EVALUATION AND ASSESSMENT

TESTING OF THE WEBGIS TOOL FOR LANDSCAPE PROTECTION

Villa Ghigi Park / Italy **December 2021**

VILLA GHIGI PARK

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

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

SITE LOCATION		
Centroid geographical coordinates	Lat. 44.47610	Long. 11.32632

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

1. Foreword

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

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

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

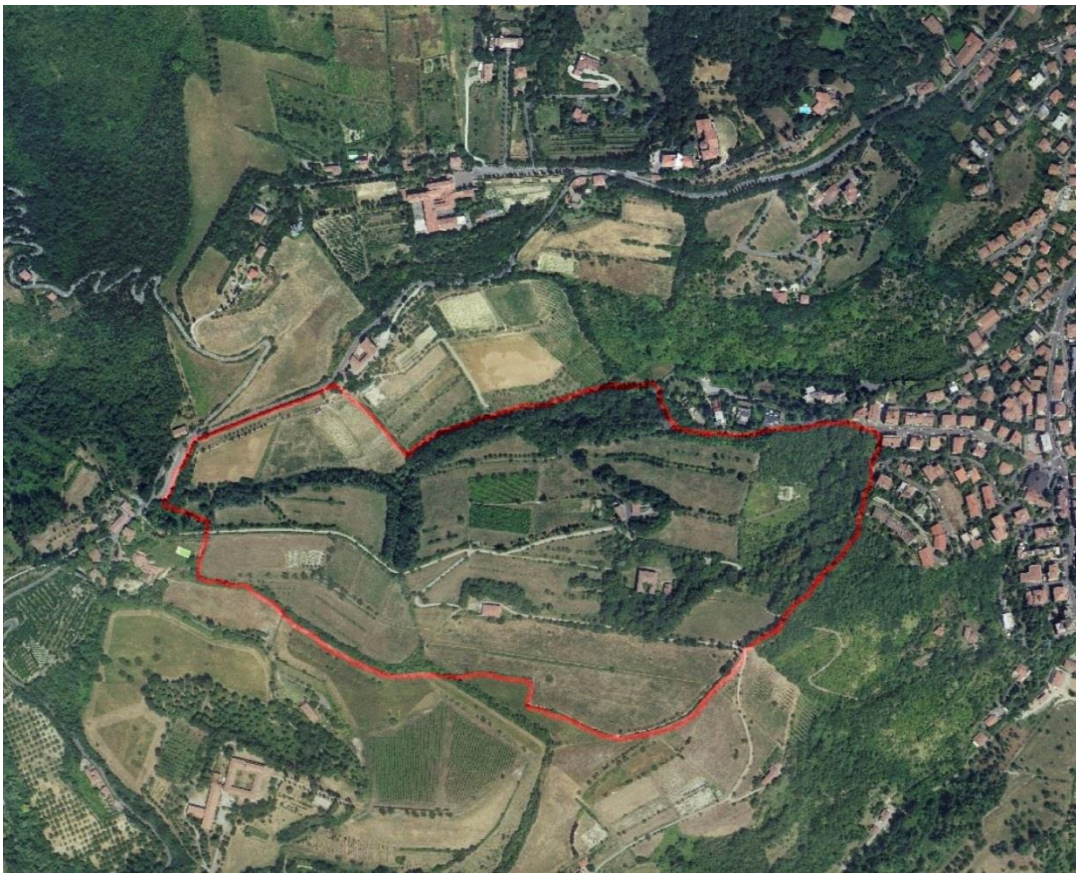
2. The site: framework and characteristics

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

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

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

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



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

The mosaic of environments that characterises the Villa Ghigi Park.


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


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

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

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

3.1 Heavy rain and flash floods

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

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

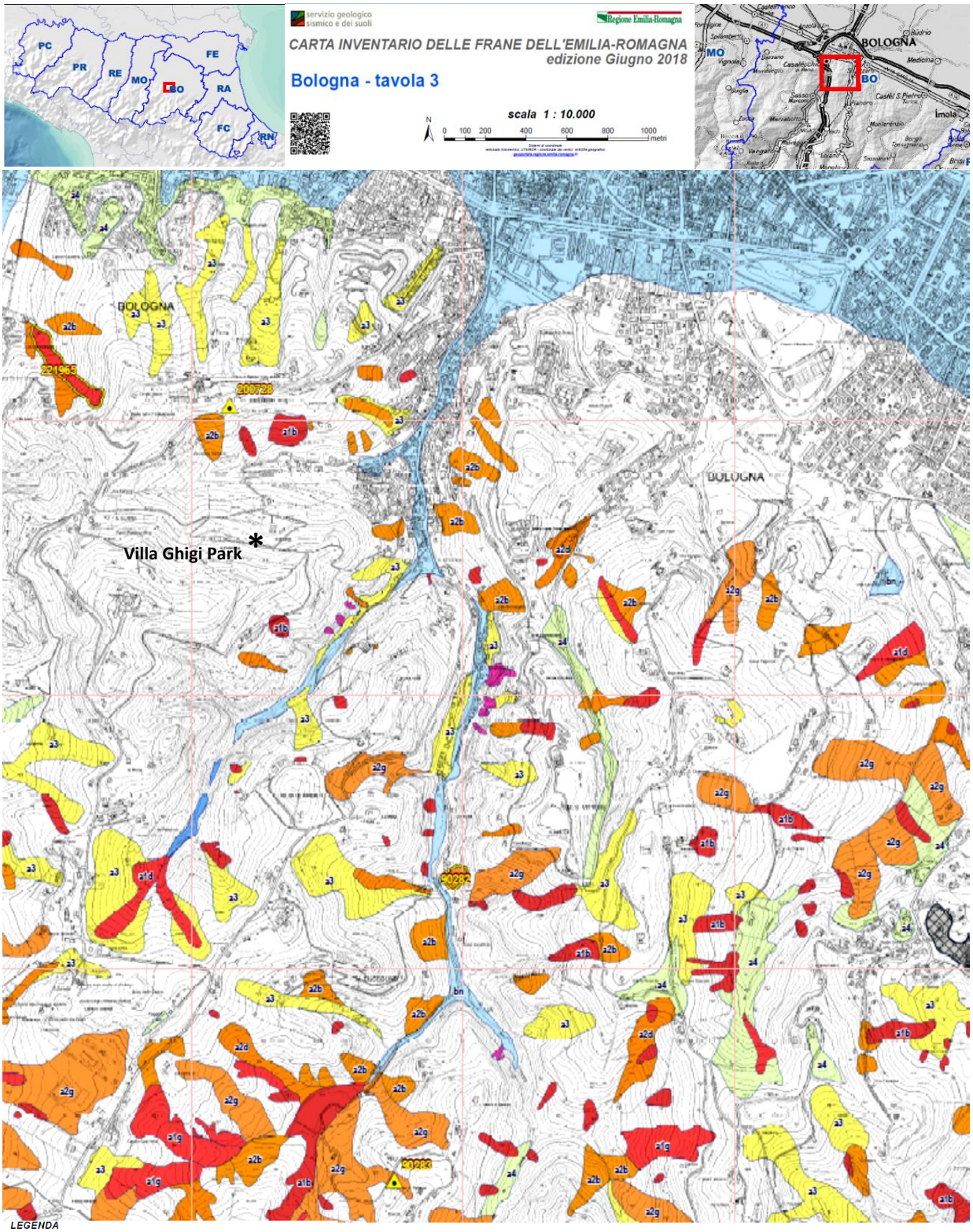
From an operational point of view, it is stressed that the constant monitoring of the green area, starting from the vulnerability map functional to highlight the most sensitive areas with respect to this specific issue (see page 14), is the basis of the programme of functional interventions to manage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

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

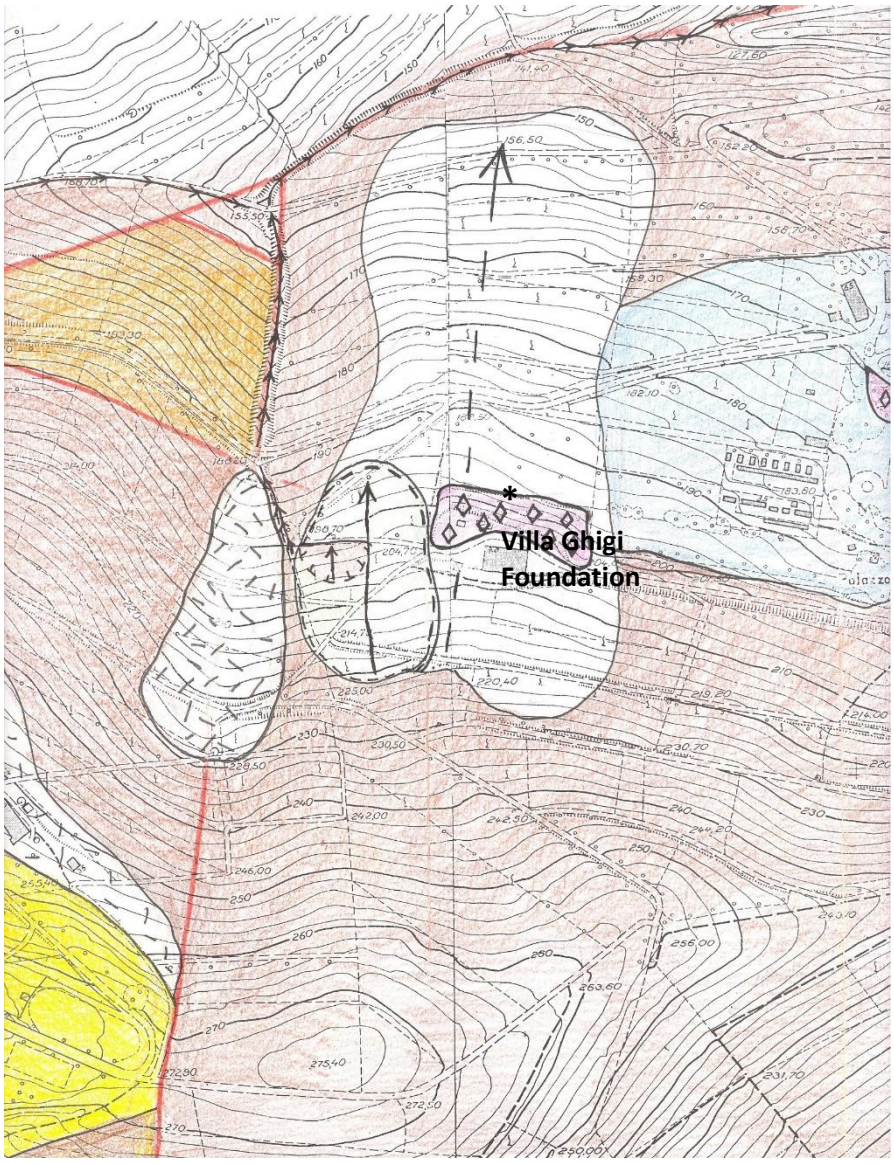
3.2 Landslides

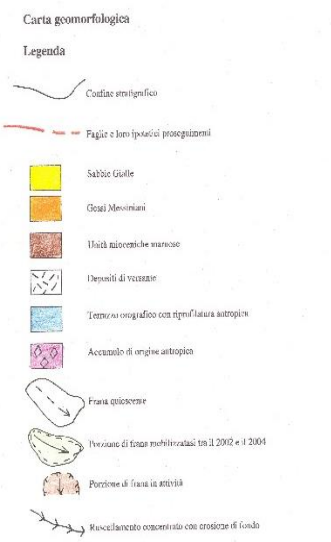
Given the geological and geomorphological nature of the valley in which the park is located, and more generally of the Bologna hills, episodes of hydrogeological instability are widespread in the area, accompanied by more or less significant landslides, as the map on page 9 clearly shows. These episodes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

