes already occurred in the DoF since the 1960s. Afterwards they are discussed with results from the Web-GIS tool.

3.1. Temperature

Time-series analysis indicated a clear trend of increasing temperatures in the DoF (see Figure 2 a). Considering the two climate periods 1971-2000 and 1990-2019, the mean annual temperature significantly increased from 9.2°C to 9.9°C. The frequency distributions of the mean annual temperatures of the two climate periods revealed less frequent “cold years” and more frequent “hot years” in the climate period 1990-2019 compared to the period 1971-2000 (see Figure 2 b). Additionally, the annual number of heat days (days with maximum temperatures of >=30°C) almost doubled from 1971-2000 (6 heat days) to 1990-2019 (11 heat days) for the climatic region to which the DoF belongs.

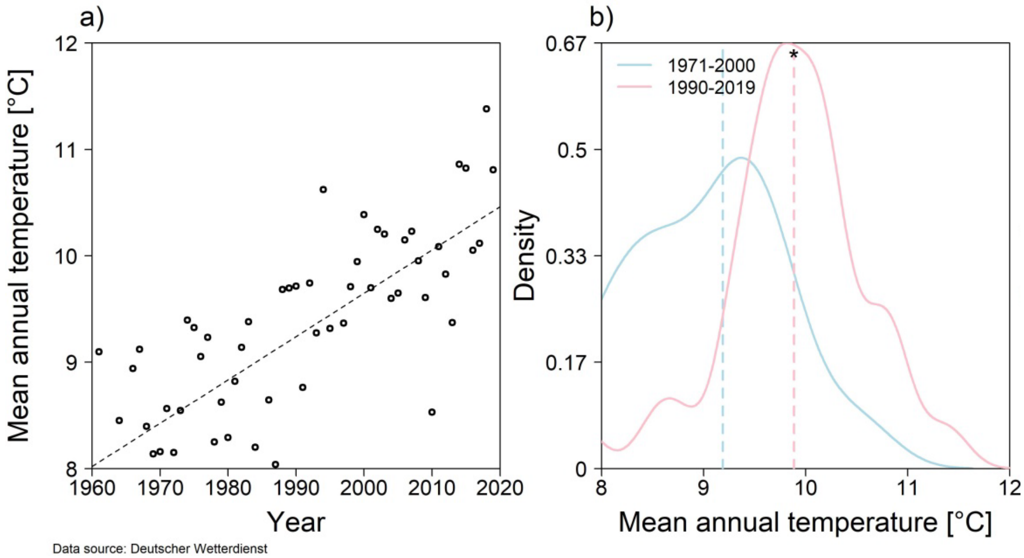


Figure 2: Temporal development mean$_{median}$ annual temperature at a climate station in the District of Forchheim a) and frequency distribution of mean$_{median}$ annual temperature considering the two climate periods 1971-2000 and 1990-2019 b). The coloured dashed lines illustrate the median of the respective climate period. The linear regression line and the * symbol were only displayed when statistical significance was observed.

Moreover, interestingly, the observed 30-year running mean of annual temperatures in spring and summer already reached the predicted median of the climatic period 2071-2100 following RCP2.6 at the climatic region to which the DoF belongs to (Figure 3).

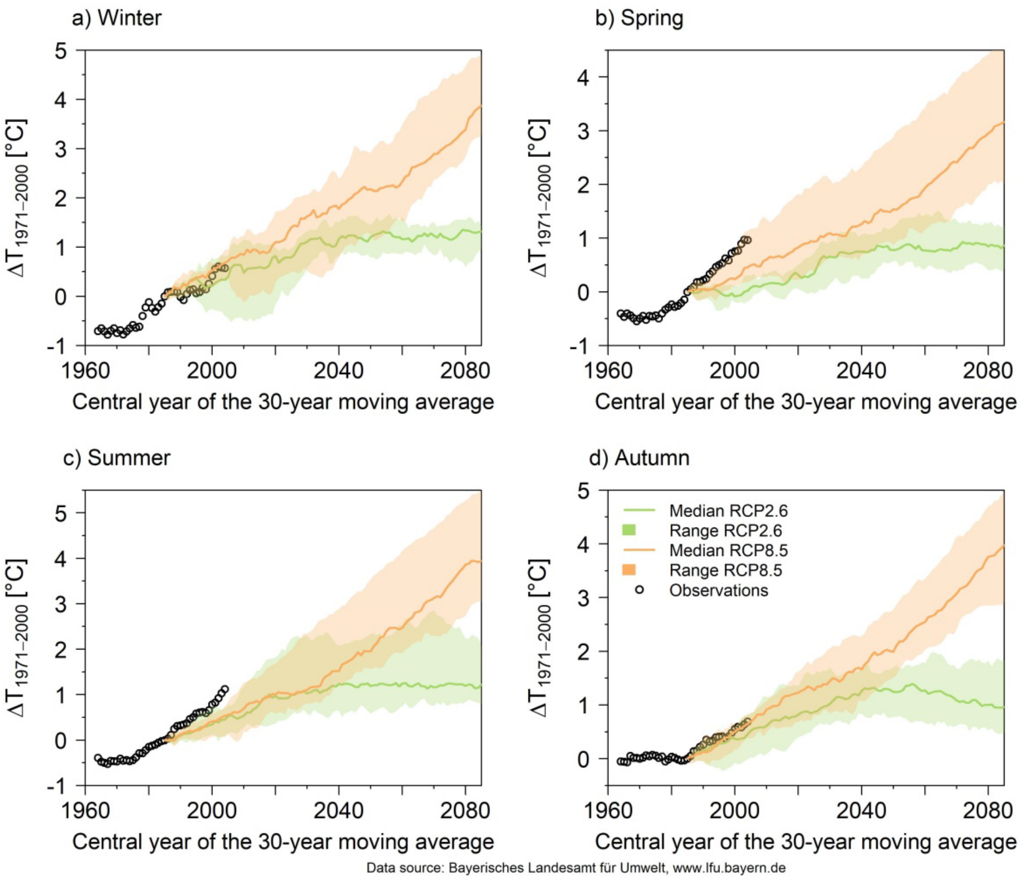


Figure 3: Climate projection of the 30-year moving average of the temperature anomaly (reference period: 1971-2000) for the climatic region of the DoF following RCP2.6 and RCP8.5 considering the seaons winter (Dec-Feb) a), spring (Mar-May) b), summer(Jun-Aug) c) and autumn (Sept-Nov) d).

3.2. Sunshine Duration

A significant increase in sunshine duration was found for the District of Forchheim (DoF) based on data derived from the DWD (Deutscher Wetterdienst) (see Figure 4 a). Considering the two climate periods 1971-2000 and 1990-2019, the mean annual sunshine duration significantly increased from 1557 hours (1971-2000) to 1664 hours (1990-2019). Considering the frequency distributions of annual sunshine duration of the two climate periods a significant shift towards less frequent years with “low” sunshine duration and more frequent years with a “high” and sunshine duration was identified (Figure 4 b). Also, new extremes occurred in the climate period 1990-2019, such as the exceeding of 1900 sunshine hours in 2018 and 2019.

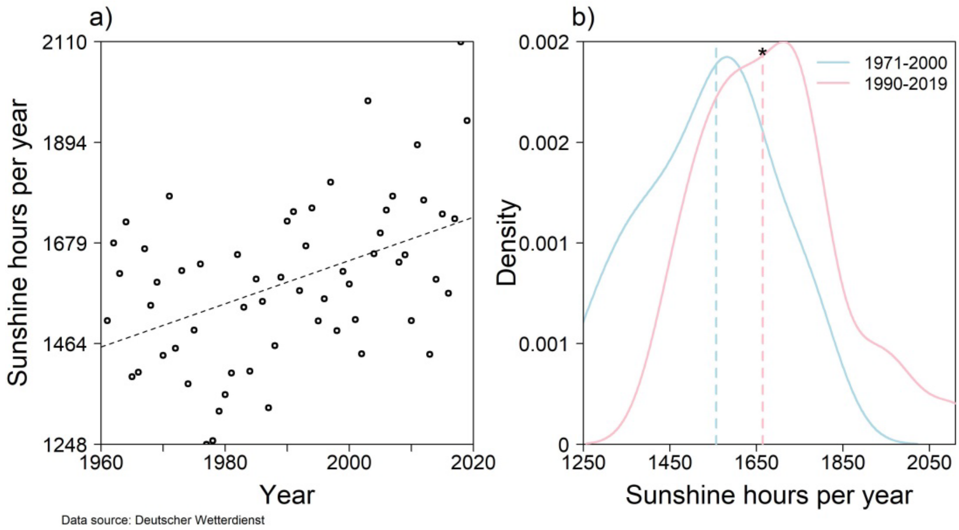


Figure 4: Temporal development of annual sunshine duration at a climate station in the DoF a), and frequency distribution of annual sunshine duration considering the climatic periods 1971-2000 and 1990-2019 b). The coloured dashed lines illustrate the median of the respective climatic period. The linear regression line and the * symbol were only displayed when statistical significance was observed.

3.3. Phenology

The District of Forchheim (DoF) is a well-known cherry- and apple-growing area. Thus, the phenology of cherry and apple tree was of special interest in the climate analysis. In particular, the beginning of flowering was investigated for cherry and apple tree, respectively. Time-series analysis indicated a significant earlier beginning of flowering for both apple (displayed in Figure 5 a) and cherry tree in the DoF. Considering the two climate periods 1971-2000 and 1990-2019, the mean beginning of flowering decreased from 127 to 117 for apple trees (see Figure 5 b) and from 115 to 109 for cherry trees. Notably, the mean beginning of flowering in the climatic period 1971-2000 corresponds to an extremely late beginning of flowering in the climatic period 1990-2019 for the cherry tree and the apple tree in the DoF, respectively.

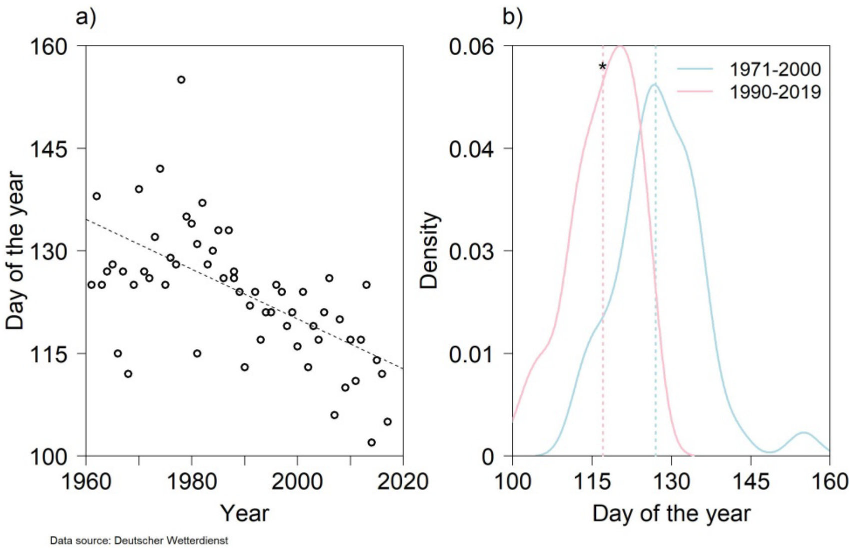


Figure 5: Temporal development of the beginning of flowering of apple trees at a climate station in the DoF a), and frequency distributions of the beginning of flowering of apple trees considering the two climate periods 1971-2000 and 1990-2019 b). The coloured dashed lines illustrate the median of the respective climate period. The linear regression line and the * symbol were only displayed when statistical significance was observed.

