DELIVERABLE D.T2.2.1 (PP3)

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

Inhalt

An introduction to the Wachau

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

Figure 1 Typical Wachau landscape. ©Stefan Rotter

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

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

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

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

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

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

Cultural Heritage at risk in the Wachau region

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

Dry Stone Walls as tangible and intangible cultural heritage

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

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

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

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

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

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

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

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

Castles, Palaces and Monasteries

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

Figure 3 Schloss Schönbühl. © Donau Niederösterreich/Lachlan Blair

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

Figure 4 Roman remains in Mautern. ©Eva Kuttner

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

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

Agriculture (apricot trees) & Viticulture

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

Figure 5 Cultural landscape Wachau. ©ÖWM/Robert Herbst

Artistic treasures

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

Figure 6 Venus of Willendorf. ©NHM

[4] https://www.donau-limes.at/besuchen/regionen/nibelungengau-wachau/ (accessed 22.12.2021)
[5] https://info.bmlrt.gv.at (accessed 22.12.2021)
[6] https://www.nhm-wien.ac.at/forschung/praehistorie/forschungen/venus-forschung (23.12.2021)

Historic medical city centres

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

Summary of Cultural Heritage Assets Wachau Region

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

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

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

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

1) Melk Abbey

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

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

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

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

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

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

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

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

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

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

Vulnerability evaluation: **Vulnerability = 0.194875**

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

2) Duernstein

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

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

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

For the case study analysed:

Vulnerability evaluation: **Vulnerability = 0.351235**

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

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

3) Krems / Stein

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

Figure 9 Stein an der Donau. © Kaiser

Vulnerability evaluation: **Vulnerability = 0.18242**

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

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

Summary Melk, Duernstein, Krems/Stein:

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

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

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

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

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

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

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

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

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

Heavy Rain

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

Landslides

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

Fire due to Draught

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

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

Examples of past calamities

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

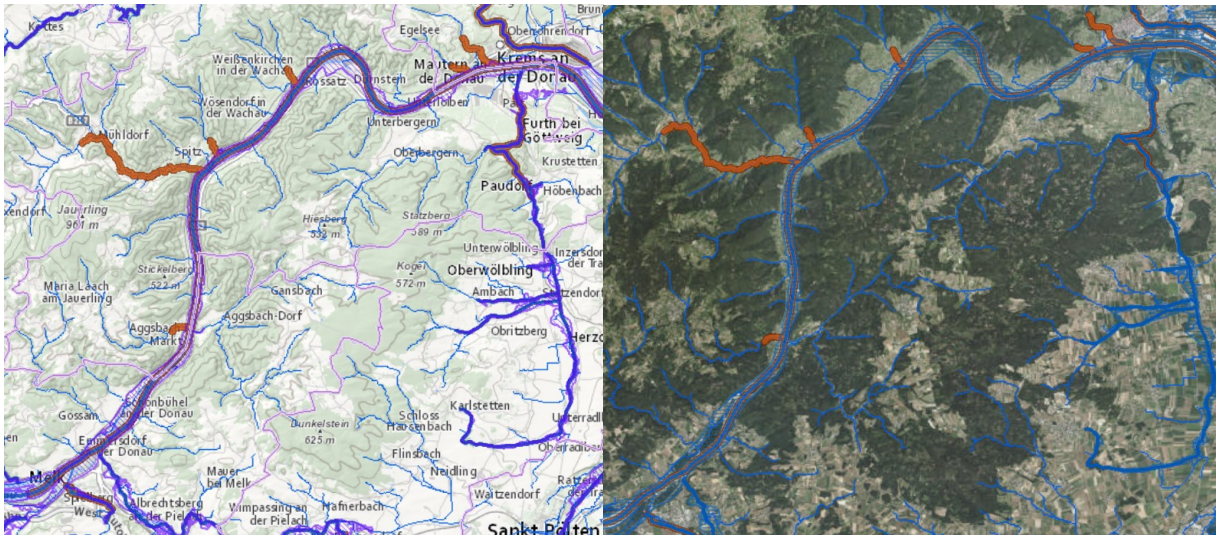


Figure 10: Screenshots of flood map of Lower Austria with the Wachau area[10]

Recent recorded flood incidences

Some of the more recent recorded flood incidences include:

- 13/07/1954, large scale river flood in Danube region being the most severe since 1899 submerging an estimated 100.000 hectares of land and requiring immediate rescue of approx. 40.000 people.[11]
- 02/07/1975, river flood in Danube region.
- 04/08/1991, river flood in Danube region.
- 14/08/2002, river flood in connection with heavy rain in Danube region

- 2008, flash flood/overflow of the tributary Grubbach (during the construction of the flood protection) in Weißenkrichen town (Wachau).

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

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

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

Figure 11 Austrian Army disaster relief

Figure 13 Austrian Army disaster relief

Figure 12 Clean-up efforts. © APA

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

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

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

Hydrological details on four major floods in the Wachau area

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

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

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

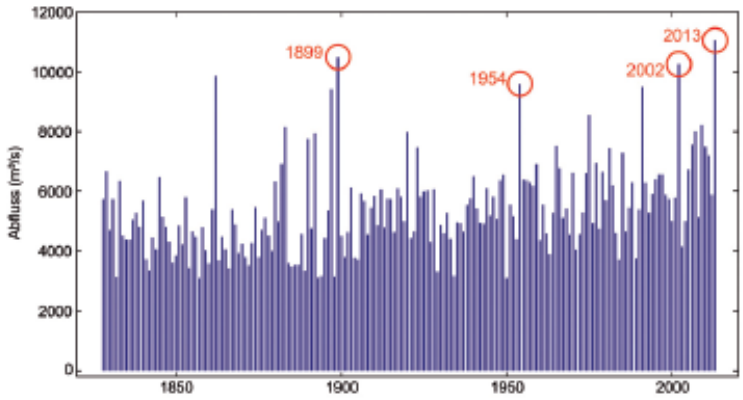


Figure 14 Annual floods of the Danube at Vienna since 1828

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

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

[17] See note 14.