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



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





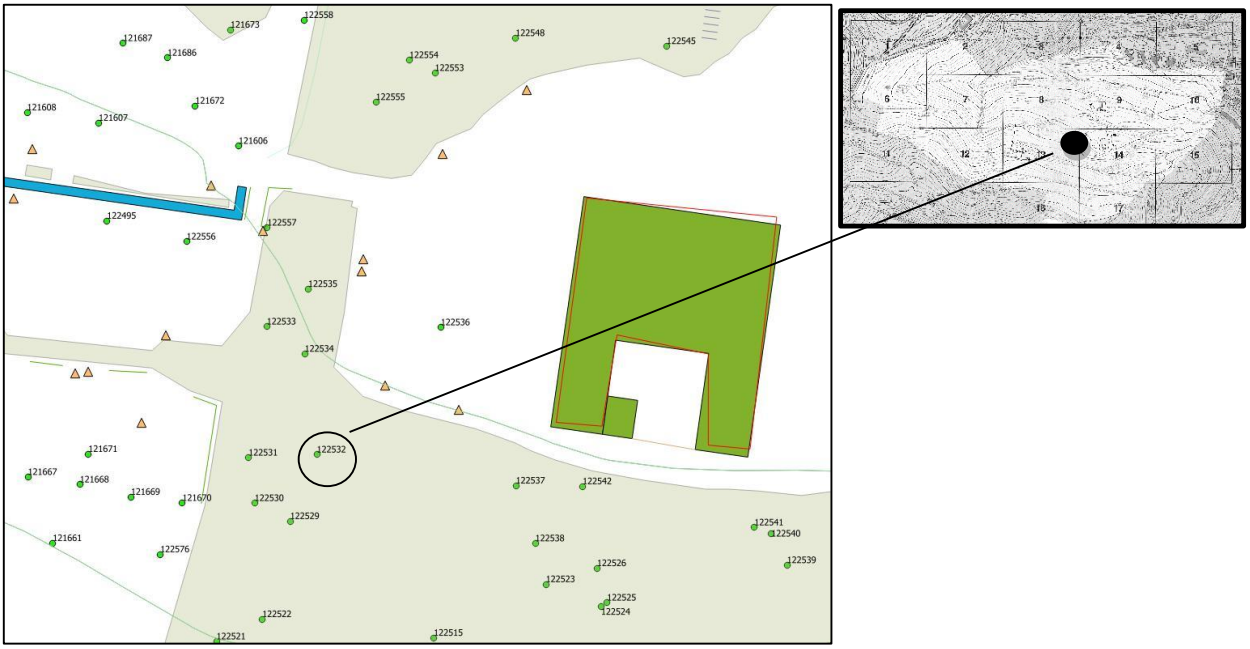
The specific geological survey carried out in Villa Ghigi Park showed the presence of active movements (highlighted by the arrow with a continuous line) and quiescent landslides (highlighted by the arrow with a dotted line) also inside the park. In the image to the side a detail of the geological map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

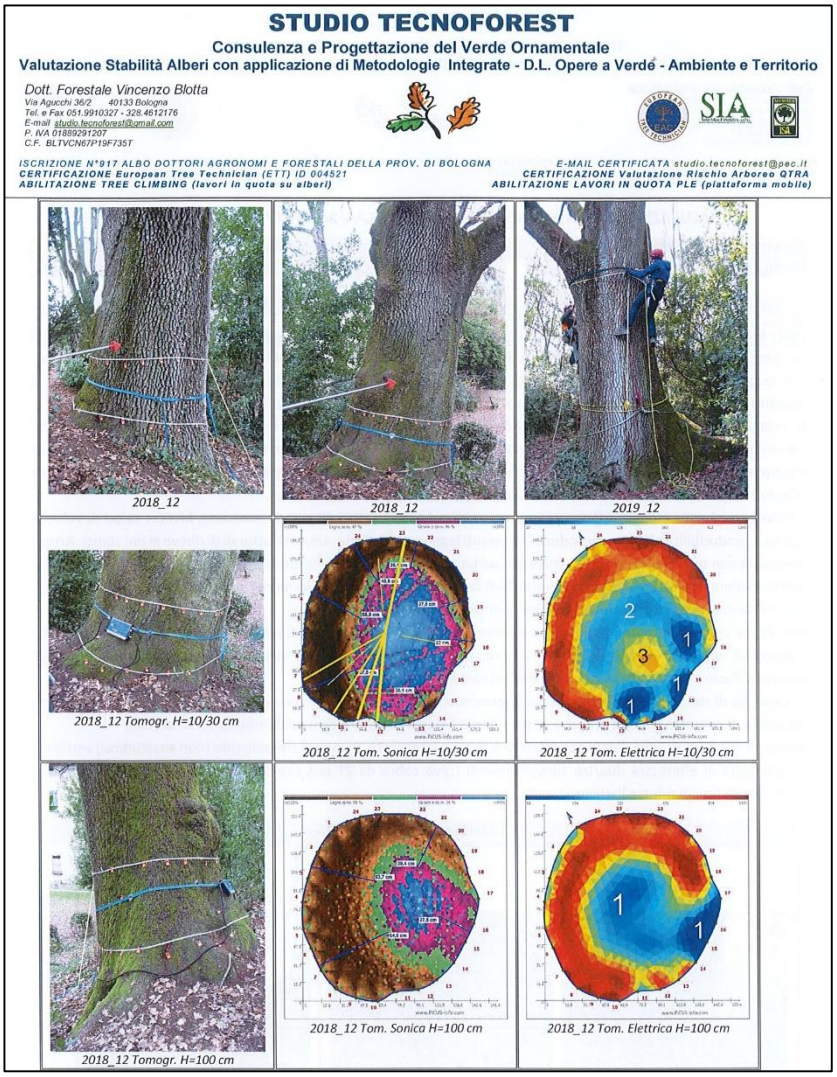
3.3 Windstorms and snow

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

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

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





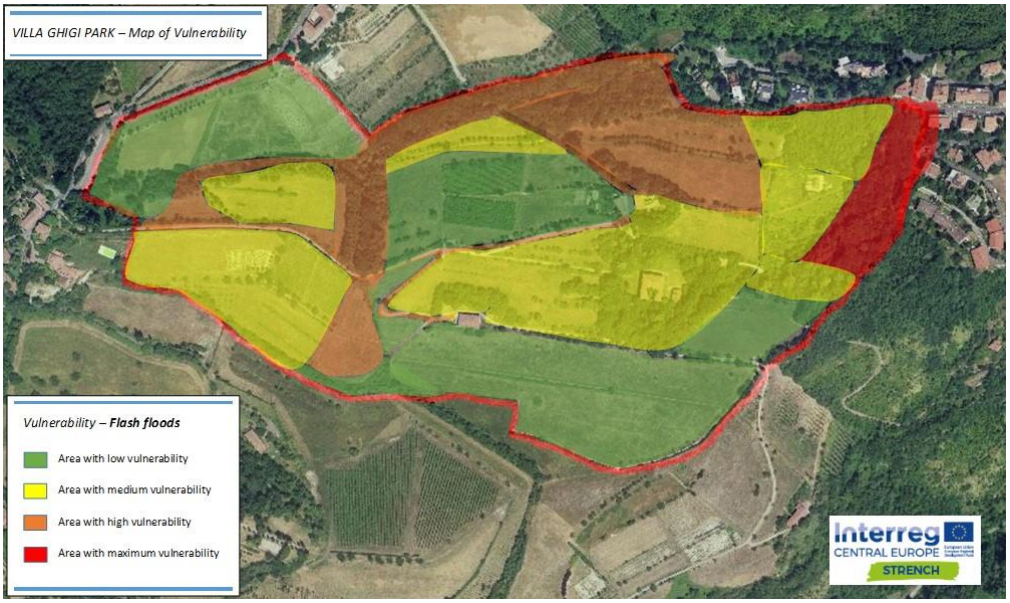
A centuries-old oak tree (Quercus pubescens) with a stem diameter of 160 cm, located in the centre of the historic garden near Villa Ghigi, is one of the plants included in the Census of the park's arboreal heritage (no. 122532) and has been the subject of constant monitoring and instrumental static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

3.4 Long term increase of temperature and drought

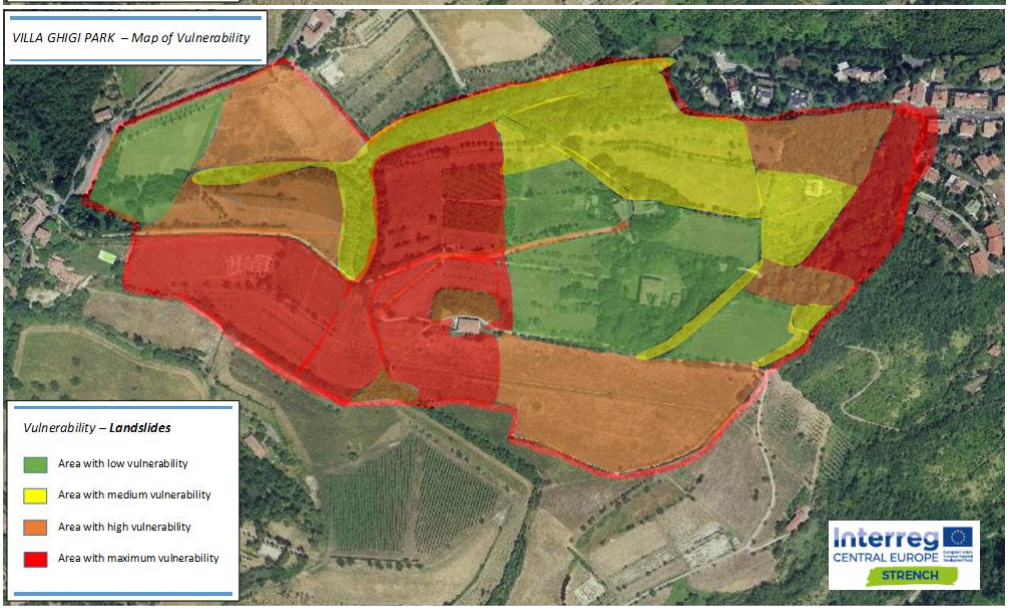
The damage to the vegetation due to the increase in drought periods and temperatures is now evident both in the whole Bologna area and in the park, and the climatic trends underway have been amply confirmed by the WGT data, both historical and projected for the future. Crossing the data extrapolated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