3.4. Drought

The soil moisture index (SMI) provided by the Helmholtz-Zentrum für Umweltforschung is determined by estimating the percentile of the monthly soil moisture value with respect to its site specific climatology. The SMI can be classified into two major classes, i) abnormally dry (0.3 ≤ SMI < 0.2; yellow area in plot) and ii) drought (0.2 ≤ SMI; orange area in plot). Considering the meteorological half-years, the summer half-year showed significant lower top-soil SMI and total-soil SMI in the District of Forchheim (DoF) for the climatic period 1990-2019 compared to the period 1971-2000. Thus, the DoF had to face more frequent and more extreme drought and abnormally dry conditions in 1990-2019, exacerbating the “normal” dry soil conditions especially in summer.

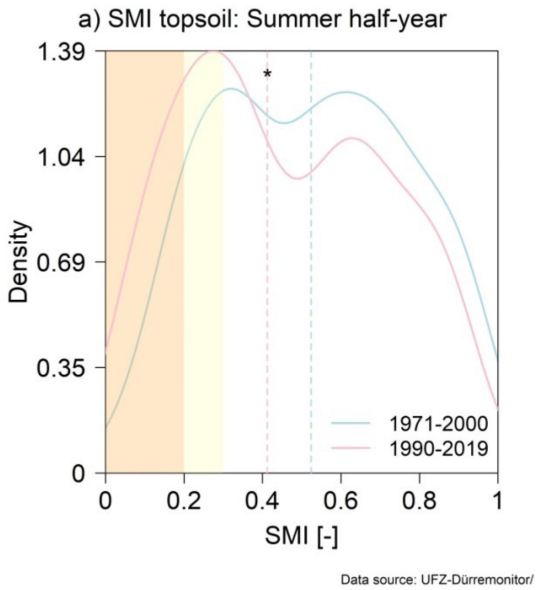


Figure 6: Frequency distributions of the top-soil SMI in the DoF considering the two climatic periods 1971-2000 and 1990-2019. The coloured dashed lines illustrate the median of the respective climatic period.The * symbol is only displayed when statistical significance was observed

4. Testing the Web-GIS Tool

In the next step the District of Forchheim (DoF) analysed the potential impacts of future climate extreme events. Therefore we used the Web-GIS tool which provides climate model ensemble statistics for several climate risk indices with a spatial resolution of 12 x 12 km, under RCP 4.5 and RCP 8.5 scenarios. This very promising Web-GIS tool is accessible under https://www.protecht2save-wgt.eu/.

The Web-GIS was tested exemplarily with a set of indicators which are displayed in Table 1 and which represent the risks i) heavy rain, ii) flooding, iii) drought and iv) extreme heat for the DoF.

Table 1: Risks and indices considered in the testing of the Web-GIS tool.

Risk	Index	Description
Heavy Rain	R20mm	**Very heavy precipitation days:** Number of days in a year with precipitation larger or equal 20 mm/day
Flooding	Rx5day	**Highest 5-day precipitation amount:** Yearly maximum of cumulated precipitation over consecutive 5 day periods.
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.
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.

To obtain robust and statistically significant results, which then can be communicated to local politicians and regional stakeholder, for each index it was investigated:

- How the index behaves under the climate scenarios RCP4.5 and RCP8.5
- How the index differs between the near and the far future
- How the index is affected by climate model ensemble statistics. Outcomes were only considered significant when the minimum, mean and maximum value of an index were either all positive or all negative.

Therefore, **in total 48 maps were generated** to evaluate the risk indices listed in Table 1.

To illustrate the results from the Web-GIS tool clear, no maps generated with the WGT are shown in this document, but the values obtained from the WGT for the DoF are displayed in Table 2.

Table 2: Results obtained from the Web-GIS tool for the District of Forchheim. For each risk index i) the near and far future, ii) RCP4.5 and RCP8.5 and iii) the maximum, minimum and mean value of the model ensemble statistics were considered.

		Near Future 4.5			Near Future 8.5			Far Future 4.5			Far Future 8.5		
Risk	**Index**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
Heavy Rain	R20mm	2-3	0-1	0- -1	3-4	1-2	0- -1	3-5	2-3	0	5-7	4-5	1-2
Flooding	Rx5day	5-10	2-3	-6 - -7	10-15	4-6	-5 - -12	20-25	5-6	-5 - -8	25-30	10-12	0 - 4
Drought	CDD	2	0	-2	3	0	-3	2-3	0-1	-1 - 0	4-6	0-1	-2 - -1
Extreme heat	Tx90p	5-8	5-6	4-6	9-12	5-8	6-8	19-20	10-15	7	32-35	20-25	18-20

4.1. What do the results obtained from the Web-GIS tool say for the DoF?

For each of the investigated risk indices it is shortly described, what the obtained results say for the DoF

R20mm (risk: heavy rain)

- For the *near* future no final conclusion can be drawn of whether the climate index R20mm will develop in the DoF, since for none of the considered climate scenarios the minimum, mean or maximum values are all positive. Thus, the climate models did not indicate a consistent trend for the climate index R20mm for both climate scenarios in the near future.
- For the *far* future there is a tendency of a significant increase of the climate index R20mm for both considered climate scenarios in the DoF. All values of the ensemble statistics are positive. While under scenario RCP4.5 the mean number of days in a year with precipitation larger or equal 20 mm/day will increase by around 5 days, the mean number under RCP8.5 will increase by approximately 11 days.

Rx5day (risk: flooding)

- For the *near* future no final conclusion can be drawn of whether the climate index Rx5day will develop in the DoF, since for none of the considered climate scenarios the minimum, mean or maximum values are all positive or negative. Thus, the climate models did not indicate a consistent trend for the climate index Rx5day for both climate scenarios in the near future.
- The same applies for the *far* future under the climate scenario RCP4.5
- Considering the *far* future under the climate scenario RCP8.5 there will be a significant increase of the climate index Rx5day index. All values of the ensemble statistics are positive. Consequently, there will be a significant increase in the yearly maximum of cumulated precipitation over consecutive 5 day periods under RCP8.5 in the DoF.

CDD (risk: drought)

- Neither for the *near* future, nor for the *far* future a significant pattern of the climate index CDD was obtained for both climate scenarios. While the maximum values of the ensemble statistics projected an increase of CDD and the mean values showed a slight increase of CDD, the minimum values of the ensemble statistics were all (slightly) negative for both climate scenarios. This indicates that climate models do not indicate a consistent trend for the climate index CDD.

Tx90p

- For both the *near* and the *far* future the results of the Web-GIS tool indicated for both considered climate scenarios a significant increase of the climate index Tx90p. As all values of the ensemble statistics are positive, the climate models indicate a consistent trend for Tx90p. Thus, there is a high probability that the percentage of days in a year when daily maximum temperature is greater than the 90th percentile will increase in the DoF.

4.2. Discussing some aspects of the Web-GIS tool

- A big advantage of the Web-GIS tool is that it provides climate data and data of climate risk indices. In particular when data are scarce the Web-GIS tool is very helpful and can significantly improve the analysis of climate risks. In our case for example data on precipitation were scarce and the Web-GIS tool supported us in identifying that in particular in the far future under RCP8.5 the indices R20mm and Rx5day will highly likely increase the risks of flooding and heavy rain in the DoF.
- To our opinion, a "manual" of how the results provided by the Web-GIS tool should be evaluated would be very useful. From our perspective it is very important to communicate significant and robust results of climate data analysis to local politicians. Such a manual could prevent some kind of "result"-picking, meaning that different groups with different interests pick only the results which confirm their view. For example a group of climate activists will probably use the maximum values obtained from the far future under RCP8.5 because they support their view. In contrast a group of climate sceptics, will probably use the minimum values obtained either from the near or far future to demonstrate that climate change is not that critical as scientist or activists claim. Another benefit by such a standardized analysis is, that it is possible to identify real climate risk, which than can be prioritized and focused on.
- Contradictory results were obtained for the risk drought. While the results obtained from the Web-GIS tool for the index CDD did not indicate an increase of the risk 'drought', our data-analysis revealed a significant increase of the risk 'drought' since the 1970s (see Figure 6). A reason for this contradictory results could be that the index CDD only considers precipitation but not evapotranspiration, which is next to precipitation a very important parameter affecting drought. Thus, in this case the index SPEI (standardized precipitation evapotranspiration index), which also considers evapotranspiration, would be more meaningful than the parameter CDD.
- We were glad that the Web-GIS tool supported our results showing that extreme temperatures are more frequent and more extreme due to climate change in the DoF. Thus, the Web-GIS tool can be used for supporting results obtained from other analysis.
- Similar to the parameter Tx90p (risk extreme heating), which considers daily maximum temperatures greater than the 90th percentile of a given reference period, a similar parameter

could be used for the risk heavy rain. Many studies focusing on heavy precipitation events do not investigate changes in R20mm but on how the 99th percentile of rain events is changing due to climate change.

- In our case the parameter phenology is of great importance since cherry-growing is part of the history of the DoF. Unfortunately, the parameter ‘beginning of flowering’ was not part of the Web-GIS tool. However, other data sources were available which allowed us to analyse this parameter. Nevertheless, it can not expected that such a parameter is provided by the Web-GIS, since it the beginning of flowering is of very local interest. Thus, the Web-GIS tool should be seen as a tool which provides very broad information on climate change and climate projections, but it does not claim the right to be all-encompassing.
- One parameter, which was missing in our opinion, was erosivity. The ‘erosivity’ is a parameter which describes the energy with which rain hits the soil and it is especially relevant for soil erosion. As soil erosion is of European importance and in particular relevant for cultural landscapes, it may be added as climate index to the Web-GIS tool. In our case erosivity will almost double in the near future which means, that soil erosion double if no preventing measures will be undertaken.

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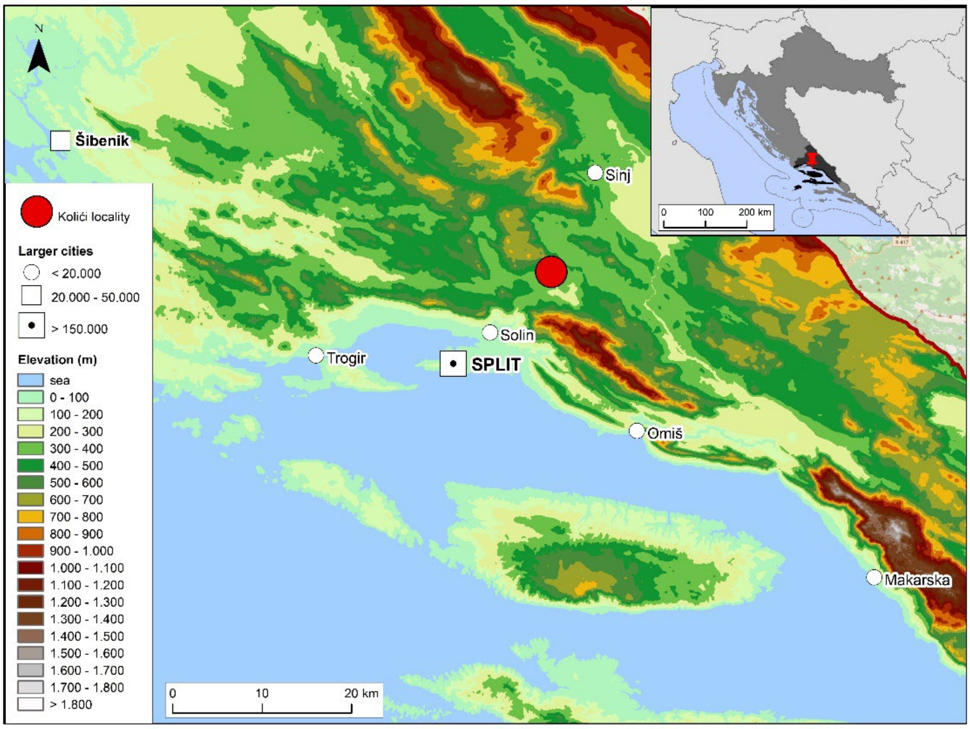
ANNEX 9 - DELIVERABLE D.T2.2.2

Testing of the WebGIS tool for ruined hamlets protection, Kolici, Croatia

12 2021

1.1. Site location and description

Kolići is a hamlet situated in Dugopolje municipality, Croatia (Split-Dalmatia County), on the northeast side of the Mosor mountain, which represents a natural barrier to the Adriatic coast. It is an example of a settlement with preserved traditional architecture and authentic construction methods typical for the area of Adriatic Croatia. There are two antique pathways dating to 1st century AD, out of which one (Kolići-Podi) is registered as protected cultural heritage of the Republic of Croatia. There is evidence that proves that hamlet was populated in acient Roman times, which is seen in Roman pathways and Roman gardens (Grubuša). According to the typology of cultural heritage and due to its position, Kolići belongs to the category of a hamlet in mountainous areas. Within the last century, there is a great stagnation of population in Kolići following a tendency to reside in more developed areas, mostly in wider urban area of the city of Split. Such a state in which the settlement records depopulation in turn makes it more sensitive to natural disasters. However, the traditional houses are still preserved and represent valuable example of autochthonous Dalmatian architecture.



