Ministry of Environment and Physical Planning

Climate Change and Cultural Heritage

Findings of a Rapid Vulnerability Assessment and recommendations towards National Strategies for cultural heritage protection in the context of climate change

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It is thanks to the great effort of these and many other colleagues who remain unmentioned that we were able to gather an amount of material required which allowed us to make some initial judgments on potential vulnerabilities of cultural heritage to climate change, to analyze past climate change related phenomena and to identify specific risks and challenges for the future. In some cases essential data required for detailed predictions, such as soil analysis or stratigraphies of geological layers were not available and hence our analyses and recommendations need to be seen as preliminary steps towards a future process of more detailed analysis.

We hope that this report will be useful to those who assisted us and can make a relevant contribution to the forthcoming national communication in the context of the UN Framework Convention on Climate Change. We hope that cultural heritage will find mentioning in this communication as one of the valuable resources of Macedonia which are at risk of destruction and decay as result of climate change phenomena.

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This report was prepared in the context of the regional project “Climate Change Adaptation in Western Balkans” on behalf of German Ministry for Economic Cooperation and Development (BMZ) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the project “Third National Communication to the United Nations Framework Convention on Climate Change” financed by GEF and implemented by the United Nations Development Programme.

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Introduction

The findings in this report are the result of a rapid vulnerability assessment in relation to the climate change phenomena for cultural heritage in Macedonia. The assignment the authors undertook consisted of two phases: a familiarization phase during which the Macedonian heritage professionals from the Ministry of Culture, the cultural Heritage Protection Office and other responsible institutions selected three case study sites, and which was followed by the undertaking of a rapid vulnerability assessment for these different heritage site as well as the development of recommendations for the protection of cultural heritage to withstand climate change phenomena.

The report is based on information obtained through UNDP and GIZ in Skopje as well as materials provided by the Ministry of Culture, the NI Conservation Center - Skopje for the aqueduct, the protection office in Stobi and the heritage administration in Ohrid. It is further based on site visits to the three selected locations. The authors undertook two missions to Macedonia, carried out between 30th June and 2nd July as well as 22nd and 28th of August 2013. The objective of research and analysis during these visits was to collect material and create sample studies which would be able to contribute to the incorporation of climate change considerations related to cultural heritage into Macedonia's "Third National Communication to UNFCCC". The study in this context attempts to bring to the awareness of climate change concerned authorities, the different impact phenomena which affect cultural heritage, as well as relevant policies or plans which could assist the protection of the cultural heritage at national and local level.

Terms of Reference

To achieve the above stated aim – a relevant contribution to the preparation of the Third National Communication to UNFCCC with focus on climate change and cultural heritage – the following terms of reference were agreed upon between UNDP, GIZ and the IHM – Institute for Heritage Management. The IHM, under the direct supervision of the GIZ Project Manager, and in close collaboration with UNDP, the Ministry of Culture and the Cultural Heritage Protection Office of Macedonia, was made responsible to:

- Undertake a rapid vulnerability assessment (RVA) of climate change impacts on Macedonian cultural heritage; this RVA should consider three specific Macedonian cultural heritage sites, selected in close and constant consultation with the Ministry of Culture and the Cultural Heritage Protection Office. For each of the three sites in-situ rapid vulnerability assessments will be carried out. The consultant will be responsible to prepare documentation reports on these rapid vulnerability assessment reports and recommend the best strategies and approaches for specific measures at these three vulnerable sites.
- Prepare recommendations for adaptation of cultural heritage to climate change, including an Action Plan for the national communication to UNFCCC and action plans for adaptation measures at the selected sites. These action plans shall include strategic goals, time-scale, funding requirements, research and capacity-building needs, administrative and institutional partners as well as quality assurance indicators for monitoring.

Cultural Heritage and Climate Change in Macedonia

The certain phenomena of climate change and their increasing trends over the past decades represents a significant challenge for cultural heritage to be addressed at both policy and management levels from the local to the regional and global context (IPCC 2007). As can be demonstrated, human activity has led, either directly or indirectly, to measurable climatic changes such as increases in global average air and sea temperatures, ranging around 0.74 °C over the past 100 years. In this context, the recent period of 1995-2006 registered the warmest years since the beginning of instrumental record of global surface temperature in 1850. It was observed that land masses warm much faster when compared to the oceans. This, in turn, has caused an increased melting of snow and ice, which consequently led to increased average sea level (with a global average rate for sea level rise of 1.8 mm per year over the period 1961 to 2003 and at an average rate of 3.1 mm per year from 1993 to 2003 (IPCC 2007)), as well as an increased frequency of extreme weather events (including heavy precipitation and floods, heat waves, droughts, and tropical cyclones).

An array of modeled scenarios developed to anticipate climate change phenomena for the 21st century indicate that the observed climatic changes in the last decades are likely to intensify, with an expected increase of between 1.1 to 6.4°C in global average temperatures, and an increase in global sea level rises of between 0.18 to 0.59 m by 2099. Europe in such scenarios is particularly likely to experience increased risks of inland flash flood events, glacier retreats, and reduced snow cover in mountainous areas.

In spite of its relatively small size, Macedonia, located in the central Balkan Peninsula in Southeast Europe, exhibits a rather diverse climate, influenced by different seasons and weather events. The region in particular has been identified as extremely vulnerable to climate variability and is expected to be faced with higher temperatures and droughts, but also an increase in wildfires, soil deterioration, reduced water availability and consequently reduced crop productivity. The current climate in Macedonia ranges from alpine in the west and north-west of the country, to Mediterranean in the southern districts of the Vardar River valley and is characterized by cold winters, hot summers a highly variable precipitation regime. Alternating periods of long drought and high intensity rainfall are also a common feature of this particular climate (Ministry of Environment and Physical Planning, 2013).

Climate change projections for both temperature and precipitation have been reported up to the year 2100. According to the results of several models, the average increase in temperature will be 3.8°C by 2100, with the highest increases seen in air temperature by the end of the century in the summer season (Karanfilovski, 2012). The average sum of precipitation for the country is expected to steadily decrease from the current level by 13% by 2100. This decrease is to occur in summer with partially no change in the precipitation expected during the winter months (Karanfilovski, 2012; Bergan 2006).

Models that have studied the Eastern Mediterranean and the Middle East in more detail using higher resolution datasets (long-term meteorological datasets for the period 1901-2006 along with regional climate model projections for the 21st century) suggest a continual, gradual and relatively strong warming of the area of about 1-3°C in the near future (2015-2039), 3-5°C in the midcentury period (2030-2069) and 3.5-7°C by the end of the century (2070-2099)

(Kuglitsch et al 2010). Daytime maximum temperatures appear to increase most rapidly in the Balkan Peninsula with extremely high summer temperatures projected to become the norm by 2070-2099 and with the coolest summers at the end of the century still much warmer than the current summer temperatures. The models indicate a continuation of increasing intensity and duration of heat waves observed in Macedonia since 1960 (Kuglitsch et al 2010; Lelieveld et al 2012).

Climatic change will unquestionably affect Macedonia and its population in a multitude of ways, with direct, indirect and cumulative impacts to be expected. This, in turn, reveals not only the importance of understanding the causes and dynamics of climate change, but also the necessity to assess the impacts and to understand risks and vulnerability in order to take measures for mitigation, preparedness and adaptation. From an economic point of view, it has been demonstrated that the costs of an early response to climate change are significantly lower than those that might be triggered by future damage (Stern Review 2007).

Although quite often omitted from impact assessments, vulnerability studies, or policy priorities with regard to climate change, cultural heritage will most likely be affected by the changing climatic patterns, both in its physical and its intangible form. Whereas other ecosystem elements may have regenerative potential, the impacts of climate change on cultural heritage are expected to determine, if no preventive action is taken, irreversible alterations or even disappearance.

Historic structures were designed in response to and for a specific local climate often differing from the current and future climatic contexts. Hence cultural heritage will be in need for adaptive measures to ensure its survival. The built fabric is threatened by increased rainfall and water penetration into the masonry structures, which increases the risk of damp, condensation, rot and fungal growth.

These changes may not only affect the structural security of buildings, but also their decorative elements (e.g. historic buildings have a more porous fabric, drawing water from the ground and evaporating it through the surface; an increase in moisture may determine more salt mobilization and as result damaging crystallization on decorated or plastered surfaces through evaporation).

Increased frequency of floods or extreme weather events (storms, winds) may cause significant structural damage to historic buildings and sites, or increase decay processes of wood and stonework. Dramatic temperature changes (diurnal or seasonal) or increase in wet/dry and freeze/thaw cycles will trigger not only the deterioration of facades and wall paintings, or internal damage of brick, stone and ceramics (Sabbioni et al. 2006) but can in worst cases lead to fractures in constructive elements which put the stability of monuments at risk. Soil alteration, as well as changes in hydrological, chemical and vegetation patterns may lead to the destruction of archaeological artifacts buried in the ground, especially those materials with a poorer level of resistance to changes in humidity levels. Shifts in ecosystems may lead to biological infestation and the resulting migration of pests may introduce new structural threats to timber and other organic building materials. Overall, physical damage on historic structures and sites is caused by a variety of impacts which could change in the furthering of climate change including temperature (range, freeze, thaw, thermal shock), water (precipitation, humidity cycles, time of wetness) and wind or pollution (SO_2, NO_2, pH) (Brimblecombe et al. 2006).

Depending on the type of a specific heritage asset, the main areas of concern appear to be the impacts of rainfall, flooding and soil water saturation, extreme weather events, temperature and relative humidity, pests and diseases, plant physiology and distribution, human comfort, health and safety, water table chemistry, and strong wind currents (cf. Cassar 2005).

Impacts of similar intensity are likely to be experienced at a cultural heritage landscape level as well. Rising sea levels and increased storm events may threaten cause the disappearance of entire coastal settlements (ICOMOS 2007). Increased temperature, droughts and extreme climatic conditions may irreversibly affect cultural landscapes (especially agricultural and pastoral ones). Land-use patterns and management practices which have been developed in relation to traditional cultural systems and local climatic environments are often geographically isolated, in fragile ecosystems and with limited natural resources. Climatic changes may therefore lead to a loss of these cultural landscapes and their rich heritage, forcing communities to gradually abandon these traditional practices. Depopulation and abandonment of living sites will subsequently trigger the loss of important traditional knowledge in particular with regard to sustainable land-use practices and building techniques, erosion of physical structures, but also the break-up of communities and the loss of spiritual values and cultural memory. Also social impacts of climate change on cultural heritage should not be neglected, such as demographic alterations, changes in socio-cultural preferences and behavior, or in people's relationship with the environment (UNESCO 2007, 2008). The below diagram developed at a project on climate change impacts on cultural heritage by the Centre of Sustainable Heritage, UCL, summarizes the key climate change impact factors on different types of heritage.

