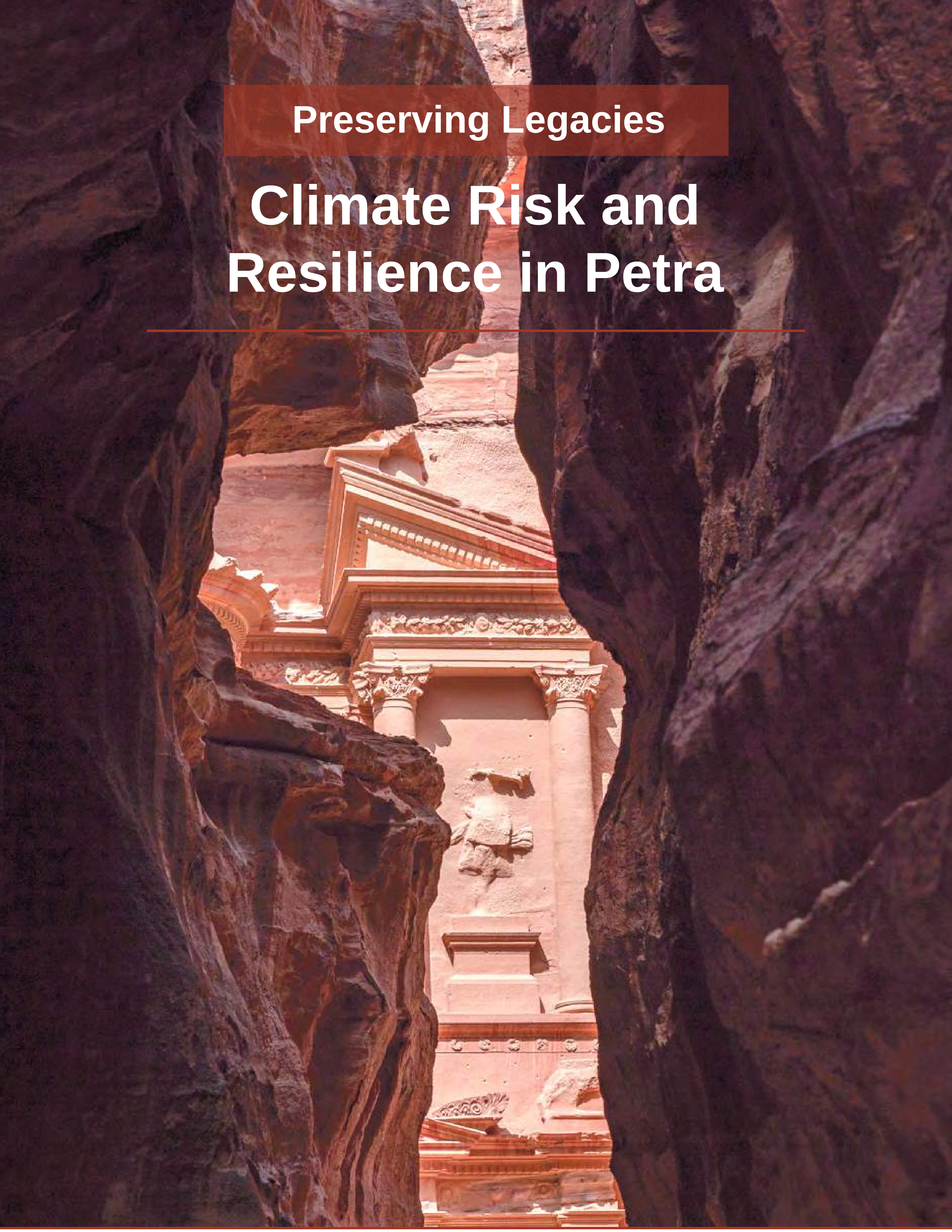
Preserving Legacies

Climate Risk and Resilience in Petra



PETRA NATIONAL TRUST
الجمعية الوطنية للمحافظة على البترا

Petra
Petra Development & Tourism Region Authority
سلطة إقليم البترا التنموي السياحي

PRESERVING LEGACIES

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Petra National Trust (PNT), Is a non-governmental, non-profit organization established in 1989 as the first leading pioneer in cultural heritage conservation and preservation. When first established, PNT focused on the UNESCO World Heritage site of Petra.
Three decades later, PNT has become a regional center of excellence in cultural heritage protection and grew to offer heritage protection solutions and services across the Middle East and North Africa (MENA).

Petra Development Tourism Regional Authority (PDTRA), established in 2009, is an autonomous financial and administrative body with a comprehensive vision to foster economic, social, cultural, and touristic growth in the region. It plays a pivotal role in the preservation and promotion of cultural heritage within the Petra region. As an independent financial and administrative authority, PDTRA's mission goes beyond mere economic and social development. It aims to nurture the rich tapestry of Petra's cultural heritage while bolstering its status as a renowned tourist destination. Governed by a distinguished Board of Commissioners, PDTRA's strategic objectives prioritise the preservation, discovery, and enhancement of urban heritage. It works in tandem with national and international entities to safeguard archaeological sites and foster a deeper appreciation for Petra's historical significance. Through its steadfast commitment to cultural stewardship and sustainable development, PDTRA embodies a vision of holistic progress that reveres and revitalises the cultural legacy of the Petra region.

Preserving Legacies, established in 2022, is an initiative in partnership with the National Geographic Society, the International Council on Monuments and Sites (ICOMOS), and the Climate Heritage Network (CHN). Using innovative science, capacity building, and networking, Preserving Legacies enables communities worldwide to design and implement low-carbon solutions that safeguard cultural heritage from climate change. Working with two Primary Sites in 2023, Petra, Jordan, and the Ifugao Rice Terraces, Philippines, and eight Observer Sites in 2023, Preserving Legacies integrates scientific, local, and Indigenous knowledges to find sustainable and culturally appropriate solutions to the long-term, low-carbon preservation of cultural heritage sites on every continent. With a commitment to growing a global community of practice and sharing hopeful stories of climate adaptation and heritage sites, Preserving Legacies aims to empower every community with the scientific knowledge and technical training to achieve appropriate place and people-based climate adaptation actions.

Preserving Legacies

Climate Risk and Resilience in Petra

PETRA NATIONAL TRUST
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سلطة إقليم البترا التنموي السياحي

PRESERVING LEGACIES

ICOMOS
international council on monuments and sites

Climate Heritage Network

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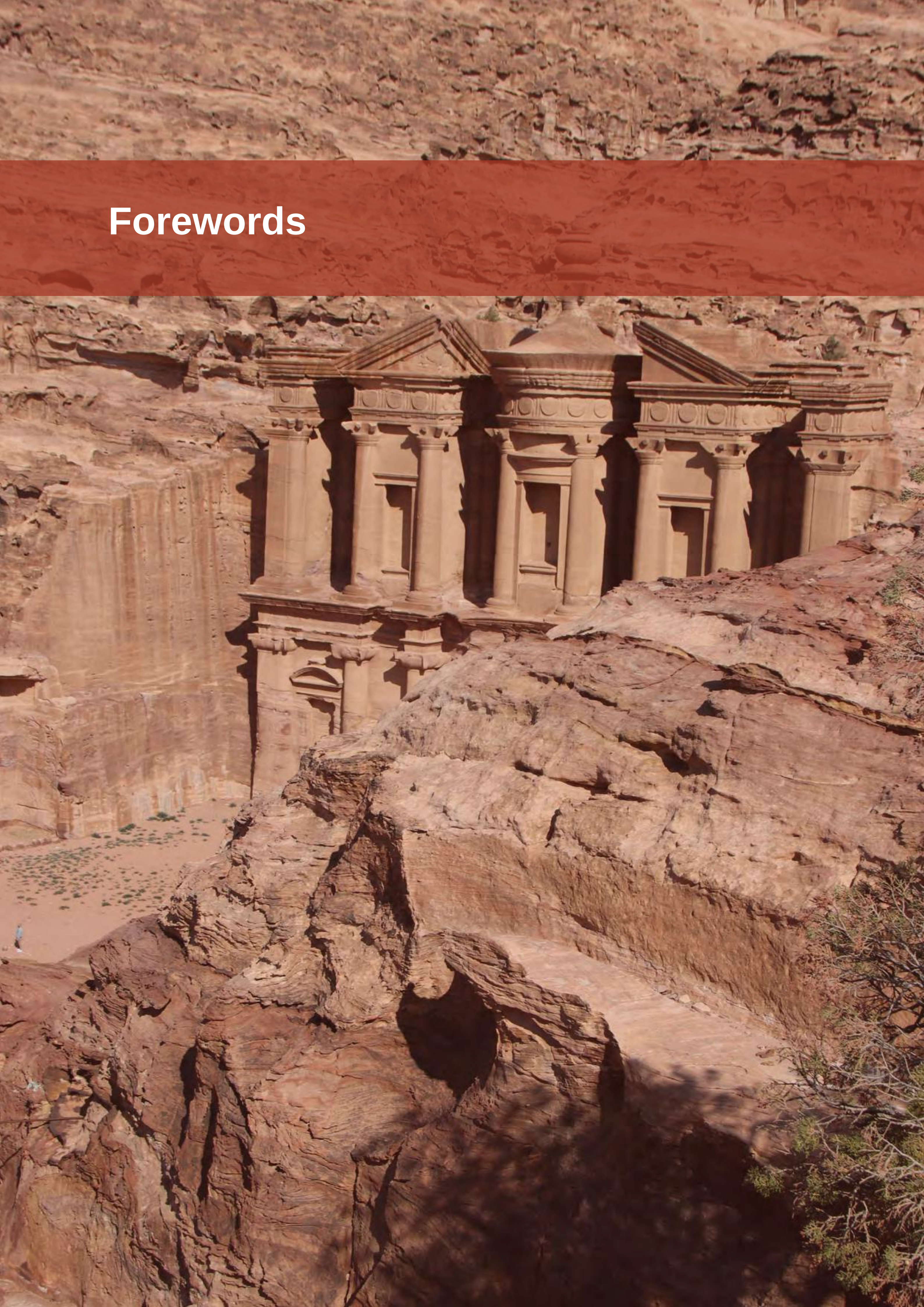


Foreword by
Her Royal Highness Princess Dana Firas, President of the Petra National Trust

We, at the Petra National Trust, are proud to join the Preserving Legacies Project to better understand the impacts of climate change on the World Heritage Site of Petra, and its communities, and to develop place-specific and people-centred climate change adaptation plans.

Today, we are working against time. The climate emergency is placing stress on places and communities globally, and our response must be ready, rapid and relevant. So far climate action has fallen short, particularly in relation to the interconnections with culture and heritage.

Through the course of the project, the Petra communities placed specific emphasis on the economic value of heritage, primarily through agriculture and tourism, in addition to the historic, archaeological and natural values. For the people of Petra the integrity of monuments, buildings, landscape, plants and animals of Petra was important as were activities in and around the site that contributed to their wellbeing – and all are experiencing damage as a result of climate change. This damage is pervasive and persistent, requiring a dynamic and continuous response requiring significant investments of time, resources and effort.

As a result, our work through Preserving Legacies focused on finding an innovative and effective approach that emphasised inclusion, valorized local voices and created a space to integrate science, knowledge, learning and community values. By bringing together this diversity of knowledge systems, the project sought to design more nimble, implementable, sustainable and culturally appropriate solutions and adaptation methodologies.

We are pleased to be able to share our findings in this report and to contribute to creating a connected global community of practice, sharing experiences and learning from one another as we address the challenges of climate change impacts on our cultural heritage. Ultimately, we all face a global threat and we share a common goal: to safeguard our heritage for future generations.

I would like to thank our partners, the Petra Development and Tourism Regional Authority (PDTRA), the Petra communities, the International Council on Monuments and Sites (ICOMOS), the Climate Heritage Network and National Geographic for their support and contributions.

Previous Page Photo By: Khansa Bouaziz, 2023

Foreword by

Dr Faris Al-Breizat, Chairman of the Board of the Petra Development and Tourism Regional Authority

The Petra Development and Tourism Regional Authority (PDTRA) is considered one of the most significant national institutions in Jordan. We collaborate with various national and international entities to preserve Petra Archeological Park the capital of the Arab Nabataeans and one of the key symbols of the Jordanian national cultural identity and a world heritage site. Petra holds a special place in the hearts of the Jordanian people and their Hashemite leadership reflecting the deep historical and cultural roots of Jordanians.