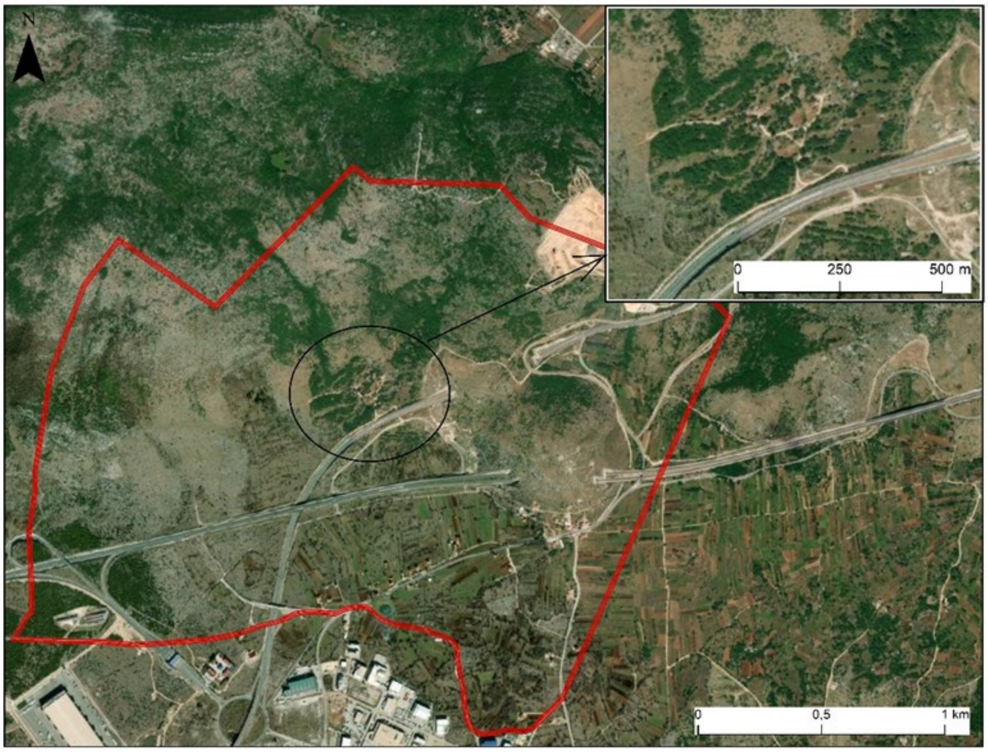
Location of Kolići hamlet within wider area of Split-Dalmatia County

1.2. The features of the Kolići hamlet and main risks affecting the site

Located in the mountain, as well as in the Mediterranean area, Kolići hamlet is threatened by an intensive insolation and a high risk of drought and forest fires that can endanger and damage the cultural heritage in this area which includes prehistoric mounds along the ancient road as well as a ruined medieval settlement. These hazards pose an increasing threat to this area, especially due to climate change. They can have significant consequences for the cultural, historical and artistic values of an area, can affect the safety of citizens and have negative consequences for local economies related to the development of tourism.

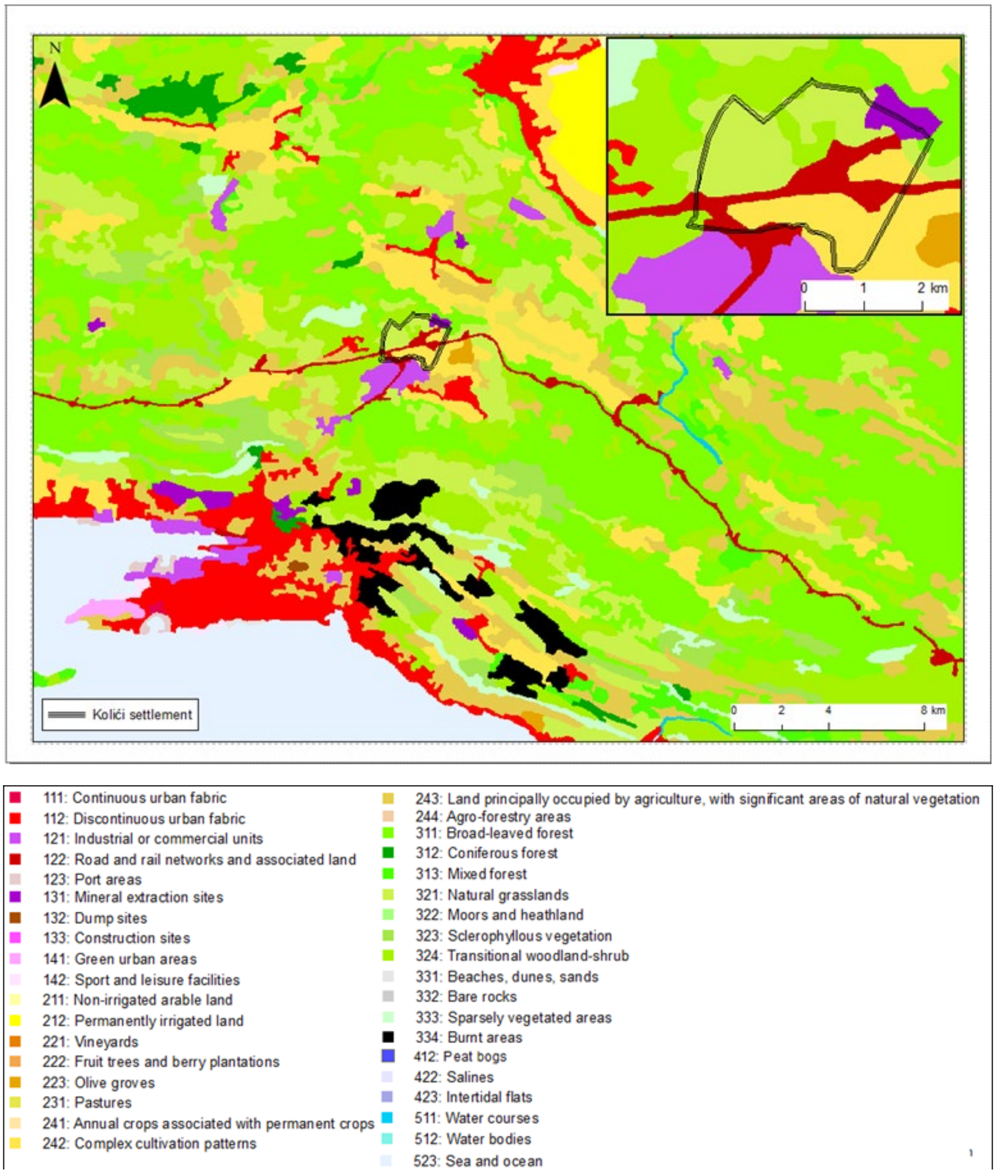
Features of Kolići hamlet cultural heritage

Geomorphologically, the site is located in a sensitive karst area with geological structure based on limestones and dolomites. These rocks are of a high degree of karstification, broken by tectonic processes and due to cavernous-fissure porosity they own good permeability. Because of those characteristics, there are no surface flows or near-surface groundwater in the area, but rainwater briefly flows off the surface and sinks underground. In the wider area of the scope (at a distance of up to 5 km from the boundaries of the Kolići hamlet) there are watercourses Jadro with tributary Ozrnski potok, sinkhole rivers that spring near the sea. From the pedological aspect in the wider subject area, the most common are rendsina and brown soil on limestone. These types of soils have developed with regard to the geological base and the characteristic of karst area. Since hamlet is located on the slopes, it is also endangered by the slope processes.



Area of Kolići hamlet with wider cultural heritage site

Hamlet Kolići is mainly made of lime-bound stone material while the stone fences are built using the drywall technique, which has been recognized and protected by UNESCO on the World Intangible Heritage List. Due to poor housing conditions and underdevelopment, the environment around houses and outbuildings was often not paved. Because of their construction, houses in hamlet have a certain resistance to natural and human disasters but the vegetation that surrounds it does not withstand the increasing droughts and fires in this area. According to the Corine land cover nomenclature (used for environmental information) in the immediate vicinity of the hamlet the most common categories in the class of forests and semi-natural areas are natural grassland, transitional woodland-shrub and brad-leaved forest. Due to the anthropogenic impact, the forest vegetation that makes up the climazonal vegetation of this area has decreased and remained only in a small part of the area. Yet, the existing cover represent easily burning vegetation wherefor this area is particularly vulnerable and requires special attention during valorization and preservation. Each summer the area is under a threat of devastating fires quick to get a great magnitude due to the impact of winds, droughts and vegetation that is easy to burn. The impact of wildfires on the environment in the wider area is well shown on the Corine land cover map where a significant proportion of the territory is marked as 'burned areas'. In the narrower radius, agricultural areas of various denominations are significantly represented (at the locality of Kolići hamlet, these are mostly areas with complex cultivation patterns). Speaking of artificial structures, a highway passes through the hamlet, near the protected cultural heritage site. Northeastern from the hamlet there is also a stonepit.



Corine land cover and land use map

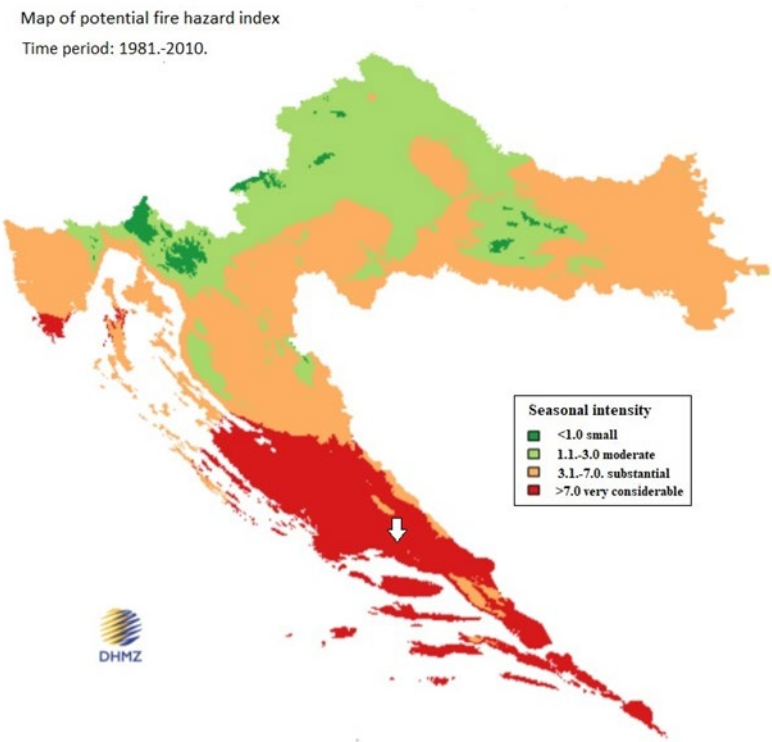
2. Weather-related risks in the Split-Dalmatia County and Kolić hamlet

In order to illustrate the impact of weather-related risks on the local case study area, this chapter will briefly present some of the climatic characteristics of the Split-Dalmatia County, in which Kolići hamlet is located.