Given the complexity of observed and projected changes, assessing the impacts of climate change on cultural heritage must take into consideration a wide range of variables that integrate nature, culture and people. Through understanding the risks and the vulnerability of sites, adequate monitoring mechanisms and adaptive management responses should be developed and implemented, in order to prepare cultural heritage for future climate change stresses and to prevent potential irreversible loss.

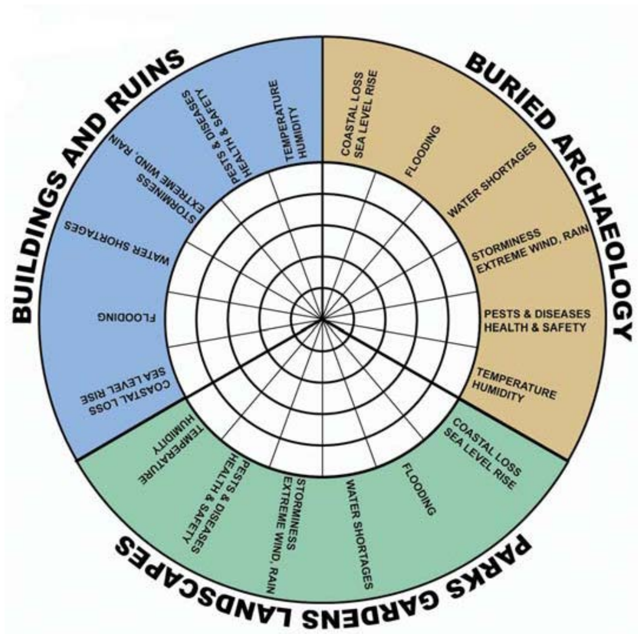

Figure 1: Key Climate Impacts on Cultural Heritage (Source: UCL, Centre for Sustainable Heritage)

Selection of Sample Sites

The selection of cultural heritage sites to be analyzed as part of the rapid vulnerability assessment was based on a workshop of cultural heritage professionals identified by the Ministry of Culture and National Heritage Protection Office and organized by UNDP and GIZ. The workshop allowed participants in a participatory fashion to suggest cultural heritage sites, which they thought were particularly suitable for such study or challenged by climate change phenomena.

Eleven sites were suggested during this brainstorming process. As a second step, the workshop attendants were invited to select those sites among the eleven which they thought would be most beneficial in terms of the aims and objectives of the project. Each participant was given three votes to select three sites of his or her preference. As a result two sites received an overwhelming majority of votes, Ohrid and Stobi, and the following third highest amount of votes was given to the Aqueduct of Skopje.

The three sites were intended to present different categories of cultural heritage according to the National Heritage Legislation. The Skopje Aqueduct was seen as a monument but was also perceived as component of a wider cultural landscape following the results of a revalorization project of the NI Conservation Centre – Skopje, the Archaeological Site of Stobi as an archaeological site and Ohrid as both a historic city and a cultural landscape. Unfortunately the later site visits indicated that these intended differences were not as had been expected. The monument of Skopje Aqueduct illustrated more characteristics of an archaeological site than an architectural monument and was exposed and vulnerable to climate change phenomena which were largely comparable to the situation at Stobi. The sheer size of Ohrid, both in terms of the historic city and the cultural landscape made it impossible to conduct meaningful studies of climate change vulnerabilities within merely two days. On site, it was hence discussed how certain elements, locations or a group of buildings could be focused on what would bring forth relevant results towards the national communication as well as a helpful tool for local protection and management. The local authorities suggested, that the site of Plaosnik, which is part of the Ohrid World Heritage Site and located at the top plateau of the north-western historic city below the citadel, would be the most interesting case study in terms of potential for protection and management as a number of changes were currently underway on site and new protection approaches may subsequently need to be sought.

It hence turned out that the three case studies shared in one way or another archaeological features and climate change phenomena that were most obvious at archaeological sites. However, they significantly differ in their specific settings which allowed for genuinely different observations of damage phenomena and climate change influence at the three sites. The Skopje Aqueduct is located on the slopes of a hill outside Skopje in medium high terrain and a small river passes downhill through the site. The archaeological site of Stobi however is located on lower hill slopes which reach into the lowest sections of a valley close to the confluence of two larger rivers, Vardar and Crna, the regular flooding of which affecte the site since ancient times. Lastly, the archaeological site of Plaosnik in Ohrid is located on the upper plateau of the steep lake cliffs and remains uninfluenced by natural water streams. However, the plateau location is very exposed to extreme weather events and illustrates past damages of wind and rain erosion.

Assessment Methodology

Recent climate change phenomena and climate variations are beginning to have effects on several natural and human systems. Alongside long-term temperature increases, there is growing concern that extreme weather events may be changing in frequency and intensity as a consequence of temperature rise and as a result of past and present human influences on climate. As such, the impacts of climate change on cultural heritage may be perceived best through the impacts of extremes.

Long-term increases in temperature are likely to bring about changes in the number and intensity of heavy precipitation events (Groisman et al 1999; Frich et al 2002; Beniston et al 2007). These may cause damage due to increases in surface runoff (Parry & Rosenzweig 1990) and the occurrence of flooding events, increased erosion and increased ground instability as well as high winds (Dixon & Turner 1991; Lighthill et al 1994; Emanuel 2005). Heavy precipitation events are likely to induce changes in humidity (Arnell 1999), while increased incidences of extremely high sea levels may stimulate flood events and cause salinization of salt water intrusion into low lying coastal areas.

Changes in precipitation patterns including heat waves and warm spells are expected to increase over most land areas and will undoubtedly lead to changes in soil moisture, drought and lowering or fluctuations of groundwater tables (Schär et al 2004; Dai et al. 2004). Decreased soil moisture in many regions will increase soil aridity, soil erosion and the occurrence of dust or sand storms (McTainsh 1998; Zhang et al 2003) in combination with high winds.

Climate change will also likely increase or decrease the frequency of freeze/thaw cycles (temperature fluctuations around 0°C) (Grossi et al 2007;Susan et al 2007; Henry 2007; 2008). In regards to flora and fauna, there have been recently growing concerns that climate change may rapidly and extensively alter global ecosystems with the resilience of many ecosystems likely to be exceeded by unprecedented combination of climate change and associated disturbances (flooding, drought, wildfire, and insects) which are likely to bring about changes in biomes (No 2007). Furthermore higher temperatures have been known to modify the chemistry of a number of chemical pollutants resulting in significant alterations in their toxicities and pollution risks (Schiedek, et al 2007).

Predicting impacts of climate change on cultural heritage can only be considered on the basis of a case by case study as it depends on the local context and the specific materials utilized at each heritage site. At a principle level it requires:

- Determining the characteristic impacts of short term and long term climate parameters und climate events with potential implication on cultural heritage;
- Identification of parameters characterizing the built or archaeological heritage and the surrounding of the specific site in question;

- Identification of materials and construction techniques used and consideration of their likely vulnerability to climate change phenomena;
- Assessment of specific climate change affects which are likely to occur at a specific site and assessment of their potential impact on the cultural heritage resource.

Climate change risks / Potential receptors of impacts	Long-term temp. increase	Increase in the number of freeze/thaw cycles (temp. fluctuations around 0°C)	Heavy rain events	Increased flood events	Changes in humidity	Increase in wind gusts and/or sand storms	Increase in thunder-storms and/or tornados	Fluctuations in water-table levels	Increased surface run-off	Accelerated pollution based on climate factors	Changes in flora / fauna	Eco-system switches
A: Archaeological site:												
Static and integrity of archaeological remains												
Static and integrity of reconstructions												
B: Stone / brick deterioration:												
Stone / brick surface												
Stone / brick integrity												
Mortar												
Surface colour												
Stone / rock carvings												
C: Decorative elements:												
Mosaics												
Stone and wall paintings / frescos												
Ceramics												
D: Surrounding landscape:												
Slopes												
Ravines and gullies												
Soils												
Coastal zones												

TABLE 1: IMPACT MATRIX OF CLIMATE CHANGE RISKS ON CULTURAL HERITAGE

Table 1 shows an impact matrix of risks to be expected by climate change and the relevant parameters determining the composition of the site and the surrounding area. The main objective of the matrix is to highlight the specific risks caused by different climate parameters and events of climate change potentially affecting the historic assets of the built or archaeological heritage as well as the abiotic and biotic environments. The site specific vulnerability will be evaluated by scaling the relative importance of both the magnitude of the impacts of climate change and the sensitivity of the historical construction including relevant environmental criteria of the surrounding area. The impact matrix thus can be seen as a scoping matrix. Resultantly, impacts are to be screened in accordance to five levels of significance. These are, impacts not expected or predicted (0); impacts that are likely to occur but will also likely pose insignificant threats to the particular site (-); impacts likely to be significant (+); highly significant impacts with the potential to cause major damages to the cultural heritage resource (++), and lastly impacts that require further study (?). The matrix allows indicating these categories both by symbols and color codes for increased visibility.

Based on expert judgment, available descriptions of the site should be assessed in combination with the likelihood of changing climate parameters and climate events for the specific region. National climate change scenarios, like the “Climate Change Scenario for Macedonia” (2012) offer necessary information about climate change predictions with a spatial resolution even below the national scale. In addition weather data from the past, in the Macedonia available on a daily basis for selected weather stations since the beginning of the last decade of the 20th century, provide information about past weather extremes, their frequency, temporal characteristics and long term trends assuming that climate change is already a relevant factor today. While long term trends as the increase of the (global) temperature (often shown as warming trends up to 2100) and precipitation changes are presented, a focus on climate scenarios of specific threats, such as extreme events like heavy rainfall, storm surges or flooding has a much higher potential to arrive at vulnerability scenarios for cultural heritage and are consequently the majority of significant climate change risks listed in table 1.

The impact matrix identifies key areas of concern for the archaeological heritage structure as relevant to the case studies investigated and should be considered a basis for more detailed impact prediction, assessment and measures enhancing the specific resilience of the site. The impact matrix could be used for specific site surveys and further rapid impact assessments, based on combining the available and obvious information about the site with the specific observable and potential damages according to the listed criteria as well as the identified threats caused by climate change. For most of the heritage sites in depth studies about research and measures on preservation and restoration are useful information for an assessment of impacts by climate change. In addition local and national expert knowledge about the built structure and implication of the recent history could be considered as important information characterizing the degree of vulnerability of the site resulting from different human and natural pressures. Therefore the severity of the damage potential of climate change needs to be assessed by balancing the actual against the predicted impacts. Impacts of climate change on built heritage have to be understood in this context as an accelerated process of already visible and existing climate threats to a cultural heritage site.