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

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



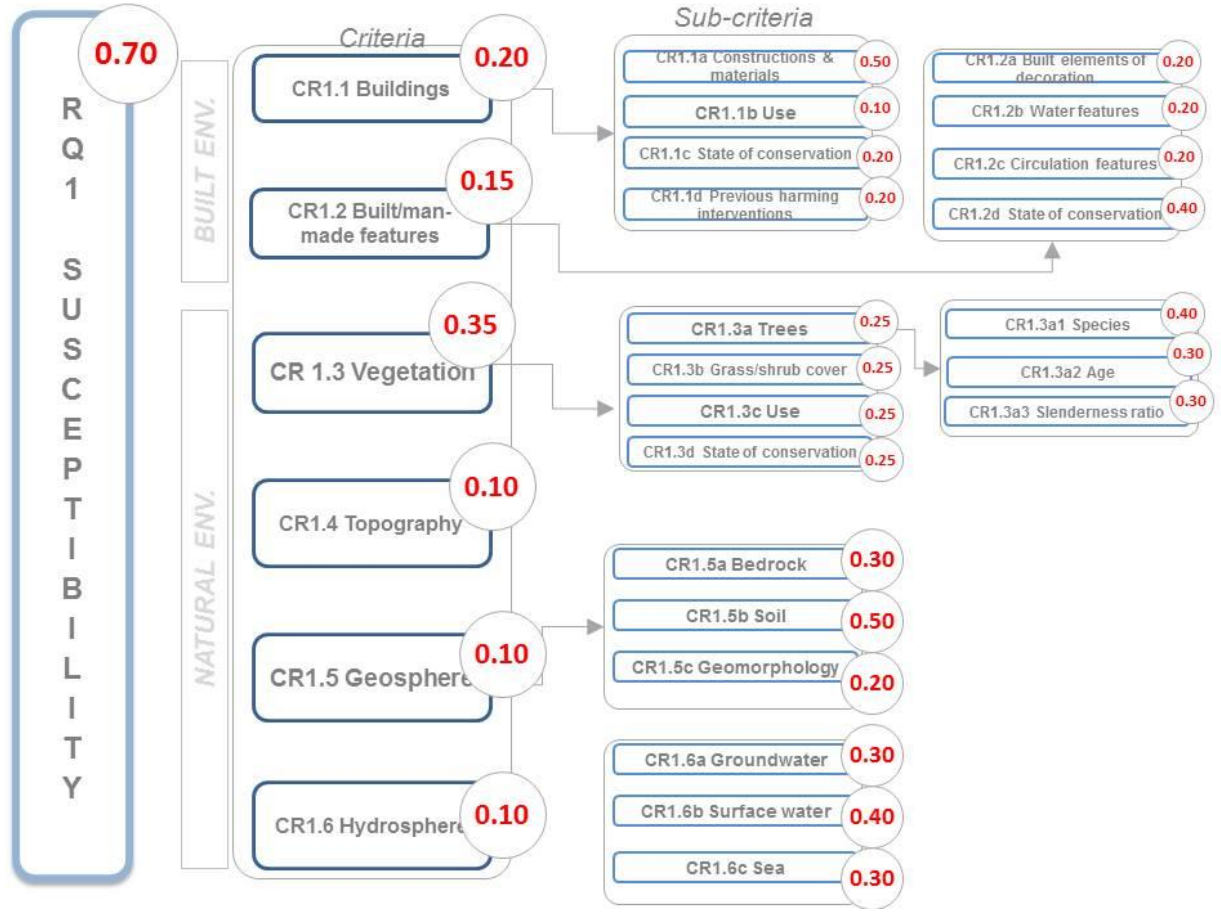
As part of the Park Management Plan, the area of the Villa Ghigi Park pilot site was zoned according to the main vulnerabilities identified in order to improve management and set up pre- and post-event contingency plans.

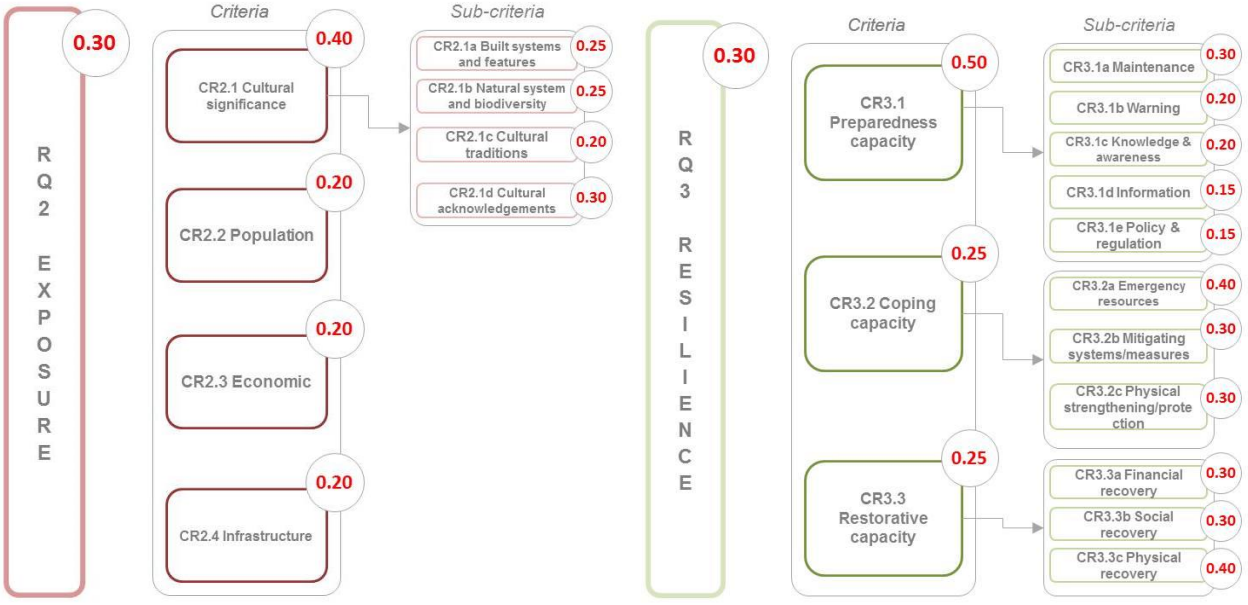


More attention has been paid to areas that may be subject to flash floods (top map), those at risk of landslides (side map) and areas of the park that may be subject to damage in the event of high winds or snowstorms (bottom map).

3.5 Methodology for ranking vulnerability of cultural heritage

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





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

The vulnerability value for Villa Ghigi Park calculated is:

Vulnerability= 0.70 x Susceptibility + 0.30 x Exposure - 0.30 x Resilience

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

Vulnerability = 0.375

With 0<V<1 (low to high vulnerability)

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

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

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

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

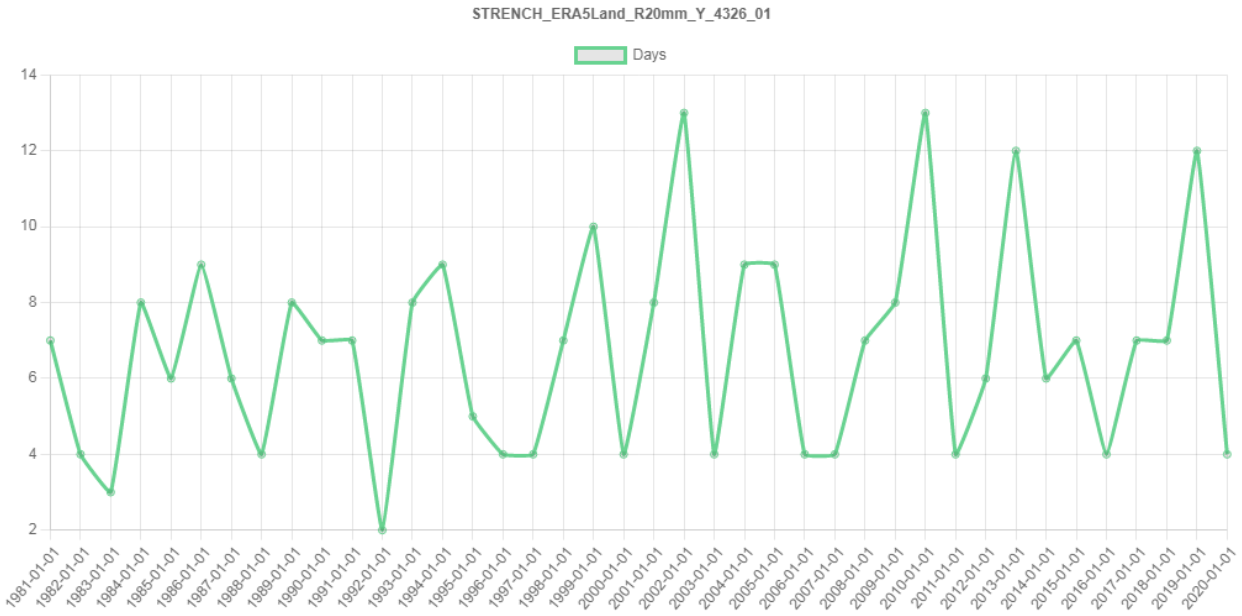
4.1 Use of WGT for investigation of past events

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

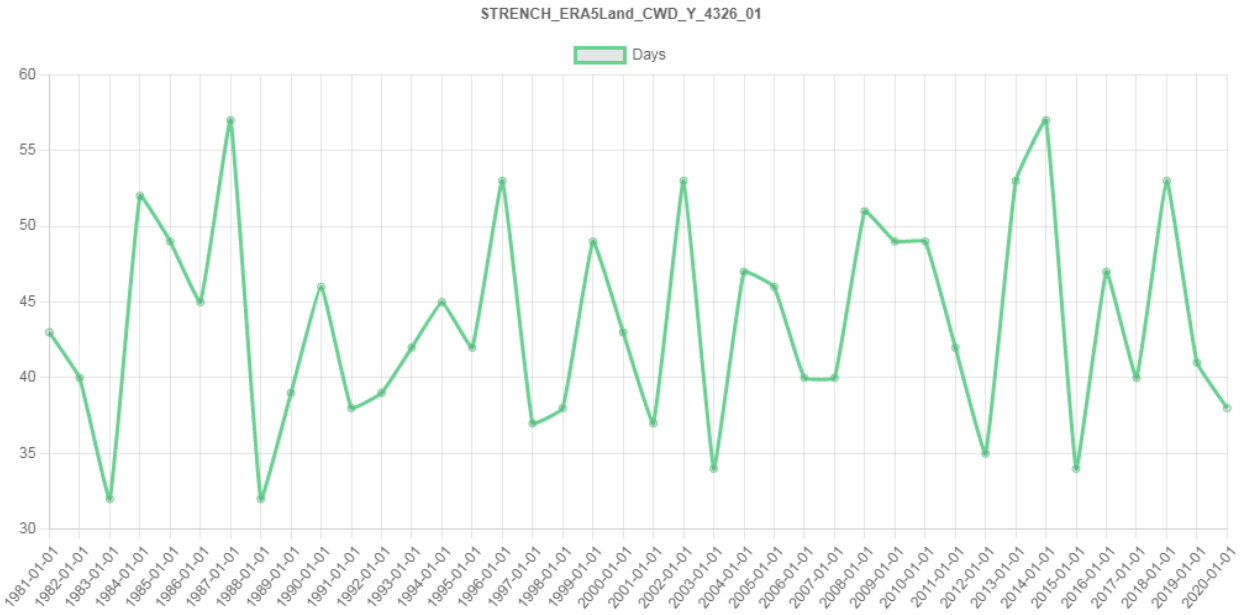
Among the various indices available, some provided by the Copernicus satellites were selected. They show particularly significant data for the pilot site because they are linked to important events that have affected the park in the past.