The Split-Dalmatia County in geographical terms includes hinterland, the coastal flysch zone and islands. Since the Kolići hamlet is located in the hinterland, special emphasis will be placed on that area. Climate of the hinterland is moderately warm and humid with hot summers (Cfa), while the coastal area and islands have a Mediterranean climate with hot, dry summers (Csa). Hot summers are the result of the intense daily warming of the relatively low relief, while the soil is mostly porous and dry (Šegota, 1996).

2.1. Fire risk

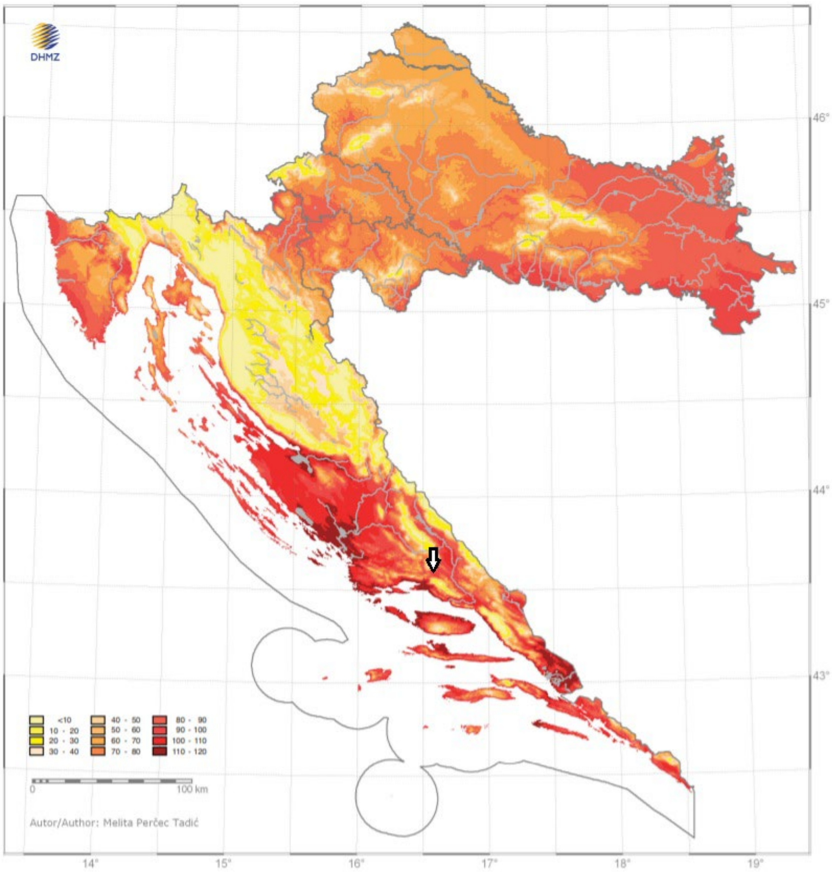
Weather conditions and forest fires are closely related as a cause-and-effect relationship between climate weather, human activities and the state of combustible material (humidity, types of vegetation and biomass production) in a shorter period of time. According to Disaster Risk Assessment for the Republic of Croatia, Split-Dalmatia County stands out as one of two most endangered counties in Croatia when it comes to fire risk, where orographic factors such as altitude, exposure to sunlight or wind, slope and terrain shape increase the likelihood of fire. It is generally considered that the potential risk of vegetation fire is very high if the SSR (medium seasonal intensities index) is > 7. According to the analysis of the period 1981-2010, average SSR values in the region of Dalmatia are mostly in the range of 8 to 12 with the exception of the surroundings of Split where they reach almost up to 16. In the local context it is particularly worrying that spatial analysis of medium seasonal intensities (SSR) of the last three decades have shown the expansion of areas with high potential fire risk of vegetation from the Dalmatian islands and coast to the hinterland compared to the standard climate period 1961-1990.



Map of potential fire hazard index in Croatia

In the Split-Dalmatia County, one of the biggest fires in Croatian history happened in the July of 2017. Fire covered an area of 4,500 ha in the vicinity of the city of Split and great material damage was recorded. The fire destroyed small villages on the slopes of Mount Perun, as well as large areas of the cultural landscape that includes dry stone walls, olive groves and vineyards that form typical Dalmatian landscape. Although this fire is highlighted as the one that caused great damage, it is no exception. For example, in the year 2020 alone, the police conducted an investigation into 834 fires in the Split-Dalmatia County, of which 640 fires were recorded in the open area. Fire peak in the most coastal areas is in July and August and it is related with forest fires (dense and unmaintained coniferous forests that usually exist with a slope of more than 30%, away from access roads and available water for firefighting, burdening the space with additional people-tourists …). In the hinterland, there is also a greater risk of fire breaks in spring when the agricultural work starts.

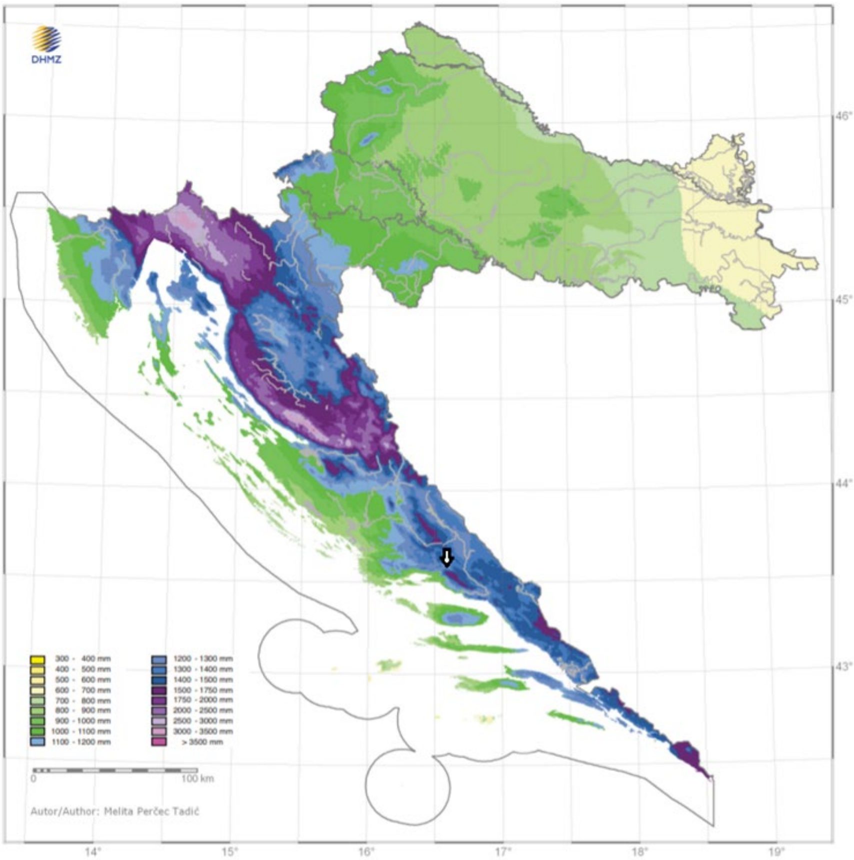
In the area of Dugopolje municipality (in which hamlet Kolići is located) there are buildings and open areas that are classified in the highest categories of endangerment and monitoring. Because of such state, local patrols performe in days of high and very high class of danger of fires and open fires. Although fires may occur at different temperatures, indicating that fires occur independently of temperature; nonetheless their number is dependent on temperature increases. For the area of Dugopolje municipality, mean annual number of warm days is around 90 up to 100, which is less then mean number of warm days in narrow coastal zone, but is still significantly high. In the context of fires, it is also necessary to mention local winds. The winds in Dugopolje Municipality are dominated by *bura* and *jugo*, whose annual frequency is 35% to 55%.



Mean annual number of warm days (tmax≥25°C)

2.2. Heavy rainfall

Local factors that may enhance or weaken the development of precipitation are especially present in Croatia. By reason of that, different vertical gradients of precipitation even at small horizontal distances can be seen on the map of the spatial distribution of the mean annual precipitation totals. For the area of Split-Dalmatia County differences in annual precipitation between hinterland, coastal area and islands are result of the relationship between land and sea, then highly developed orography which is an obstacle to maritime airspace masses at the transition from the Adriatic to the mainland and also for continental air masses towards the Mediterranean. At the same time, in certain weather situations, mountains and smaller hills cause air masses to lift, resulting in condensation and intensified precipitation. According to Croatian Meteorological and Hydrological Service, the mean annual precipitation in the area of Dugopolje Municipality ranges somewhere between 1200 mm and 1400 mm. In the coastal area (city of Split) it ranges from 1000 to 1100 mm. The highest amount of precipitation in nearby area falls at the slopes of hill Mosor (from 1500 to 1750 mm). The precipitation regime has all the characteristics of a maritime Mediterranean type of climate which is distinguished by the fact that in the winter half of the year it falls almost 2/3 precipitation. Statistics indicate that during 30-year period (1971– 2000), there was a little decrease in the mean annual precipitation amount in Split-Dalmatia County.



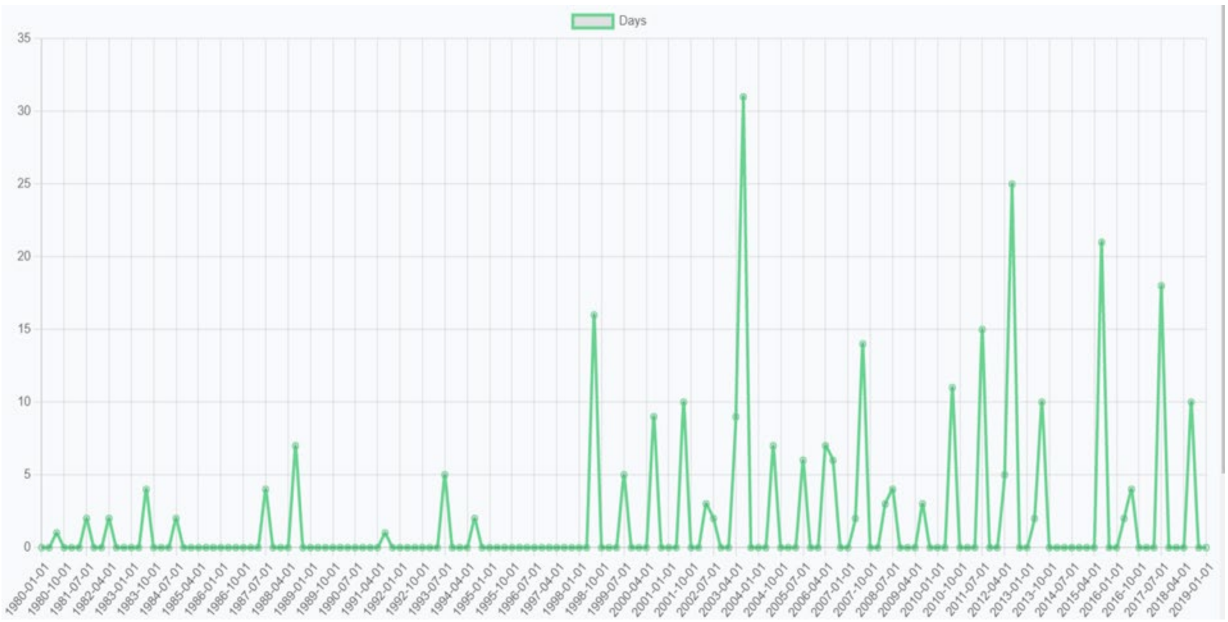
Mean annual precipitation

Extreme precipitation amounts and the probability that they will occur are important characteristics of the precipitation regime. They are most common cause of increasing floods, landslides and are often linked with climate change. Hamlet Kolići are specially endangered by the slope processes but also flash floods which can also cause structural damage to buildings in the hamlets. Since there is a lot of groundwater in this area, during heavy rains springs can get activated and flood the fields. Such an event occurred recently, when in December of 2020 heavy rain was falling for three days and caused floods in the area of Dugopolje, generated by a Mediterranean cyclone. This resulted in flooding and activating landslides throughout Split-Dalmatia County. In accordance with Preliminary flood risk assessment created by Hrvatske vode (legal entity for water management in Croatia), Municipality Dugopolje has been declared as "Area of potentially significant flood risks".