At PDTRA, we, along with our partners nationally and globally, understand the importance of preserving cultural and natural heritage as a right for future generations and humanity as a whole. Therefore, we have consistently upheld a strategic goal that we will not deviate from: "Petra Forever." This commitment has led us to respond to the global initiative extended by National Geographic in 2021 for projects focusing on safeguarding threatened World Heritage sites affected by climate change and/or conflicts. In collaboration with the International Council on Monuments and Sites (ICOMOS), Petra was chosen as one of the main sites for the inaugural year of the project "Preserving Legacies."

I would like to take this opportunity to express my gratitude to Petra National Trust (PNT) for their efforts in this field. They are an active partner with PDTRA in heritage preservation and raising awareness of its importance. Additionally, we acknowledge the collaboration with the Jordanian Department of Antiquities, sharing the responsibility of preserving our historical and cultural heritage.

Recently, PDTRA has implemented a series of remedial and preventive measures to enhance the concept of preserving both the tangible and intangible heritage elements in the Petra region. We have also initiated efforts to manage the relationship between the local community and the archaeological site, which is surrounded by six communities with over 40,000 residents heavily dependent on tourism.

Recognizing the evident impacts of climate change, we have given special attention to this issue. Collaborating with partners, we have established an early warning system for flash floods resulting from sudden and rapid rainfall. We have maintained and rehabilitated the pathways of flowing water through the archaeological site, undertaken maintenance programs, and restored the Nabataean water system and terraces surrounding the site. Additionally, we have organized visitor traffic to ensure their safety and facilitate our response to any exceptional conditions the region may face.

Foreword by

Dr Victoria Herrmann, Director of Preserving Legacies

Preserving Legacies: A Future of Our Past is a global initiative that aims to meet that need by empowering every community with the scientific knowledge and technical training to achieve appropriate place and people-based climate adaptation plans. Funded by Manulife and in partnership with the National Geographic Society, the International Council for Monuments and Sites, and the Climate Heritage Network, Preserving Legacies equips communities with the capability to understand and visualise climate change impacts on a local scale, map the vulnerability of their sites and the community values they hold to those impacts, and act to minimise the adverse consequences of climate change and maximise the opportunities it presents.

Preserving Legacies is built on a training program that enables local leaders to understand climate science and empowers them to turn that knowledge into site-saving action. In January 2023, the project kicked off its inaugural 12-month education program for 30 site custodians from 10 cultural and natural heritage sites around the world, seen in the below map. While this diverse first cohort spans continents, cultures, and climate impacts, they all share a deep commitment to learn, connect, and build something new together. Through a combination of recorded lectures, live online delivery, readings, and in-person workshops, the site custodians are learning about community values, climate science, site vulnerability, adaptation approaches, and storytelling for impact sequentially in a five-unit course.

In this first year of Preserving Legacies, two primary sites, Petra, Jordan and The Ifugao Rice Terraces, Philippines, will go through a more robust program to link climate science and site conservation by enabling access to locally downscaled climate change models and organise a community-led workshop of the sites' climate vulnerability as well as impacts on local communities. Alongside these two primary sites, eight observer sites have been chosen to fully engage in climate heritage training and a peer-to-peer learning experience. Site custodians from these sites will shadow the full process at Petra and the Rice Terraces, including attending their workshops, to better prepare for their own assessments in 2024.

Parallel to the Jordanian vulnerability workshop that produced this assessment report, site custodians from the nine other Preserving Legacies sites flew to Jordan and took part in a parallel observer networking experience, where they observed the workshop with simultaneous translation and had their own programming. The aim of this experience was for each site custodian to have, through experiential learning, acquired the knowledge needed to run their own workshops at their home site in 2024.

We hope that our work in Jordan is just the start to a multi-year program. We want to scale Preserving Legacy's reach to every community across the world that is facing climate change impacts and transform conservation as a field. This year, we will learn, connect, and build something new together. And in years to come, we will work to democratise Preserving Legacies' capacity building model to scale our impact to thousands of sites.

Acknowledgements

Acknowledgements

We are delighted to present "Preserving Legacies: Climate Resilience in Petra," a comprehensive publication that reflects the culmination of collaborative efforts and dedication from various stakeholders. This project, aimed at assessing and enhancing climate resilience in the iconic Petra World Heritage Site, would not have been possible without the invaluable contributions and support from the following individuals, project partners, and institutions.

We extend our heartfelt gratitude to the Department of Antiquities, the Ministry of Environment (MoEnv), and the United Nations Development Programme (UNDP) for their unwavering support and partnership. Their commitment to environmental conservation and sustainable development has played a pivotal role in the success of our initiatives.

Special thanks go to the local community for their active participation in our workshops. Their insights, traditional knowledge, and commitment to the preservation of Petra have significantly enriched our understanding and shaped the outcomes of this project. We acknowledge the workshop participants by name (details in the annex) for their valuable contributions.

The expertise and dedication of our report authors have been instrumental in presenting a thorough analysis and recommendations. We express our gratitude to Haifaa Abedalhaleem, Taher Falhat, Majed Al Hasanat, Willian Megarry, Khansa Bouaziz, and Victoria Herman. In addition, Asmahan Khames for designing this publication.

Additional Contributors: A list of other staff members who have played crucial roles in this endeavour is provided in the annex.

This publication represents a holistic approach to heritage preservation, addressing not only the challenges posed by climate change but also emphasising the importance of community engagement, interdisciplinary collaboration, and sustainable practices. The findings and recommendations outlined herein are intended to contribute to the ongoing dialogue on climate resilience in heritage sites and inform future conservation efforts.

The Legacies project would not have been possible without support from the National Geographic Society and Manulife and we would like to thank both for their ongoing commitment to preserving the world’s heritage from climate change.

Previous Page Photo By: Khansa Bouaziz, 2023

We express our deepest appreciation to all involved, from project partners to local communities, for their commitment to safeguarding Petra's rich legacy in the face of environmental challenges.

Finally, we would like to acknowledge and pay our deepest respects to Dr Etadal Al-Hassant whose valuable, wise and thoughtful contributions were so important in the workshop.

Photos of Dr. Etadal Al-Hassant during the workshop at Wadi Musa
(Photos: Michael O. Snyder 2023)

Author Biographies

Haifa Abdalhaleem holds a master's degree in Heritage and Tourism Management and Development, accumulating over 18 years of expertise. In her current role as a Climate Heritage expert, she leads projects in Jordan, specialising in the meticulous assessment of climate impacts on heritage sites. With a significant tenure at IUCN, Haifaa played a pivotal role in the success of the IUCN-Tabe'a Programme, demonstrating her proficiency in natural World Heritage. Her skills encompass capacity building, providing technical advice, and contributing significantly to conservation efforts, including state of conservation monitoring, protection, and management. Haifaa's accomplishments extend beyond World Heritage, showcasing a deep commitment to broader environmental and conservation issues.

Taher Falahat is a passionate advocate for cultural heritage preservation, holds both a Bachelor's and Master's degree in Cultural Heritage Management. Since 2018, he has been an integral part of the Heritage Resources Department at the Petra Archaeological Park. With a keen focus on conservation and restoration, Taher has successfully led several impactful projects within the park, contributing significantly to the protection and longevity of Petra's rich historical legacy. Beyond the site, Taher has represented Petra and Jordan in several local and international programs and conferences, elevating awareness and fostering collaboration in the global heritage community.

Majed Al Hasanat is a Ph.D. candidate in Biodiversity Conservation and is concurrently pursuing an MSc in MBA. With over 20 years of experience, he served as the Ex-commissioner for Petra Development and Tourism Region Authority (PDTRA), including roles as Petra Archaeological Park Commissioner and Infrastructure Commissioner. Prior to PDTRA, he worked extensively in biodiversity conservation, protected areas management, and natural resource management, showcasing practical expertise in managing protected areas, policy development, planning, sustainable use, and natural resource governance.

Khansa Bouaziz is an architect by training. She began her career at the National Heritage Institute in Tunisia, working on four different heritage sites, three of which are world heritage sites. Her academic background is varied and multifaceted, having studied architecture, urban planning, archaeology, heritage conservation and site management. Most of her research is related to desert studies, interpretation technologies and climate resilience.

Salma Sabour is a physical and environmental engineer and a climate heritage specialist that integrates technical expertise with a strong foundation in social science. Her interdisciplinary research at the University of Southampton focuses on climate change impacts on values and communities, sea-level rise, extreme events, climate risk assessments, resilience and adaptation. Collaborating with renowned researchers, she engaged in international research projects (ICOMOS, IPCC, UNESCO) and consulted for local governments and international organisations on waste and coastal management (World Bank), as well as water resources (UNDP) in Morocco and Nigeria.

William Megarry is an archaeologist and heritage management specialist based in Ireland. He teaches at Queen's University Belfast and is focal point for climate change at the International Council on Monuments and Sites (ICOMOS). He is also an expert member of the International Committee on Archaeological Heritage Management (ICAHM). His work has focused on climate change impacts to cultural heritage with a particular focus on assessing risk and vulnerability and on building climate awareness and literacy. He is a Fellow of the Society of Antiquaries of London and the Society of Antiquaries of Scotland.

Victoria Herrmann is a storyteller and geographer working with communities around the world on climate change adaptation. As a National Geographic Explorer and Assistant Research Professor at Georgetown University, she has spent the past decade leading research initiatives and directing capacity building programs to support communities adapting on the front lines of the climate crisis in the U.S., U.S. Territories, and Arctic.

Executive Summary

Executive Summary

Climate change represents the single greatest threat to heritage worldwide. Effectively responding to this threat is of utmost importance, yet there is a lack of methods to identify risks and capacities to respond to those risks within the heritage sector. Empowering every community to safeguard their cultural and natural heritage against climate change impacts the mission of the Preserving Legacies project. This project equips local leaders with the scientific knowledge and technical training to develop place and people-based climate change adaptation actions.

This report presents the results from a climate risk assessment facilitated by the Petra National Trust (PNT) and the Petra Development Tourism Regional Authority (PDTRA) and organised as part of the Preserving Legacies project. It took place between March 2023 and June 2023 and included a series of three community focus groups and a three days workshop which brought together a diverse range of stakeholders to discuss key components of the assessment. This included identifying key values of the heritage site, highlighting social and economic vulnerabilities, gauging adaptive capacities, and assessing climate impacts and risk.

The climate risk assessment followed a value-led approach, which began with an assessment of key property values and attributes. While these included heritage values associated with the World Heritage (WH) property, they also identified wider social and economic values important to the community. The following values were identified as being most important to the Petra community: economic values associated with agriculture and tourism, historical and archaeological values, and values associated with the natural landscape. The associated attributes for these values varied and included terraces, fields, the historical monuments and archaeological remains, and the natural flora and fauna of the area.

Workshop participants then discussed changing weather and climate based on local experiences and observations, and a report on potential future climate hazards prepared in advance. This identified likely climate change under a range of different emissions scenarios over the next 100 years. It was decided to explore potential hazards until 2060 based on RCP 4.5. This assumes a ‘middle of the road’ situation where social, economic, and technological trends will not change significantly, and is deemed by most scientists to be the most likely future climate.

Previous Page Photo By: Khansa Bouaziz, 2023

Under this scenario, increased precipitation leading to flash flooding, drought, and increased storminess were identified as the top three future climatic hazards. Following this, the impact of local social and economic factors like development and funding pressures were also discussed, as was the capacity of different parts of the community to adapt to these hazards. Of particular note were the efforts taken by PDTRA to protect the WH property through the restoration of traditional terracing and the use of flood barriers at key water catchment points within the site. These significantly reduced the risk to some key values.

The workshop decided that while the potential impact on key values ranged between moderate to extreme for increased precipitation leading to flash floods, low to moderate for drought events, and moderate for increased storminess, the overall risk when adaptive capacity was taken into account was moderate for each of the values with the exception of the archaeological and historical values where the risk was low. This was due to the adaptive efforts of PDTRA and the local community. It therefore summarised that the overall climate risk to Petra by 2060, based on a middle of the road emission scenario, was moderate.