An impact matrix trying to cover all types of built structures and landscapes identified as cultural heritage seems to be impracticable as the multiplicity of factors that would need to be recognized for different heritage categories would render it too complex to be of use. The broad range of cultural heritage as earthen architectural heritage, stone built monuments, historic villages and cities, archaeological sites, under water constructions and historical cultural landscapes have a series of construction and site specific characteristics resulting in many non-significant relations for the impact assessment of a specific site. Therefore and as the result of the site selection by the national expert meeting on 2nd July 2013 in Skopje the impact matrix was carried out with a predominant focus on the category of archaeological sites.

Additional climate change impact indicators which support the assessment and continuous monitoring of selected climate change phenomena is presented in table 2. This table further includes a parameter related to severity of change and respective vulnerability, climate change phenomena specific impact indicators and monitoring parameters to ensure comparability of findings in the future. It should be used in conjunction with the vulnerability table 1.

Climate Parameters	Meteorological Changes	Climate Indicators	Parameters	Impact Indicators	Parameters
Temper-ature	temperature range	mean monthly temperature	°C	stone deterioration fresco destruction deterioration of facade	loss of stones/bricks surface layer loss µm/y surface layer loss µm/y
	freeze-thaw cycles	temp. above and below 0°C in 24h	number of days/y		
	thermo shock	min/max temp. In 24h on surface	Δ T		
	relative humidity	range RH max.- RH min.	%	salinization	loss of stones/bricks surface layer loss µm/y, wash out of mortar
		mean RH	%	destruction of wall paintings, fungi and insect infection (e.g. dry rod) of wooden construction	species and wooden construction infested by fungi and insects
Water	heavy rainfall events	>200mm/day	number of events	static instability of buildings and archaeological remains	inclination mm/y
	long term rain periods, flood events	total rainfall of rain period >1000mm/period	number of periods	moisture content, moisture in built material	%
		total area flooded	km^2		
		height of flood	m	loss of building material and loss of collections	damage assessment report on flooding events
		duration of flood	days		
	wind driven rain	wind speed and amount of precipitation	m/sec and mm rainfall	salinization frost-damage (Winter)	loss of stones/bricks surface layer loss µm/y, surface layer loss, µm/y
	dry periods	periods without rain	days	risk of fire (hot summer month)	damage assessment report on fire
				sandstorm as indirect effect of reduction of vegetation cover	surface layer loss µm/y
Wind	Sandstorm	wind speed	m/sec	sandblast of frescos and decorated facades	surface layer loss µm/y
		wind driven sand, salt	colour		
non climate parameters	land use change	increasing area of settlement and infrastructure	km^2	Case specific	assessment report
	urbanization	sealed area in ratio to total area	%		
	pollutants	SO2, Nox, pH precipitation	mg/m^3 pH	stone recession, glass corrosion	surface loss µm/y colour of facades

TABLE 2: CLIMATE CHANGE AND IMPACT INDICATORS FOR BUILT HERITAGE AND ARCHAEOLOGICAL SITES BASED ON BRIMBLECOMBE AND GROSSI (2006) AND UNESCO (2007)

RAPID VULNERABILITY ASSESSMENT FOR CULTURAL HERITAGE

The following rapid vulnerability assessments were carried out for three cultural heritage sites in the Macedonia, (1) the Skopje Aqueduct, (2) the Stobi archaeological Site and (3) the archaeological site of Plaosnik at Ohrid. The sites were evaluated during site at an average time of 1.5 days for each. It is difficult within this limited time frame to arrive at reliable and confirmed results and assessments. Hence, the results of this vulnerability assessment should be seen as initial indications towards climate change vulnerability but may have to be verified through further detailed studies taking into consideration additional factors including the soil composition and geological stratigraphy of each site. The authors accordingly recommend to the Ministry of Culture and the cultural heritage authorities in Macedonia to continue the observations and assessments of climate change phenomena on these sites over a longer time frame to verify the findings presented in the forthcoming chapters.

SITE 1: SKOPJE AQUEDUCT

DESCRIPTION AND HISTORICAL CONTEXT

The Skopje Aqueduct is located close to the M3 motorway which connects Skopje city centre to Kosovo, south of Slovenia Boulevard and east of the settlement of Vizbegovo. The Serava River which passes through the site from east to west and flows partly underneath the aqueduct has been canalized in this section. The site is surrounded in the north by undeveloped plains, fields and meadows up to the Slovenia Boulevard, to the east by green vegetation with occasional smaller single architectural structures up to Makedonska Kosovska Brigada (yet this green area is fenced and partially private, partially part of the military compound), to the south it points towards a larger complex which was previously in military use and has retained a number of buildings, and finally to the west the site borders greenery around the valley of the Serava River as well as a small settlement between the site and the M3 motorway.

A variety of different theories and legends exist concerning the age and date of construction of the aqueduct. According to a first theory which was coined by the Englishman Arther John Evans, who visited Skopje in 1883-1884 (cf. Kitanovska and Biceva, 2013) it was built under the Roman Emperor Justinian transferring water from Skopska Crna Gora (the black mountain of Skopje) to the city centre. However, Evans highlighted that the northern part of the aqueduct might be a reconstruction of Turkish origin, which points at a second theory. The second theory attributes the aqueduct to the time of the Ottoman ruler Mustapha Pasha according to which it would then have been built in the 15th century. Finally, a third theory dates it even later, to the 16th century, as indicated by Petrov in 1962, (cf. Ibid.) which corresponds to the time that most Turkish bath were erected in Skopje.

In this context of the mission conducted, the authors were unable to confirm either of the theories – although it is believed that material analysis of mortar of the earlier southern structures may provide good and precise results to allow for dating – but according to information provided by our local partners it can be established with certainty that the aqueduct was in use until 1914. The upper level of the aqueduct illustrates evidence of piping that may have been introduced in the late 19th or even early 20th century.

Following World War II the vicinity of Skopje Aqueduct was used by the military, apparently also as a training ground. Three arches of the aqueduct have been destroyed in the 20th century and it is said that it might have been a result of military exercise on the demolition of bridge arches. It seems that these arches were reconstructed in 1967 and that at the same time other repair works may have been carried out.

The official version of the contemporary assumption with regard to the history of the Aqueduct construction as is described by Kitanovska and Biceva (Ibid., p. 7) divided the construction into six consecutive phases. They consider that it was (1) originally built in the 6th century AD and (2) extensively repaired during medieval times, however these repairs are judged as “unskilled because they were made without proper restoration of the vaults and the manner of building frontal walls” (Ibid.). A third phase (3) can be dated to the 19th century (1884-1888) where a different brick material was introduced on at least two vaults. A renewal of vaults (4) took place soon after, likely in the late 19th or early 20th century. The fifth phase (5) renewed the pipes and constructed a concrete fountain at the southern end and the latest (6) phase is the 1967 reconstruction of three vaults and further repair works (cf. Kitanovska and Biceva, 2013).

PHOTO 1: NORTHERN SECTION OF AQUEDUCT

The aqueduct visible today is a structure of 53 square and one rectangular piers, which resulted in 54 vaulted arch openings and two lateral ramps at both ends. It is preserved a length of 385.8 meters out of which some sections are only preserved in a fragmented state. The aqueduct is valued as a cultural heritage site and a historic water supply system likely dating back to the 6th century AD. However, with its elaborate masonry of alternating brick and stone components, it also has architectural and aesthetic qualities. With its linear structure changing at the one rectangular pier it provides a prominent feature and landmark in the wider landscape.

STATE OF CONSERVATION AND DAMAGE PHENOMENA

The Aqueduct of Skopje is overall in a critical state of conservation. Several arches collapsed rather recently and considerable structural and surface damage are visible. A significant amount of damages are related to environmental phenomena, including those which have the potential to became very critical to the monument’s long-term survival – and are likely to be accelerated with increased influences of climate change. However, also a rehabilitation project briefly outlined by the colleagues of the Cultural Heritage Protection Office seems to pose risks to the monument. A number of damage phenomena of specific relevance to the site will be further described according to the sources that have caused these specific damages.

CHANGES IN GROUND WATER LEVEL

The probably most significant change and damage that occurred to the Skopje Aqueduct was caused by the canalization of the Serava River. In the past, the Serava River covered a much wider area of the Aqueduct and passed further south from its present location. Its canalization reduced it to a channel under the piers 31-33 and it may be likely that the destruction of these occurred in the context of the river canalization rather than a military exercise. The relocation of the river changed the ground water saturation of the soil in the southern part of the site. Previously highly water saturated soil is now no longer connected to the river, which streams at a faster speed through a concrete canal further to the north.

As a result the less saturated soil settled over the years leading to a soil compression under the aqueduct foundations, especially in the area of piers 19-27. The pier foundations moved with the settling and compressed soil and since the compression was not identical in all areas the foundations lowered into differing directions at different levels of the aqueduct, leading the architectural structure to significantly lean. Following these shifts out of the vertical angle on which the aqueduct was constructed, the transition of architectural pressures from the key stone of each arch towards the foundations has become disturbed. As a result upper parts of the arch structures and in particular the outer ornaments are no longer properly carried by the piers. The load bearing system of the construction directing pressure towards the piers has partially lost its proper function. As a result the upper aqueduct parts which are no longer carried are at risk of collapsing if further soil movements occur. Such movements can be accelerated by earthquakes – and likely the severe 1963 earthquake contributed its part to the current condition – but will likely be caused by further changes in ground water saturation.

PHOTO 2: CANALIZED RIVER BED OF SEREVA RIVER UNDERNEATH PIERS 31-33 OF THE AQUEDUCT

PHOTO 3: STRUCTURAL DAMAGES CAUSED BY SHIFTING FOUNDATIONS

The canalization of Serava River has significantly increased this risk. Apart from withdrawing the continuous water flow and as result of the constant water saturation, it has through its impenetrable bed isolated the soil of the southern aqueduct from the underground water streams which prevents the drainage of rain water. In consequence during the rainy season rain water lakes are formed in the areas which at times lead to water erosion and increase in the water penetration into the upper layers of the monument. The seasonal changes in soil saturation and water penetration are critical, in particular at times of freeze/thaw days in winter and cause an acceleration of natural decay phenomena on an annual basis.

In this context, the project idea to re-naturalize the river bed is highly welcomed; however, it also bears significant risks. The key risk is that through the reverted continuous water saturation in lower soils which have dried and settled over time, renewed larger soil settlements and shift may occur which the already destabilized arches of the aqueduct may no longer be able to compensate for. It is therefore essential, that the river denaturalization in undertaken hand in hand with a strengthening process of the southern aqueduct foundations which would preferably carefully move these back into vertical position.