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

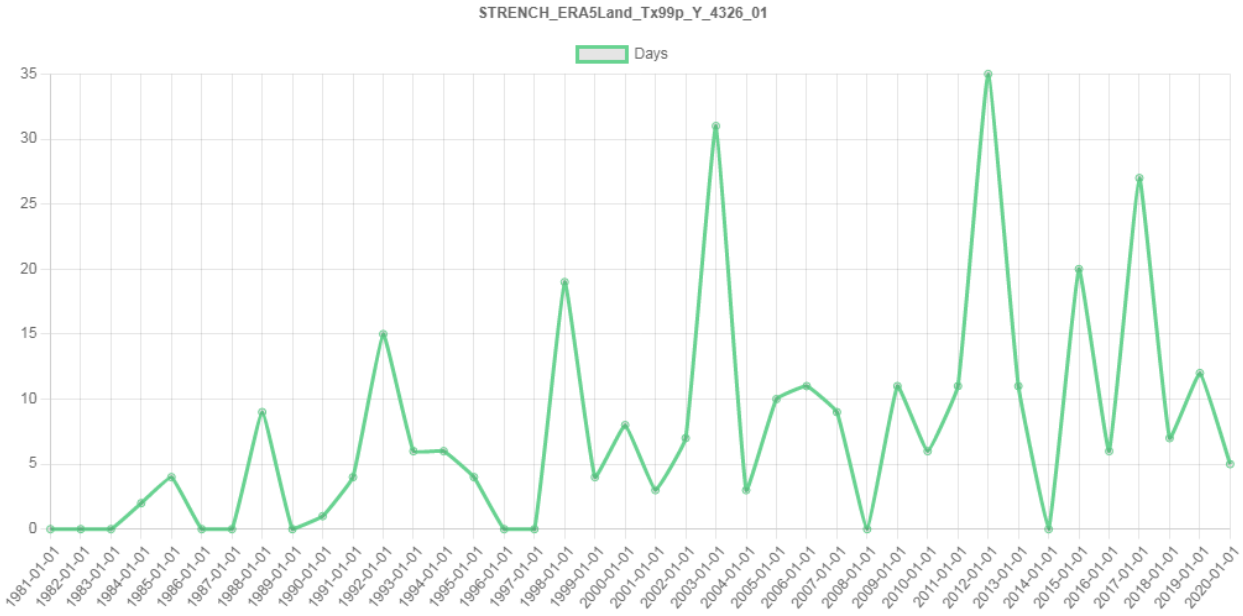
The following pages show the graphs related to the area in which the pilot site is located (Bologna hills), which have allowed us to discover or confirm in a documented way a couple of cause-effect links between some important events of various nature that occurred in the park and the climatic trends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



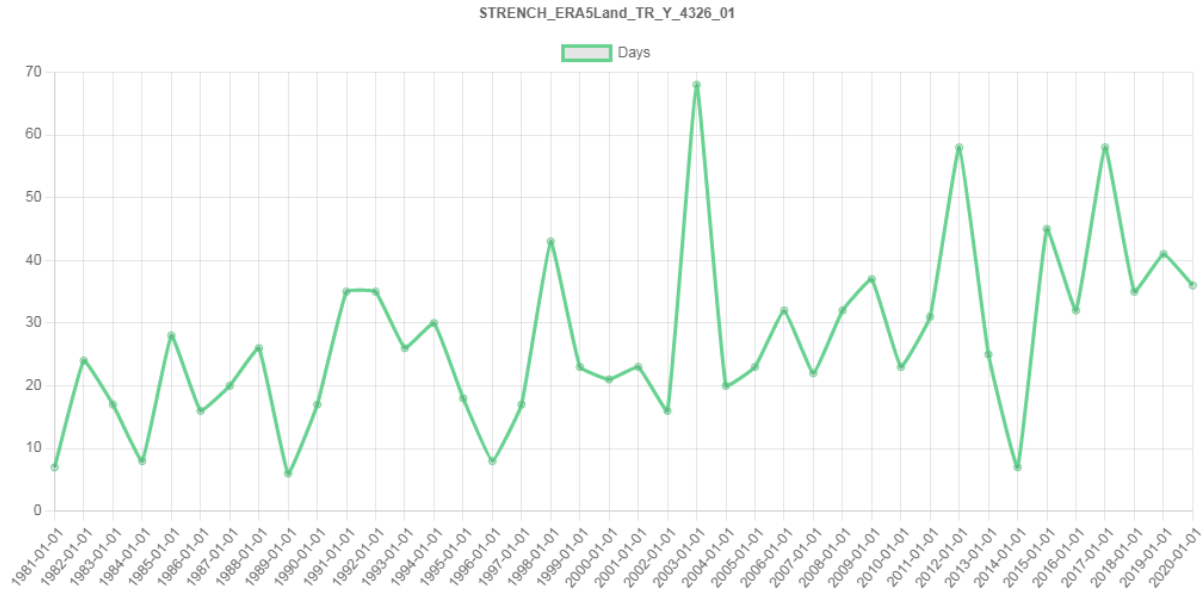
The index ***Very heavy precipitation days*** (***R20mm***) shows a significant difference between the period 1981/2000 and 2000/2020, with a marked increase in very heavy precipitation days in the latter period: there are four peaks of 12 days in two cases and 13 days in as many cases, compared with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



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



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



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

5. Use WGT for creating climate maps

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

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

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

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

- RCP 4.5 greenhouse gas emission stabilisation scenario.

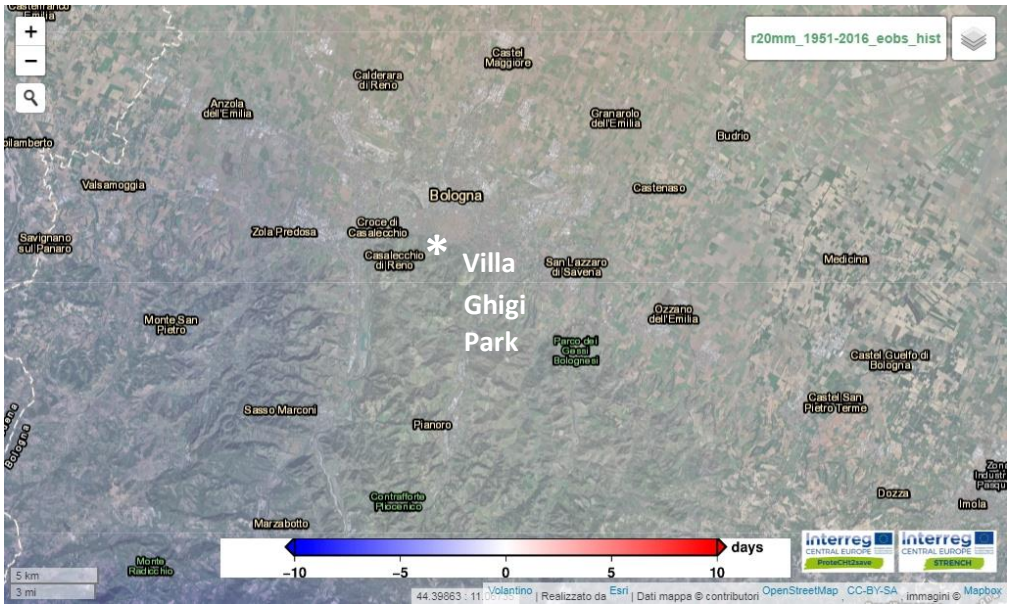
- RCP 8.5 high pathway scenario characterised by increasing GHG emissions over time.

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

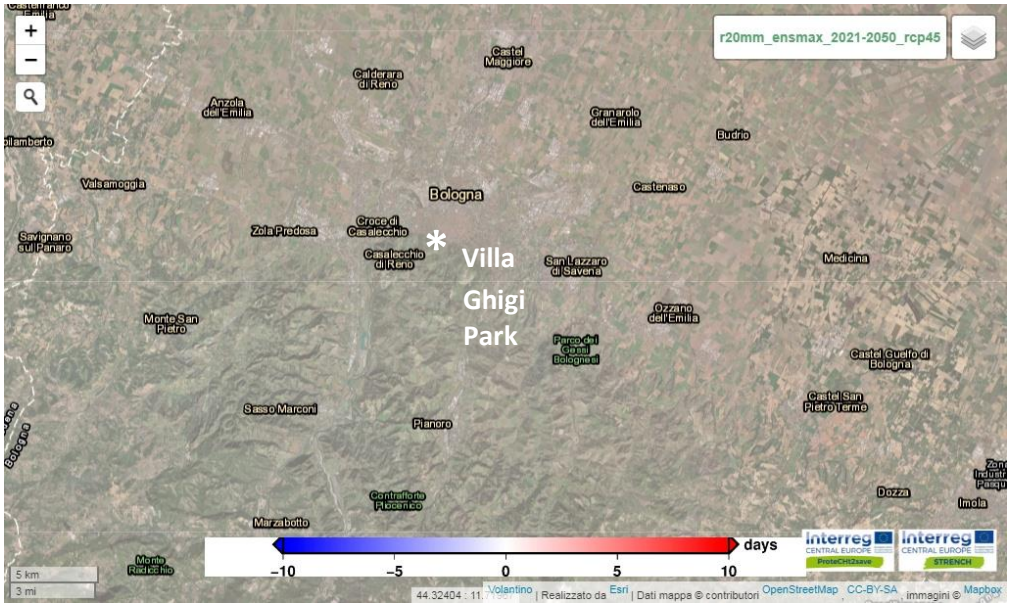
The table below summarises the values of the maps presented on the following pages.