The climate risk assessment for Petra illustrates the benefit of a locally-led climate risk assessment methodology which respects plural values, diverse knowledge systems and scientific data, and acknowledges existing adaptation efforts. It demonstrates the benefit of engaging communities in decision making by sharing knowledge and building local capacities. In doing so, it also embeds meaningful and sustainable climate action within the communities who protect and care for our most precious places.

الملخص التنفيذي

يمثل تغير المناخ التهديد الأكبر للتراث العالمي. إن التصدي بفعالية لهذا التحدي أمر ضروري للغاية، ومع ذلك هناك نقص في الأساليب والقدرات داخل قطاع التراث على المستوى العالمي. يعتبر تمكين كل مجتمع من الحفاظ على تراثه الثقافي والطبيعي من تأثيرات تغير المناخ جزءًا أساسيًا من مشروع Preserving Legacies. يوفر هذا المشروع للقادة المحليين المعرفة العلمية والتدريب الفني لوضع خطط التكيف مع تغير المناخ استنادًا إلى السياق المحلي واحتياجات الأفراد.

يقدم هذا التقرير نتائج تقييم مخاطر التغير المناخي الذي أجرته الجمعية الوطنية للمحافظة على البترا PNT وسلطة اقليم البترا التنموي السياحي PDTRA، والذي تم تنظيمه كجزء من مشروع Preserving Legacies . جرى التقييم بين مارس 2023 ويونيو 2023، وشمل سلسلة من ثلاث مجموعات تركيز مجتمعية و ورشات عمل لمدة ثلاثة أيام، جمعت مجموعة متنوعة من المعنيين و المحليين لمناقشة المكونات الرئيسية لهذا التقييم. وشمل ذلك تحديد القيم الأساسية، وتسليط الضوء على نقاط الضعف الاجتماعي والاقتصادي، وقياس القدرات التكيفية، وتقييم تأثيرات التغير المناخي ومخاطره على المنطقة.
أتبع تقييم مخاطر التغير المناخي نهجًا يركز على القيم الثقافية و الطبيعية، حيث بدأ باستقراء القيم الرئيسية للممتلكات والسمات. بالرغم من أن هذه القيم تشمل القيم التراثية المرتبطة بالممتلكات التراثية العالمية، إلا أنها أيضًا حددت القيم الاجتماعية والاقتصادية الأوسع نطاقًا والمهمّة للمجتمع المحلّي. تم تحديد القيم التالية كونها الأكثر أهمية لمجتمع البتراء: القيم الاقتصادية المرتبطة بالزراعة والسياحة، والقيم التاريخية والأثرية، والقيم المرتبطة بالمناظر الطبيعية. إنّ السمات المرتبطة بهذه القيم متنوعة، و قد شملت الحقول والأحواض والصروح التاريخية والمواقع الأثرية والنباتات والحيوانات البرية الطبيعية في المنطقة ككل.

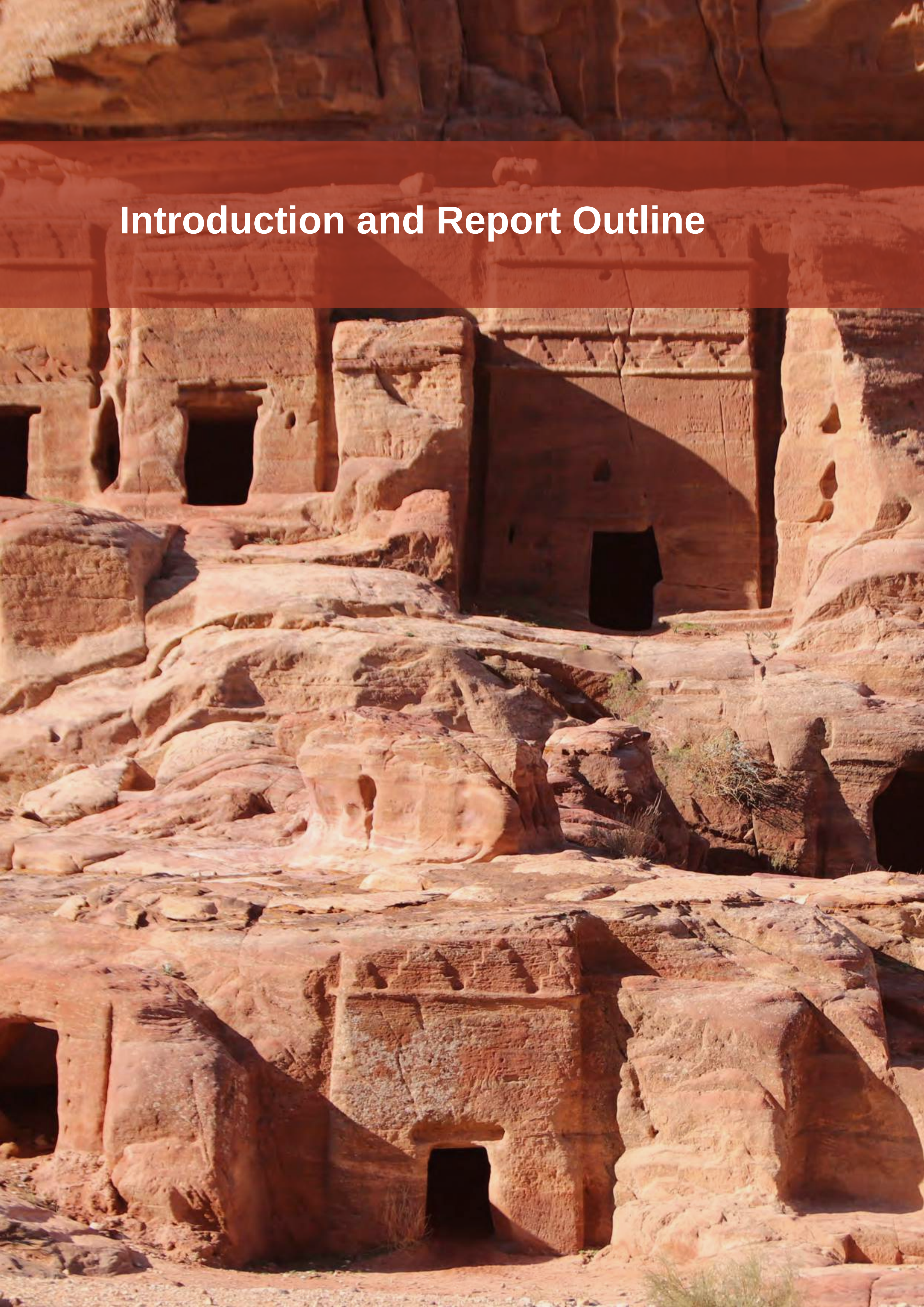
تناول المشاركون في ورشة العمل بعد ذلك مناقشة التغيرات في الطقس والمناخ استنادًا إلى التجارب والملاحظات المحلية، بالإضافة إلى تقرير موعد مسبقا عن المخاطر المناخية المحتملة في المستقبل. حدد هذا التقرير التغير المناخي المحتمل في مجموعة متنوعة من السيناريوهات المختلفة للانبعاثات على مدى الـ 100 عام القادمة. وتقرر استكشاف المخاطر المحتملة حتى عام 2060 استنادًا إلى المسارات الاقتصادية والاجتماعية المشتركة المعروفة بRCP. يفترض هذا السيناريو وجود وضع "وسط المسار" حيث لن تتغير الاتجاهات الاجتماعية والاقتصادية والتكنولوجية بشكل كبير، ويعتبر بوجه عام الوضع المناخي المستقبلي الأكثر احتمالًا. وتم تحديد زيادة في الهطول المطري التي تؤدي إلى الفيضانات السريعة والمفاجئة، والجفاف وزيادة في حدة العواصف كأهم ثلاثة مخاطر مناخية مستقبلية. بعد ذلك، ناقش تأثير العوامل الاجتماعية والاقتصادية المحلية مثل التنمية والضغوط التمويلية، وكذلك قدرة أجزاء مختلفة من المجتمع على التكيف مع هذه المخاطر. يُلاحظ خصوصًا الجهود التي بذلتها سلطة اقليم البترا التنموي السياحي PDTRA، لحماية الممتلكات التراثية العالمية من خلال استعادة الحواجز الترابية التقليدية واستخدام حواجز الفيضانات في نقاط تجميع المياه الرئيسية داخل الموقع، مما ساهم بشكل كبير في تقليل المخاطر المحدقة ببعض القيم الرئيسية.

تبنت ورشة العمل فكرة أنه بينما تتراوح التأثيرات المحتملة على القيم الرئيسية بين المعتدلة والشديدة لزيادة في الهطول المطري، مما يؤدي إلى الفيضانات السريعة، ومنخفضة إلى معتدلة لحالات الجفاف، ومعتدلة لزيادة في حدة العواصف، إلا أن المخاطر العامة عند مراعاة القدرة التكيفية كانت معتدلة بالنسبة لكل القيم باستثناء القيم الأثرية والتاريخية حيث كانت المخاطر ضئيلة

ويعود ذلك إلى الجهود التكيفية التي بذلتها سلطة اقليم البترا التنموي السياحي PDTRA والمجتمع المحلي. لذلك، توصلت الورشة إلى أن المخاطر المناخية العامة لموقع البترا و المحيط بها بحلول عام 2060، استنادًا إلى سيناريو الانبعاث "وسط المسار"، كانت معتدلة.

يُوضِّح تقييم مخاطر التغير المناخي للبترا فوائد منهجية التقييم المحلية التي تحترم القيم المتعددة، والأنظمة المعرفية المتنوعة، والبيانات العلمية، وتقدير الجهود التكيفية الحالية. فهو يُبيّن فوائد مشاركة المجتمعات في صنع القرارات من خلال تبادل المعرفة وبناء القدرات المحلية. وبذلك، يضمن أيضًا تنفيذ إجراءات مناخية ذات مغزى ومستدامة ضمن المجتمعات التي تحمي وتعتني بأماكننا الأكثر قيمة.

Introduction and Report Outline



Introduction

This report outlines the results of a climate risk assessment of the Petra archaeological site and the wider landscape undertaken in Wadi Musa in June 2023. It was organised and facilitated by the Petra National Trust (PNT) and the Petra Development and Tourism Regional Authority (PDTRA) as part of a wider global initiative called Preserving Legacies. Funded by Manulife and in partnership with the National Geographic Society, the Preserving Legacies project aims to empower every community with the scientific knowledge and technical training to achieve appropriate place and people-based climate adaptation plans. Through training and support, the project works with local heritage professionals around the world to provide the key skills and capacities necessary to respond to the climate crisis in a robust and sustainable way.

While climate change is a global problem, its impacts are locally experienced. It is essential that heritage professionals learn to respond effectively and embed climate preparedness with site management structures. These actions need to incorporate communities in a people-centred and place-based way. A key part of the Preserving Legacies project is locally-led and community-focused climate risk assessment workshops, which are an essential prerequisite for climate adaptation. At Petra, this workshop was held over three days and heard from a broad range of community stakeholders.

The results of this effort are presented in five parts outlining the results, outcomes, and key findings from the workshop. These are further informed by both focus groups, which preceded the workshops, and surveys, undertaken after the event to validate outcomes. Sections introduce: (1) an overview of the assessment methodology; (2) an exploration of the key values and attributes of Petra, its landscape and community as defined by local stakeholders; (3) a presentation of current and future climate projections including climatic hazards likely to impact the site in the future; (4) an exploration of the impact of these hazards on the site values, including an assessment of their exposure, sensitivity, and a discussion on local social and economic vulnerabilities; and (5) an exploration of both heritage and local adaptive capacities, and a final section exploring the key areas of risk and suggesting some possible areas of focus for adaptation initiatives.