PHOTO 4: LEANING PIERS (CA. 19-27) IN THE SOUTHERN PART OF THE AQUEDUCT AFFECTED BY SOIL SETTLEMENTS

RAIN INDUCED DAMAGES

Rain water damages include those described above which cause the differences in ground water saturation and include surface water retentions, but also damages on the upper part of the architectural structures which shall be focused on in this section. Strong rain events have caused water erosion phenomena on the upper parts of the aqueduct affecting in particular the more recent piping elements of the early 20th century. Cracks and structural damages allow rain water to penetrate deep into the monument causing further damages, especially during frost periods. Damage phenomena which have occurred include signs of classic erosion along the edges of the upper levels but also further structural disintegration as shown on the image below.

PHOTO 5: AQUEDUCT TOP SURFACE WITH DAMAGES CAUSED BY WIND AND WATER EROSION

PHOTO 6: DAMAGES CAUSED BY FROST EXPANSION FOLLOWING RAIN WATER PENETRATION

PHOTO 7: VEGETATION ON THE AQUEDUCT

PHOTO 8: VEGETATION COVERAGE NEAR PIPE

VEGETATION

Vegetation constitutes a third cause of decay and at times destruction, which has become quite massive after decades of no maintenance. In particular on the upper level on both sides of the pipe system vegetation is dense and roots of small trees inside crack and joints create internal forces pressing on the most exterior layer of brick stones. Regular maintenance could reduce this impact to negligible levels.

ANTICIPATED CLIMATE CHANGE IMPACTS

Climate change is expected to primarily affect the statics of the aqueduct and even to have a pronounced impact on the structural integrity of the monument. Table 3 shows that the monument will be damaged in its entirety due to highly significant effects (denoted by ++) associated with climate change such as an increased number of freeze/thaw days, increased heavy precipitation and flooding, as well as fluctuations in the water table.

Climate change risks / Potential receptors of impacts	Long-term temp. increase	Increase in the number of freeze/thaw cycles (temp. fluctuations around 0°C)	Heavy rain events	Increased flood events	Changes in humidity	Increase in wind gusts and/or sand storms	Increase in thunder-storms and/or tornados	Fluctuations in water-table levels	Increased surface run-off	Accelerated pollution based on climate factors	Changes in flora / fauna	Eco-system switches
A: Archaeological site:												
Static and integrity of archaeological remains	0	++	++	++	0	0	–	++	+	0	0	–
Static and integrity of reconstructions	0	+	+	+	0	0	–	0	+	0	0	–
B: Stone / brick deterioration:												
Stone / brick surface	0	++	0	0	0	+	–	–	0	(+)	0	–
Stone / brick integrity	0	++	0	0	0	0	–	–	0	0	0	–
Mortar	0	++	++	++	0	0	–	++	+	(+)	?	–
Surface colour	–	–	–	–	–	–	–	–	–	–	–	–
Stone / rock carvings	–	–	–	–	–	–	–	–	–	–	–	–
C: Decorative elements:												
Mosaics	–	–	–	–	–	–	–	–	–	–	–	–
Stone and wall paintings / frescos	–	–	–	–	–	–	–	–	–	–	–	–
Ceramics	–	–	–	–	–	–	–	–	–	–	–	–
D: Surrounding landscape:												
Slopes	0	0	+	+	0	0	–	0	+	–	0	–
Ravines and gullies	0	0	+	+	0	0	–	0	+	–	0	–
Soils	+	0	+	+	0	0	–	+	+	0	0	–
Coastal zones	–	–	–	–	–	–	–	–	–	–	–	–

TABLE 3: CLIMATE CHANGE IMPACTS ON SKOPJE AQUEDUCT

Significance of potential impacts:

0 - impact not expected; – - insignificant or non-applicable for the particular site; + - significant; ++ - highly significant; ? - further investigations required;

The number of freeze/thaw days measured at the weather station in Skopje is relatively high compared to other regions at approx. 60-80 days (out of a total of 150 from November-March). Even by the year 2050, the number of days with predicted temperature maxima and minima above and below zero within a 24 hour timeframe remains high, despite the predicted overall warming in the Macedonia. While countries north of the Danube have cold winter frost days with sub-zero temperatures and temperatures in western European states rarely drop below freezing, in Skopje nearly half of the days in winter months from November to March have a freeze/thaw cycle.

The damage to the bricks at the top of the aqueduct arches caused by frost shattering has currently reached a level where the sum total of the static structure is in acute danger. As a result of this damage, a brick arch loses its stability and collapses into itself. Built in the 19th century, the concrete channel on the apex of the aqueduct and the associated reconstruction project resetting the upper brick works in concrete mortar (photo 9) do not contribute to improved stability of the structure, but rather they will create a relic with no remaining structural integrity after the collapse of the arch.

PHOTO9: DAMAGE TO THE BRICKS AT THE TOP OF THE AQUEDUCT AND BETWEEN ARCHES CAUSED BY FROST SHATTERING

The vegetation currently covering the apex of the aqueduct is accelerating the destruction of the structure. By 2100, despite climate-induced warming with increased aridity and predicted extreme temperatures in the hot summer months of July and August, it cannot be assumed that the drought-resistant grass species growing mainly on the top of the aqueduct will recede due to a reduced water supply.

Similar climate-related effects on the grout in the structure have been determined to be highly significant. The lime mortar is continually washed out from seams by weathering and increased heavy rainfall, which ultimately leads to the deterioration of the brick itself.

Increased incidences of heavy precipitation in the surrounding mountains will lead to temporary flooding. The concrete Serava canal near the aqueduct, as a result of its water flow design and margin, will ultimately lead to an increased rate of high velocity flow during floods. The enclosed channel shafts built in four sites in 1967 underneath the aqueduct also forms a barrier during heavy floods and subsequently floods the lower-lying areas containing the aqueduct arches. An increase in climate-related floods, therefore, will further degrade the already eroded aqueduct arch bases (photo 10) and flash flooding will continue to destabilize the overall statics of the structure.

PHOTO 10: LOWE PIER AREAS WHICH ARE VULNERABLE TO FLASH FLOODS AND WATER EROSION

As a result of the Serava River canalization, the groundwater level was lowered by approximately 4 m. Low water levels in the summer and temporary floods occurring after the snowmelt will combine with future climate extremes to lead to increased fluctuations in groundwater levels. The foundation of the aqueduct arches composed primarily of boulders and large stones and exposed to large fluctuations in groundwater level is subject to subsidence due the heavy weight of the structure. As a result, the aqueduct leans to either side, with the risk of collapsing in the future.

In summary, it should be noted that climate-related effects are destabilizing the aqueduct, and with the current extent of static damage, a collapse of certain sections must be expected. As a result, the still contiguous structure would decay into several individual pieces.

SITE 2: STOBI ARCHAEOLOGICAL SITE

DESCRIPTION AND HISTORICAL CONTEXT

The archaeological city of Stobi with remains of the late Hellenistic period represents all main Roman periods and indicates the urban development starting from the early Roman period a few decades of AD to the early Christian period of late 6th century AD. The initial, Late-Hellenic City of Stobi, , covered a small area of just 2 hectares and, typical for cities during this period (2nd century BC), was situated on the highest point of the northern terrace (the acropolis). Graves of the late Hellenic period were excavated on the middle terrace (under the House of Peristeria) which constituted the furthest extension of the city and illustrated that the late Hellenic city did not extend to the lower terrace (Blazevska, 2013).

The urban structure of Stobi can be understood as a well preserved example of impacts of climate change in historical times after the last postglacial, 11,000 years ago. “In the time of Augustus (late 1 century B.C. – early 1 century A.D.) the city rapidly spread and covered the largest area on all three terraces, until the bank of Crna River to the East. The outer early Roman wall was located close to the river, which means that in this period up to the late 3 century A.D. the inhabitants of Stobi did not have any problems with the floods of Crna. This is confirmed by the fact that in the 2 century, on the lower terrace, several buildings of public and residential character were built (Casa Romana, Building with the Arches, Temple of Isis), which were used until the 4 century.” (Ibid.) Alluvial sediments of the Vardar and Crna Rivers are the result of rain fall caused by erosion of soils and is interpreted as a change from moderate to dry climate (Folk, 1973). The location of the previous Outer City Wall and the later built Inner City Wall, together with foundations two to three meters above deposits of 2nd century AD, the buildings of the 4th century were constructed as adaptations to severe flooding events damaging large parts of the early Roman city of Stobi. The abandonment of Stobi about 600 AD could be seen as a result of a number of reasons including climate phenomena. After the Gothic invasion towards the end of the 5th century and the earthquake in 518 AD a last phase of late Roman urbanism developed in Stobi (Mano-Zissi, 1973). As an additional impact factor of the decline of Stobi the climate became again drier around the year 500. The direct effects of repeated floods, which damaged the urban area in addition to reducing vegetation cover in the surroundings of Stobi was an increasing frequency of dust storms. Loss of top soils and dry periods made agriculture more difficult and by the end of the 5th century Stobi become a place of low quality habitation conditions (Folk, 1973).

HISTORIC AND CONTEMPORARY INFLUENCES OF CLIMATE CHANGE

Both climatic changes and natural disasters are discussed in archaeological literature in relation to the changes in settlement structure of the Roman city of Stobi between its founding in the 1st century BC and its abandonment in the 6th century AD. The settlement’s starting point, the Roman phase, is suspected in the upper third of North-eastern slope. On the other hand, the Roman city follows the initial geographical situation in the estuary between Vardar River and the Crna tributary.

The climate change problems and the floods of Crna River started in the Late Antiquity, in the 4th and the 5th century AD In order to protect themselves from the floods in the late 4th century and latest by the mid 5th century, the inhabitants of the city built the internal wall at the middle part of the lower terrace, which is literally positioned on the buildings from the Roman Imperial period (2nd – 4th century AD). The internal wall split the lower terrace into two halves, of which the eastern one (outside the internal wall) was completely abandoned during the 5th and 6th century, while on the internal, western side of the wall, some buildings were reconstructed and adapted and continued to be used even by the end of the 6th century, that is, until the city was abandoned. At this time, the city center, the rich residential buildings and public structures, were mainly concentrated on the middle and the upper terrace.