Flood in fields of Dugopolje municipality, 2020

3.1. Meteorological observations of past events

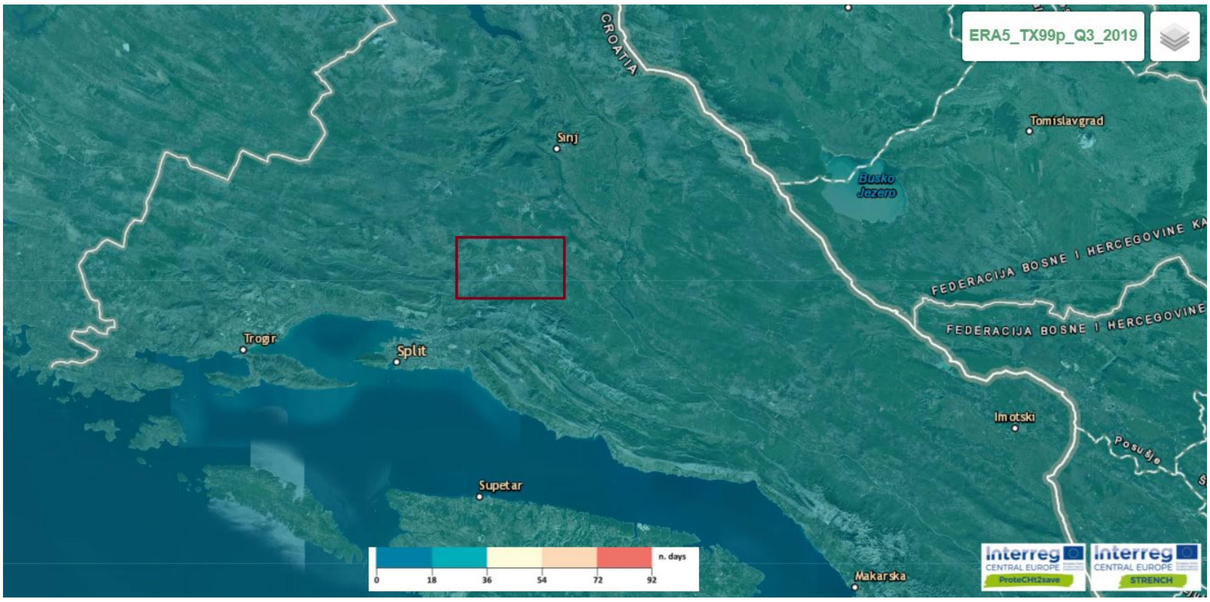
According to ERA5, the number of hot days has increased significantly in the last 20 years. Since 2000, only in 2014 no hot days have been recorded, while until 2000 only ten years with hot days had been recorded. Also, pre-2000 years are marked by a significantly lower total number of hot days. If we compare the years with the highest number of hot days with the years in which the highest number of fires was recorded in the Split-Dalmatia County, some parallels can be drawn. For instance, in 2003 the largest number of forest fires in 10 years (2003-2013) was recorded in Split-Dalmatia County as well as the largest burned forest area, which is also the year with the greatest number of hot days in the observed period. Very large number of more than 1000 fires was recorded in 2011 when more than 15 hot days was recorded. Also, more than 900 fires were recorded in 2008, 2012 and 2015, while in 2014 (the year with absence of hot days) minimum number (415) of fires occurred.



Number of extremely hot days in the year (TXPP90 – ERA5) in the period of 1980-2019

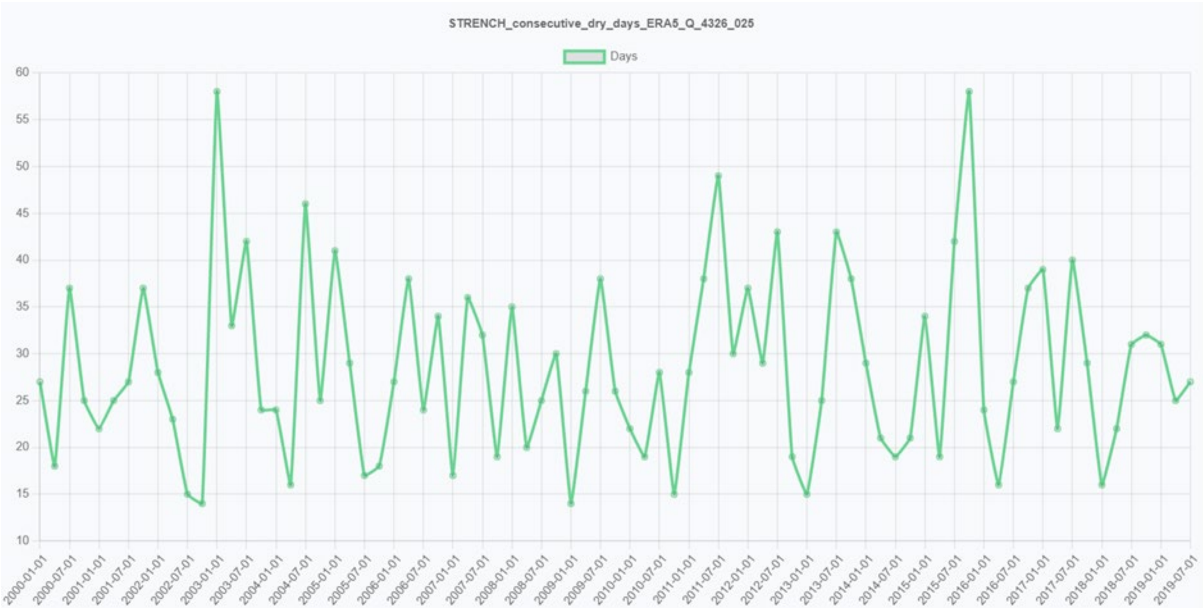
Bellow, two years were taken (1980 and 2019) as examples of general changes in the number of hot days over the past 40 years.

Extremely hot days in summer of 1980 (ERA5_TX99p_1980)



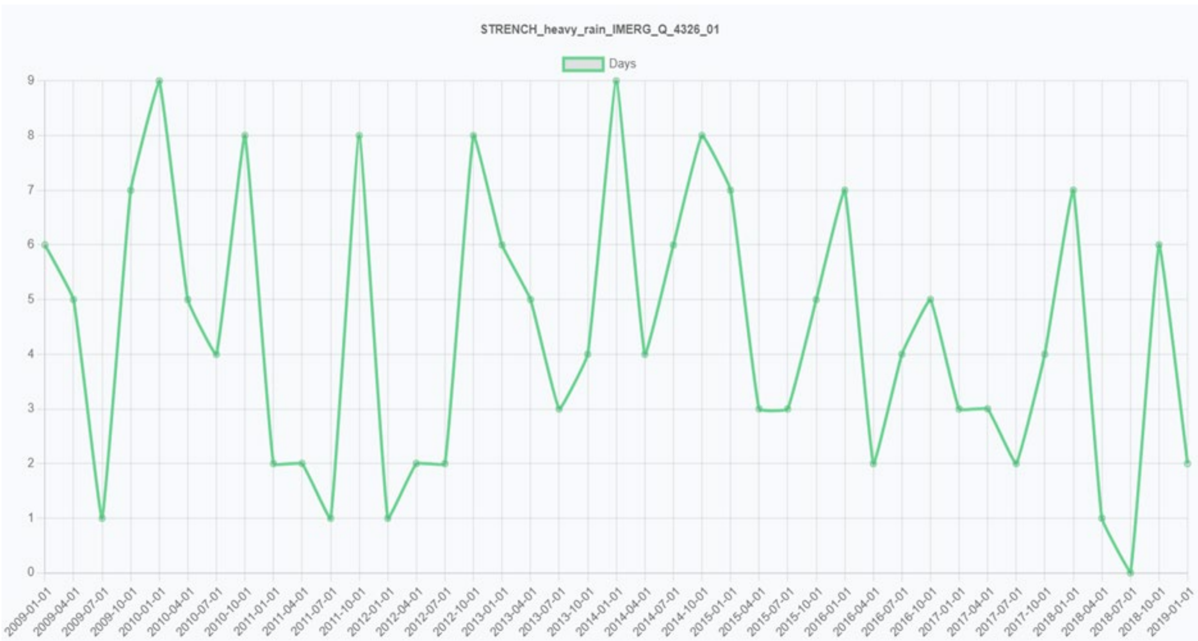
Extremely hot days in summer of 2019 (ERA5_TX99p_1980)

The years with the highest number of recorded consecutive dry days (2003, 2011, 2012, 2015) partly coincide with the years with the highest number of hot days, but also with the years in which the largest number of forestfires in Split-Dalmatia County have been recorded (2003, 2008, 2011, 2015, 2016).



Consecutive dry days (ERA5) in the period of 2000-2019

In the ten-year period 2009-2019 the lowest number of days with extreme rainfall was recorded in summer, while the highest number of days with extreme rainfall was recorded in winter and for some years in autumn. Such events are connected with higher risk of slope processes and the possibility of flooding of wider area, which in this area usually occurred in winter. This dataset can be correlated with some past events is the region of Split-Dalmatia County, for instance, at the beginning of 2010, larger areas of region were under a threat of floods and slope processes. Due to heavy rains, sea levels and levels of local rivers rose, as well as underground waters.



Heavy rain days (R20mm - IMERG) in the period of 2009-2019

3.2. Vulnerability for the site of Kolići hamlet

The vulnerability value for the Kolići hamlet which was calculated in the framework of the STRENCH project earlier, is medium (0.52).

Some of the shortcomings highlighted in evaluation were:

- very bad state of conservation
- prevalence of species not tolerant to local natural and climate threats
- prevalence of mature/veteran trees
- water table prone to sudden fluctuations
- non cultural acknowledgements (to be adjusted according to the national adopted scale)
- absence of early warning systems
- absence of physical protection
- absence of emergency human and economic resources

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

- **Fires** – fires represent one of the mayor threats for the area of Split-Dalmatia County in general. Prevalence of warm days and conductive dry days are local climate characteristics which in a way "encourage" the occurrence of fires. Forest areas are particularly endangered by fires, and the occurrence of increasingly frequent fires in the hinterland of the Split-Dalmatia County is also worrying. In the case of the Kolići hamlet, the situation is particularly unfavorable because the site is surrounded by easily burning vegetation. Although hamlet Kolići is mainly made of lime-bound stone material which is to a certain degree resistant on that kind of hazard, the fire could do great damage to the cultural landscape, but also to agricultural land and human settlements nearby.