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

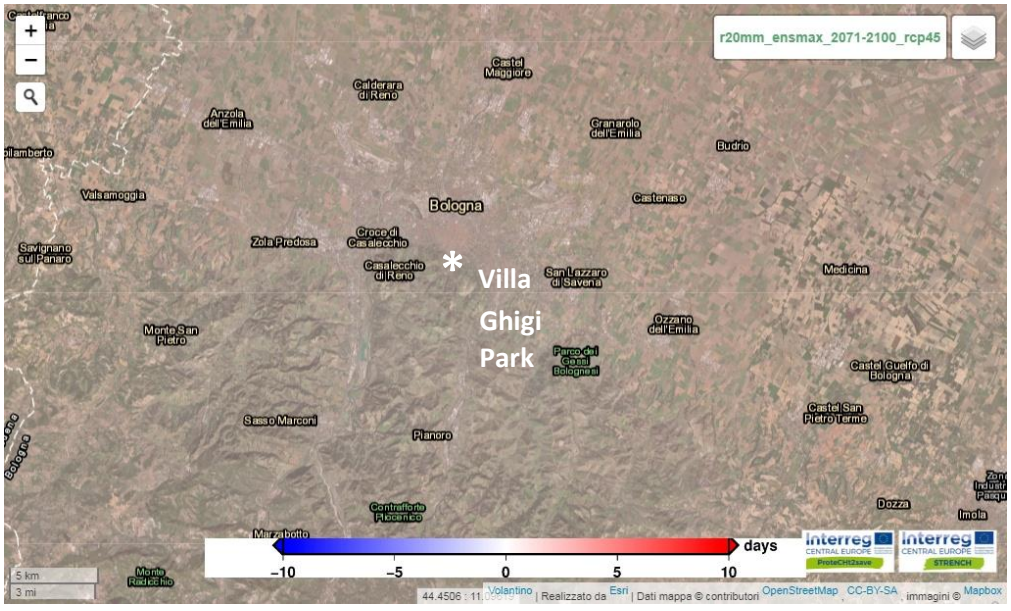
5.1 Very heavy precipitation days



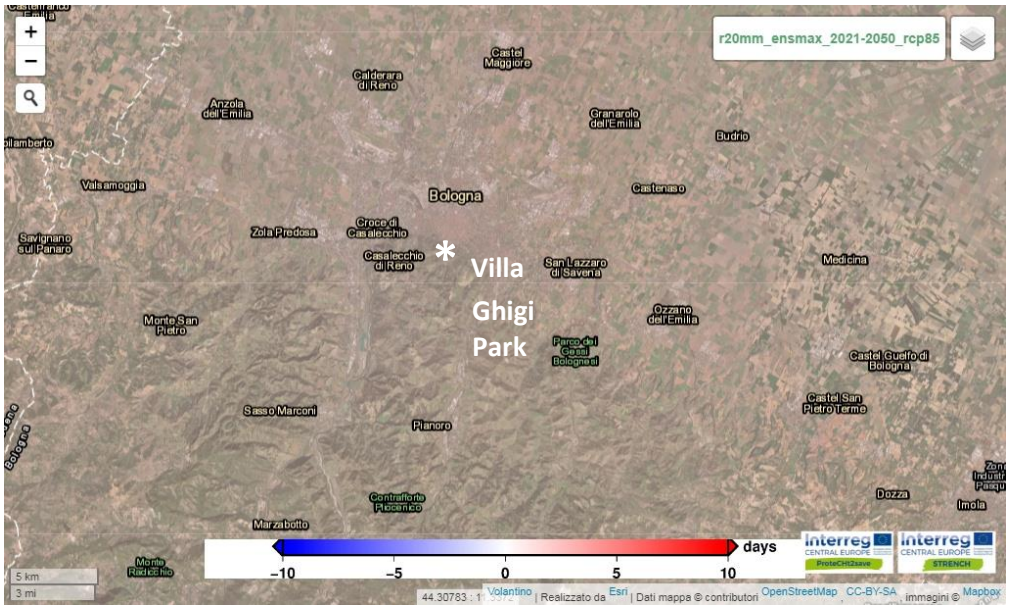
Map for the historic dataset on r20mm



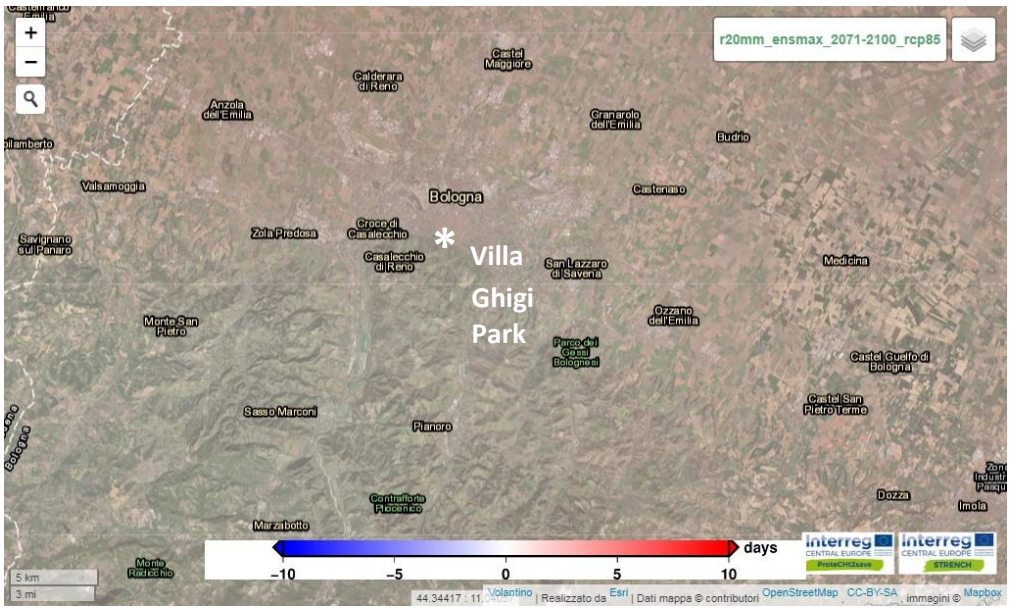
Map for the near future dataset on r20mm in the rcp45 scenario



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



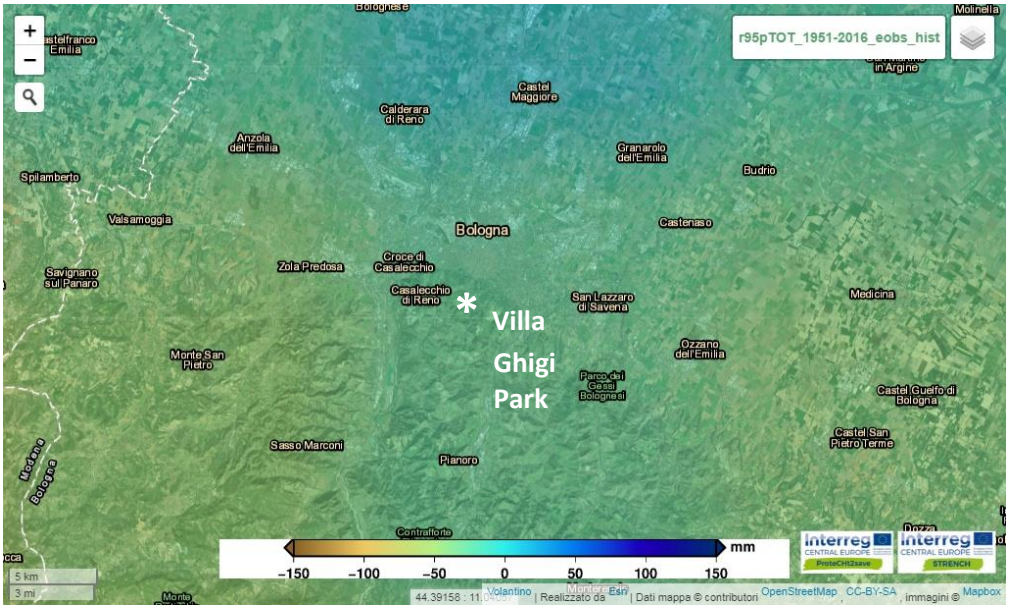
Map for the near future dataset on r20mm in the rcp85 scenario



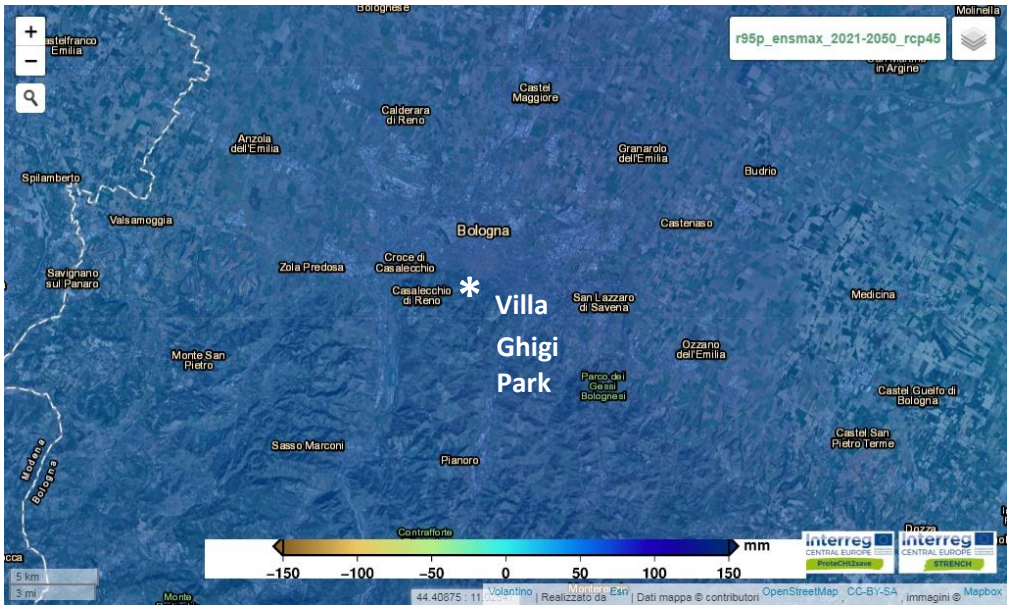
Map for the far future dataset on r20mm in the rcp85 scenario

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

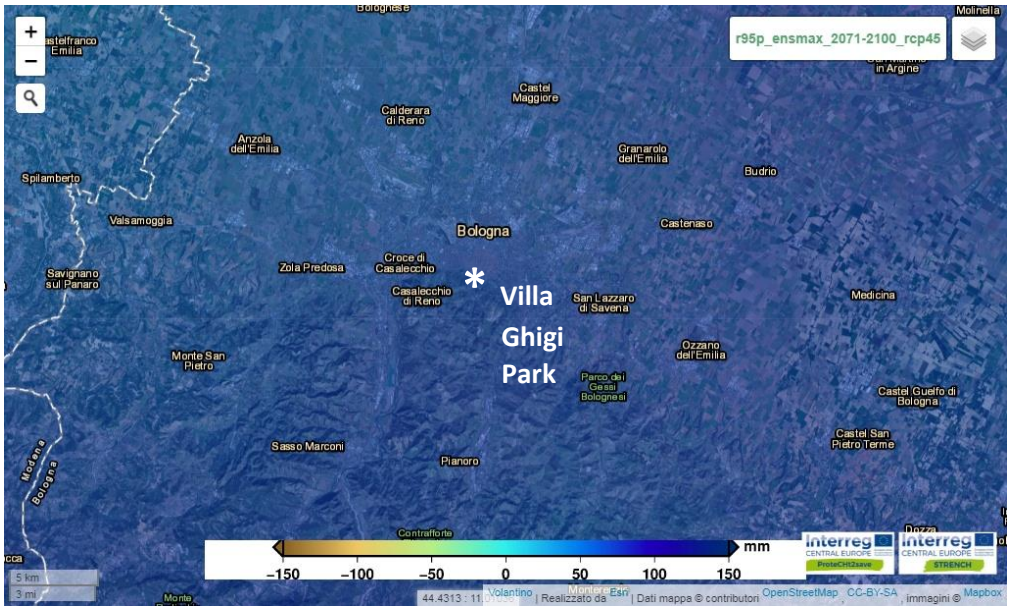
5.2 Precipitation due to extremely wet days