A major excavation of the early Roman period is the complex of buildings of the Casa Romana, which was discovered under a four meter thick layer of sediment fluvial deposits. Mano-Zissi (1973) uses the frequent flooding of the Erigon as justification for the abandoning of buildings eastward of the inner fortified wall by the end of the 3rd century AD. The part of the inner fortified wall that was westward connected to the outer fortified wall was constructed between the late 4th century and the mid5th century and formed the boundary between lower and middle terrace with a terrain height difference of about 5 m. However, the difference in height here is only partly due to the natural slope and is largely due to anthropogenic embankments. Thus, the building of the 4-6th century were built west of the inner fortified wall on several meters of a powerful regolith that overlaid the earlier construction of the 2nd century (Mano Zissi, 1973). The composition of the rock layer formed in the 4th century consists mainly of rubble and stones of different sizes. Sediment layers that are characteristic of fluvial deposits are, on the other hand, formed only sporadically with low thickness. An extensive terracing of the land to enable the preferred ground-level architectural style representative of public and private buildings cannot qualify as justification, because the type of buildings near the inner fortified wall are composed predominantly of homes that were mostly inhabited by the poorer population. The land embankment as well as the predominantly simple buildings can be considered as a further indication of frequent flooding and a resulting drop in living quality in the lower part of the middle terrace.

Archaeological literature suspected a massive landslide in the 4th century to be the cause of continuous flooding in the 5th century in the estuary area of the Erigon, which led to a temporary recurring flood of the river course. Accordingly, this was particular during the spring, with the onset of snow melting on the over 1000 meters high mountains around the catchment area of the river. Enormous quantities of water also had to be expected after heavy precipitation events primarily in the low-lying areas close to the river of the city of Stobi. Due to the frequent floods and the associated rise in groundwater, the settlement areas of the lower terrace were completely abandoned after the 4th century AD. The documented earthquake in Roman sources in the year 518 AD, with catastrophic destruction in the region resulted, however, only in minimal damages in the area of Stobi (just like the earthquake in 1963). The complete abandonment of the Roman city of Stobi towards the end of the 6th century AD is in close connection to the encroachment of Mongolian tribes.

Historical changes in the water balance in the landscape around the catchment area of the Vardar and Crna Rivers sustainably influenced the structure and history of the Roman city of Stobi in its Late Antique Period (4^{th} – 6^{th} century AD). Ground water rise during this phase caused an increasing annual precipitation and/or heavy downpour events, and were likely the reason of significant landslides. Hence, it is probable that the developmental history of the Roman city of Stobi is connected to these climatic changes in the regional water balance.

Regular floods in areas around the banks of the Crna River, particularly the flood disaster of 1962, were the reasons behind the construction of a 16 km dam above the catchment area of the Crna. In spite of the flood regulatory measures, the water level of the flood of 2010 was just 20cm below the contemporary canteen buildings and restoration workshops on the lower terrace. The ground water likely communicating with Crna River penetrated into the lower levels of the Building with Arches, which is connected to the inner side of the internal wall (cf. Blazevska, 2013). It is relatively far from the banks of Crna River, at about 60 meters distance (Ibid.) Flood risks occur predominantly in spring, during which with the onset of snow thawing more water runs into the Vardar and Crna Rivers. Extraordinary persistent precipitation events in 2010 are documented in the limited number of field working days of archaeologists (only 18 field working days compared to the annual average of 26 field working days with equal periods of excavation campaigns). Excavations around the lower terrace area in the last decades of the 20th century had to be abandoned due to high ground water levels (e.g. the excavation campaign of the University of Texas in cooperation with the Belgrade and Stobi museum of Casa Romana between 1971 and 1973), which clearly shows that the ground water rise since the early Roman phase has persisted until present time.

State of Conservation and Damage Phenomena

The current damage patterns are results of an evaluation during a two days field survey on the 24th and 25th August 2013 in the company of onsite archaeologists specialized in climate relevant aspects. Extensive examinations were not previewed with the framework of the evaluation, although they are necessary for the monitoring and success rating of possible adaptation measures. Conspicuous is the partially intense weathering of rocks and the ongoing washout of the bonding materials. Both sides of the wall exposed during the excavation of the middle and upper terrace are unstable in many parts and are characterized by progressive rock decay. The soft sandstone rock shows in a first macroscopic decay phase a plate-like cracking (see photo 11) probably the result of frost damage.

Photo 11: Sandstone Decay as result of Frost Damage

Photo 12: Decay phenomena on different stone materials

The particular sensitivity of gray sandstone against frost damage is shown by an ancient staircase in the middle terrace through the use of the different rock materials on photo 12. Here it is expected that the complete ancient appearance of the stairs will be lost in just a few decades.

Further rock decay is characterized by the leaching of fine-grained particles whereby, the antique worked stone successively decays and loses its structural function in the rock mass. As a result, large areas of the rock mass will be removed (see photo 13) and/or both sides of the exposed walls will tip to the side (see photo 14).

PHOTO 13: REMOVAL OF STONES AFTER BY THE LEACHING OF FINE-GRAINED PARTICLES

PHOTO 14: TIPPING OVER AND COLLAPSE OF EXPOSED WALLS FOLLOWING MORTAR AND PARTICLE EROSION

PHOTO 15: COLLAPSED WALLS CHANGING THE CHARACTER OF THE ARCHAEOLOGICAL SITE

PHOTO 16: CLAY VESSELS EXPOSED TO POTENTIAL FROST DAMAGE FOLLOWING THEIR EXCAVATION

Progressive loss of the structure, especially both sides of the exposed wall, in addition to the decay of rocks represented above will be caused primarily by the washing-out of the bonding materials and mortars. This concerns both the unprotected walls and the lateral regions. As a result walls may break apart with loss of the original character of the antique site (see photo 15). Excavated and on-site remaining clay vessels are, despite their general strong resistance to external influences, equally exposed to potential damages by freeze/thaw events.

Anticipated Climate Change Impacts

The representation of the expected impacts of climate change, illustrated in table 4, on the archaeological site of Stobi is based on collected damage patterns and the climate change scenario for Macedonia (Climate Change Scenarios for Macedonia, 2012). The significance of this test is determined by a correlation of relevant climate effects in conjunction with the site-specific sensitivity. The significance test determines the vulnerability of the city Stobi on the basis of field surveys and conducted interviews with experts and forms a rapid vulnerability assessment, an initial assessment of the likely impacts of climate change in conjunction with the priority adaptation measures to be initiated.

Highly significant (++) climate change impacts due to heavy precipitation events are expected (see table 4, column 3), these potential impacts will be evaluated for the preservation of exposed walls and thus the integrity of the archaeological site.

Climate change risks / Potential receptors of impacts	Long-term temp. increase	Increase in the number of freeze/thaw cycles (temp. fluctuations around 0°C)	Heavy rain events	Increased flood events	Changes in humidity	Increase in wind gusts and/or sand storms	Increase in thunder-storms and/or tornados	Fluctuations in water-table levels	Increased surface run-off	Accelerated pollution based on climate factors	Changes in flora / fauna	Eco-system switches
A: Archaeological site:												
Static and integrity of archaeological remains	0	++	++	++	0	+	–	++ x1	+	0	0	–
Static and integrity of reconstructions	0	+	+	++	0	+	–	0	+	0	0	–
B: Stone / brick deterioration:												
Stone / brick surface	0	++	+	0	0	0	–	++	0	?	0	–
Stone / brick integrity	0	++	0	0	0	0	–	++	0	?	0	–
Mortar	0	++	++	++	0	0	–	++	+	?	?	–
Surface colour	–	–	–	–	–	–	–	-	–	–	–	–
Stone / rock carvings	0	+	+	0	0	0	–	-	0	?	0	–
C: Decorative elements:												
Mosaics	0	++	0	0	0	+	–	++	+	?	0	–
Stone and wall paintings / frescos	–	–	–	–	–	–	–	-	–	–	–	–
Ceramics	0	++	0	0	0	0	–	+	+	?	0	–
D: Surrounding landscape:												
Slopes	0	0	+	+	0	0	–	+	+	0	0	–
Ravines and gullies	0	0	+	+	0	0	–	+	+	0	0	–
Soils	+	0	+	+	+	+	–	+	+	0	0	–
Coastal zones	–	–	–	–	–	–	–		–	–	–	–

Table 4: Climate Change Impacts on Stobi Archaeological Site

Significance of potential impacts:

0 - impact not expected; – - insignificant or non-applicable for the particular site; + - significant; ++ - highly significant; ? - further investigations required; x1: only relevant for lower terrace, further investigations are required. Not relevant for the middle and upper terraces.

A similar negative effect is expected through increased wash-out of ancient bonding materials due to prolonged heavy rainfall. The causes are the increase of Mediterranean depressions, which has led to prolonged rainfall events and specific VC weather conditions in the Balkans and in the middle and lower Danube respectively. Increased flooding events of Crna River are to be expected for Stobi if snow falls during the winter months.

Climate change related increase of precipitation events will lead to erosion in transition areas of excavated sites and steep escarpments of the surrounding terrain. Photo 15 shows terrain slope slides as a result of erosion, following which, not only the archaeological structures of the upper layers collapse or move towards deeper levels of excavations, but also the structural stability of the ancient walls has become more vulnerable. Furthermore, temporary flooding of the ground surfaces of antique structures in the excavation areas is lower than in the surrounding buildings. As a result, soil surfaces are muddied by eroded sediment, which with increased fine clay portions and with a lower proportion of clay in subsequent dry periods can lead to cracking (see photo 11). Furthermore, self-binding clay is largely irreversible and during frequent and repeated cleaning, damage to the antique floor coverings is probable.

As a consequence of climate change, the number of days with temperature variations around the icing point is high, based on current climate prognosis. During winter months, weather stations for the archaeological sites in the neighbouring Negotino, record for an average of 40 to 60 days in November to March, temperature minima and maxima which vary around the freezing point within 24 hours. Therefore, the effects of thaw/frost days on the various components of the excavations in Stobi, are rated as highly significant (++) (cf. Table 3).

Freeze/thaw weather cycles accelerate stone deterioration of gray tertiary sandstone, the main construction material for walls of the ancient city Stobi. Despite of the fact that climate change scenarios foresee a reduction of the frost period in winter, the total number of days with freeze/thaw events will not be significantly reduced according the climate scenarios for Macedonia. The total number of freeze/thaw weather events is recorded between 40 and 60 days during the winter season (weather station Negotina) between 1993 and 2010. For the period from 2025 to 2050 to number of freeze/thaw days is predicted only slightly lower with a range between 41 and 58 days. Therefore long-term frost damages are critical to the built structure and ceramics of the site of Stobi and will likely remain on the same level.