- **Strong winds –** in the context of criticalities, katabatic wind of bora (specific for the Adriatic coast) can be mentioned. Since the area of Kolići hamlet lies of foothills of mountain Mosor, strong winds that reach high speeds are not unusual occurrence. In the case of a fire, such a phenomenon may have a negative impact on fire spreading.

- **Heavy rainfall** – specific combination of physical-geographical factors in the area combined with heavy rainfall can bring different types of risks, as shown above. Each year dozens of rockfalls and small landslides are recorded in the area of Split-Dalmatia County while problems with erosion of the slope surface are an everyday occurrence. For the locality of Kolići hamlet, special threat present possibility of landslide.

4. Evaluated site: Kolići hamlet

Since the area is in the greatest risk of hazards such as fires and slope processes, four Climate extreme indices (R20mm, R95pTOT, CCD, Tx90p) connected to these calamitous events were chosen to be analyzed through maps collected from WebGIS application. These maps show variations of precipitation and temperatures over past and possible variations in the future (projections included maps from Model ensemble statistics / maximum values / RCP 4.5), divided in four segments due to four index defined bellow. Each map is showing wider area of Split-Dalmatia County with a fitting smaller area of Kolići hamlet locality marked in every map (red square).

WebGIS indices used:

- **TX90p – Percentage of extremely warm days**

  o 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.

  o Index used cause of possible fire hazards due to high temperature
- **CDD – Maximum number of consecutive dry days**

  o 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

  o Index used cause of possible fire hazards due to long time dry periods
- **R9pTOT- Precipitation due to extremely wet days**

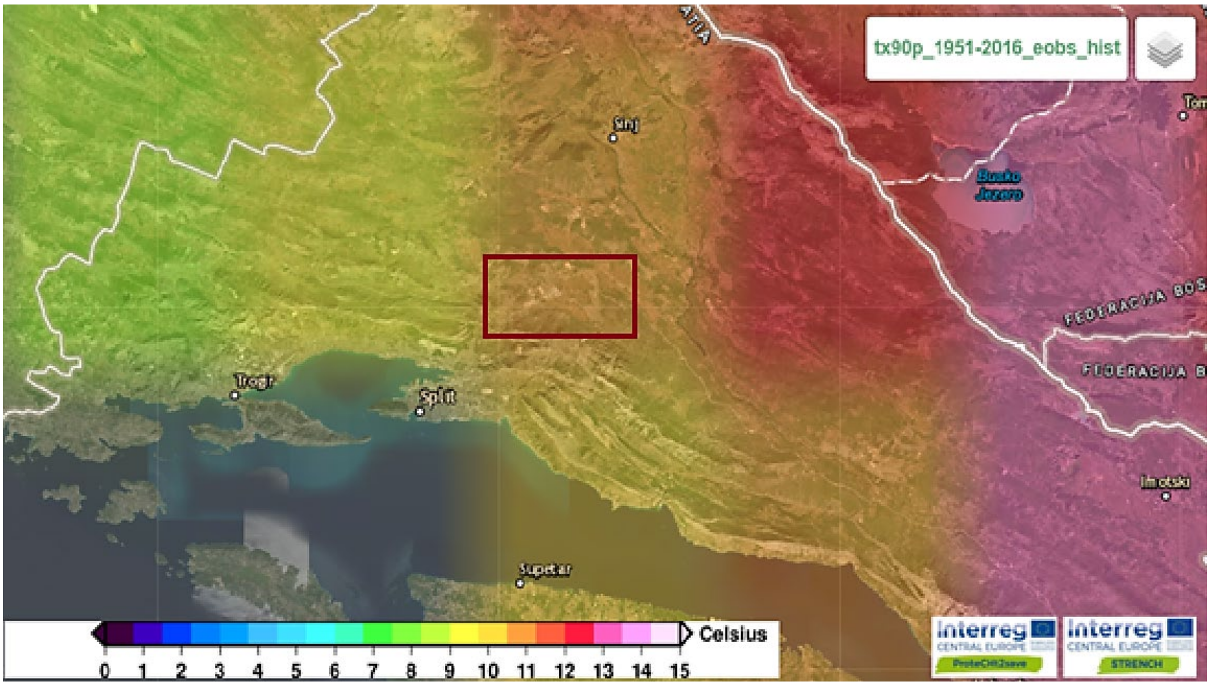
  o The total precipitation in a year cumulated over all days when daily precipitation is larger than the 95th percentile of daily precipitation on wet days. A wet day is defined as having daily precipitation ≥ 1 mm/day. A threshold based on the 95th percentile selects only 5% of the most extreme wet days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

  o Index used cause of possible threat of slope processes and landslide
- **R20mm - Very heavy precipitation days**

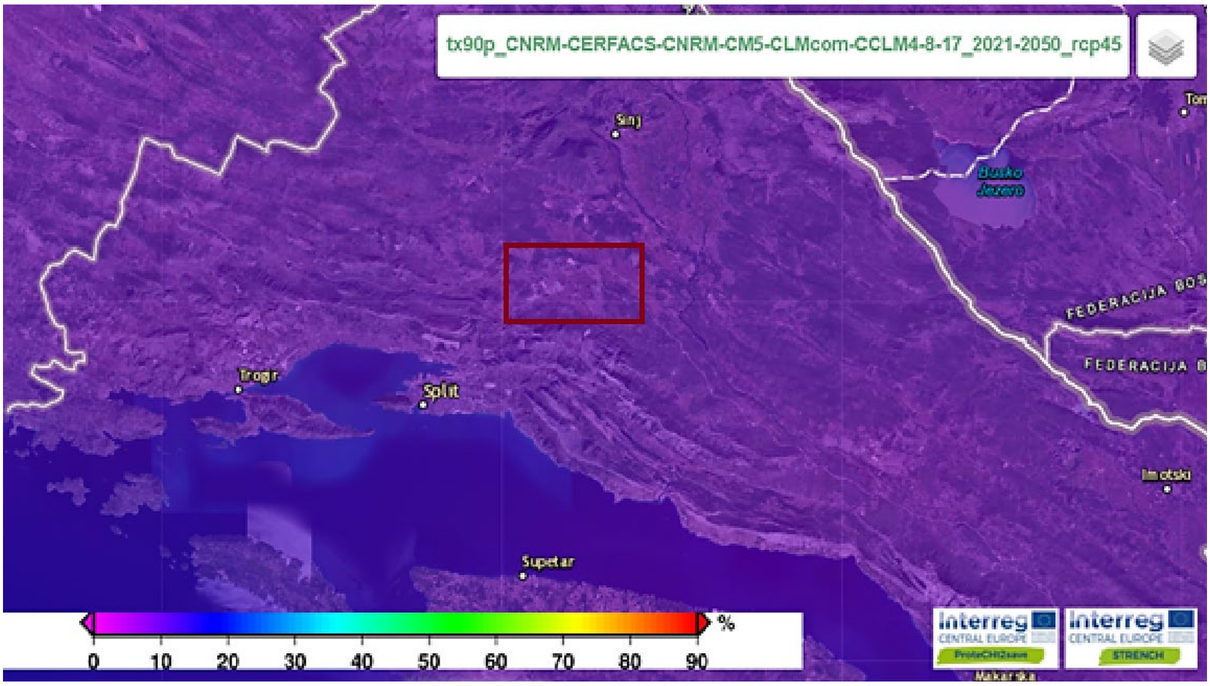
  o Number of days in a year with precipitation larger or equal 20 mm/day.

  o Index used cause of possible threat of slope processes and landslide

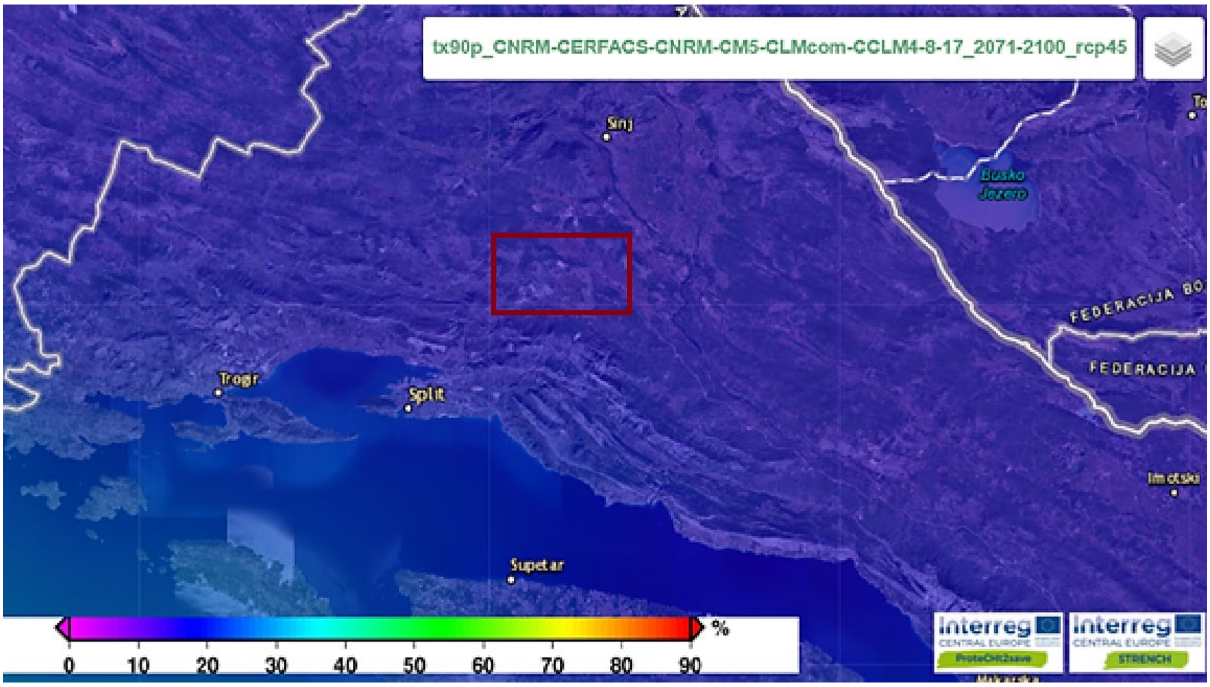
1. **Percentage of extremely warm days (TX90p)**



Historical observation (1951.-2016.)