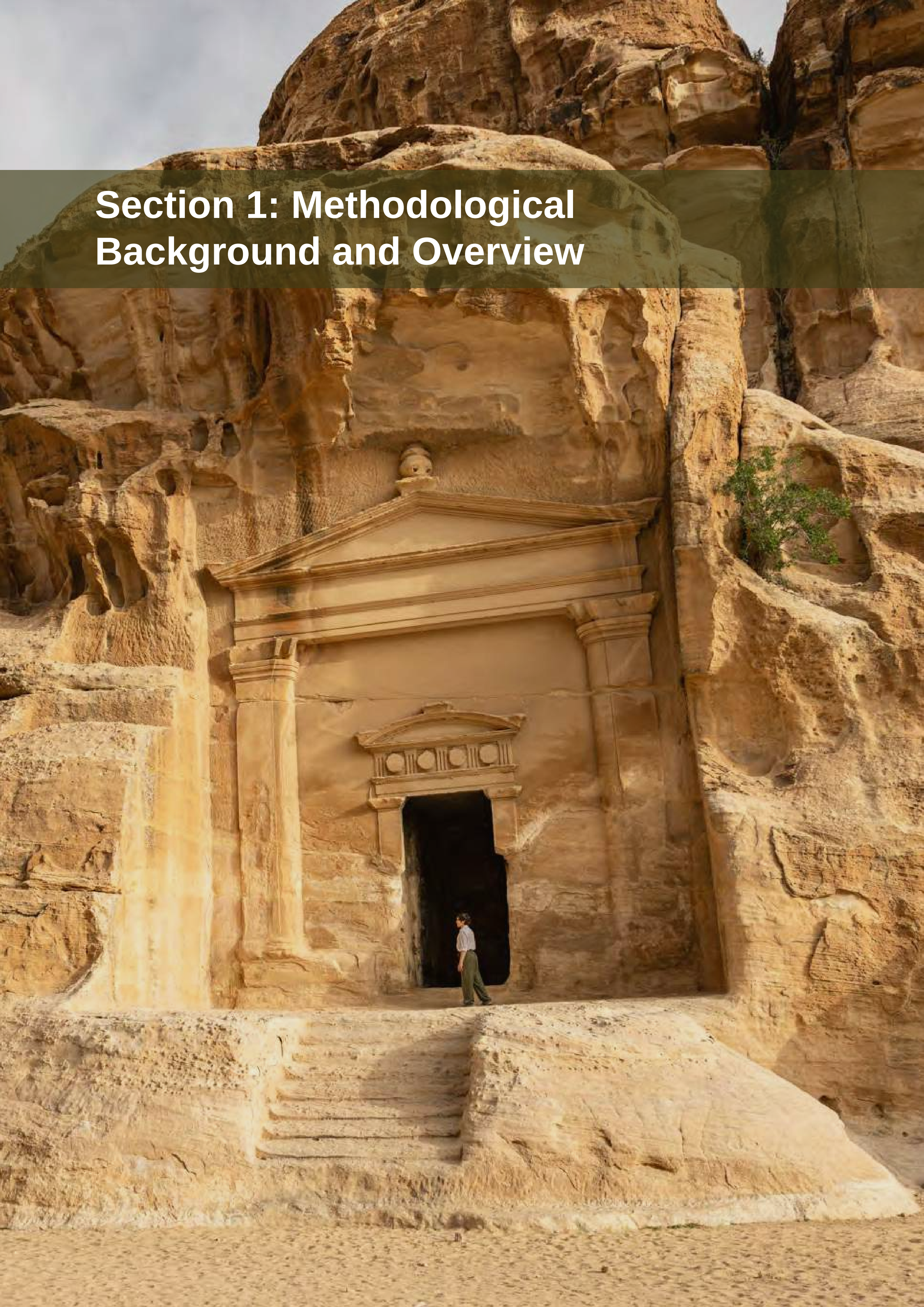
Previous Page Photo By: Khansa Bouaziz, 2023

Figure 1: Some workshop attendees with global site custodians from the Preserving Legacies Project (Photo: Michael O. Snyder 2023)

The Preserving Legacies project is committed to creating a global community of heritage professionals engaged in climate action who can support each other and share experiences from different types of heritage sites. To facilitate this, the project brought nine site custodians from Bangladesh, Cambodia, Columbia, The Federated States of Micronesia, Fiji, Ireland, The Philippines, and Togo and Benin to listen and share their experiences with the local community (Figure 1). This engagement provided a rich and rewarding cultural experience for everyone involved in the workshop. It also provided a valuable learning experience to the wider group who will be adapting and duplicating the experience at their own sites. As such, the Petra workshop is a seed that, now planted, will grow and yield fruit globally.

Fundamentally, the results presented in this report represent the beginning of a journey rather than a destination. The impacts of climate change on heritage are already extensive and will only get worse in the future. Understanding how these impacts will be experienced at Petra will enable and catalyse effective climate adaptation strategies locally to help to preserve this outstanding site in the future.

Section 1: Methodological Background and Overview



Section 1: Methodological Background and Overview

► Cultural Heritage and Climate Change

Climate change is the most significant threat to cultural and natural heritage globally. It has been estimated that one in three natural sites and one in three cultural sites are at risk from the impacts of climate change; however, it is very likely that these are under estimates (UNESCO 2021). While broad risk categories like rising sea-levels or increased storminess are well documented and reported, the specific risks to and vulnerability of individual sites, properties and places are not. This problem is particularly acute at sites from the Arab Region and is exacerbated by the lack of standardised tools, approaches, and capacities in the heritage sector to analyse risk of and respond to climate-related threats (World Economic Forum 2015). As noted by ICOMOS, 'There is a need to promote open access tools and approaches to vulnerability assessment, mitigation techniques, monitoring and damage assessment, conservation and adaptation efforts' (ICOMOS 2019, pp 32). It is very important that these tools include the voices of peoples and communities who live in and around heritage sites. As noted in the recently published Global Research Action Agenda from the ICOMOS-ICOMOS-IPCC International Co-Sponsored Meeting on Culture, Heritage, and Climate Change, there is a need for tools and methodologies which both engage with established risk assessment mechanisms, and take into account diverse value systems and worldviews (Morel et al 2022, 38).

> *"In order to reduce risk to culture and heritage, a better understanding of their relation to climate impacts, exposure and vulnerability is needed… There is also a need to address outcome biases in risk and vulnerability assessments which ignore community-led approaches and fail to take account of world views, values, practices and preferences of diverse actors, including Indigenous Peoples and local communities"*
>
> (Morel et al 2022, pp 38)

The scale of this challenge is enormous. Studies have repeatedly illustrated the growing risks posed by climate change to heritage sites globally, both cultural and natural. Many of these studies have focused on iconic World Heritage (WH) sites; however, the problem is even more acute at less well-known sites that often lack the resources to effectively respond (Megarry 2023). To meet the scale of this challenge, new tools and approaches need to be both openly available to heritage professionals and easy to use and apply.

Previous Page Photo By: Michael O. Snyder, 2023

They also need to be malleable and adaptable to a diverse range of heritage typologies, from tangible heritage like prehistoric archaeological sites and 20th century buildings to more intangible properties like cultural landscapes often centred on living heritage and traditions. As noted in the ICOMOS ‘Futures of Our Past’ report, responding to climate change must become ‘a baseline competency for heritage managers’ (ICOMOS 2019, 7).

Previous efforts to develop tools and methodologies have laid a strong foundation for this project. This has included initiatives by project partners including the Values-based Climate Change Risk Assessment: Piloting the Climate Vulnerability Index for Cultural Heritage in Africa (CVI Africa) project which explored the application of an existing tool at two African World Heritage sites (Megarry et al. 2024; Day et al 2022; Heron et al 2022). These approaches tended to be based around a single facilitated workshop where stakeholders were brought together to share their experiences and opinions. The experiences of CVI Africa highlighted the need for a values-based methodology centred on community engagement and decision making. It also identified the importance of knowledge-sharing and capacity building to empower site managers and custodians to implement meaningful and sustainable actions at their sites (Megarry et al 2024). The methodological approach of Preserving Legacies reflects the learnings from CVI Africa. The methodology of Preserving Legacies is based around practical training and is not focused on a single tool or assessment technique. Rather, Preserving Legacies aims to equip site custodians with the key concepts, competencies, and practicums to understand climate risk and associated vulnerabilities at their unique sites (Figure 1). The training of Preserving Legacies and application of risk assessment used at Petra builds upon the vulnerability framework approach described in the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007), but requires the assessment to be locally-led and tailored to the community context, with a focus on identifying and respecting plural value systems and hearing from diverse voices.

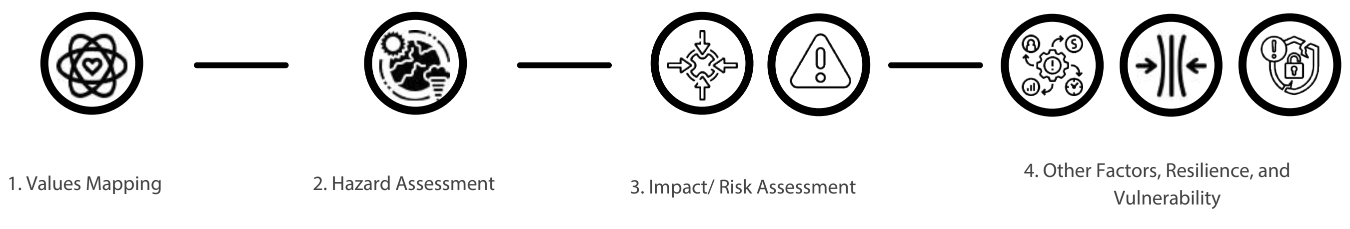


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Figure 2: Key components of climate risk and vulnerability assessment of sites

Step 1: Values Mapping

Values refer to ‘the meanings and values that individuals or groups of people bestow on heritage’ (Díaz-Andreu, 2017, pp 2). At most WH sites, the preservation of the Outstanding Universal Value of the property takes precedence over other values. This is reflected in many existing climate risk assessment approaches, for example the CVI which focused specifically on impacts to OUV (Megarry et al 2024). The Preserving Legacies project is not solely focused on WH properties, and its approach has a broader appreciation of values. This aligns with the spirit of the Burra Charter in attempting to ‘‘identify and take into consideration all aspects of cultural and natural significance without unwarranted emphasis on any one value at the expense of others’. The identification of key values involves wide community consultation. This can take many forms but is often done as part of a multi-stakeholder workshop bringing diverse actors together to make decisions in consensus. While very effective at some sites, community focus groups and workshops can reinforce existing power dynamics where certain actors dominate discussions and so care must be taken to ensure that all voices are heard equally.

As intangible concepts, values do not exist in isolation to physical attributes. Attributes are physical features which attest to and demonstrate these values. This can include collections, buildings and structures, intangible traditions, and archaeological deposits. Identifying these attributes are key to understanding site values as these physical features are often what climate change impacts.

Step 2: Climate Futures and Hazard Assessment

Local communities, especially Indigenous peoples and those working with agriculture, are often acutely aware of changing weather patterns and climate change. This knowledge is a unique and valuable resource when assessing current climate risk and vulnerability. Understanding future climates is more of a challenge for knowledgable community members because, with climate change and our response to mitigate current and future greenhouse gas emissions, the future both looks different than the past and is not yet set. The actions taken over the coming decade will have a huge effect on future climates. Models have been developed to explore potential climatic conditions under different emission scenarios and over different time periods. These models allow us to identify possible future climate hazards (like changing precipitation or temperature patterns) and prepare for different scenarios. Local and scientific knowledge systems are key sources of data for these models and key resources for understanding current and future climate hazards.

Step 3: Impact and risk assessment

Not all values will be equally impacted by climate hazards. Some may not be impacted at all while others may be at significant risk. The degree of risk depends on both the exposure (the nature and degree to which a system is exposed to significant climatic variations) and sensitivity (the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli) of the physical attribute which conveys its value. The potential climate impact on an attribute and its value can be exacerbated or alleviated by a range of other factors, which should also be assessed.

Step 4: Other Factors, Resilience, and Vulnerability

Many factors can exacerbate climate impacts and risk. These include social and economic vulnerabilities like lack of conservation, under-development, poor planning, unmaintained infrastructure, and over-tourism. These vulnerabilities may impact some values more than others. For example, climate impacts to built heritage like walls or archaeological ruins may be exacerbated by poor conservation or the pressures of over-tourism. Similarly, values associated with the wider landscape may be exacerbated by poor planning or water management.