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

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

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

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

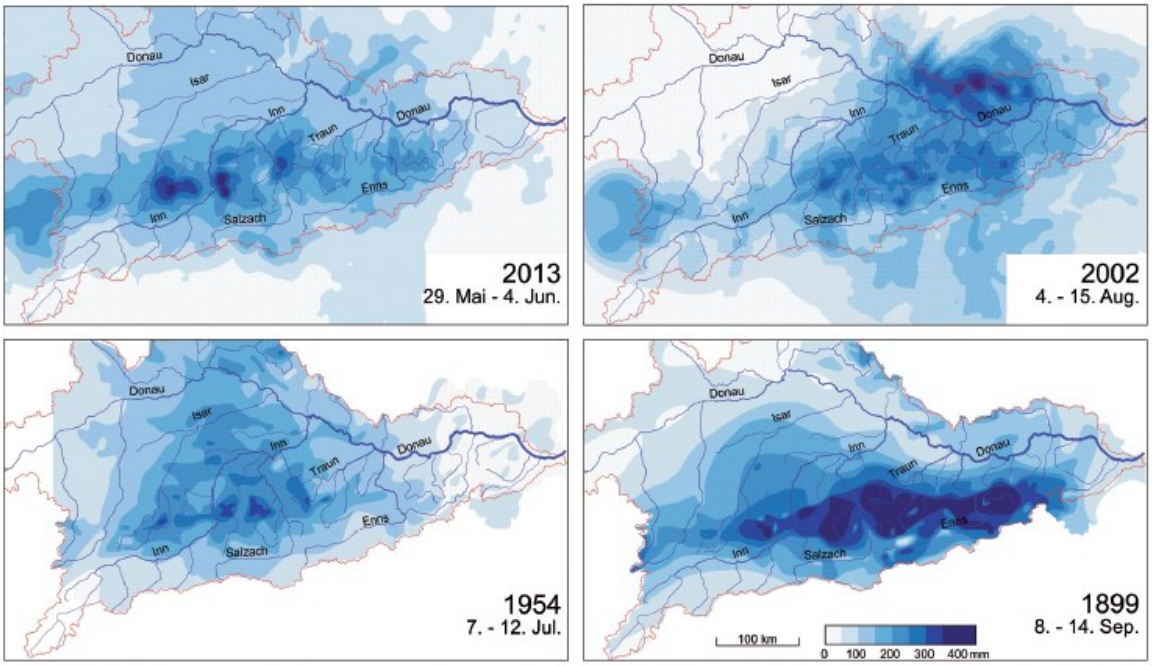
[18] Blöschl, G., Nester, T., Parajka, J., Komma, J. Hochwasserprognosen an der österreichischen Donau und Datenassimilation, in: HyWa 2014/2, pp. 64-72. DOI: 10.5675/HyWa_2014,2_1; Blöschl, G. et al., The June 2013 flood in the Upper Danube Basin, and comparisons with the 2002, 1954 and 1899 floods,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

[19] See note 16.

[20] See note 16.

[21] See note 16.

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



[22]

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

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

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

[23]

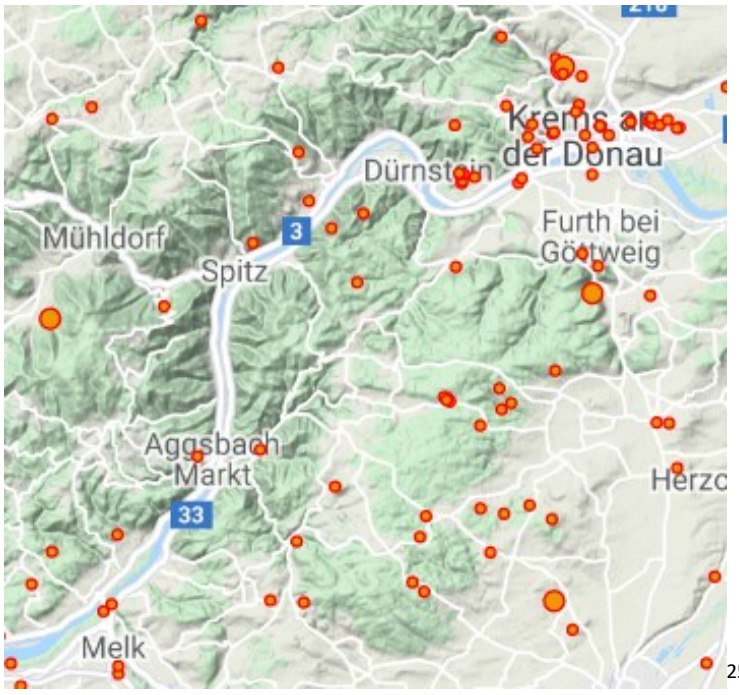
Figure 16 Summary of relevant hydrological and meteorological details, based on Blöschl et at, 2014

[23] See note 16.

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

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

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



[25]

Figure 17 Forest & Vegetation Fires since the year 2000

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

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

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

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

Risk matrix for the Wachau cultural landscape.[26]

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

Site evaluation using the WebGIS: Wachau Region

Location: Lat. 48.39018 – Long.15.47489

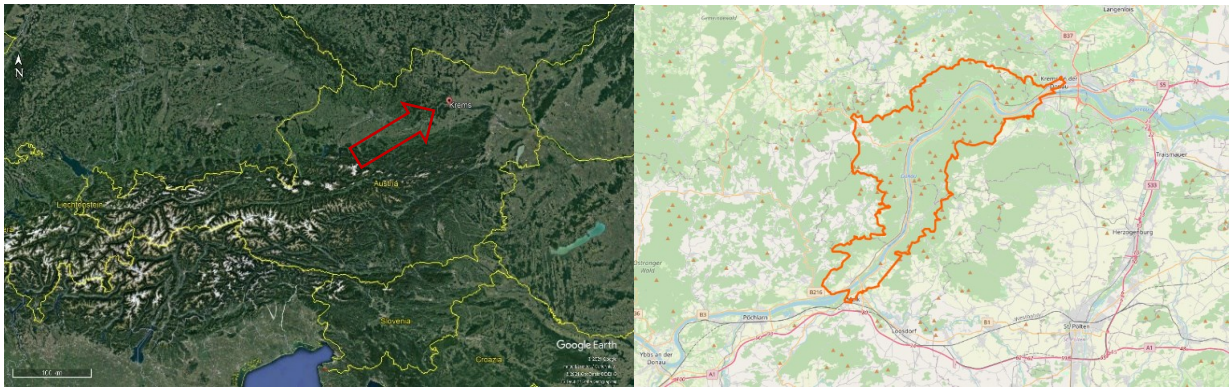


Figure 18 Google Earth screenhots showing the location of the Wachau.

Utilized WebGIS Indices & Climate Variables:

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

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

WebGIS indices and climate variables used.

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

Numerical observation

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

Figure 19 Numerical observation graph taken from the WebGIS tool.

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

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

Visualization of Extreme Event Indices

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

Very Heavy Precipitation Days (R20mm)