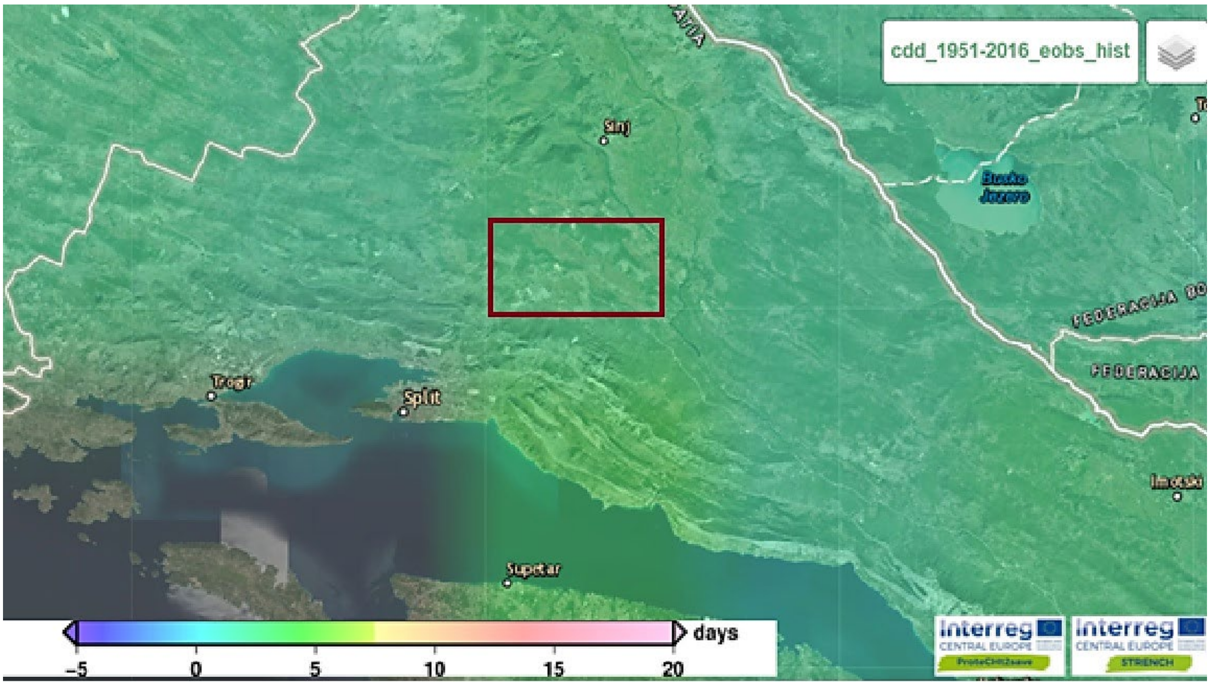
Near future (2021.-2050., RCP 4.5)



Far future (2071.-2100., RCP 4.5)

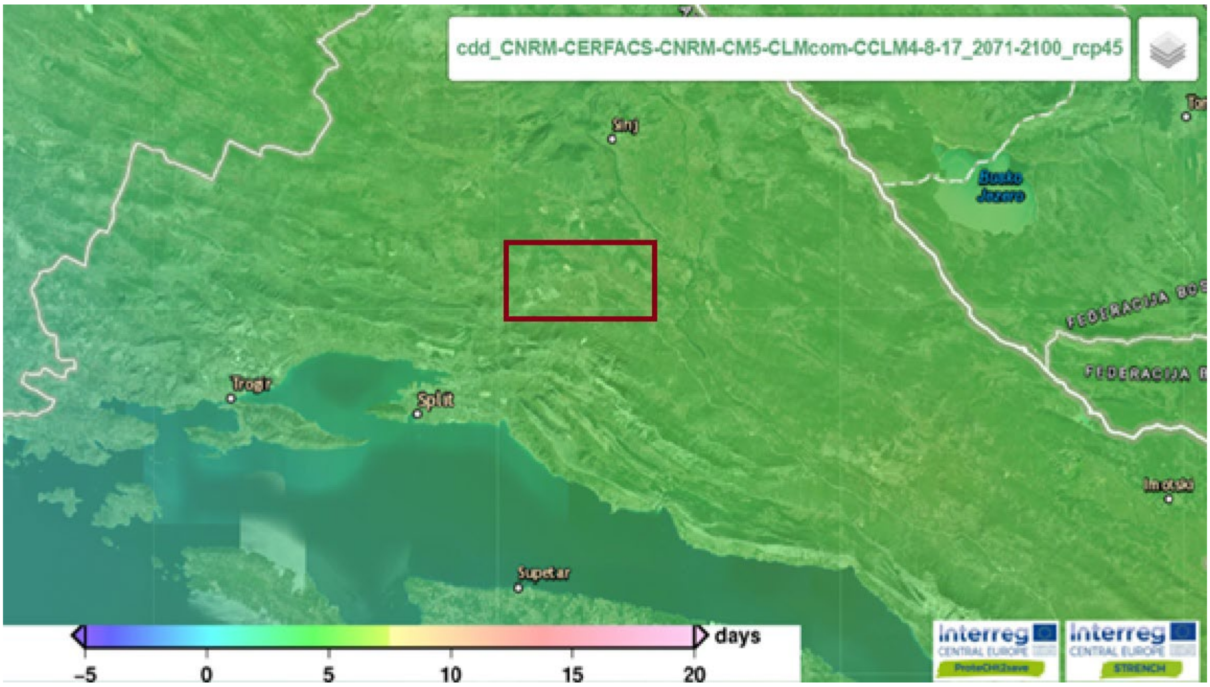
The maps are showing increase in the number of hot days in the next 30 years by 10 %. Far future projection also indicates a further rise, up to 20 %. Such occurrence of high temperatures dry out the soil and vegetation, so the area is more at risk of fire frequency in the future.

2. Maximum number of consecutive dry days (CDD)



Historical observation (1951.-2016.)

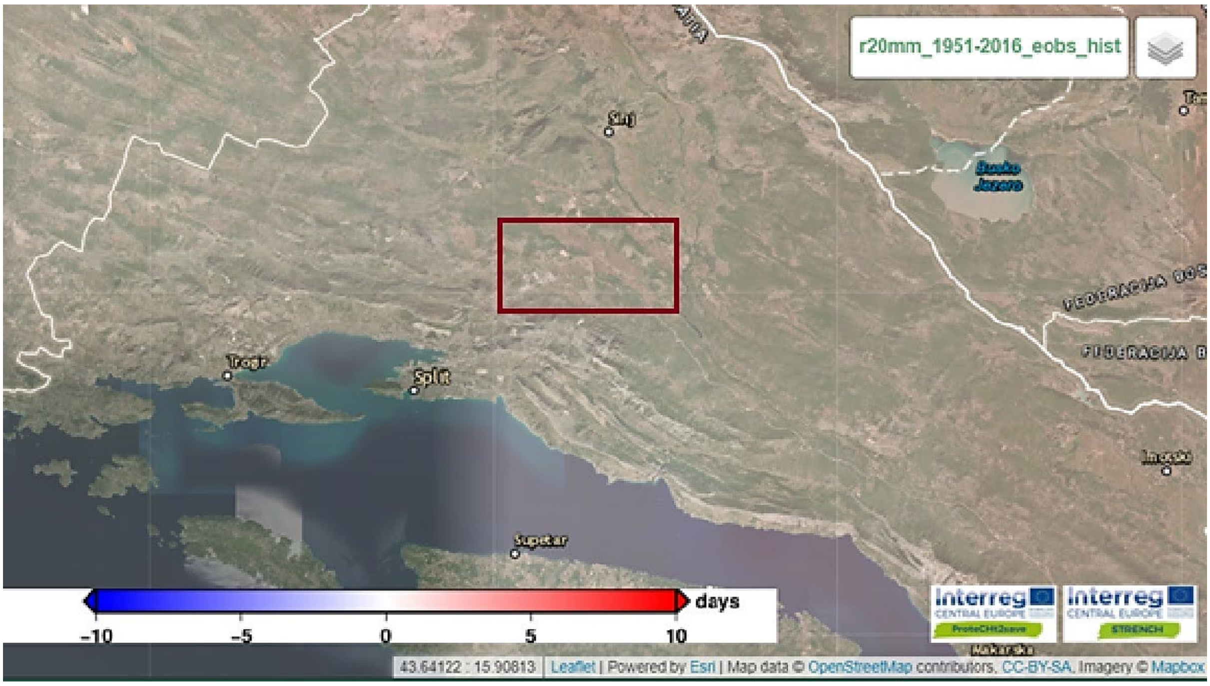
Near future (2021.-2050., RCP 4.5)



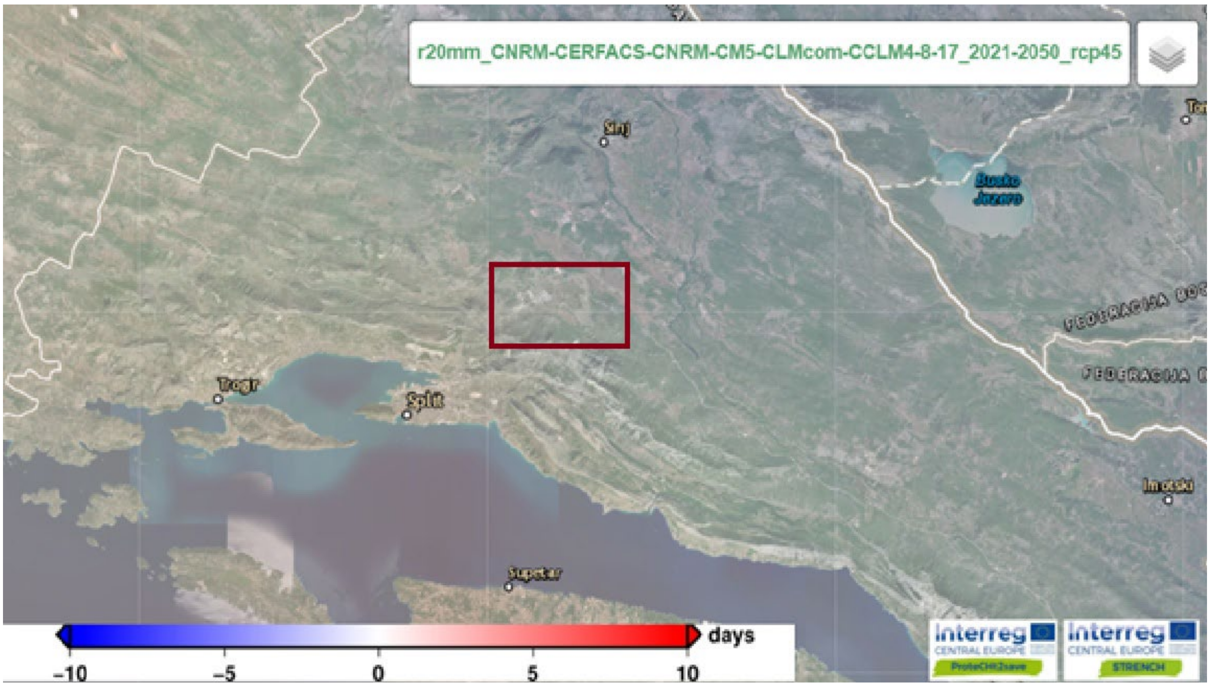
Far future (2071.-2100., RCP 4.5)

Maps are showing slight increase in maximum number of consecutive dry days in period of near future with the similar values in the far future. The prolong of the drought periods also lead to increased fire risk.

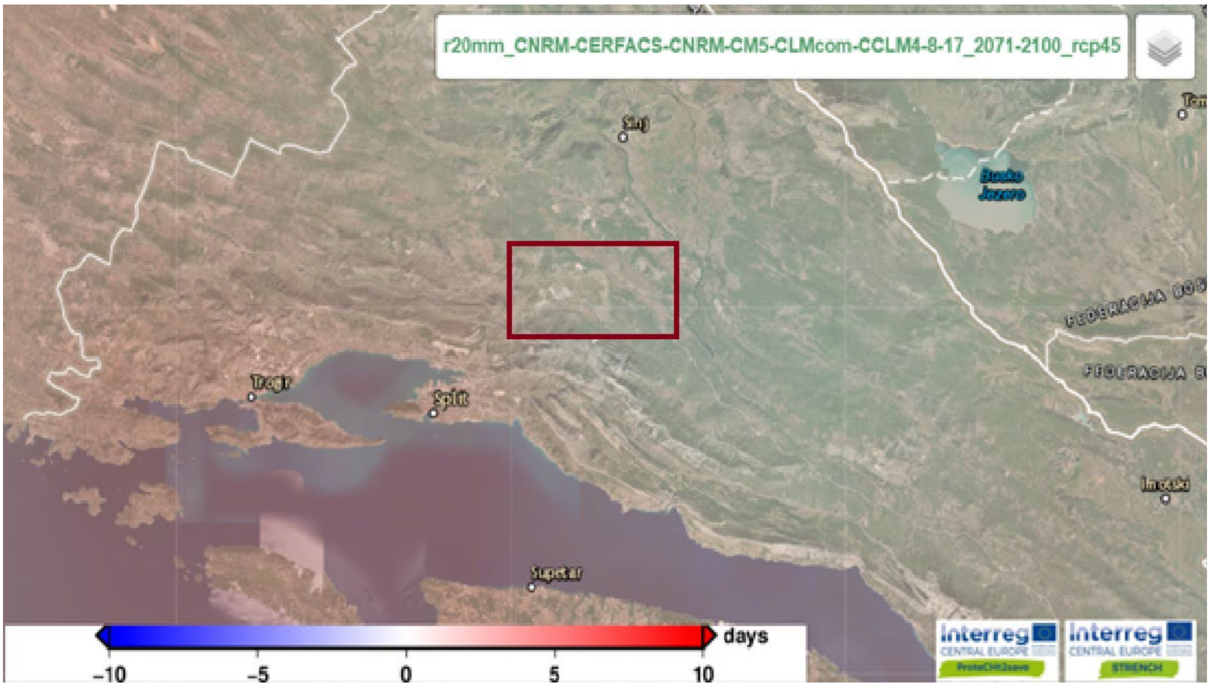
3. Very heavy precipitation days (Rm20)



Historical observation (1951.-2016.)