The temperature rise prediction for the summer months until 2100 (Climate Change Scenarios for Macedonia, 2012) with expected maximum temperatures in July and August are less relevant for archaeological remains. The predicted temperature increase of Stobi up to 2050 (weather station Negotina) for the months of July and August, is an increase in the maximum daily temperatures and a decrease in precipitation. Considering the discussion on the possible causes for the abandonment of the Roman city Stobi in the late 6th century, Folk (1973) assumes the arid and hot climate period around 600 AD to have been the main reason. A decline of the vegetation cover exposed the city of Stobi to dust and sand storms reducing the quality of life. An ongoing deposition of wind transported material buried the upper parts of the city of Stobi by approximately one meter. Folk (1973) classified the origin of these layers as wind transported sediments and eliminates flooding of 7 to 16 meters above the Crna River as a reason for deposits. Folk (1973) estimates a wind transported deposition of up to three meters thickness over the last 1000 years in Stobi.

Photo 17: Testimony of recent major flood events at Crna River

Photo 18: Flood and Rain Erosion of steep archaeological structures on lower terrace

Photo 19: Separation of Surface layers as result of Frost and Vegetation

Increasing aridity is associated with an increase in extreme events such as heavy rainfall, wind driven rain and sand storms. Although the cover layer on the ancient remains of the city Stobi is mainly composed of wind-transported loess, sand storms with higher winds transport sand grain of greater fraction sizes. The sharp sand will damage the colored mosaics of the floors in ancient buildings, which currently still have an excellent state of preservation. Therefore, the effects of sand storms on the integrity of the excavations of Stobi and the exposed mosaics are assessed as significant (see Table 3, column 6) for the period 2100.

Flooding in the area of the lower terraces will affect the sub-surface archaeological remains by ground water changes. Fluctuating water table levels could damage the stratigraphic integrity close to the river bank of the Crna River. Ground water changes cause ongoing wash out of clay mortar and destabilize foundations and wall constructions of future excavation areas. Furthermore fresco paintings will be damaged by changes of anoxic and oxygen conditions.

As a result of the rapid vulnerability assessment on whether the archaeological site Stobi is exposed to climate change impacts, it can be stated that severe damage to the ancient walls could be expected before 2100. In particular the high number of days with a temperature range above and below 0°C (freeze-thaw weather), increased heavy rainfall and unpredictable flood events will affect the archaeological remains. These physical impacts of climate change affect both the structural stability of the archaeological remains as well as the building materials. The gray tertiary sandstone, as the most important material of the Roman buildings, is most vulnerable to climate caused damage processes including surface recession and stone deterioration.

SITE 3: ARCHAEOLOGICAL SITE PLAOSNIK IN OHRID

DESCRIPTION AND HISTORICAL CONTEXT

The archaeological site of Plaosnik is a site that comprises remains of the prehistoric period (Late Bronze Age), the Antique and Late Antique Period, and contains early Christian and medieval evidence (cf. Kuzman et al., 2009). It has been a religious centre since its early history and its key features of significance remain the monastery of St. Clement and the basilica attributed to St, Panteleimon. The site and in particular St. Clement monastery is attributed to St. Clement of Ohrid, who arrived in Ohrid in 886 but found an early Roman complex, which already integrated a 5th century basilica with stunning mosaics. St. Clement created a new spiritual centre at Plaosnik and became the first Slavic bishop who continues to be venerated as a saint and enlightener (cf. Board for the Instauration of St. Clements University, 2011).

Archaeologists assume that the site once hosted what could have been the first institution teaching the use of the Glagolithis alphabet, known as Cyrillic script, which allowed for first translations of the Holy Bible into Slavonic language. The monastery of St. Clemet was built on the remains of an earlier Roman basilica, still visible today, and the founder himself remains buried in the crypt which justifies the religious significance of the site. Between the 15th and 17th century the monastery was heavily damaged as a result of armed conflicts and changes in reign. Under Ottoman rule the monastery was turned into a mosque, the Imaret mosque or also named as Sultan Muhammad Mosque. From its period of Islamic relevance further tombs, for example the tomb of Sinan Chelebi, the founder of a charitable institution, remain in the archaeological precinct.

The archaeological features of the site extend across the entire plateau; however the presently most visible features are the recent reconstruction of St. Clements and St. Panteleimon Church in the centre, which was completed only in 2002. It functions again as an active house of worship and hosts reliquaries of St. Clement of Ohrid. It has over the years become the central location for the celebration of liturgies on important holidays, such as Easter or Christmas, when larger crowds gather on site to partake in the events.

A second newly emerging but increasingly visible feature is the new development, locally termed instauration, of a massive complex on site which will host a new monastic complex, St. Clements University including a library, conference centre and student accommodation as well as representative facilities for international universities branching in Ohrid. The ambitious plan foresees structures which cover up to one third of the archaeological sites, in several locations built into or above the early Christian excavated remains.

In the context of this report, the development project of St. Clement's university and monastery shall also be considered in terms of its evident and potential role in the acceleration of climate change phenomena, in particular rain water drainage mechanisms and soil water levels. Regardless of the climate change impact considered here, the project is likely to considerably change the physical and visual environment of the site. The study presented here can only roughly estimate the future impacts of constructions currently underway. The authors recommend undertaking further detailed studies and analyses once the constructions have progressed to a stage which would allow for judgment of the water flow off processes underneath and between the new concrete structures.

PHOTO 20: ST. CLEMENT CHURCH AS RECONSTRUCTED IN 2002

PHOTO 21: ON SITE PANEL ILLUSTRATIONS OF THE ST. CLEMENT UNIVERSITY DEVELOPMENT IN RELATION TO THE EXISTING ST. CLEMENTS AND ST. PANTELEIMON CHURCH IN THE CENTRE

State of Conservation and Damage Phenomena

The site of Plaosnik is to the most extent well protected although several historic activities and conservation measures would likely be considered too extensive by international standards. It seems that after completion of archaeological excavations the archaeological remains are often consolidated by the addition of new top layers of stone which cover the historic ones and protect these from direct rain and wind erosion. In many places these additions are not only surface layers of a few centimeters but large wall sections built above the historic walls as reconstructions aimed at illustrating the former position and shape of the archaeological structures. More lately, mortar in slightly differing color has been applied to indicate the transition between historic and added substance.

Photo 22: Additional upper layers introduced for the preservation of excavated Historic walls

The key damage phenomenon on site – apart from the new construction – is uncontrolled vegetation growth. Harmful vegetation cover occurs in almost all sections of the archaeological property and affects not only the clay and stone floors, which have already been largely replaced to protect the original stones, but also the wall segments underneath the new additions. Merely below the shelters which were introduced for the protection of mosaics in the Roman basilica and a second liturgical structure further south, vegetation growth has been prevented by regular maintenance. In all other parts of the site maintenance routines for removal of destructive vegetation are urgently necessary to prevent further severe damages to the archaeological substance.

Photo 22: Vegetation growth in historic walls underneath later additions

Photo 23: Reconstructed Brick floor illustrates Damage by frost and vegetation

PHOTO 24: WATER RUNOFF STREAMS IN ARCHAEOLOGICAL EXCAVATIONS

PHOTO 25: IMPACT OF NEW CONSTRUCTION ON ARCHAEOLOGICAL STRUCTURES

Additional damage phenomena occur as a result of thaw transition and frost as well as rain water runoff and wind erosion. Although these phenomena are widely controlled, partly by shelter structures, partly by temporary drainage systems installed on site, yet, their occurrence cannot be fully prevented. Especially the rain water runoff is of concern for the anticipation of future climate change phenomena, as the newly developed structures on site seem to block previous drainage directions and run off patterns.

It seems to the authors that the project of St. Clements University Campus and auxiliary buildings and the new monastic complex of St.Clements will also significantly change the authenticity and integrity of this segment of the UNESCO world heritage site. Archaeological remains had to be partly removed and will be partly covered by the new overarching concrete structures of several storeys high. The currently prominent church of St. Clement and St. Panteleimon will be surrounded by two massive buildings of three storeys on each site, with its cross remaining just a little higher than the university conference centre.

Unfortunately given the limited time frame of the site visit and despite the very generous and effective assistance of the representatives of the National Institution for Protection of Monuments of Culture and Ohrid Museum, who made a number of project drawings and a description available to the authors, it was difficult to judge the impact of the development's infrastructure needs – in particular in of water and drainage pipes as well as foundations – on the archaeological remains in the ground of Plaosnik. However, during their site visit, the authors gained the impression that the concrete foundations reached into the ground at a depth of at least two meters and that a number of previously excavated archaeological structures must have been removed to allow for the construction. At the same time, the design is an obvious attempt to retain much of the archaeological remains in a museum hall on the ground floor. The images on the following page illustrate the ongoing constructions.

Photo 26: Construction of the Monastic complex of St. Clements on the eastern part of Plaosnik

Photo 27: Integration of Archaeological structures in the new Monastic complex of St. Clements on the eastern part of Plaosnik

Photo 28: Construction of the St. Clements University Complex with integrated museum on the western part of Plaosnik

Photo 29: Integration of archaeological remains in St. Clements University Complex

Anticipated Climate Change Impacts

Climate change risks / Potential receptors of impacts	Long-term temp. increase	Increase in the number of freeze/thaw cycles (temp. fluctuations around 0°C)	Heavy rain events	Increased flood events	Changes in humidity	Increase in wind gusts and/or sand storms	Increase in thunder-storms and/or tornados	Fluctuations in water-table levels	Increased surface run-off	Accelerated pollution based on climate factors	Changes in flora / fauna	Eco-system switches
A: Archaeological site:												
Static and integrity of archaeological remains	0	++	++	-	-	+	-	?	++	0	0	0
Static and integrity of reconstructions	0	+	+	-	-	-	-	0	+	0	0	0
B: Stone / brick deterioration												
Stone / brick surface	0	++	-	-	-	+	-	0	0	0	0	0
Stone / brick integrity	-	+	+	-	-	-	-	0	++	0	0	0
Mortar	-	+	+	-	-	+	-	0	0	0	0	0
Surface colour	-	-	-	-	-	-	-	0	0	0	0	0
Stone / rock carvings	-	-	-	-	-	+	-	0	0	0	0	0
C: Decorative elements:												
Mosaics	-	+	+	-	-	+	-	?	-	0	0	0
Stone and wall paintings / frescos	-	-	-	-	+	-	-	-	-	0	0	0
Ceramics	-	+	-	-	-	-	-	-	-	0	0	0
D: Surrounding landscape:												
Slopes	-	-	++	-	0	0	-	?	0	0	+	0
Ravines and gullies	-	-	++	-	0	0	-	?	++	0	+	0
Soils	-	-	+	-	0	0	-	?	+	0	0	0
Coastal zones	-	-	-	-	-	-	-	-	-	-	-	-

Table 5: Anticipated Climate Change impacts at Plaosnik Archaeological Site

Significance of potential impacts:

0 - impact not expected; – - insignificant or non-applicable for the particular site; + - significant; ++ - highly significant; ? - further investigations required.