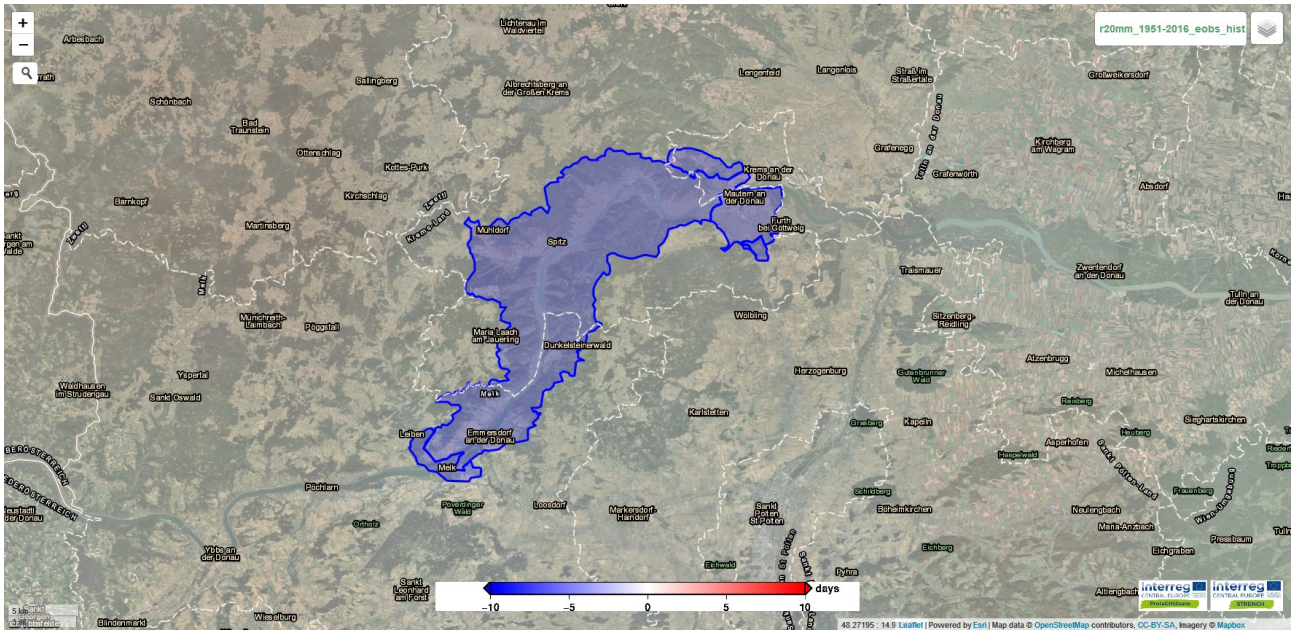


Figure 20 Historical Observation 1951 – 2016, WebGIS tool. (R20mm)

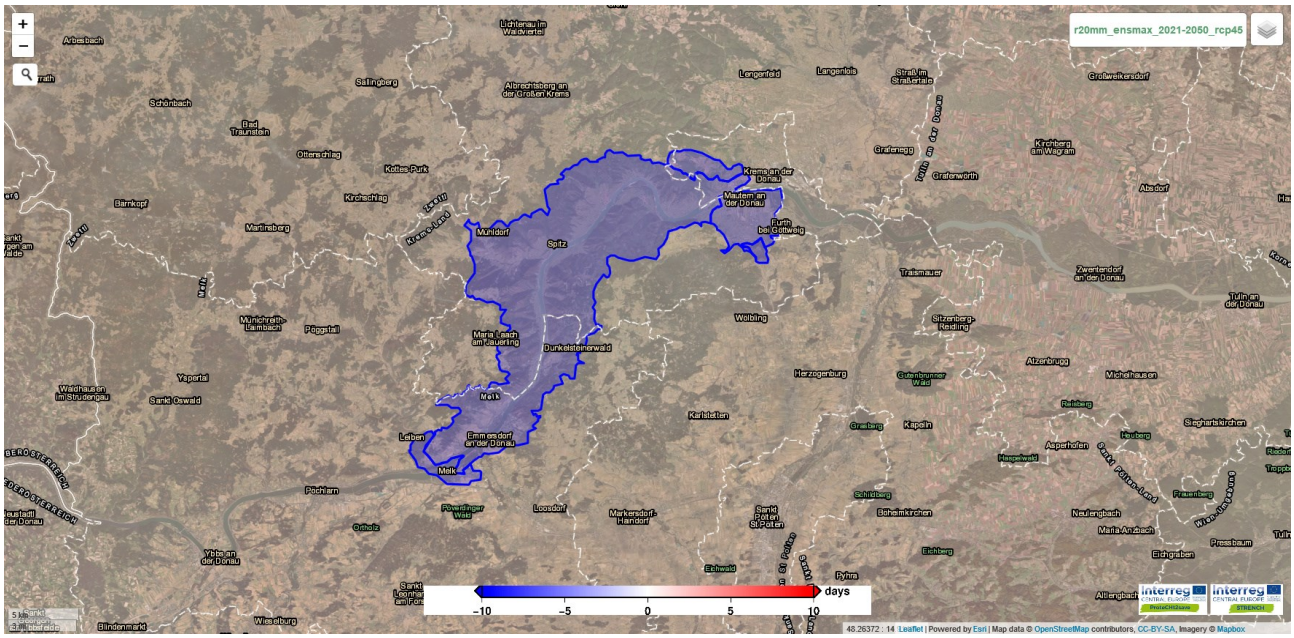


Figure 21 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (R20mm)

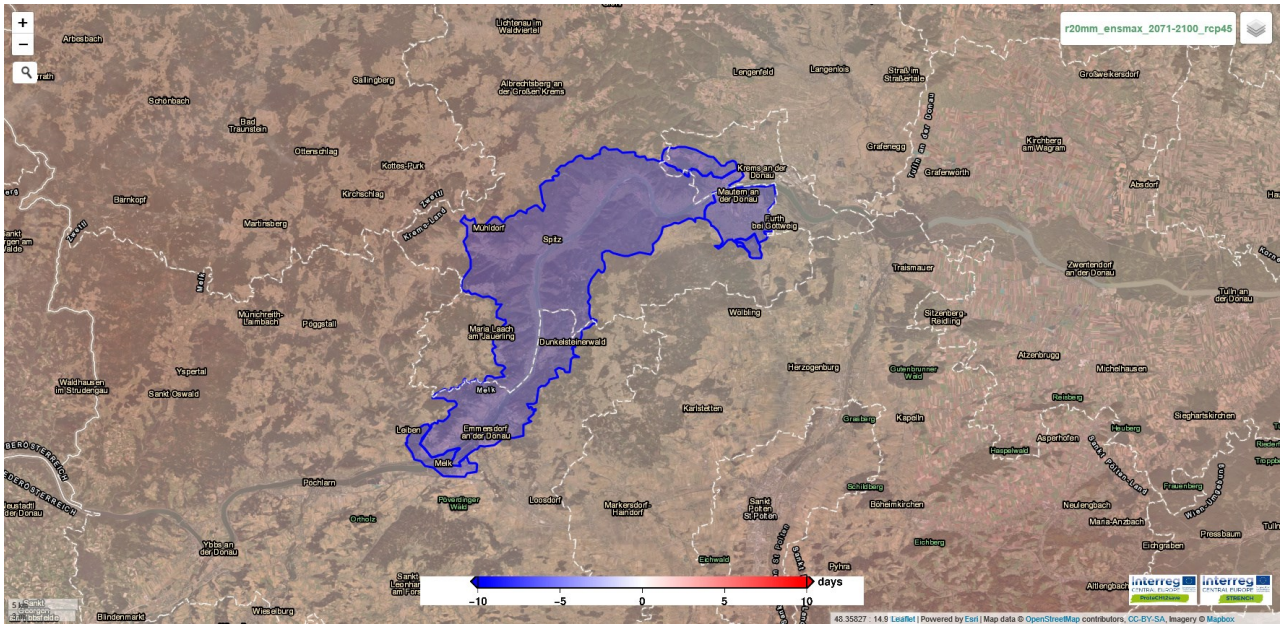


Figure 22 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool. (R20mm)