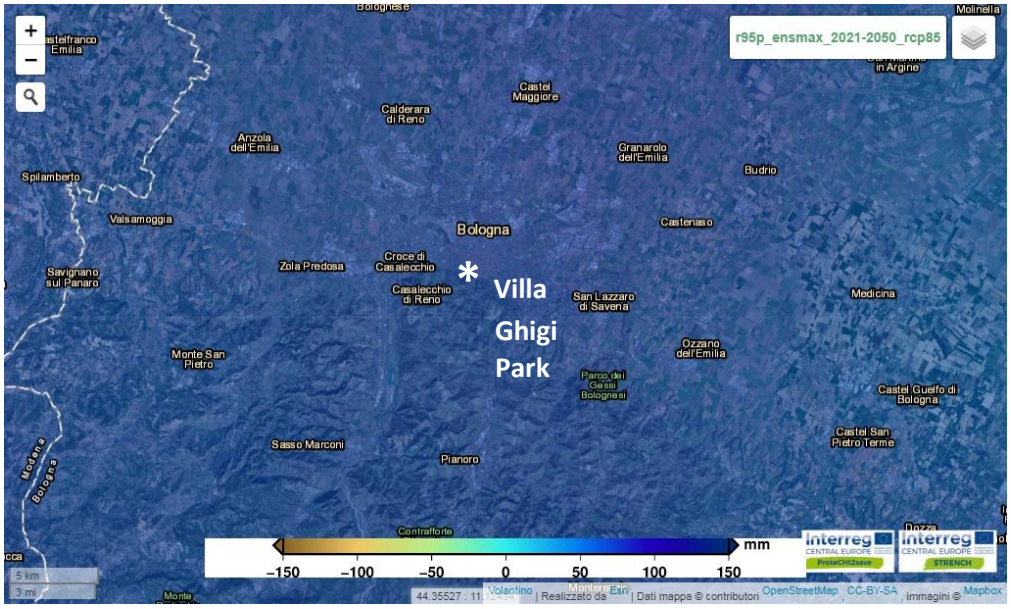
Map for the historic dataset on r95pTOT



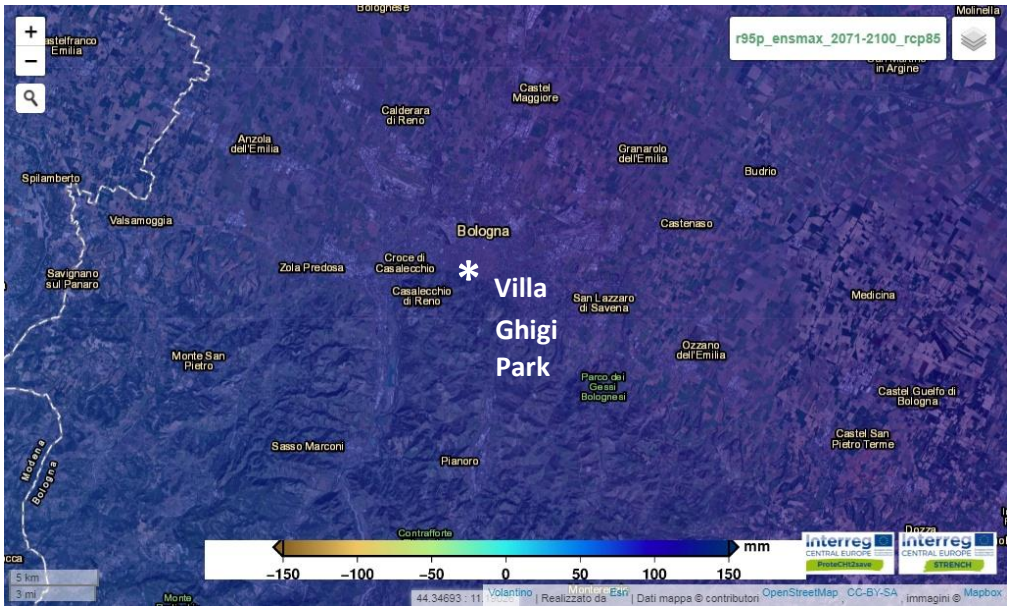
Map for the near future dataset on r95pTOT in the rcp45 scenario



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



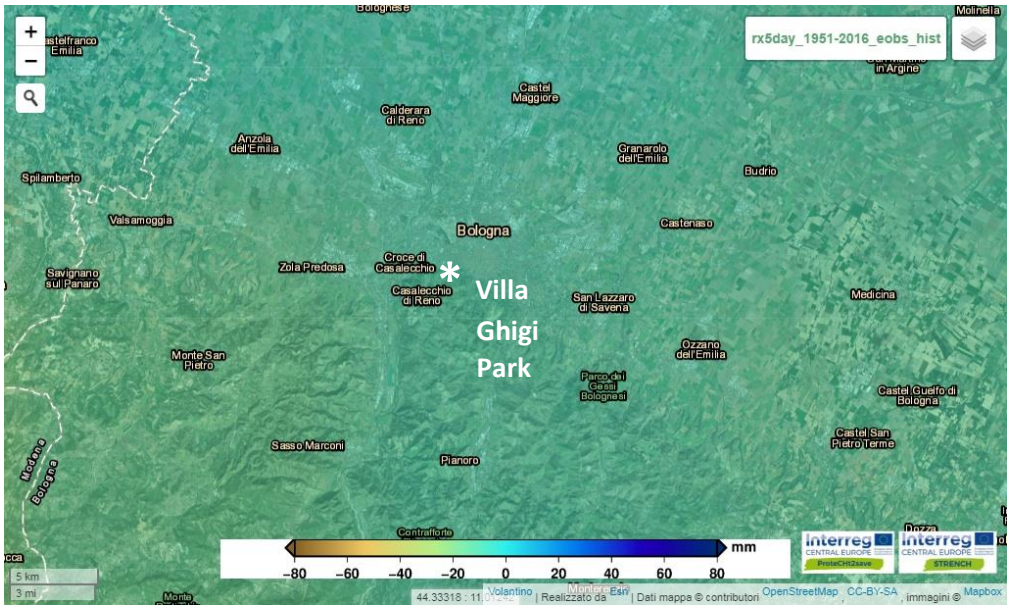
Map for the near future dataset on r95pTOT in the rcp85 scenario



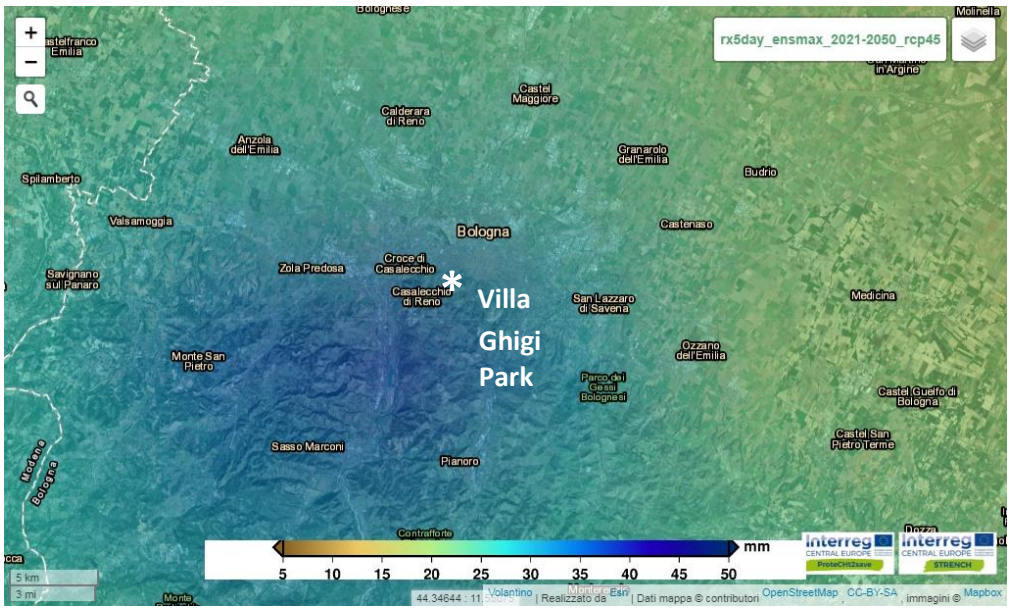
Map for the far future dataset on r95pTOT in the rcp85 scenario