Figure 3: Taher Falahat of PDTRA inspecting recently consolidated Nabatean terraces above the Petra archaeological site (Photo: Michael O. Snyder 2023)

Just as some factors may make climate impacts worse, some actions may reduce these potential impacts. These are referred to as resilience or adaptive capacity and may include existing climate adaptation measures like flood defences, strong conservation plans, or a skilled and knowledgeable professional sector. The could also include traditional or ancient technologies or traditions which reduce risk like the Nabatean water management system at Petra, which controlled and redirected water away from the site. These should be taken into account when assessing climate risk and vulnerability.

► The Petra Workshop Methodology

The methodology of the Petra climate risk assessment is outlined in Figure 4. Preparatory work is crucially important to ensure that data used in the assessment is robust and correct. At Petra, this included the preparation of downscaled climate scenarios prior to the remote based on agreed timeframes and scenarios. As a World Heritage site, certain values have already been defined in the Statement of Outstanding Universal Value (OUV) and these were also extracted prior to community engagement. As discussed in the previous section, this process of engaging the community in climate risk and vulnerability assessment is critically important at every stage. The many diverse stakeholders at Petra including heritage professionals, local businesses, the tourism sector and wider members of the local community necessitated a wider engagement strategy which included hosting focus groups before the workshops. Participants in both the workshop and at the focus groups are listed in Appendices 1 and 2.

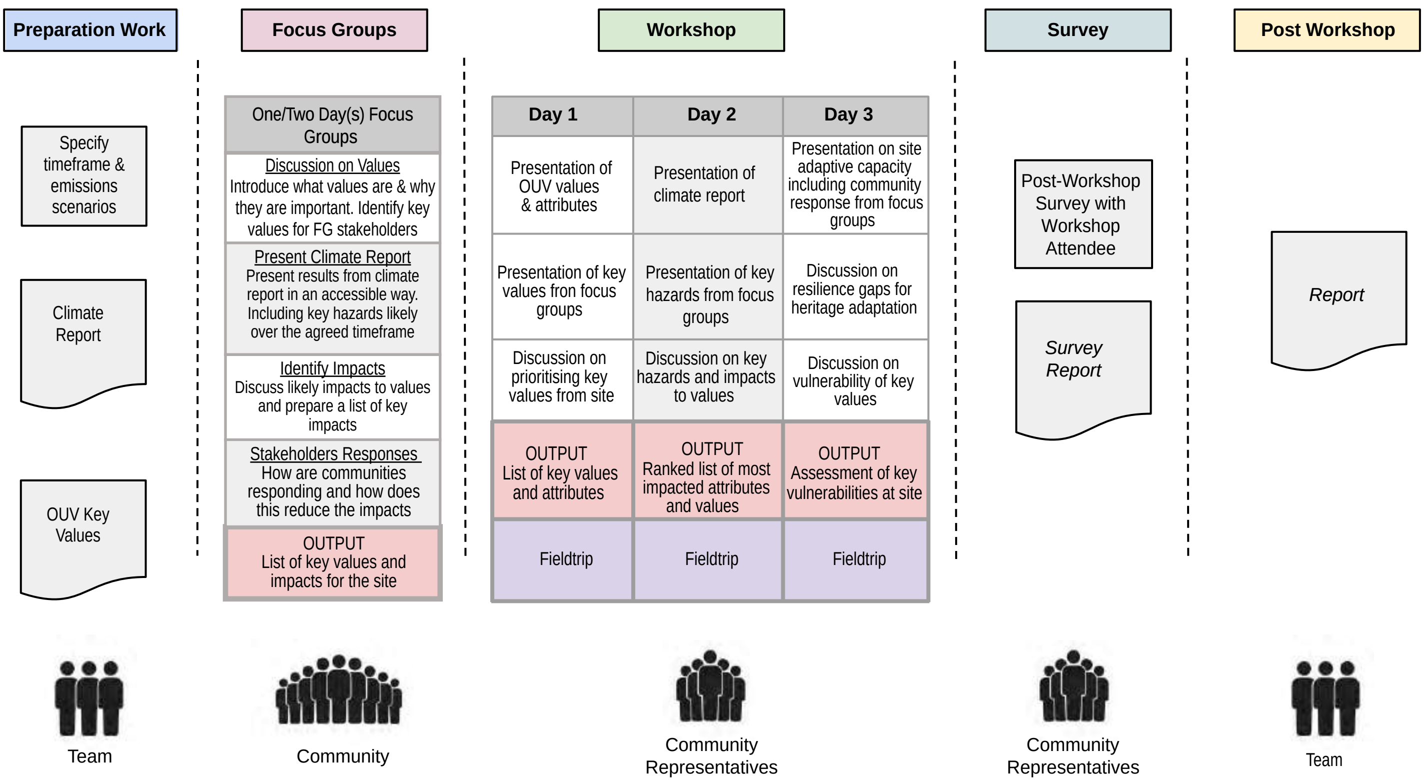


Figure 4: Workshop methodology showing preparation work including research and focus groups, the workshop, and post-survey actions including a survey of participants

To encourage participation and promote inclusiveness, specific groups of stakeholders were invited to attend different focus groups held in a local cultural centre (Table 1). Participants were asked to discuss a range of questions as outlined in Appendix 5 and these saved time and contributed to key themes discussed in the workshop (Figure 4).

Table 1: Focus groups held in advance of the workshop

Focus Group 1	Focus Group 2	Focus Group 3
Saturday 13th May 2023	*Sunday 14th May, 2023*	*Sunday 14th May, 2023*
NGOs, CBOs, Cooperatives and those working in the local economy	Heritage professionals including PDTRA employees	Tourism Service Providers including tour organisers and guides

Figure 5: Focus groups sessions (Photo: Khansa Bouaziz, 2023)

The workshop created a space for local stakeholders to discuss and make decisions about key components of the climate risk assessment. It was held over three days and representatives from each stakeholder focus group were invited to explore key aspects of the risk assessment and agree on an overall risk for the property. Key steps in this assessment are outlined in Figure 4. During the workshop, participants were first asked to rank key site values and identify main climate-related hazards within an agreed timeframe and scenario. Summary results from the focus groups were presented to workshop participants to discuss and this greatly expedited these two steps.

Figure 6: Haifa Abdelhaleem presenting a summary results of the focus groups (Photo: Salma Sabour)

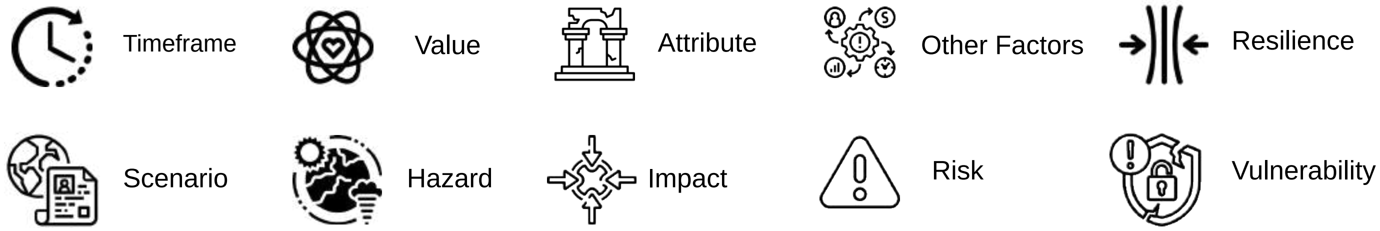
Table 2: Relative rankings for different assessment components

Potential Impacts, Exposure and Vulnerability, and Social and Economic Vulnerabilities, Overall Risk	Not Discussed	Adaptive Capacities	Not Discussed
	None		None
	Low		Low
	Moderate		Medium
	Extreme		High

Table 3: Component parts of the Petra climate risk assessment

Impact to Date	Significant Factors	Potential Impact[1]	Adaptive Capacity	Overall Risk

[1]By 2060, as decided by workshop participants



(Icons from Flaticon.com)

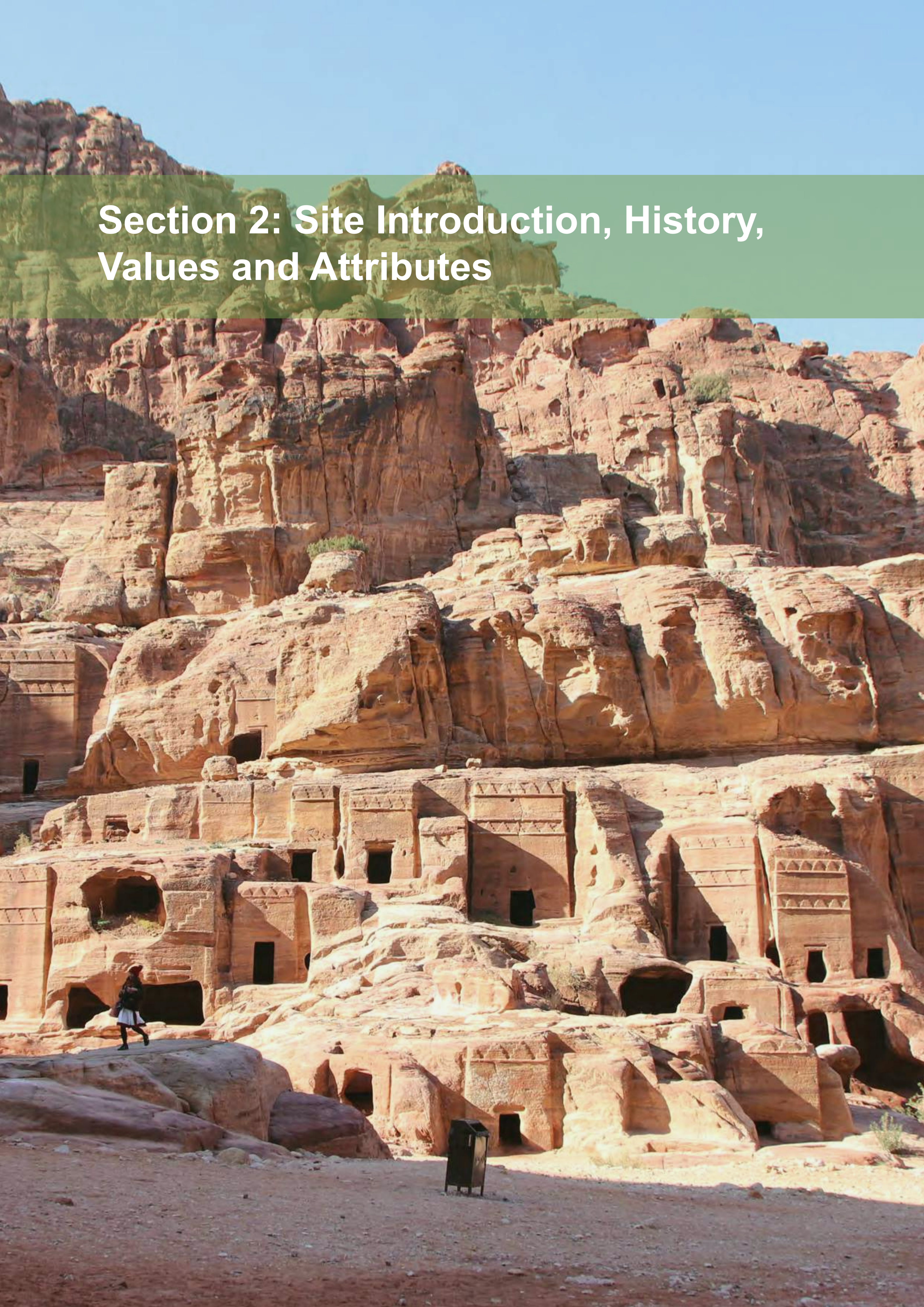
Figure 7: Icons used during the workshop for key terms and concepts

During both the focus groups and the workshop, participants were asked to rank the different components of the assessment using a relative scale of none, low, moderate, and extreme to rank potential impacts, and none, low, medium and high for the adaptive capacity of Petra and surrounding communities (Table 2). The decision to use relative rankings was based on previous experiences, which strongly showed that participants are better able to assess more complex and situational concepts in relative terms. This allows participants to prioritise responses in an applicable and real-world manner suitable for decision making. It also satisfied the precautionary principle by making decisions in the present without causing delay. These components are outlined in Table 3.

> 'The workshop experiences was wonderful and very useful. It provided enriching valuable insights into the gravity of climate change and the necessity for proactive measures to safeguard Petra's rich heritage and communities'
>
> *Etedal Al-Hasanat, PhD, Workshop Participant*

Following the workshop, a survey was carried out of participants using mobile phone messaging. This ensured a broader response from all participants. Questions including validating workshop findings and assessing how participants felt about the methodology. A summary of results is presented in figure 6.