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

Precipitation due to extremely wet days (R95pTOT)

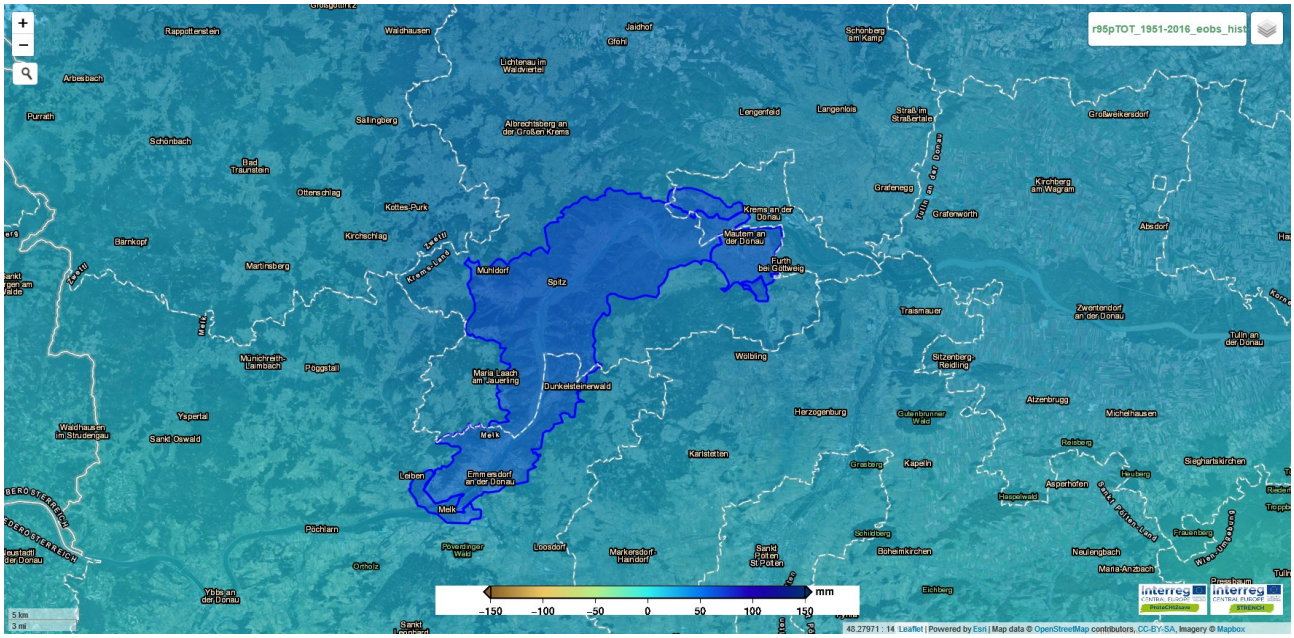


Figure 23 Historical Observation 1951 – 2016, WebGIS tool. (R95pTOT)

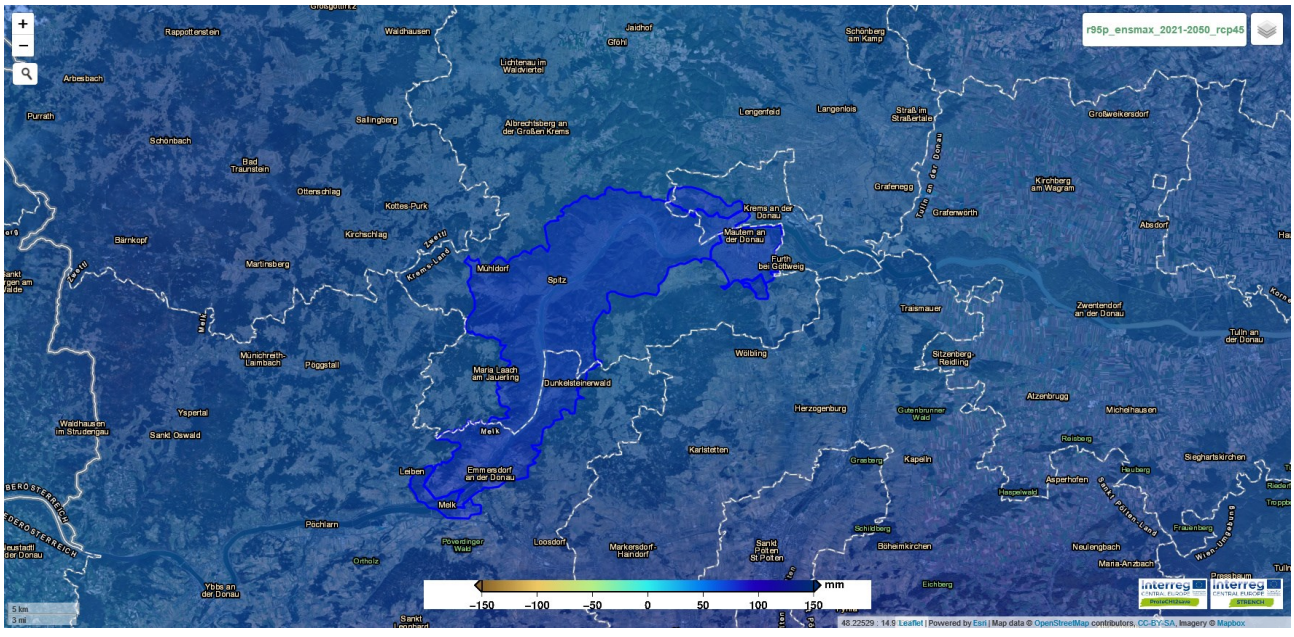


Figure 24 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (R95pTOT)