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

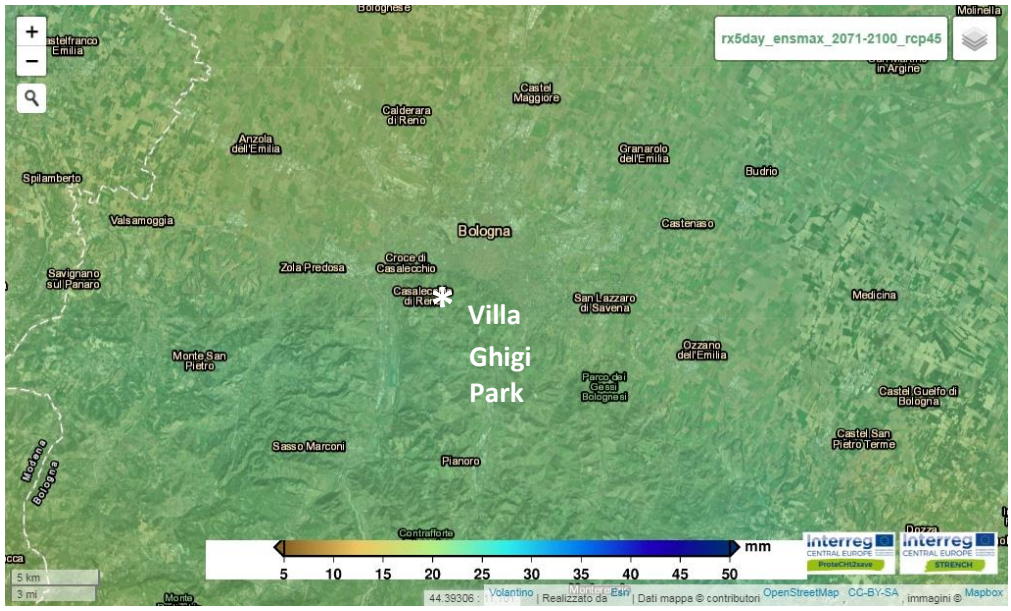
5.3 Highest 5-day precipitation amount



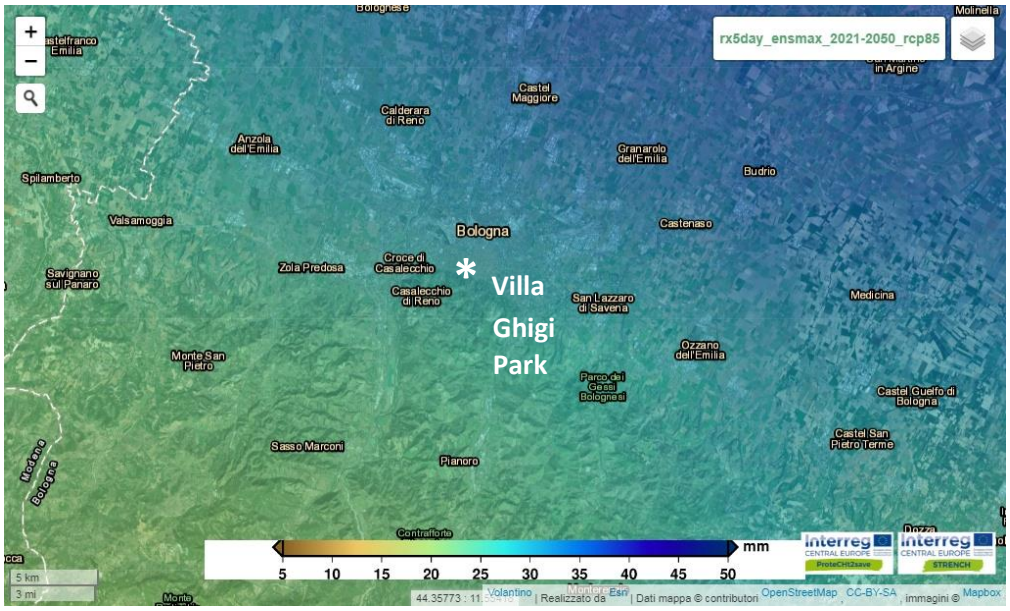
Map for the historic dataset on Rx5day



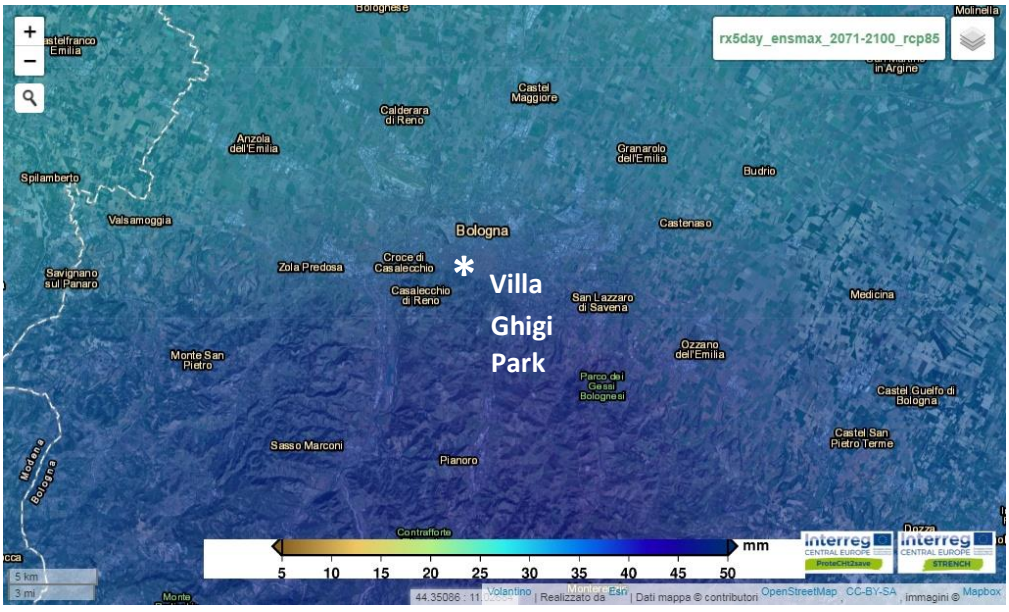
Map for the near future dataset on Rx5day in the rcp45 scenario



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



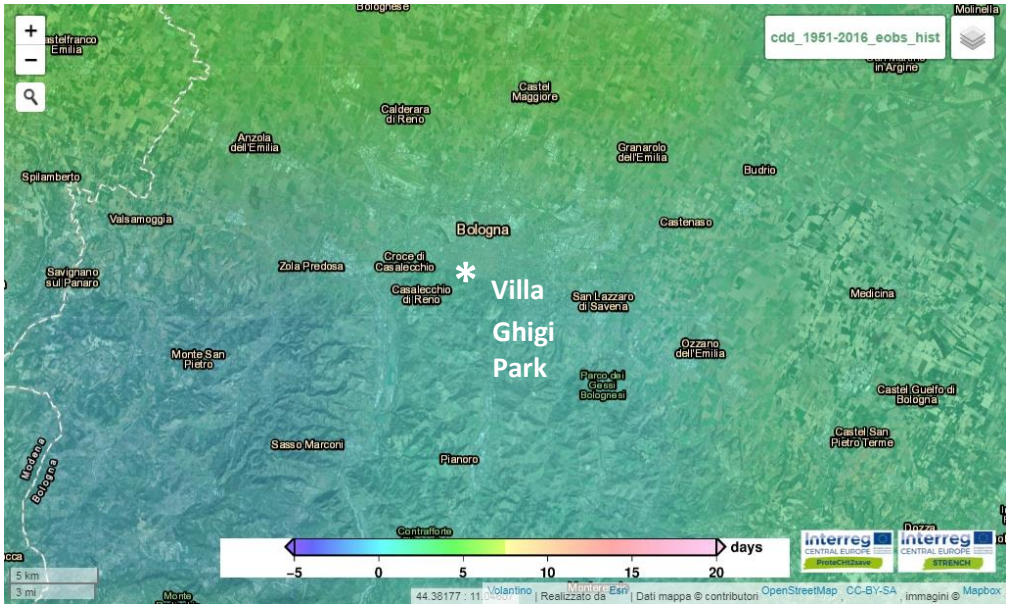
Map for the near future dataset on Rx5day in the rcp85 scenario



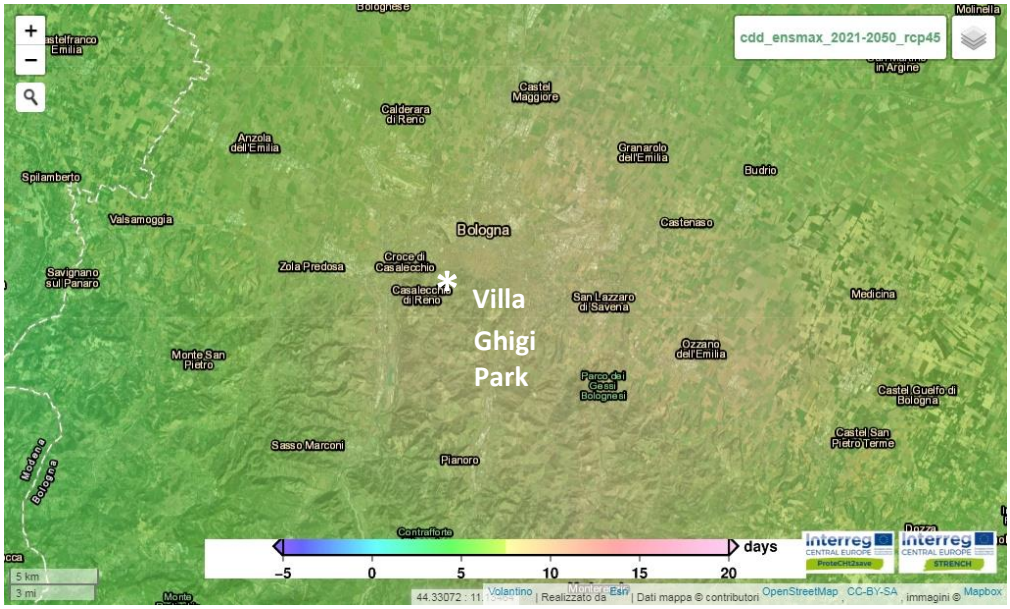
Map for the far future dataset on Rx5day in the rcp85 scenario

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

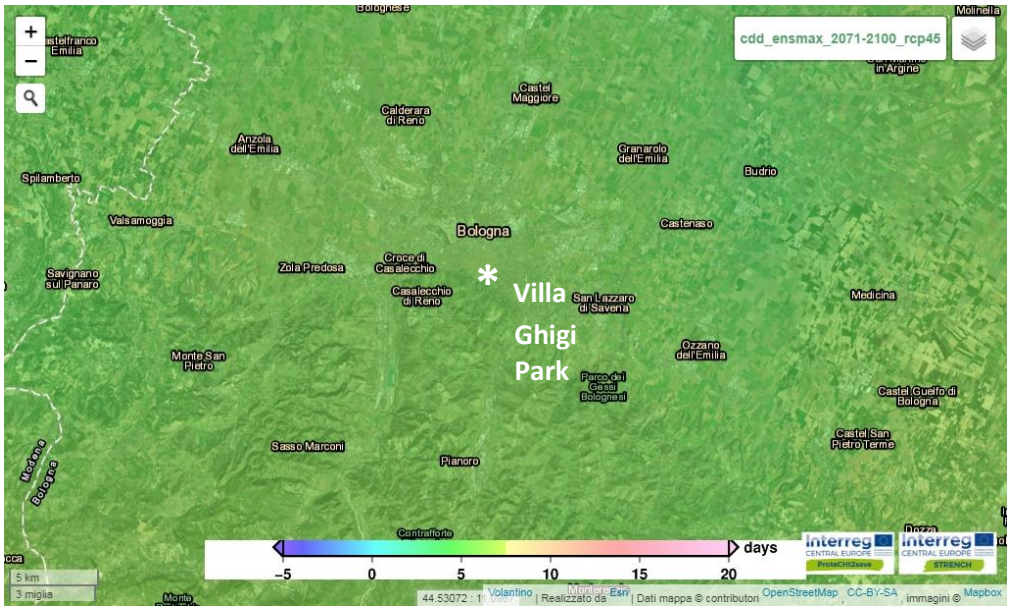
5.4 Maximum number of consecutive dry days



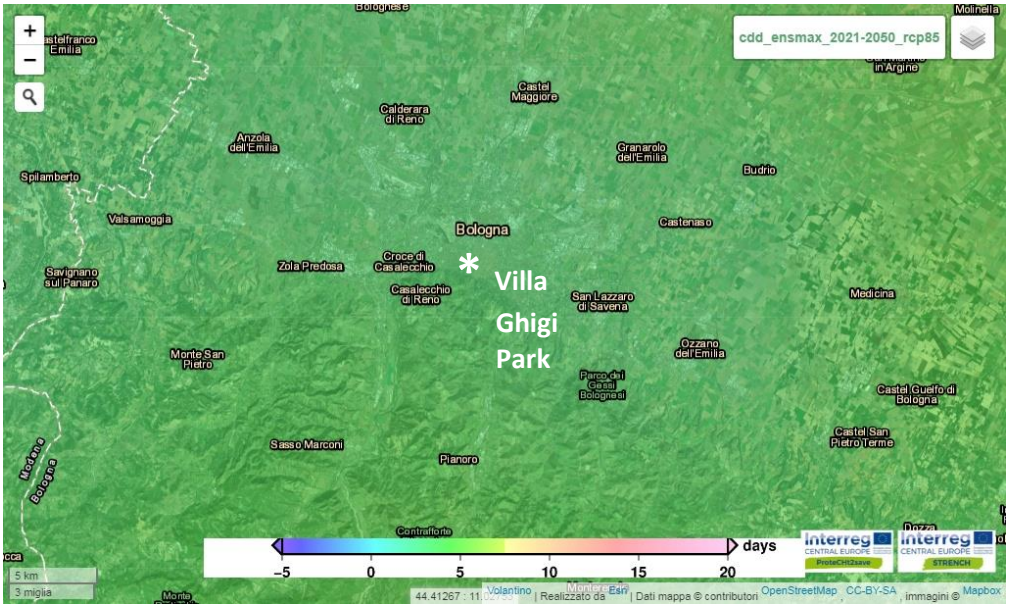
Map for the historic dataset on cdd



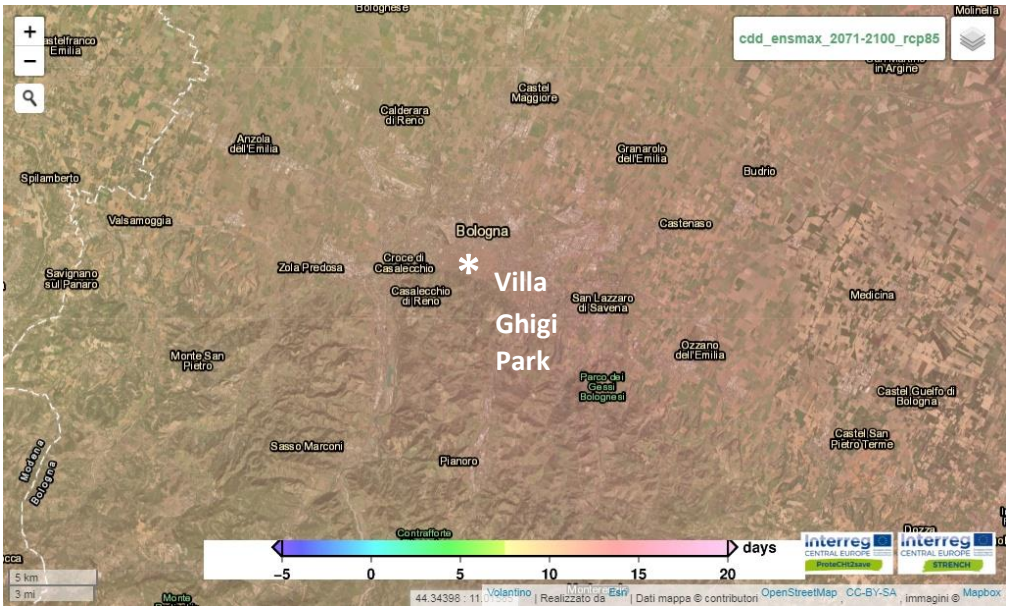
Map for the near future dataset on cdd in the rcp45 scenario