Under normal circumstances the archaeological site of Plaosnik would not be significantly exposed to potential threats caused by climate change. Although wind and water erosion phenomena are likely to increase with a larger number of extreme weather events predicted for the region, the recently added preservation layers on most archaeological walls reduce the wind and water erosion impacts significantly. Water erosion merely remains a significant risk to the soil of the archaeological elements as rain water runoff streams, especially following heavy rain events, could wash out soil segments underneath the archaeological stratigraphy and wall foundations. Such wash out processes increase with runoff speed and water volume but may at times cause the collapse of walls or unexcavated archaeological remains following the creating of cavities in the ground.

The mosaics and other valuable archaeological features have been protected by shelters and temporary roofing structures which provide complete rain protection and also largely prevent wind erosion processes. As for the two sites previously analyzed, also for Plaosnik the number of freeze/thaw days measured at the weather station in Ohrid is relatively high compared to other regions and frost damages comparable to those described for Stobi can be expected. Yet, due to the large scale of mortar repair and surface coverage of the archaeological remains, this phenomenon may cause less significant damage than anticipated for the two previous sites.

Among the climate change induced or accelerated damage phenomena, water runoff during heavy rain events remains the key challenge to the archaeological structures at Plaosnik. The specific challenge here is that while current runoff stream locations are clearly visible and damages caused by past runoff streams are limited, the situation of rain water drainage is expected to change significantly in the near future. In the current plans of the developments for St. Clements University complex, rain water drainage does not seem to have been given adequate consideration. No channels or drainage routes seem to have been provided below the architectural structures and the foundations show a tendency to block or intersect past underground water and drainage streams.

Following the completion of the architectural structures rain water during heavy rain will likely create new streams through areas that remain open and undisturbed by built constructions and may be channeled through locations of higher archaeological value than those presently affected. It is recommended that the rain water runoff during heavy rain events is carefully studied and that any occurring destabilization for the archaeological site, in particular in light of an expected increase of heavy rain events, is reduced through creation of appropriate drainage solutions, including through and around the newly built architectural complexes.

The authors further recommend investigating whether the north-south channel created between the two new high building complexes on the top of the Plaosnik plateau with full exposure to Ohrid lake, will create particularly strong wind currents and drifts and may be expected in such artificial channels. If wind speed and strength increase disproportionally in comparison to other locations in and around the archaeological site, further protective measures against wind erosion would need to be taken. Such measures can either be the regular maintenance of added top layers which act as sacrificial layers for wind erosion to preserve the historic substance, the backfilling of parts of the previous excavations or the deliberate creation of wind breakers in form of glass walls or other features to protect particularly valuable sections of the archaeological site.

PHOTO 31: ARCHAEOLOGICAL STRUCTURES BETWEEN THE TWO DEVELOPMENTS WITH POTENTIAL TO BE AFFECTED BY WIND AND WATER EROSION

DEVELOPMENT OF A NATIONAL ACTION PLAN

Climate Change Risk Assessment and Adaption for Cultural Heritage in Macedonia

BACKGROUND

The following statements are the result of two short term missions to Macedonia from 30th of June to 2nd of July and from 22nd to 28th of August 2013. While in the 1st mission three cultural heritage sites were selected by national experts of Macedonia, the 2nd mission was dedicated to visiting and analyzing the three selected sites Stobi, Orhid and the aqueduct of Skopje. The sites were investigated by a field survey accompanied by national experts. In addition available documents and climate data for the three sites were provided by GIZ in cooperation with its international and national project partners. The project on Climate Change Adaptation was initiated by UNDP in cooperation with Ministry of Culture and The Ministry of Environment and Physical Planning of the Republic of Macedonia.

OBJECTIVES AND COMPONENTS

The development of a National Action Plan on risk assessment and adaptation of climate change related phenomena on cultural heritage is based on preliminary findings resulting from these two short term missions and should be jointly discussed with the relevant authorities in Macedonia. The overall goals of a National Action Plan could be identified by the recommendation of the Council of Europe for research work on impacts of climate change on cultural heritage (Sabbioni et al., 2008). A full consideration of all relevant aspects of global climate change impacts on cultural heritage in Macedonia requires in depth investigations and step by step implementation, with focus on the following aspects:

(1) Improving the understanding of adverse impacts of climate change on cultural heritage;

(2) Assessing the vulnerability of built and archaeological heritage as well as historical cultural landscapes in Macedonia by rapid impact assessment;

(3) Establishing a monitoring program for damages on built and archaeological heritage as well as historical cultural landscapes for short term extreme weather events and long term climate change;

(4) Identification of tools and adaptation measures for the main categories of cultural heritage in Macedonia;

(5) Limiting damages through implementation of long term management strategies related to the adaptation of climate change impacts on heritage in Macedonia.

The proposed goals of the National Action Plan were requested to be considered in a gradual approach starting with case studies of the different categories of cultural heritage. Based on the results of the workshop conducted on 2nd July 2013 and the field surveys of three selected sites Stobi, Orhid and the aqueduct of Skopje first findings for the category of archaeological sites are available and could be used for the identification of main action fields. Therefore impacts of climate change on cultural heritage, the vulnerability of built heritage as well as adaptation measures should be investigated, documented and steadily improved.

The authors suggest approaching the implementation of a national action plan for climate change and cultural heritage through the design of specific short and medium term work packages. Hence, five sample work packages are suggested below, which we hope can provide inspiration as to how such work packages can be designed and could contribute to a formulation of climate change adaptation goals in relation to cultural heritage.

By implementing the following five work packages as a first phase towards the formulation of specific climate change strategies for cultural heritage, a comprehensive and integrated assessment approach will be available for Macedonia. Such approach ensures that further damages on cultural heritage caused by global climate change will be limited as far as possible. The descriptions of these five work packages have to be once more understood as suggestions intended to inspire the formulation of activities for the involved Macedonian ministries and governmental institutions responsible for research and preservation of cultural heritage as well as external stakeholders. The final decision about the proposed work packages as relevant action fields for a National Action Plan should ideally be taken in participatory workshops, following the provision of ample background information to all partners involved. During the development of a National Action Plan on Climate Change Risk Assessment and Adaption for Cultural Heritage in the Republic of Macedonia the general public should be involved in order to enhance the public awareness and to integrate wider social and economic benefits.

However, climate change will be a key pressure with increasing severe damages, in particular on built heritage, even accruing nowadays and with a risk potential difficult to predict. Thus any adaptation strategy has to be seen in the context of the uncertainty of extreme climate events which have an unpredictable damage potential and the comparable uncertainty in material and soil composition of cultural heritage sites. While these uncertainties allow for general approached at an academic level they require to always consider adaptation solutions within a specific local context.

Draft Work Packages

WP 1: Understanding Impacts

Objective

Improving the understanding of adverse impacts of climate change on cultural heritage

Rationale

Cultural heritage is exposed to global climate change. Furthermore impact assessment of climate change is often investigated and interpreted as a relation between observed climate parameters and the impacts on natural and human resources neglecting further impact factors. The recent history of the 20th century shows further development pressures effecting heritage sites on a significant level. While air pollution could be seen, at least in countries of the European Union, as an environmental problem which was successfully tackled by European as well as national programs on clean air and air protection, there are further factors leading to an ongoing loss of cultural heritage. Heritage sites in or close to urban areas are endangered by the process of rapid urbanization particular in agglomeration zones. Housing and infrastructure projects within the surrounding landscape of historic built heritage could affect the aesthetic value of the sites and is often a reason for the loss of the historical utilization.

Canalization of rivers as well as land use change has potential effects on the magnitude of flood events. Flood events are identified as a key aspect of climate change, impacts on historic built heritage should be investigated in their specific relation of general protection and management approaches and climate change phenomena.

Proposed Activities

The aqueduct of Skopje is proposed for a case study project investigating impacts of climate change in context with development projects in the surrounding environment. As long as the aqueduct was used as a water supply system the whole structure was preserved and maintained. After 1914 the aqueduct lost its original function and became gradually devastated. The still existing remains of 53 aqueduct arches are isolated and are surrounded by several buildings. The rapid urbanization process of Skopje could become a key aspect of the proposed case study project. The second research focus should be in depth investigations on flooding events affecting the foundations of the overall structure of the aqueduct. The Serava River canalization has probably destabilized the bases of piers and brick arches as a result of higher fluctuations of ground water levels as well as flood events. In this context the proposed rehabilitation project of the Serava River should be investigated with particular focus on models predicting ground water fluctuations and flooding.

Deliverables and Results

The outcomes of a research project on the aqueduct of Skopje will provide important findings for both “Impacts of climate change and urbanization on cultural heritage” and “Impacts of climate change and water projects on cultural heritage”.

Target Group and Participants
Cultural, environmental and water authorities. The municipality of the city of Skopje. Research institutions and universities.
Time Schedule
A research project proposal should be carried out in 2014
Estimated Costs
45,000 Euro
Potential funding sources
World Monument Fund (WMF) – This funding resource would require a project delay due to the requirement of an initial World Monument Watch List nomination of the Skopje Aqueduct in 2014 (expense around 5,000 Euros) to apply for funding in 2015. The funding provided requires a partial contribution of the local authorities and/or other donors. If working with German partners the Cultural Preservation Programme of the Federal Foreign Office.