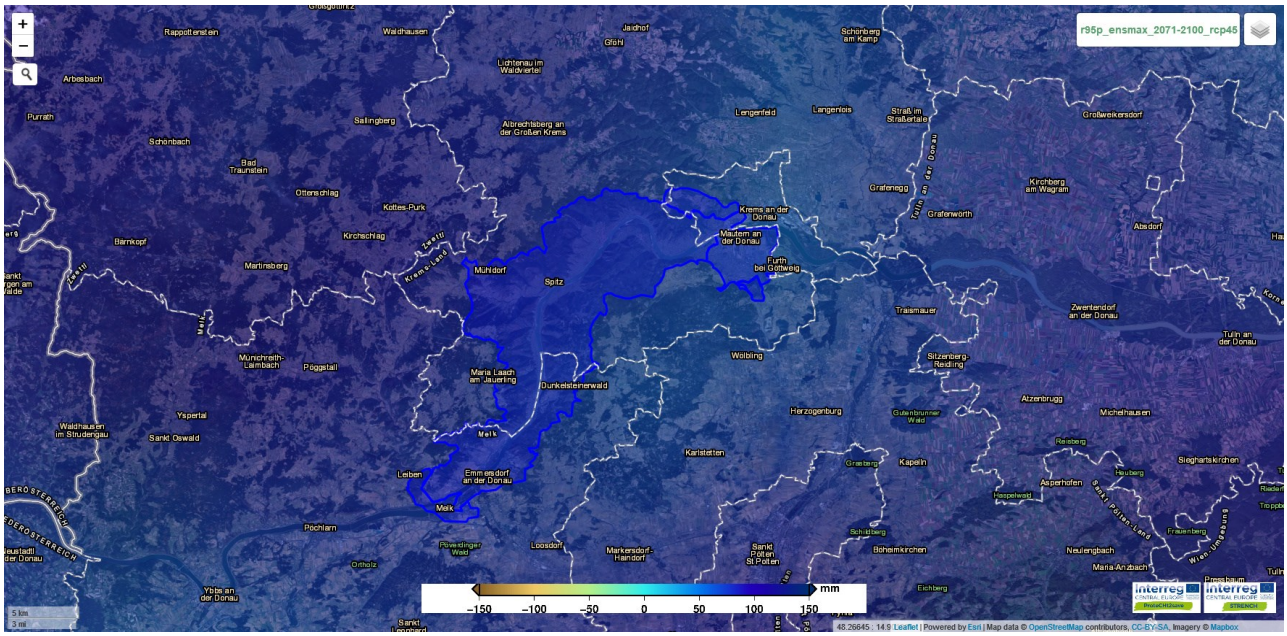


Figure 25 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool. (R95pTOT)

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

Highest 5-day precipitation amount (Rx5day)

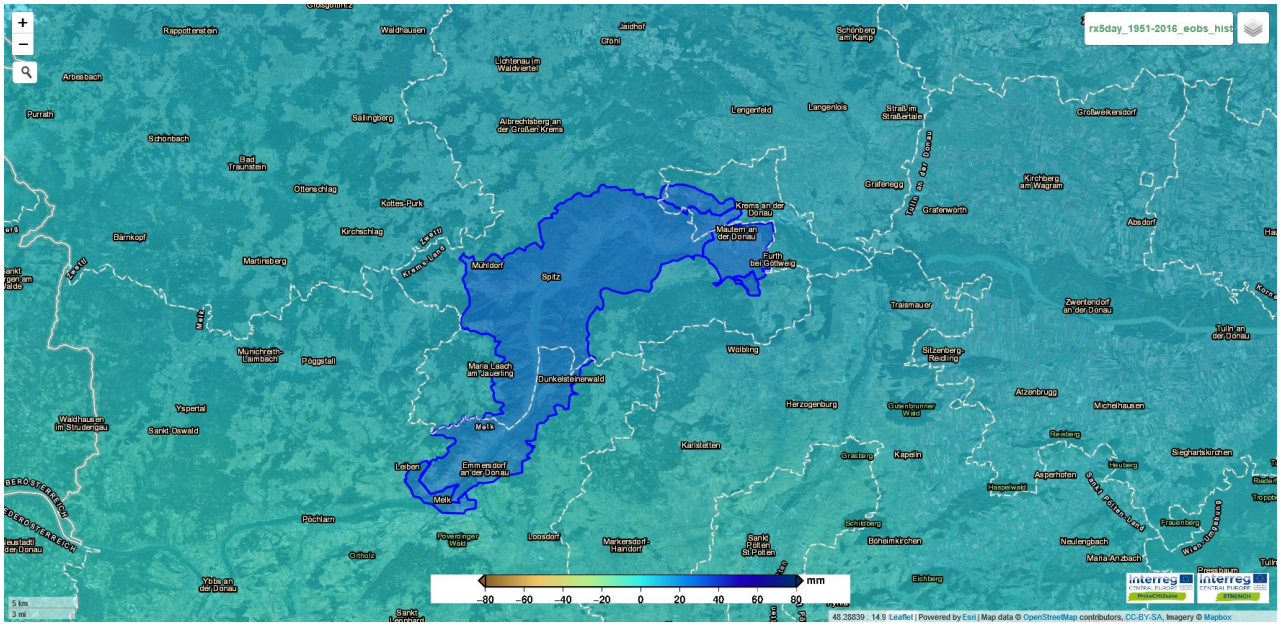


Figure 26 Historical Observation 1951 – 2016, WebGIS tool. (Rx5day)

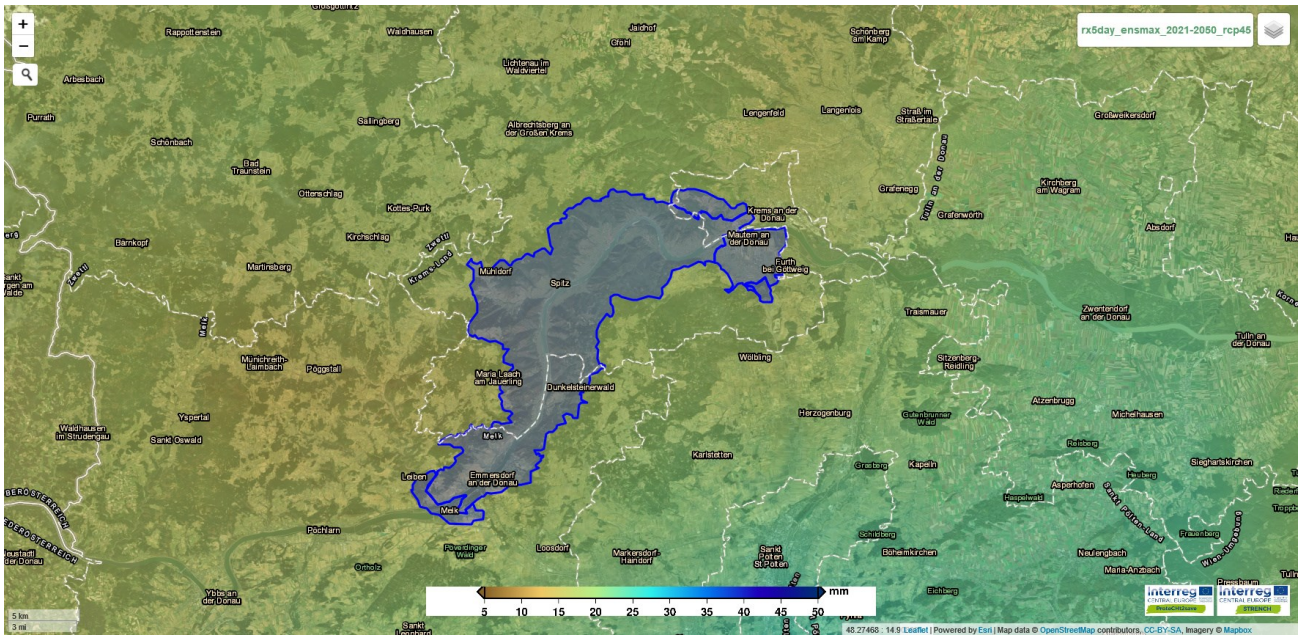


Figure 27 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (Rx5day)