Section 2: Site Introduction, History, Values and Attributes



Section 2: Site Introduction, History, Values and Attributes

▶ An Introduction to Petra

Petra was a Nabatean city established in the 4th Century BC. Skillful in carving, trade, and water management, the Nabateans established Petra (known locally as Raqmu or Raqēmō) as a bustling and important trading centre. It was a long-lived urban centre, continuing through the Roman and Byzantine periods. While always known to locals, the site was brought to global attention by the Swiss traveller Johann Burckhardt in 1812.

The water management technology at Petra has been widely studied (Ortloff 2005), as the hydraulic Nabataean technology "is inextricably linked to the history of Petra" (Comer, 2015, 231). In fact,Mansour Shqiarat from the Department of Archaeology, Al Hussein Bin Talal University, in his study on Nabataean hydraulics, focused on examining the collection, distribution, and strategic engineering of the Nabataean water management in Petra. Traditionally viewed as a practical resource, this study explores the role of water in relation to Petra's establishment as an urban settlement, with emphasis on irrigation, storage, and the significance of the Siq. The paper details the water management system, encompassing methods, controlling devices, and using water sources during the Nabataean period (Shaqirat, 2019).

Geologist Nizar Abu Jaber and his colleagues studied the implementation of terracing and a flood control system that provided a unique opportunity to study landscape changes from the Late Iron Age until the modern era. They focused on the Hremiyyeh catchment, which flows into the core of the Petra archaeological site, and gave insights into human settlement in the region. The study thoroughly documented the ancient city's topography, geology, and archaeology, along with dating terraces construction. It revealed that the hydrological interventions, beginning in the Late Iron Age, intensified during the Nabataean and Early Roman periods; then, the abandonment of the system in the Byzantine to Early Islamic periods resulted in collapses, gullying, and bedrock downcutting. This seminal study also documented the restoration of the upper terraces built in the 11th century CE, possibly by nomadic settlers (Abu-Jaber et al., 2022).

Much ink has been spilled on the topic of water management at Petra in recent decades proposing a wide range of recommendations and approaches (see Abdelal et al 2021) Comer (2015) highlights the deterioration of the water collection infrastructure around the archaeological site, and his recommendations call for a meticulous examination and subsequent implementation of strategies to redirect water flow awayfrom the site, with the main aim of mitigating the negative impact on the archaeological remains associated with the ongoing deterioration of the water collection and management system.

Previous Page Photo By: Khansa Bouaziz, 2023

Petra as a World Heritage site

Petra was inscribed as a World Heritage site in 1985 for its outstanding universal value (OUV) to all humanity. It was inscribed under criteria (i), (iii), and (iv) of the World Heritage Convention as a masterpiece of human creative genius that bears exceptional testimony to a past cultural tradition and is an outstanding example of a type of building, architectural or technological ensemble which represents an important period of human history. All WH sites have a statement of OUV that outlines how the property meets one or a selection of the criteria of the WH Convention. This is a very valuable document as it outlines key heritage values and attributes to justify the inscription. Preserving these values lies at the core of WH site management as a loss of OUV can lead to the removal of the site from the WH List. The Statement of OUV for Petra can be seen in Appendix 3. The key values and attributes outlined in the Statement of OUV centre on three main areas. These are outlined in table 4.

Table 4: Key values and attributes extracted from the UNESCO WH Statement of OUV [2]

Key Value	Attribute
The importance of Petra as a nexus for trade and exchange in the region between the fourth century BC and the first century AD	The fusion of local Nabatean, Assyrian, Hellenistic and Byzantine architectural styles evident in buildings and tombs throughout the site
The ingenious water management system which allowed the city to thrive in an arid environment represents an outstanding example of water management from the first centuries BC to AD.	The remnant channels, tunnels and diversion dams that combined with a vast network of cisterns and reservoirs which controlled and conserved seasonal rains
The unique architectural achievement of the city manifests in the integration of architecture and landscape.	The dramatic Nabataean/Hellenistic rock-cut temple/tombs approached via a natural winding rocky cleft (the Siq), which is the main entrance from the east to a once extensive trading city, represent a unique artistic achievement

The statement of OUV also outlines management and conservation challenges that risk impacting the integrity of the site. These include over-tourism, wind erosion exacerbated by overgrazing, flash flooding, and local development. All of these factors arose during the focus groups and subsequent workshop, and were considered within the context of climate risk at the site.

[2] https://whc.unesco.org/en/list/326

Figure 8: Majed Al Hassanet discussing the results of the focus groups with the local participants (Photo: Khansa Bouaziz,2023)

▶ The Wider Landscape of Petra

In 2017, Petra joined Jordan's National Protected Areas Network, which acknowledges the importance of Petra's ecosystems as home to more than 750 plant and animal species in addition to the site's historical and archeological features. The Protected Areas Network, part of UNDP's "Mainstreaming Biodiversity Conservation in Tourism Sector Development in Jordan (BITS)" and supported by the Global Environment Facility and implemented in Petra by the Petra Development and Tourism Region Authority (PDTRA), is also an important step towards designating the landscape nature reserve.

Designating Petra as a part of the Protected Areas Network highlights the value of biodiversity as an asset for tourism promotion in Petra, the need to monitor and manage the impacts of tourism within Petra, and the need to enhance conservation and create public awareness about the sensitivity of Petra's unique biodiversity. It is worth mentioning that the earliest management plans for Petra Archaeological Park emphasised the need to conserve biodiversity in this area; however, little attention was given to the implementation of these recommendations. The nomination area lies along one of the world's largest bird migratory flyways. Soaring birds in particular (such as raptors, storks, and ibises) make use of the warm thermals provided by the deep wadis all along the Rift Valley (Wadi Araba) flyway during their migration between Europe and Africa. This makes Petra an attraction site for bird watchers from all over the world.

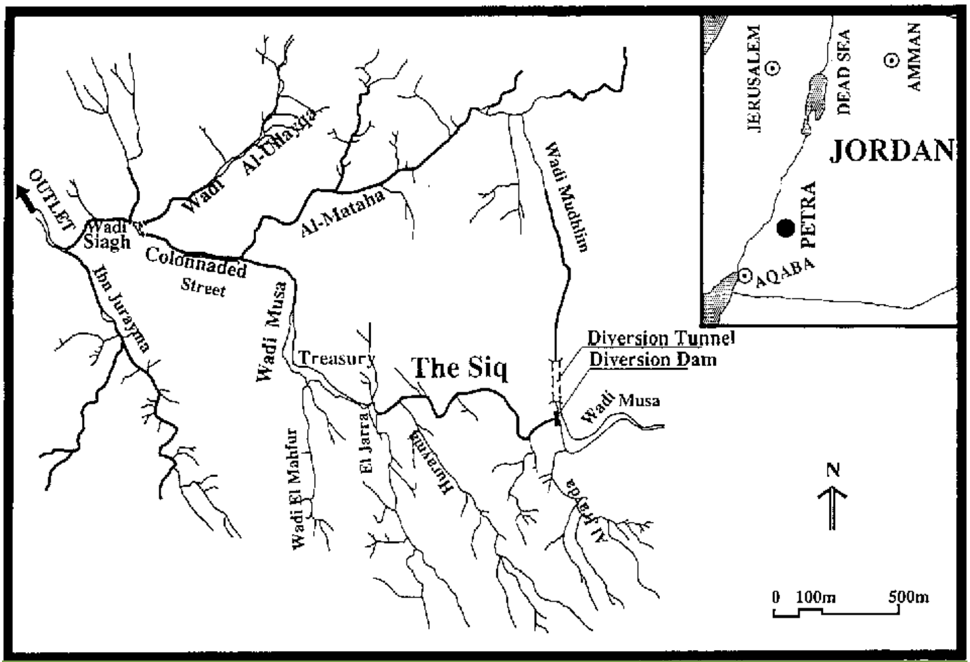


Figure 9: The Petra water catchment (Source: Al-Weshah et al, 1999,170-177)

Petra holds significant geomorphological importance within the desert landscape. The southern Jordanian region of Wadi Rum bears remarkable similarities to Petra, featuring a stunning array of sandstone mountains and valleys adorned with extraordinary natural arches. The monuments of Petra are concentrated in the lowest part of the drainage area, where various water courses (wadis) converge. The primary wadi, Wadi Musa, lends its name to the town adjacent to Petra. Constructed and carved by the Nabataeans over 2,000 years ago, these monuments reside in sandstone canyons protected by limited and narrow accesses, such as gorges. The primary access gorge, known as the Siq, is a narrow passage bound by high cliffs, often only a few metres wide and exceeding 60 metres in height. With an average bed slope of about 5%, the Siq is susceptible to flooding during heavy rainfall storms occurring upstream. Despite the downstream area remaining hot and dry, a flood wave can unexpectedly inundate both the Siq and various monuments in Petra without adequate warning. To mitigate such floods, the Nabateans engineered a dam at the Siq's entrance and a tunnel to divert flood waters away from this narrow passage.

Petra is situated within the Northern Wadi Araba surface water basin, covering an overall catchment area of approximately 50 km². Divided into nine sub-catchments upstream of Wadi Siagh before its confluence with Wadi Seg El-Ghurah, the catchment exhibits similar spatial distributions of rocks and soil cover. Two main lithological units, the Ajloun formation consisting of marl-limestone alternation outcrops and the Kurnub, Disi, and Umm Ishrin sandstone formations with barren outcrops, define the landscape. This intricate natural setting emphasises the historical and environmental significance of Petra's catchment area, showcasing the delicate balance between cultural heritage and natural forces.

▶ Community Values and Key Values for the Risk Assessment

During the focus groups and workshop, the heritage and wider landscape values were presented to participants who were also asked to identify what values they felt were most important. A list of key values is outlined in Table 5 which also provides an explanation of each value and examples of associated attributes.

Table 5: A summary of key values and attributes as identified by focus group and workshop participants and discussed during the workshop

Key Value	Explanation	Attributes
Economic values (Agriculture)	The importance of the wider landscape as a source of food	Terrace and field structures in and around the site
Natural values	The importance of the wider natural landscape, its fauna and flora and its geological formations.	Natural features including flora and fauna and geological formations, mountains, gorges and natural water systems
Heritage and archaeological values	The global significance of the WH site as a centre for trade and the exchange of ideas and its outstanding architecture and hydraulic system.	The WH site and its rock-cut structures, key buildings which show the interface of different cultures and its hydrologic systems as outlines in the statement of OUV
Economic Values (Tourism)	The importance of direct revenue from visitors to the archaeological site	The archaeological site and the rock-cut buildings in particular
Economic Values (Local businesses)	The importance of indirect revenue from visitors to the archaeological site	The archaeological site and the rock-cut buildings in particular. Also, Wadi Musa and the surrounding landscape where tourists stay.
Political Values	The importance of Petra as a political centre in the past	The impressive structures in the archaeological site, in particular those which speak to the international connections and importance of the site.
Religious Values (Zwarah)	The importance of religious sites to the local community.	Different buildings including Ayn Musa and the Jebel Harun (Tomb of Aaron).
Planning values	The importance of past infrastructure to manage the site and as a global exemplar of water management and security.	Infrastructure associated with water management and flood management, for example. Cisterns, dams and water channels.

During the workshop, participants were asked to rank these values in terms of importance to different stakeholder groups. Four key values emerged: The economic values associated with tourism at the World Heritage site; the economic values associated with agriculture in the wider Petra landscape; the archaeological and historical values associated with the World Heritage site; and the natural values and the wider landscape in and around the World Heritage site. Potential impacts to these values formed the core of the climate risk assessment outlined in the proceeding sections.

1. Economic Values Associated with Tourism at the World Heritage Site

The economic values and benefits of Petra as a World Heritage Site tourist destination were identified as the most important value for the local community. This included the direct revenue from ticket sales at the site and the indirect revenue from local businesses, including hotels, restaurants, tourist souvenir shops, and transportation. It was felt that a loss of these values would have disastrous repercussions to the local community. The recent global health pandemic was often cited as an example of the impact of a decrease in tourism.