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



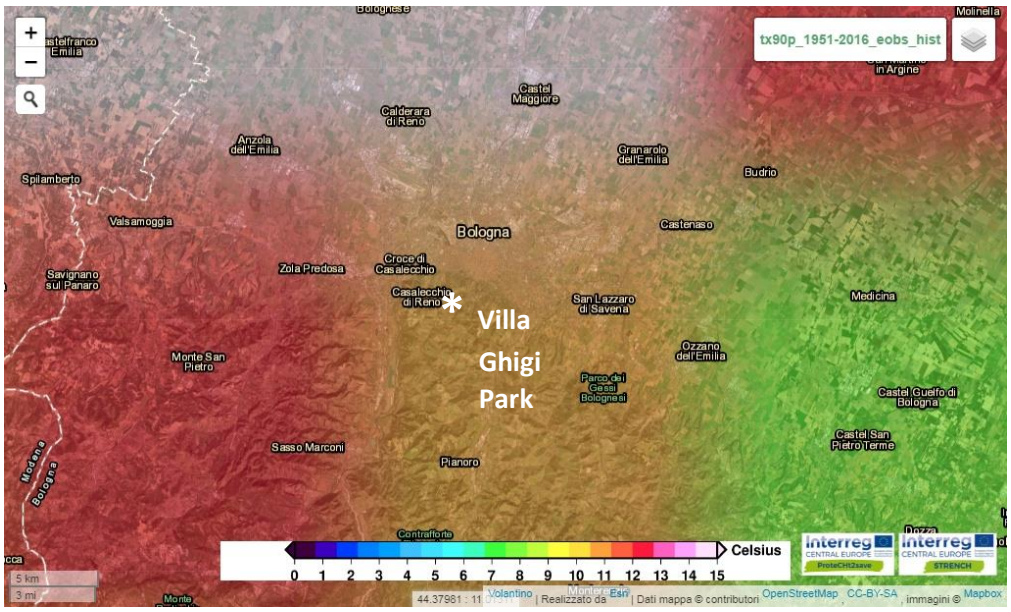
Map for the near future dataset on cdd in the rcp85 scenario



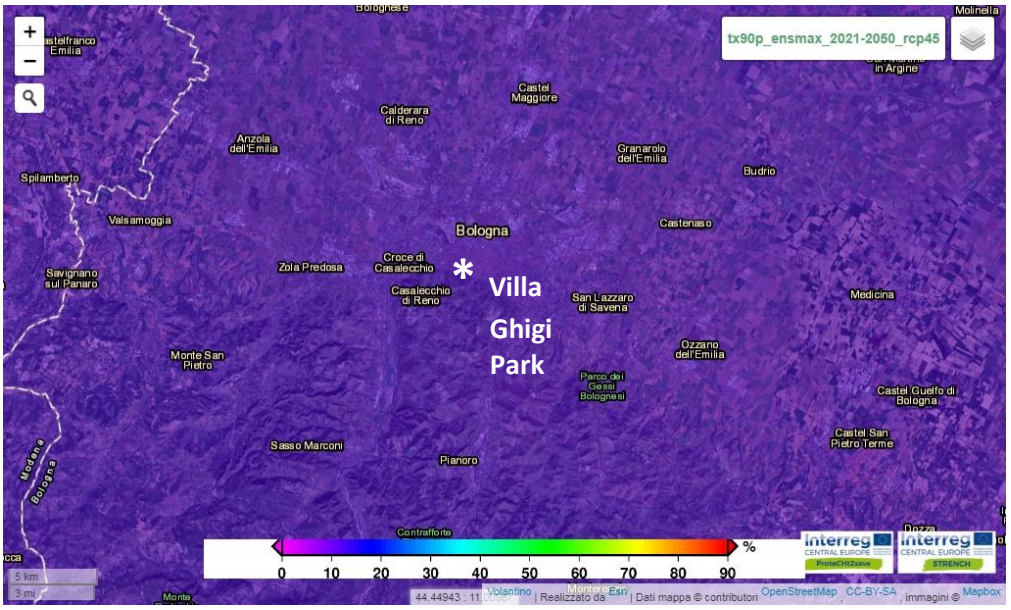
Map for the far future dataset on cdd in the rcp85 scenario

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

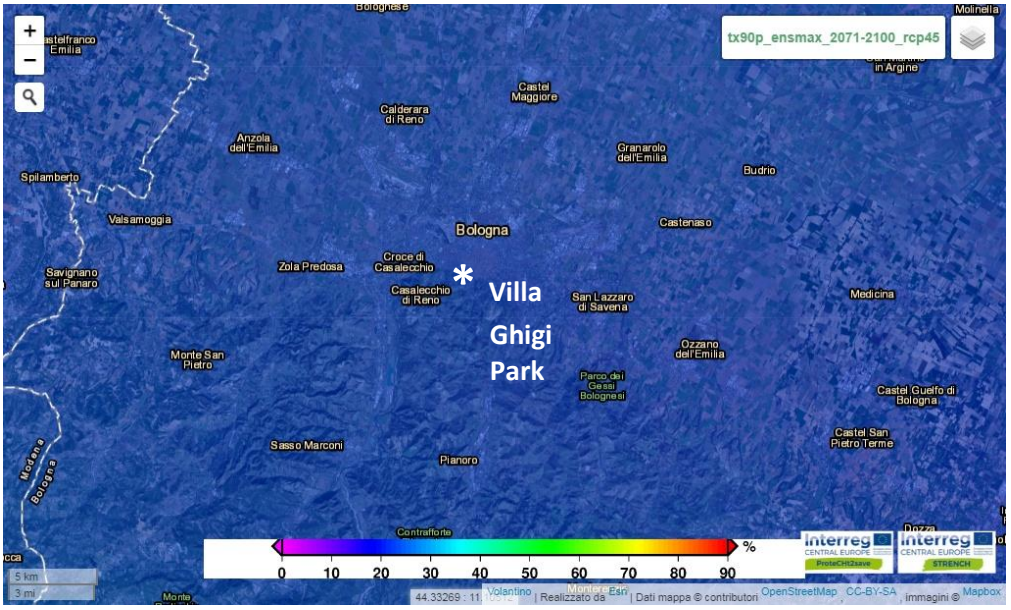
5.5 Extremely warm days



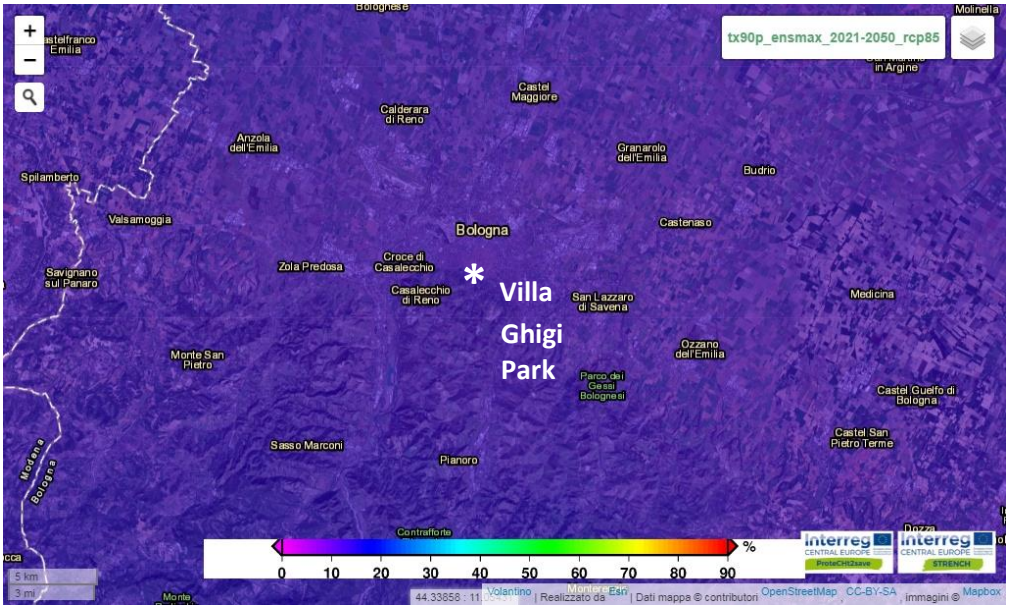
Map for the historic dataset on Tx90p



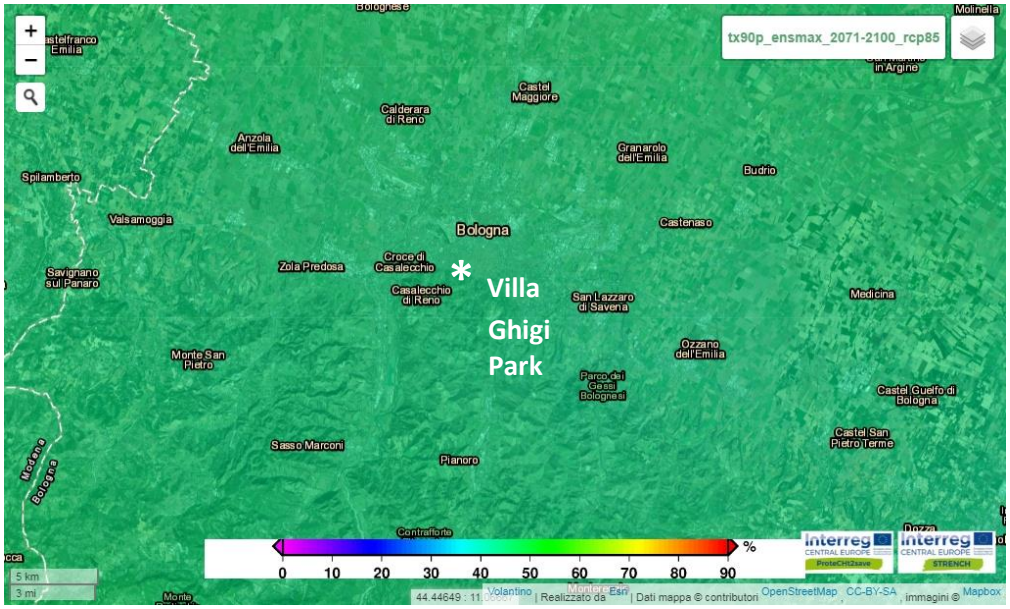
Map for the near future dataset on Tx90 in the rcp45 scenario



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



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



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

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

6. Conclusions and recommendations

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

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

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

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

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

General preparedness activity

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

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

Heavy rain and flash floods

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

Landslides

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

Windstorms and snow

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

Long term increase of temperature and drought

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