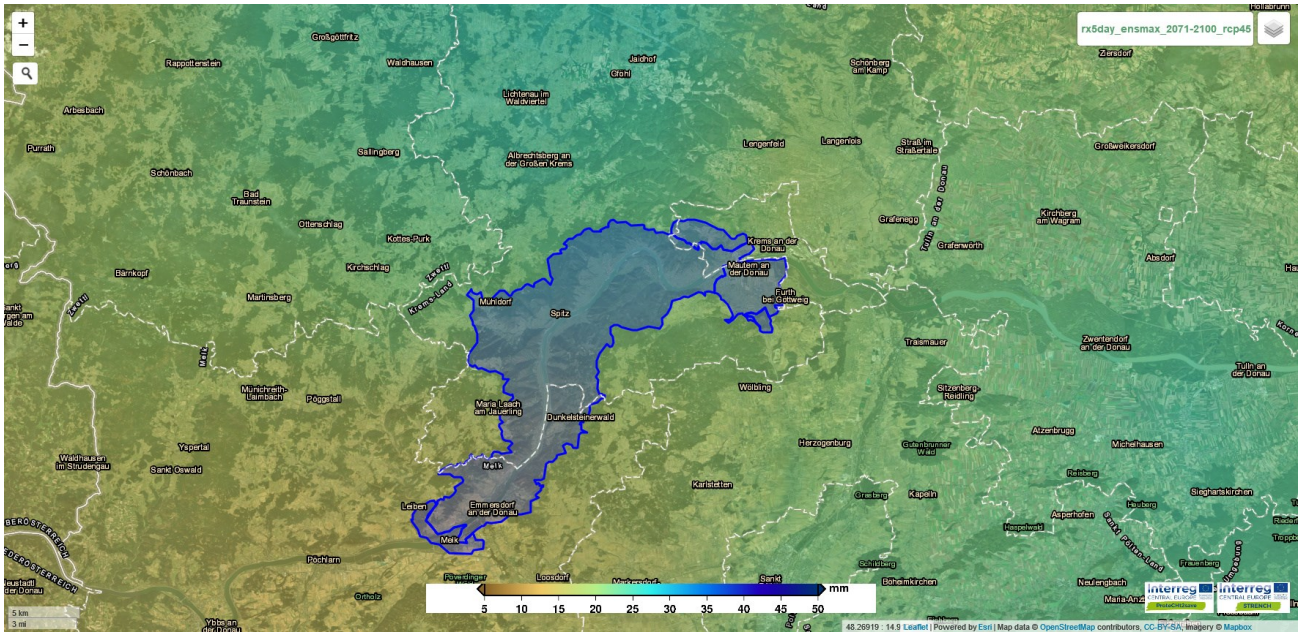


Figure 28 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool. (Rx5day)

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

Maximum number of consecutive dry days (CCD)

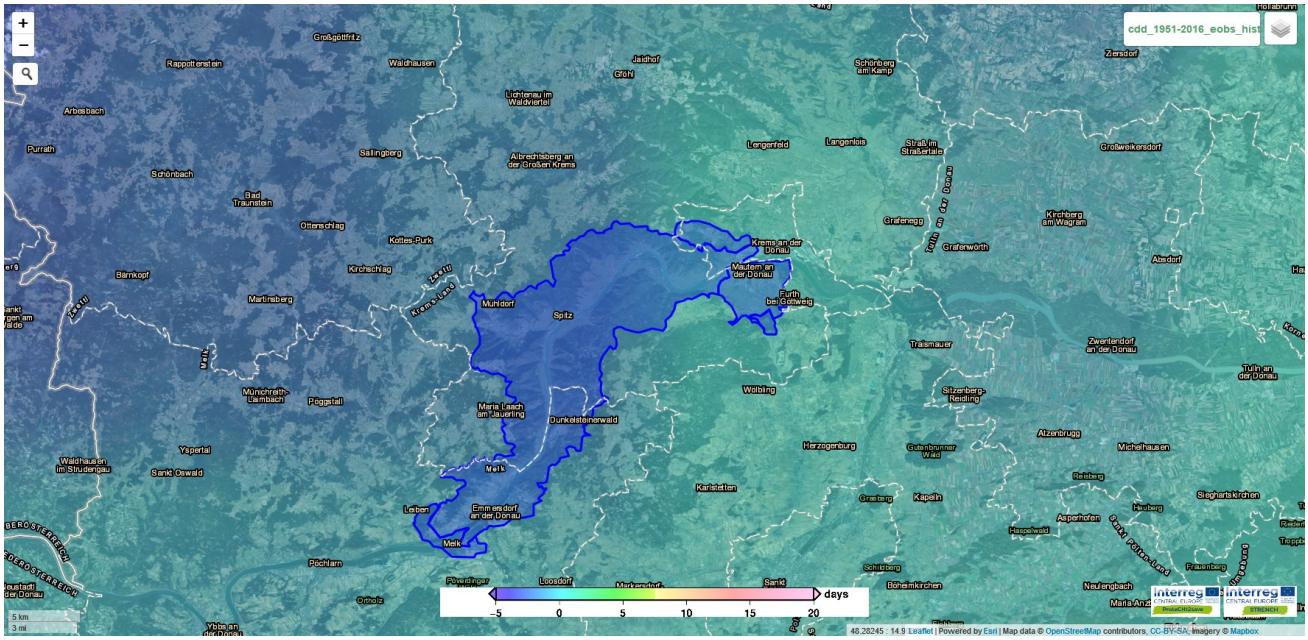


Figure 29 Historical Observation 1951 – 2016, WebGIS tool. (CCD)

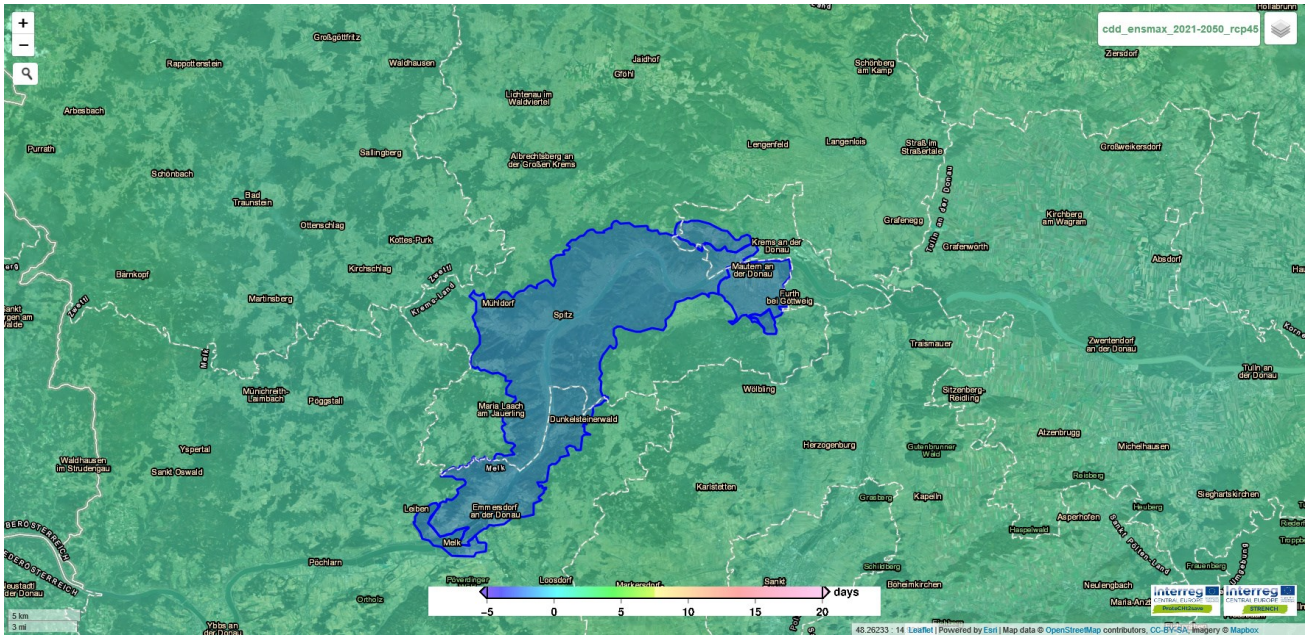


Figure 30 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050), WebGIS tool. (CCD)