Attributes: The sandstone carved historic buildings, the Siq and the cultural and natural landscape, which people from all over the world come to visit. The loss of these attributes would result in damage to the economic value of the site.

Figure 10: Tourists in the Al-Siq, Petra (Photo: Michael O. Snyder 2023)

2. Economic Values Associated with Agriculture in the Wider Petra Landscape

The importance of agriculture to the community was regularly mentioned. This included foodstuffs like fruit, vegetables and grains, but also medicinal plants which were a source of revenue for many. Agriculture is not a permanent occupation for many but most people retain some land and work the land with family to provide food.

Attributes: Field systems, terraces, olive groves, and fruit trees as well as wells, cisterns, and hydrological elements used to facilitate agriculture in and around the Petra site. Special plants with historical and contemporary medicinal use within the community.

3. Archaeological and Historical Values Associated with the World Heritage site

The global significance and importance of the World Heritage Site was identified as a key value, both to stakeholders directly involved in heritage management, staff from the PDTRA, and the wider community, who expressed deep pride at its value to others. The values are wide-ranging and include research and scholarship of Petra's archaeology and engineering.

Attributes: The sandstone carved historic buildings and the cultural landscape and the built structures (temples, roads, bathhouses, etc.). This includes the different historic layers including Nabatean, Roman, etc.

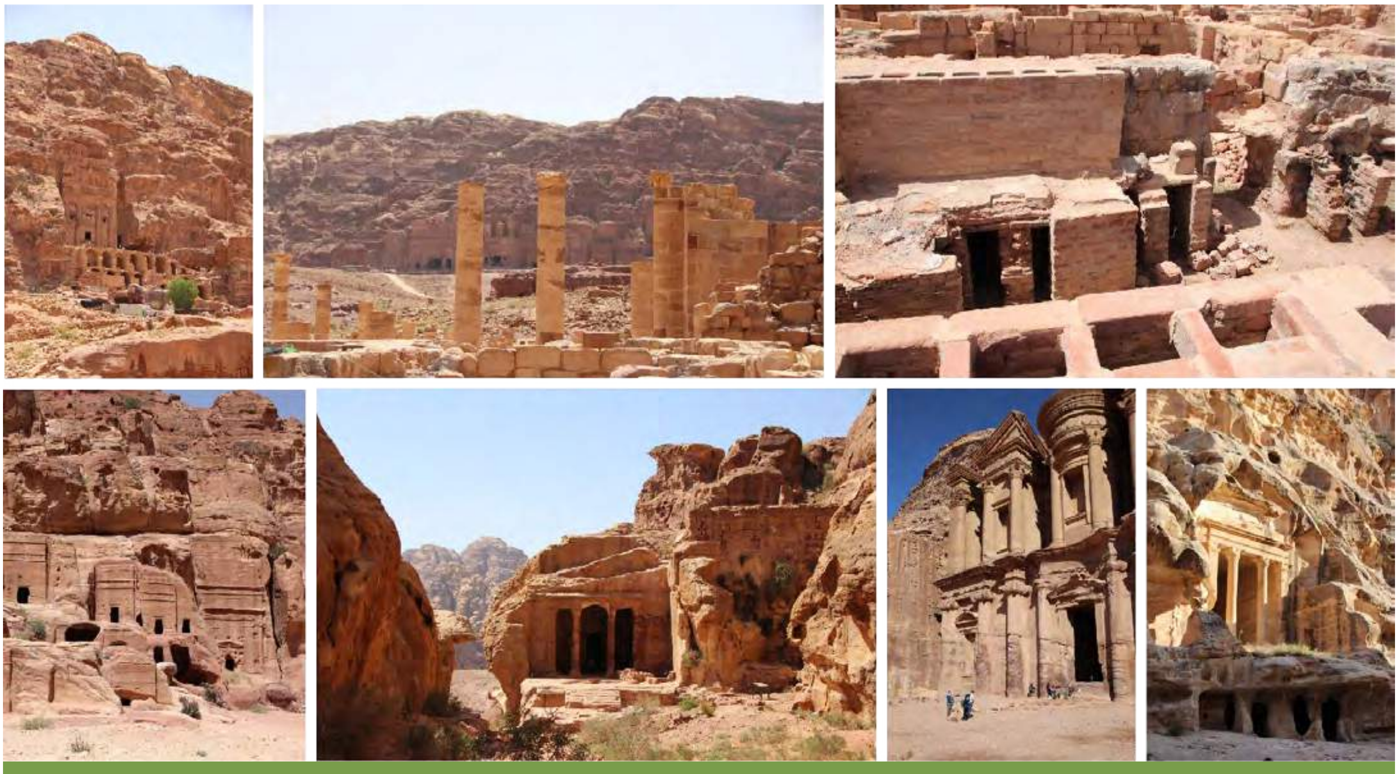


Figure 11: Examples of monuments at the archaeological site (Photos: Khansa Bouaziz, 2023)

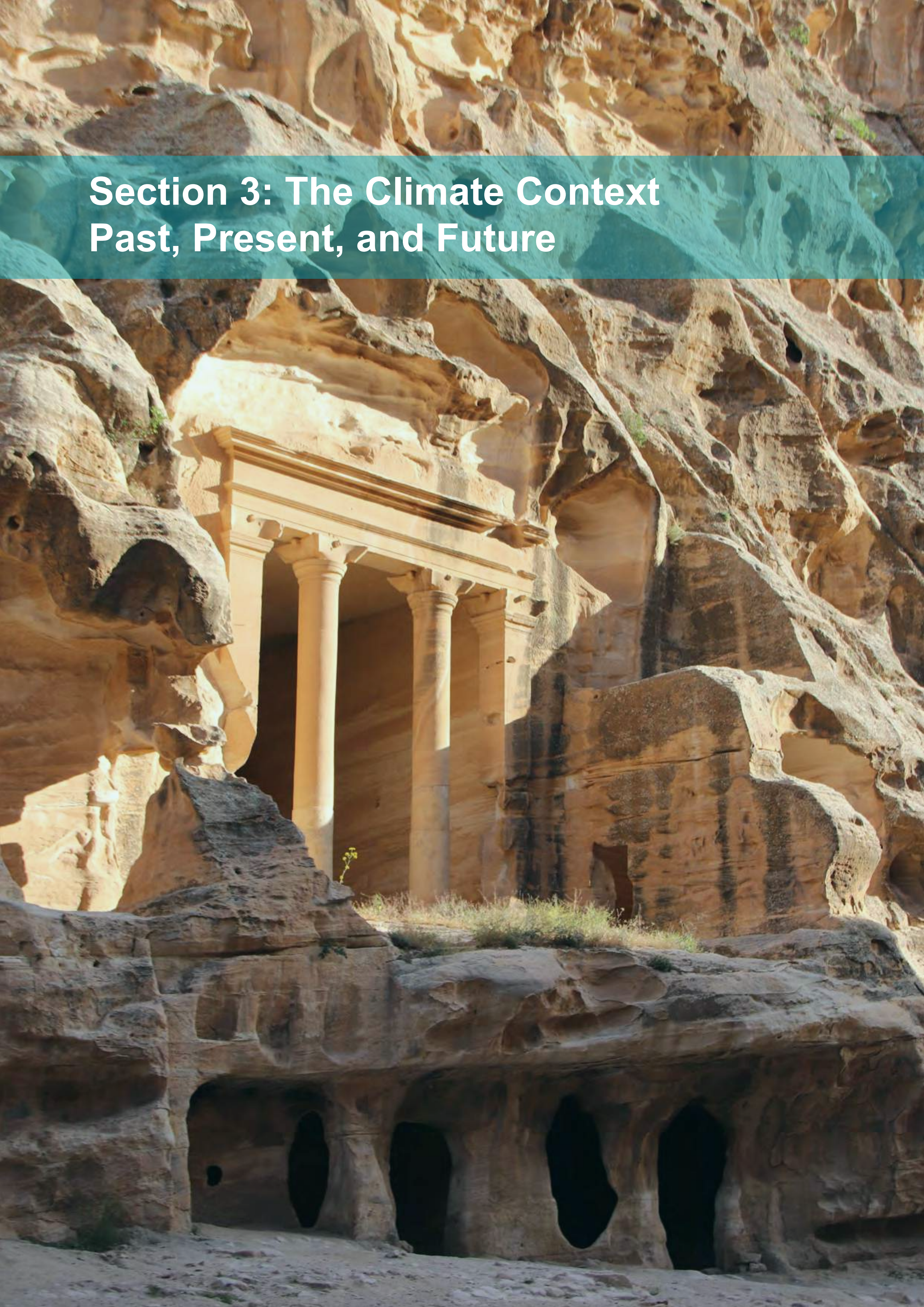
4. Natural Values and the Wider Landscape in and Around the World Heritage site

The significance of the wider natural landscape of the World Heritage Site was identified as a key value, which is often overlooked due to the predominant focus on cultural aspects of the site. It was noted that these values may too be outstanding; however, were not included in the original inscription of the site. The nature-culture divide was regularly cited as an obstacle to fully appreciate the natural values of the area.

Attributes: The environment and biodiversity (fauna and flora) of the site including plants, trees, and animals and their ecosystems. Also, geological formations, mountains, gorges and natural water systems.

Figure 12: The stunning geological formations of the Petra landscape (Photo: Will Megarry, 2023)

Section 3: The Climate Context Past, Present, and Future



Section 3: The Climate Context Past, Present, and Future

► Introduction

This section highlights the administrative, geographic, and climatic characteristics of the Hashemite Kingdom of Jordan with a specific focus on climate change in the iconic World Heritage Site of Petra. The Hashemite Kingdom of Jordan, situated at the heart of the Arab world and the Middle East, is a nation deeply rooted in the concept of pan-Arabism. Jordan is part of the Mediterranean Region, located approximately 80 km east of the Mediterranean Sea. The country's unique topographic nature is shaped by its position between 29°10’-33°45’N and 34°55’–39°20’E, resulting in a predominantly Mediterranean climate characterised by hot and dry summers and wet and cool winters. Jordan is divided into twelve Governorates encompassing various districts and sub-districts. Each Governorateis overseen by a Governor appointed by the King through the Minister of the Interior, establishing them as local extensions of the central government. Governors are entrusted with maintaining law and order in their respective areas. These Governorates, including Amman (the capital), Irbid, Zarqa, Mafraq, Ajloun, Jerash, Madaba, Balqa, Karak, Tafileh, Ma’an, and Aqaba, play a crucial role in the country's governance (see the map below Figure 13). Petra is situated in the Ma'an Governorate of Jordan.

Despite its relatively small size (89,213 square kilometres), Jordan showcases a diverse terrain reminiscent of larger countries. The topography and landscape are influenced by factors such as geography, historical influences, geopolitics, and the constraints of natural resource scarcity. Notably, approximately three-quarters of the country is characterised by desert landscapes, marked by five principal physiographic regions that extend in a north–south alignment: the tropical desert in the central Ghor or rift valley; the escarpments and mountain highlands east of the Ghor; arid plains; the Badia; and the Azraq; and Wadi Sirhan depression. These regions correspond to five major morphological zones (Ababsa, 2013):

1. Jordan Valley and Wadi Araba Rift (Ghor): This distinctive landscape is part of the Rift Valley, extending from North Syria to East Africa. The Jordan Depression, running from Wadi Araba to the Dead Sea, features significantly lower elevations than the eastern Highlands. The area is marked by the lowest depression on earth, including the Jordan River and the crucial Jordan Valley, considered the food basket of Jordan.
2. Highlands at the Eastern Edge of the Wadi Araba-Jordan Graben: This landscape, known as the Mountain Ridge and Northern Highlands, exhibits tectonic activity and structural movements. The northern Highlands extend through various mountains and deep wadis, hosting natural forests and landmarks like Wadi Rum.

Previous Page Photo By: Khansa Bouaziz, 2023

3. Central Desert Areas of East Jordan (Arid Plains): Encompassing plains between the Badiya and the Highlands, this landscape features distinctive flat or gently sloping terrain with chert rock cover. It includes the Depression of al-Jafr and rises to the escarpment of Ras al-Naqab.

4. Badiya Region (North-Eastern Desert): Covering 90% of Jordan, this extensive region meets the Arabian Desert and consists of the Northeast Jordanian Basalt Plateau and Limestone Plateau. Sparse vegetation, low rainfall, and diverse characteristics define this region.