WP 2: Assessing Vulnerability
Objective
Assessing the vulnerability of built and archaeological heritage as well as historical cultural landscapes in Macedonia by rapid impact assessment;
Rationale
Environmental climate policy has focused climate change research on prediction models mainly using the climate parameters, temperature and precipitation. Studies of potential impacts on ecosystems, integrating agricultural as well as forest systems, have mainly investigated ecosystem resources (soil, water, flora and fauna) and ecosystem services (e.g. food production, ground water recharge). Impacts of expected climate change on cultural heritage and the vulnerability of built heritage were more or less neglected in relevant climate change reports. Detailed assessment of impacts on cultural heritage caused by climate change is necessary to consider the specific vulnerability of heritage sites. The impact matrix (compare chapter Methodology of this report) offers a tool for a rapid impact assessment and the identification of key vulnerabilities for all relevant sites in Macedonia.
Proposed Activities
The impact matrix for a rapid impact assessment of climate change should be applied in a first step on archaeological sites. Gained experiences by testing characteristic impacts of short term and long term climate parameters and parameters characterizing the built heritage and the surrounding of the site should be used for improving the impact matrix. In a second step the impact matrix should be extended for other relevant categories of cultural heritage in Macedonia.
Deliverables and Results
Through conducting a rapid impact assessment on cultural heritage, the Ministry of Culture of the Republic of Macedonia and cultural authorities will gain comprehensive information about expected future impacts of climate change on all relevant heritage sites and historical cultural landscapes. An improved understanding of the vulnerability of built heritage and natural resources of cultural significance affected by future climate change is a precondition for appropriate adaptation measures.
Target Group and Participants
Ministry of Culture of the Republic of Macedonia and National Heritage Protection Office
Time Schedule
A rapid impact assessment of future climate change and the corresponding vulnerability of cultural heritage in Macedonia should be carried out until the end of 2014.
Estimated Costs
140,000 Euro
Potential funding sources

The proposed study could be conducted as an international research cooperation of a Macedonian and a foreign university and be funded by a third party or governmental research grant. Multiple grant opportunities exist for international research cooperation of universities and should ideally be applied for by the foreign partner university World Bank Disaster Risk Management (DRM) Group: Development for Prevention and Mitigation Program

P 3: MONITORING DAMAGES
Objective
Establishing a monitoring program for damages on built and archaeological heritage as well as historical cultural landscapes for short term extreme weather events and long term climate change
Rationale
Researches on cultural heritage, in particular built heritage like churches, fortifications and monuments as well as archaeological sites in Macedonia have gathered a large amount of information on the material assets, the structure of built heritage and linked interpretation on human history and changes of the environmental conditions. This includes detailed reports documenting damages on heritage sites with particular focus on built heritage and archaeological sites. Climatic parameters are intensely discussed in the context of reason for the abandonment of historic cities. The International Council on Monuments and Sites (ICOMOS) has provided important documents on stone deterioration. On the other hand research on climate change illustrates that recent warming is shown in climate parameters. With regard to global climate change the understanding of impacts on terrestrial and hydrological systems and the vulnerability to climate change was largely improved in the last decade. Documentation and monitoring on climate parameters and observed impacts are integrated parts of environmental reports of all European nations. Despite of an overlap in monitoring of climate parameters in environmental and cultural policy, responsibilities and reporting are carried out separately.
Proposed Activities
Environmental monitoring about climate data and change should be combined with site specific descriptions of damages of built heritage and archaeological sites. The coordination of a joint network should agree on the framework for monitoring climate parameters and climate events relevant to cultural heritage. Based on available reports, a review of recent damages on built heritage for the case of several significant individual monuments and archaeological sites should be correlated with climate parameters and climate events.
Deliverables and Results
Damage maps for Macedonia for the documentation and assessing the risks of climate change on cultural heritage
Target Group and Participants
Ministry of Culture of the Republic of Macedonia and cultural authorities in close cooperation with Ministry of Environment and Physical Planning and relevant environmental authorities
Time Schedule
The monitoring program should be started in 2014 and be developed throughout 2015.
Estimated Costs
85,000 Euro
Potential funding sources
MDG F Fund: Program Environment and Climate Change

WP 4: Identification of Adaptation Measures
Objective
Identification of tools and adaptation measures for the main categories of cultural heritage in Macedonia
Rationale
In general impacts by climate change on cultural heritage and responding adaptation measures have to face different uncertainties, such as: • Catastrophic disasters like coastal or river side flooding, not predictable in frequency and/or magnitude, limitations of modeling; • Synergistic effects of long term climate change risks and impacts like change in groundwater level, heavy rain events, storm surges, thermal stress in hot and dry periods, freeze-thaw damages, periods with high humidity; • Non-climate impacts like land use change, urbanization, land degradation, socio-economic factors like poverty and demographic development; • Impacts from adaptation measures like canalization and flood control of river systems. Tools on adaptation measures limiting impacts on cultural heritage by climate change over the next one hundred years should be specific to actual and expected damage processes of the built heritage like surface recession, salt crystallization of natural stones and brick metal/glass corrosion, wood destroying pests and to the surrounding landscape or the historical landscape by its own. Non-climate drivers often enhance impacts of climate change. In this context the utilization of heritage sites plays an important role for preventing damages on heritage properties.
Proposed Activities
A national network on a long term adaptation strategy for Macedonia should be established. Main tasks of the network are: (1) to stipulate research about the most important impacts by climate change and investigations about the vulnerability of cultural heritage; (2) documentation and appraisal of adaptation measures, best practice as well as failed methods; (3) Building capacity by carrying out training for heritage site managers and related professions on adaptation measures for cultural heritage; (4) Introducing the subject of impacts or climate change on cultural heritage in university courses, (5) Providing policy by a overarching national strategy with setting priorities on the most vulnerable heritage properties and required adaptation activities. Research at concrete case studies of built heritage, archaeological sites and cultural landscapes should be carried for testing of the suggested adaptation measures.
Deliverables and Results
Overarching national strategy for long adaptation of cultural heritage to climate change.
Target Group and Participants
Policy, researchers, site managers , conservators, architects and the public
Time Schedule
The development of a national strategy should be an interactive and participatory process starting in 2014 and anticipating its completion in 2016.

Estimated Costs
275,000 Euro
Potential funding sources
World Bank Strategic Climate Fund (SCF), Pilot Programme for Climate Resilience (PPCR) MDG F Fund: Program Environment and Climate Change Potential additional support via link to the Climate For Culture network, which already comprises 27 European public and private institutions and is sponsored by the European Union, as part of the CLIMATE program.

WP 5: Development of Long Term Management Strategies
Objective
Limiting damages through implementation of a long term management strategies related to the adaptation of climate change impacts on heritage in Macedonia.
Rationale
The research results which were achieved in the initial studies of the rapid vulnerability assessment and the prior working packages either remain on a general abstract level or generate very site-specific result which are difficult to be transferred. Often the cultural heritage professional start anew with the basic analysis and climate change impact assessment for each single site, where results and outcomes depend strongly on the qualification and sensitivity of the analyzing team. The rational of this work plan is to create a tool which allows to use a general guideline for climate change impact assessment to arrive at concrete recommendations for the management of a specific site.
Proposed Activities
The working package will develop a site specific sample management strategy for climate change adaptation measures which allows each site manager to choose from an array of relevant adaptation strategies and management procedures when compiling a management plan for an individual site.
Deliverables and Results
The working package will development guidelines for the development of climate change adaptation strategies for heritage site management planning. These should be able to act as a self guiding tool and enable every site manager to design meaningful climate change adaptation strategies for a specific site
Target Group and Participants
Ministry of Culture, National Heritage Protection Office, Cultural Heritage Site Managers
Time Schedule
The development of these guidelines could be undertaken in any two-year time frame, for example in 2015/16.
Estimated Costs
110,000 Euro
Potential funding sources
The proposed study could be conducted as an international research cooperation of a Macedonian and a foreign university and be funded by a third party or governmental research grant. Multiple grant opportunities exist for international research cooperation of universities and should ideally be applied for by the foreign partner university.

Conclusions and Recommendations

As a result of this initial rapid vulnerability assessment of climate change impacts on cultural heritage in Macedonia, it can be concluded that for all three case study sites analyzed, significant damage phenomena either induced or accelerated by climate change are to be expected. So far, no systematic studies on climate change and cultural heritage exist for Macedonia and the first findings indicate that further research is likely to generate relevant results and should be undertaken.

Yet, the initial analyses have also illustrated that climate change phenomena impacting on cultural heritage hardly ever exist in isolation. Often the climate change impacts have been facilitated by earlier anthropogenic changes, such as land-use changes, urbanization or development projects. These have created conditions which endanger cultural heritage for other reason but also render it far more vulnerable to effects of global climate change.

The case studies selected by our colleagues from the Ministry of Culture and the National Heritage Protection Office in the Republic of Macedonia focused on three archaeological sites. While this choice initially seemed one-sided, it has become obvious during the study that our colleagues rather conscientiously selected those cultural heritage sites which they considered strongest affected by climate change phenomena. In the process of analysis the authors were able to confirm these assumptions as all three archaeological sites illustrated significant – yet rather different – vulnerabilities to climate change as well as already existing damage phenomena. It can therefore be concluded that archaeological sites are not only one of the most important categories of heritage in Macedonia but also perhaps the most affected by climate change in the decades to come.

The surveys of the three sites could gather enough information to provide an initial and preliminary assessment of vulnerabilities to climate change. On the basis of the findings, the authors suggested work packages, which would allow for future verification of the initial data sets, participation of local authorities in the development of further assessment and management strategies as well as the design of adaptation measures. Based on the initial six day surveys it was not yet possible to suggest a full strategic plan for adaptation measures on each site, however, specific recommendations have been included in the respective earlier sections. Key challenges in the development of adaptation measures were three aspects of uncertainty, which could not be clarified during this brief mission. These are the (1) lack of research and knowledge on soil conditions, including soil stratigraphies and ground water reservoirs of the sites, (2) the difficulty to judge future plans, which were not provided in a level of detail that would have allowed for design of specific adaptation – in particular in relation to the development in Plaosnik but also the denaturalization of the Serava River, and (3) the fact that adaptation needs to be addressed to specific impact factors. These impact factors for cultural heritage are in majority extreme weather events, which remain very difficult to predict, both in terms of occurrence and impact.

Among the key achievements of this study is the formulation of recommendations and objectives for future next steps towards the development of full strategies for adaptation of climate change impacts on cultural heritage. The key objective that should be included in national strategies for climate change is to increase the general understanding of the severity of climate change impacts on cultural heritage and the need to include cultural heritage as a priority field of action in the National Communication of the Republic of Macedonia to the UN Framework Convention on Climate Change. It would likely be helpful to give this topic more prominence including at the national governance level, by e.g. an information exchange in cabinet.

Cultural heritage and climate change provides a field of action were active exchange and cooperation with colleagues from other countries in the wider region could be sought, perhaps in the context of UN/EU cooperation or participation in a trans-national or cross-regional research projects. The work packages presented as samples for future continuation highlight a few other key priorities and requirements. These require continuing the studies towards a systematic approach for vulnerability assessment and strategic management planning in form of general guidelines and toolkits which allow for easy application and adaptation at a site level. These toolkits should enable those responsible for Macedonian heritage sites to understand the risks and vulnerabilities of a specific heritage resource towards climate change and to develop adaptation strategies to prevent their occurrence.

A systematic monitoring framework, yet to be developed, would enable the Macedonian authorities to document the efforts and solutions at a variety of different heritage sites and subsequently gain a rich data base for future action and advice in specific cases, situations and perhaps regions. The authors therefore hope that the Macedonian authorities with assistance of international partners, such as UNDP and GIZ continue their efforts towards the reduction of climate change impacts on cultural heritage and development of long-term adaptation strategies.

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