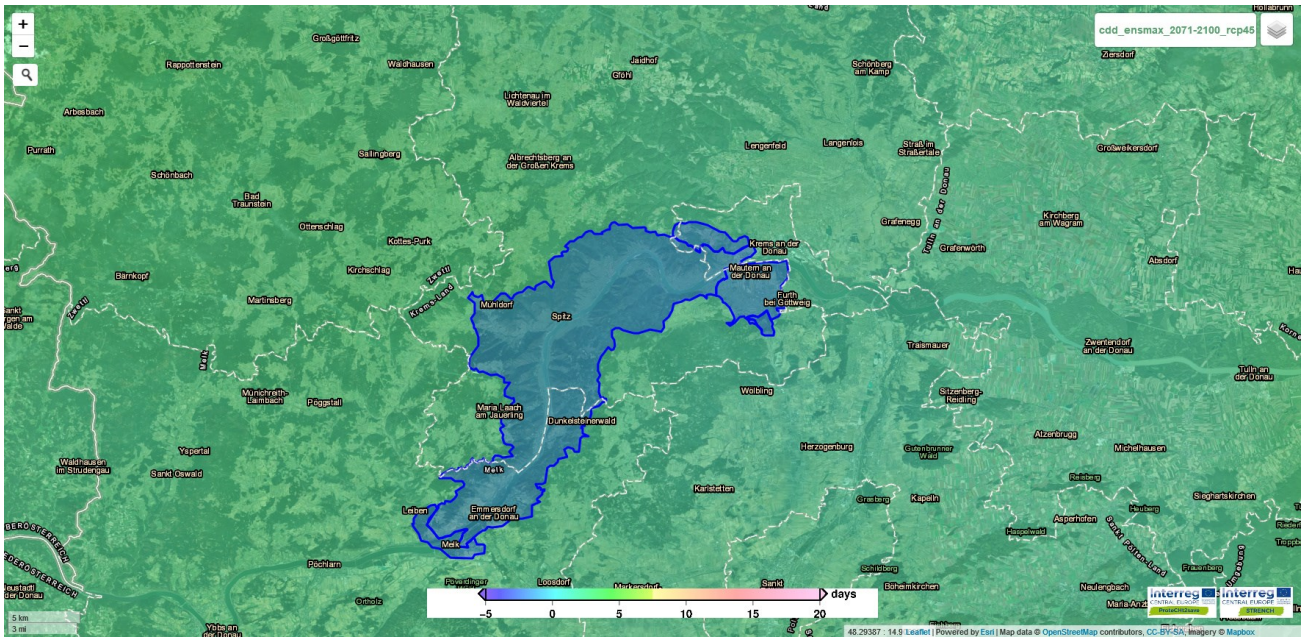


Figure 31 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100), WebGIS tool (CCD)

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

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

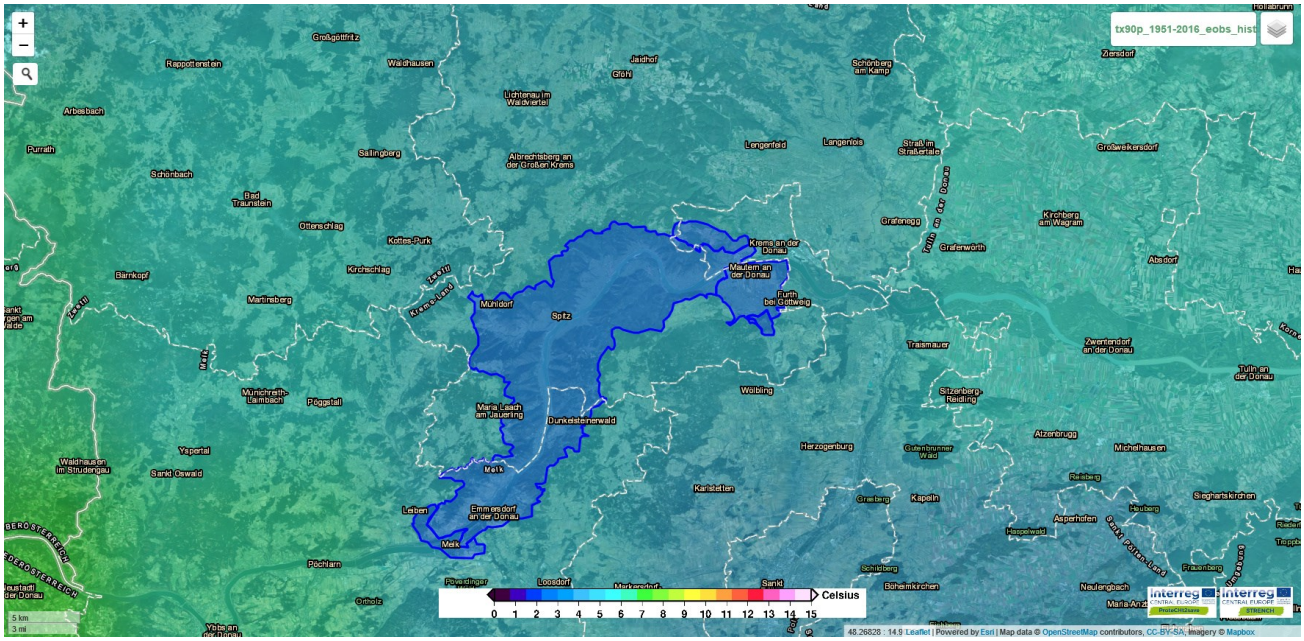


Figure 32 Historical Observation 1951 – 2016 in Celsius, WebGIS tool. (Tx90p)