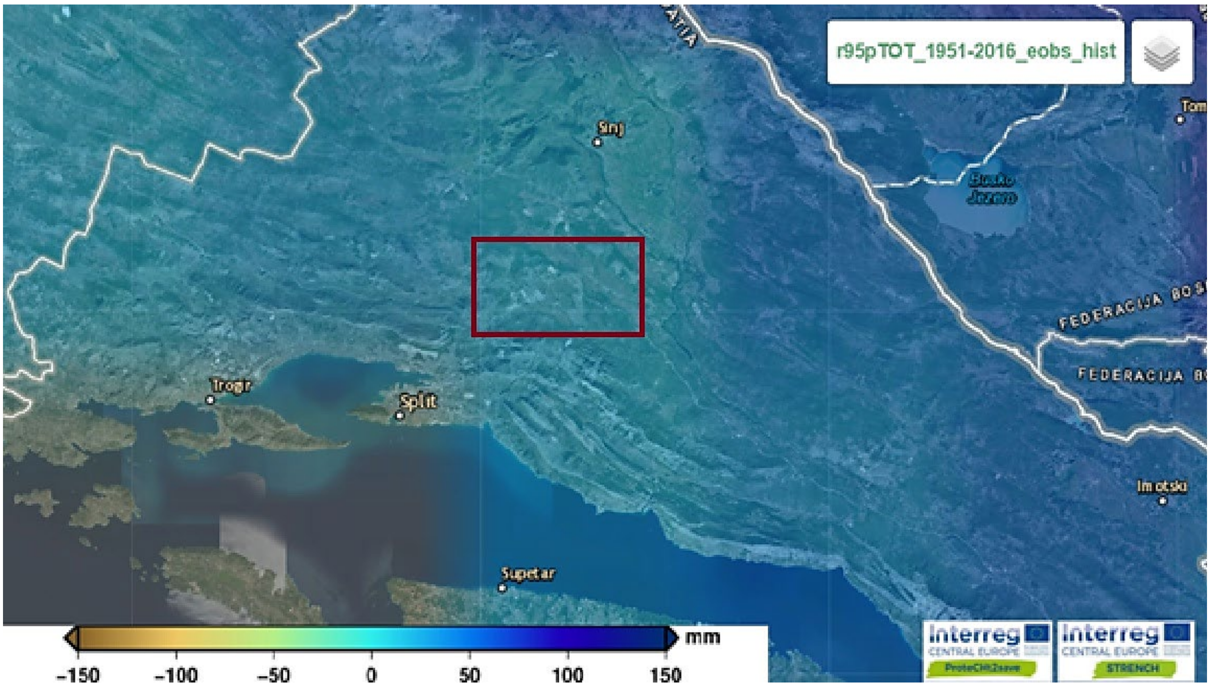
Near future (2021.-2050., RCP 4.5)



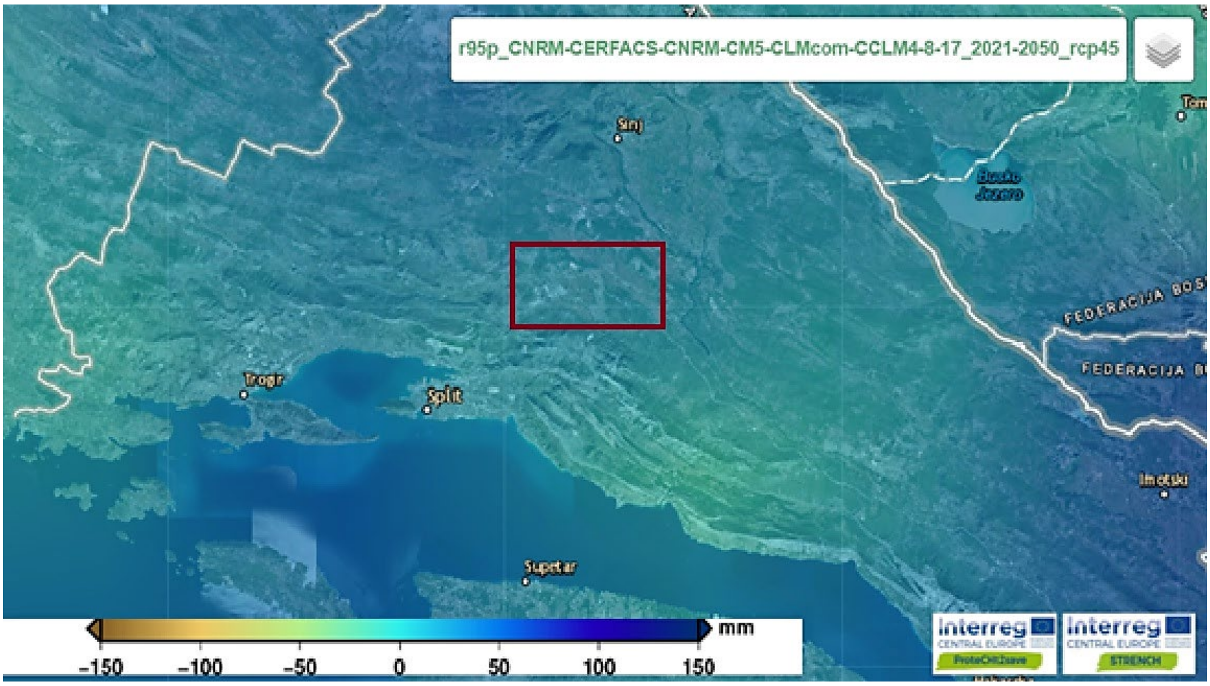
Far future (2071.-2100., RCP 4.5)

The first map is showing how the number of days with heavy precipitation is somewhere between 2-3 days range. It seems that in the near future the number of days will decrease to 0-1 days range but the far future projections show mild increase in values. It is interesting that the reduction is anticipated to be wider across the continental area while the increase is anticipated in the coastal zone.

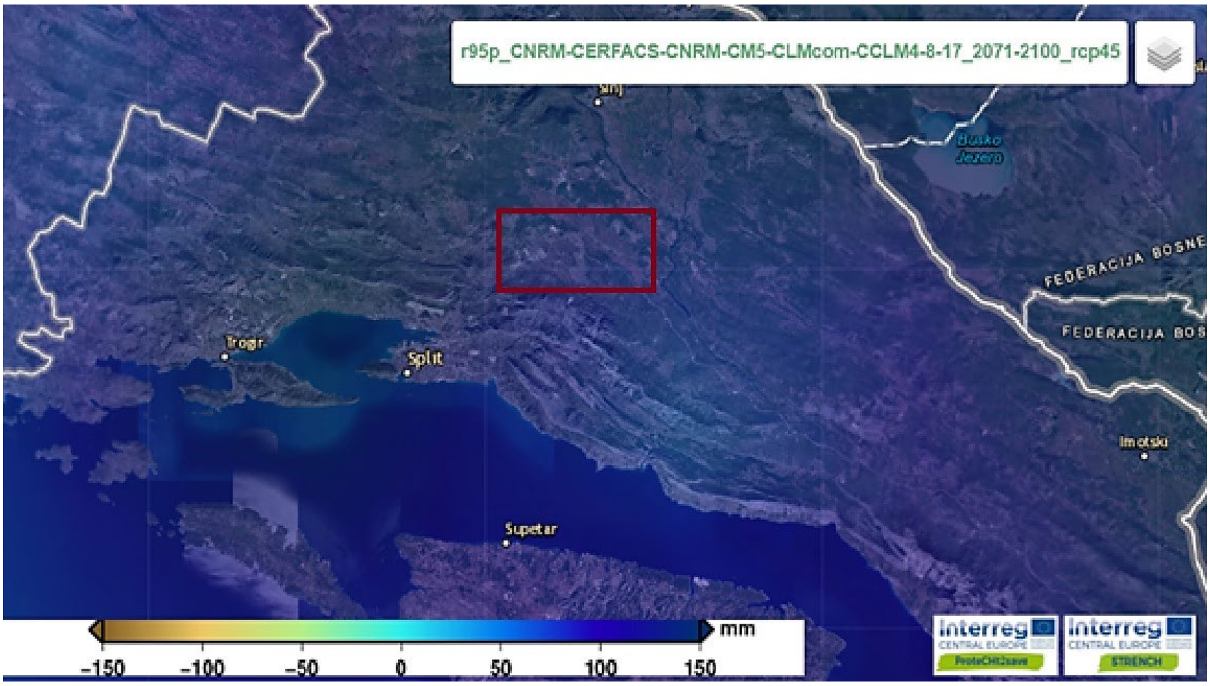
4. Precipitation due to extremely wet days (R9pTOT)



Historical observation (1951.-2016.)



Near future (2021.-2050., RCP 4.5)



Far future (2071.-2100., RCP 4.5)

Model of precipitation due to extremely wet days is predicting changes in the near future in in the wider area, primarily at coastal zone and seaside. For the far future, projection map shows significantly higher amounts of precipitation for the entire area which can consequently affect risk of flooding and slope processes.

5. Main thoughts after analysis and suggestions

Analysis made lead to certain assumptions:

- changes in temperature will contribute to an increase in the number of hot days in the observed area and will slightly prolong the drought periods. Such a condition could cause the plants to dry out and increase their vulnerability. Since the area is also facing depopulation, care for vegetation is already reduced and large areas will be left to overgrowth in the future which could also increase risks to hazards such as fire risk.
- the maps are indicating that there will be rise in precipitation due to extremely wet days in the area. This means that surface degradation processes could be reinforced but also that there is greater possibility of floods caused by groundwater.

Calculating these factors in the planning for the future, the following suggestions can be made in the preservation of Kolići hamlet and the landscape elements:

- fistly, it is necessary to raise the level of awareness of the local public about climate change-related hazards by creating suitable activities
- measures should be established to maintain the area around cultural property (regular mowing the grass, care of plants and trees)
- to have better insight into the state of watercourses in nearby area higher levels of monitoring are desirable, also as maintaining and clearing the abyss
- agricultural work should be monitored, especially during the spring when fires in the fields may occur
- local firefighters have well developed system in the case of fire outbreaks and in the case of flooding so their further empowerment and investments in their activity should be encouraged

WebGIS application with its comprehensive information and services, easy to use maps could greatly assist local management in shaping sustainable cultural heritage strategies and improve know-how on the process of dealing with the climate change. The biggest advantages of the tool come from its ease of use and effective data visualization. Although the capabilities of the tool are to be commended, we fell that some small refinements could be applied to make the tool even better (for example, more pronounced colors on maps and a more pronounced difference between individual values with the aim of clearer visualization and visibility of data).