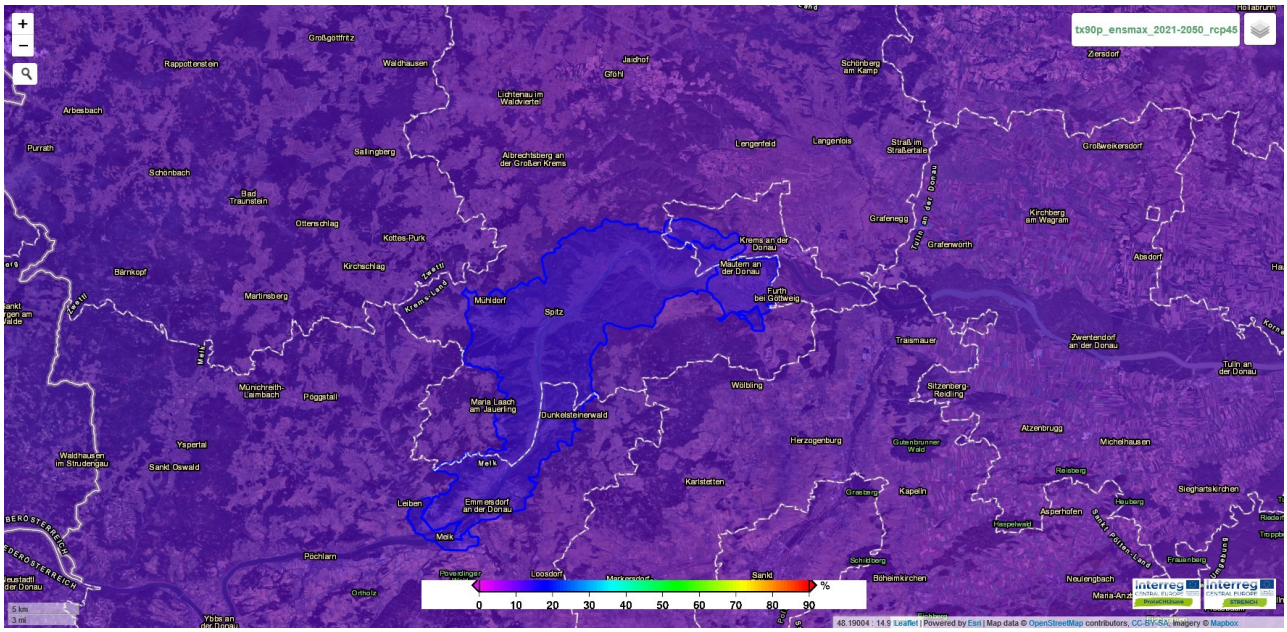


Figure 33 Ensemble statistics, maximum, RCP 4.5 Near Future (2021 – 2050). Not in Celsius but in percentage, WebGIS tool. (Tx90p)

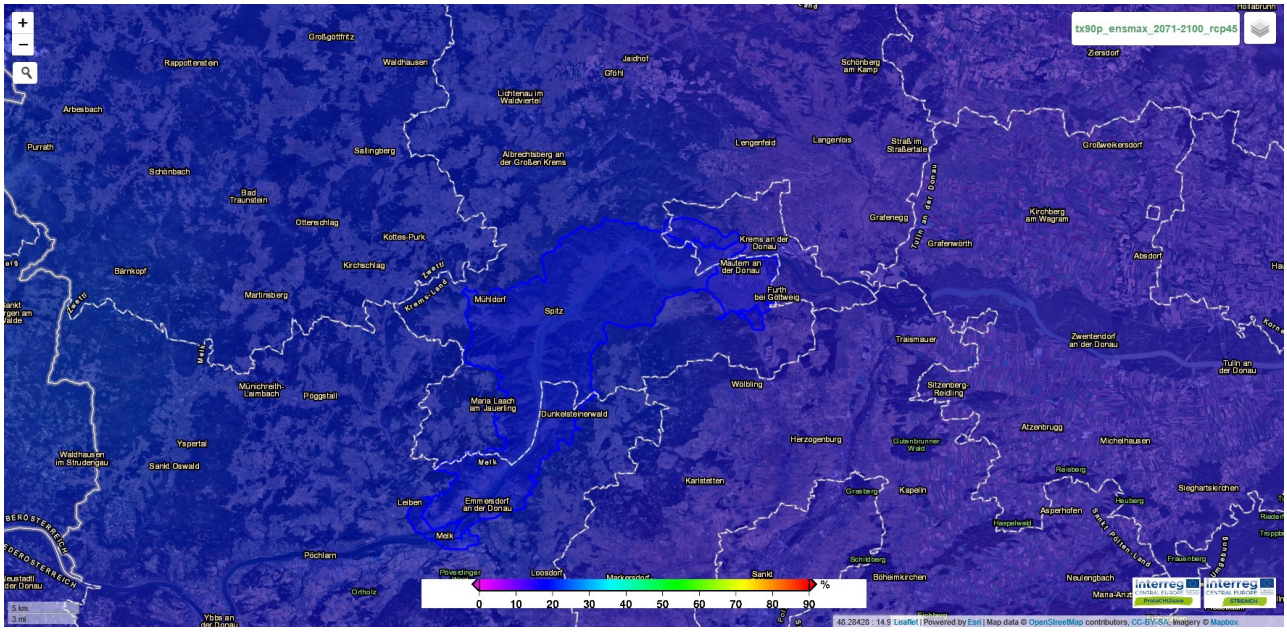


Figure 34 Ensemble statistics, maximum, RCP 4.5 Far Future (2071 – 2100). Not in Celsius but in percentage, WebGIS tool. (Tx90p)

Before drawing any conclusions for Tx90p one must bear in mind that the historic observation is based on Celsius which appear to be an average. However, the forecast (near and far) both depict the percentage of days in a year when daily maximum temperature is greater than the 90th percentile. A threshold based on the 90th percentile selects only 10% of the warmest days over a 30 year-long reference period. Therefore, the historic observation can be discarded

in this case. Nonetheless the comparison between the near and far forecasted future show that a very strong increase in extremely warm days is predicted. This again falls in line with the observed increase in extreme weather events as shown in the other observed incidences.

Observations and possible conclusions

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

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

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

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

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

Thus, the illustrative maps and information generated by the WebGIS could be a valuable asset for further fostering awareness towards cultural heritage protection and the need for risk management measures caused by climate change. It is most certainly a helpful tool which will aid in tackling future challenges for cultural heritage protectors. Combined with information and pictures in the minds of people that are provided by recent major floods in the Wachau area, the WebGIS tool has huge potential to raise the awareness of policy and decision makers

an all levels that action is necessary, also on the level of the cultural landscape in general, including cultural and natural heritage that makes the Wachau region so very special and is the Outstanding Universal Value for which it received the status of UNESCO World Heritage.

Cultural heritage and its protection in Austria

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

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

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

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

The Ministry of Defence is responsible for cultural property protection in armed conflict, based on the 1954 Hague Convention for the protection of cultural property during armed conflict, which Austria ratified in 1964. The Austrian Directive for the Military Protection of Cultural Property and the Military Safeguarding of Cultural Heritage explicitly expands the

responsibilities of the military.[27] The Austrian Army also needs to take cultural property protection into account during assistance operations for the civil government, thus not only during armed conflicts. The territorial military commands in every federal state of Austria have qualified personnel for cultural property protection, who also interact with the relevant civilian authorities and the curators of the cultural heritage institutions in order to prepare for emergency situations.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[31] BGBl I 19/2016.

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

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

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

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

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

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

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

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

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

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