5. Azraq-Wadi Sirhan Depression: This landscape rises gradually from 500 m to 700 m in the southeast, collecting water from adjacent wadis. Historically important, it served as a trade route between the Highlands and the Arabian Peninsula.

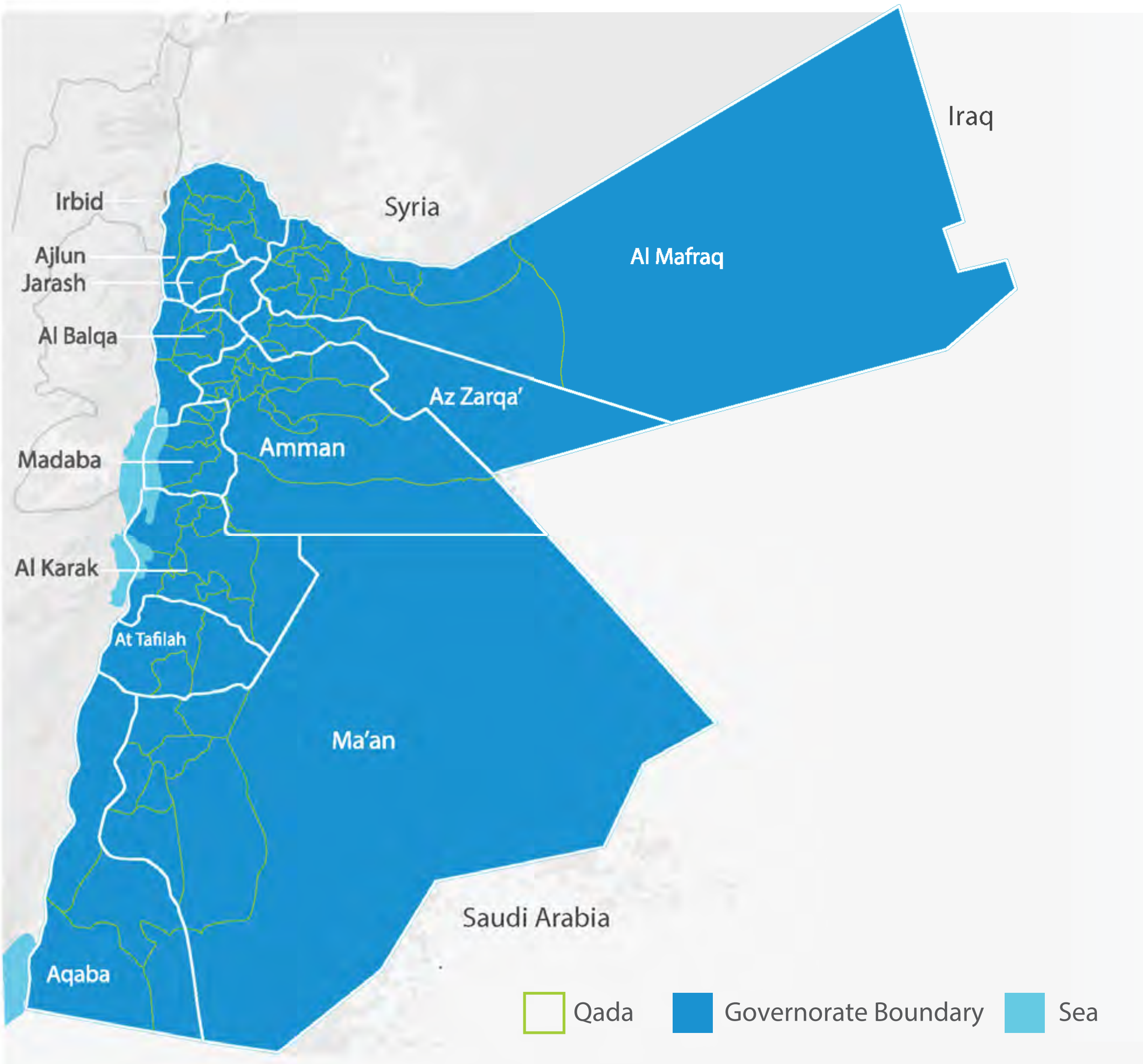


Figure 13: Map of the twelve Governorates of the Hashemite Kingdom of Jordan (The Hashemite Kingdom Of Jordan, 2015)

Climate Dynamics and Future Projections in Jordan: An in-Depth Scientific Analysis

Introduction to Jordan's Climate

Predominantly originating from the Mediterranean, depressions and air masses play a crucial role in defining Jordan’s climate, particularly during December and January when they coincide with polar air masses from northern Europe. These interactions significantly contribute to the dynamic and often unpredictable weather conditions experienced in the region. Moreover, during the summer, a notable low-pressure belt prevails over North Africa, extending across the Arabian and Indian Oceans. This belt attracts hot and dry northerly continental tropical air masses from high-pressure centres over Mesopotamia and Asia Minor, contributing to the overall climatic dynamics of the area.

The transitional seasons of spring and autumn introduce the phenomenon of 'Khamsin depressions' or 'Saharian depressions' influencing shifts in weather patterns during these periods. The impact of Khamsin and Shammal winds plays a defining role in shaping Jordan's climate. Khamsin Winds, also referred to as Dry Sirocco , emanate from the south or southeast, primarily manifesting in spring and autumn. Notorious for inducing substantial temperature anomalies, these winds can lead to rapid temperature increases of up to 15°C, significantly affecting the region. Khamsin winds are characterised by strong winds, dust clouds, and swift temperature rises, persisting for approximately a day and posing challenges such as discomfort and threats to crops through desiccation.

Meanwhile, the Shamal winds, originating from the north and northwest as a dry continental mass of polar air, dominate the summer months, specifically from June to September. Exhibiting remarkable steadiness during daytime hours and transforming into a gentle breeze at night, Shamal winds persist for extended durations. They contribute to elevated daytime temperatures, gradually moderating after sunset. While Khamsin Winds are noted for their rapid and intense nature, Shamal Winds exhibit a steadier and more persistent pattern during specific seasons, each playing distinctive roles in shaping Jordan's climate.

Temperature patterns showcase distinctive variations across Jordan's diverse landscapes and contribute to the diverse climate experienced throughout the country. They rise rapidly from dissected plateaus to very low-level graben, increase gradually from dissected plateaus to the eastern margins of the eastern desert, and decrease gradually from north to south with increasing altitude. The annual temperature ranges display substantial variation, with different regions experiencing specific temperature brackets. Jordan's seasonal characteristics manifest prominently, with a peak in the long summer observed during August, while January marks the coolest month. Notably, temperature variations during a 24-hour period are most significant in the summer months, intensifying with higher elevation and distance from the Mediterranean coast.

A comprehensive grasp of these climatic intricacies is imperative for effective management of climate change-related challenges, strategic planning in tourism and agriculture, and overall preparedness to navigate the dynamic and diverse weather conditions prevalent in Jordan.

Climate Change Hazards in Jordan

Jordan faces various climate hazards, such as extreme temperature, droughts, flash floods, storms, and landslides. These hazards are likely to increase in frequency and intensity due to climate change. Since the 1980s, Jordan has witnessed three significant flood events in 1987, 1991, and most recently in 2018 (The World Bank Group, 2021). Flash floods pose a serious threat to densely populated urban areas like Amman, the heritage site of Petra, and Aqaba, jeopardising lives and causing extensive damage to infrastructure, agricultural lands, and properties.

Landslides and erosion have been particularly concentrated in steep mountain slopes and wadis. The impending impact of climate change necessitates comprehensive adaptation planning across sectors like agriculture, coastal areas, biodiversity, urban environments, society, water resources, and health.

Jordan's diverse geography and climate pose both challenges and opportunities. With climate change intensifying hazards, adaptation planning is crucial to ensure resilience across various sectors. Understanding the country's unique topography and administrative structure is fundamental for effective governance and sustainable development.

Future Climate Scenarios in Jordan

In preparing the 4th National Communication report for the Hashemite Kingdom of Jordan, the research team conducted a detailed analysis of future climate projections using advanced modelling techniques. These projections are formulated under two scenarios, namely RCP 4.5 and RCP 8.5, utilising the de-biased and validated reference Regional Climate Models (RCM) (The Hashemite Kingdom Of Jordan, 2015). The future prediction maps for various climate indices are generated using the co-kriging technique in conjunction with local Digital Elevation Model (DEM) data (The Hashemite Kingdom Of Jordan, 2015). For clarity, the presentation condenses long-term climate variables into three temporal horizons: 2020-2050, 2040-2070, and 2070-2100.

The subsequent sections provide a concise overview of the primary findings derived from future projections related to all climate variables, followed by the implications of the climate forecasts for air temperatures, precipitation, relative humidity, wind speed, potential evapotranspiration, and other key variables. Each of these variables, integral to the climate scenario, contributes significantly to a comprehensive understanding of the challenges and opportunities that lie ahead for Jordan in the face of changing climate conditions.

Table 6 details the temporal evolution of future forecasted climate variables across short, medium-medium-, and long-term durations, offering a comprehensive insight into anticipated climatic changes. In the historical period from 1990 to 2020, Jordan experienced an average precipitation of 219.85, punctuated by maximum (Tmax) and minimum (Tmin) temperatures of 25.34°C and 12.49°C, respectively. The intricate interplay of environmental elements included a relative humidity of 44.34%, a wind speed averaging 4.68 m/s, potential evapotranspiration registering at 2529.62, and heatwave-degree-days count of 143.38.

Climate change scenarios (RCP 4.5 and RCP 8.5) paint a dynamic portrait of variability over short-term (20-50 years), medium-term (40-70 years), and long-term (70-100 years) periods. These projections illuminate the nuanced and evolving nature of Jordan's climate, urging a holistic perspective in addressing future challenges and opportunities. Under the RCP 4.5 scenario, short-term projections signify a dip in precipitation to 184.47 mm, accompanied by intensified maximum and minimum temperatures (25.87°C and 13.07°C), underscoring the pressing need for adaptive strategies. Conversely, the RCP 8.5 scenario foresees a contrasting narrative, with a substantial precipitation surge (201.56 mm) and profound shifts in various climatic parameters, emphasising the imperative for comprehensive climate change mitigation and adaptation policies across diverse time frames. As Jordan navigates these evolving climatic dynamics, fostering resilience and sustainability becomes not only a strategic imperative but a pivotal aspect of safeguarding the nation's ecological integrity and socio-economic well-being.

Table 6: Summary of the future climate forecasts regarding short, medium, and long terms: Precipitation (Pcp), Maximum Temperature (Tmax), Minimum Temperature (Tmin), Relative Humidity (RH), Wind Speed (WS), Potential Evapotranspiration (ETp), and Heatwave (HW) (The Hashemite Kingdom Of Jordan, 2015)

		Pcp	Tmax	Tmin	RH	WS	Etp	HW
Historical Period 1990 - 2020		219.85	25.34	12.49	44.34	4.68	2529.62	143.38
RCP 4.5	Short Term (20-50)	184.47	25.87	13.07	42.81	4.68	2600.03	209.08
	Medium Term (40-70)	185.15	26.24	13.48	42.54	4.68	2643.15	240.15
	Long Term (70-100)	178.36	26.50	13.72	42.23	4.67	2646.89	290.35
RCP 8.5	Short Term (20-50)	201.56	26.13	13.42	42.93	4.63	2612.92	221.85
	Medium Term (40-70)	158.13	26.97	14.07	40.65	4.63	2687.88	304.69
	Long Term (70-100)	111.88	28.43	15.26	38.02	4.58	2782.01	480.27

Future Air Temperature Projections

Jordan is expected to face a warmer climate by the year 2100. The projections indicate a significant likelihood of the minimum air temperature to rise by +1.2 °C [+0.6 °C to +2.9 °C] under RCP 4.5 (Table 6). Simultaneously, the maximum air temperature is expected to rise, with an extremely likely increase of 1.1 °C [+0.7 °C to +1.7 °C] under RCP 4.5 (Table 6). To assess the spatial and temporal exposure risks, the projected differences in average maximum and minimum air temperatures for the three-time horizons are assessed using RCP 4.5 (Figure 14 and 15, respectively).

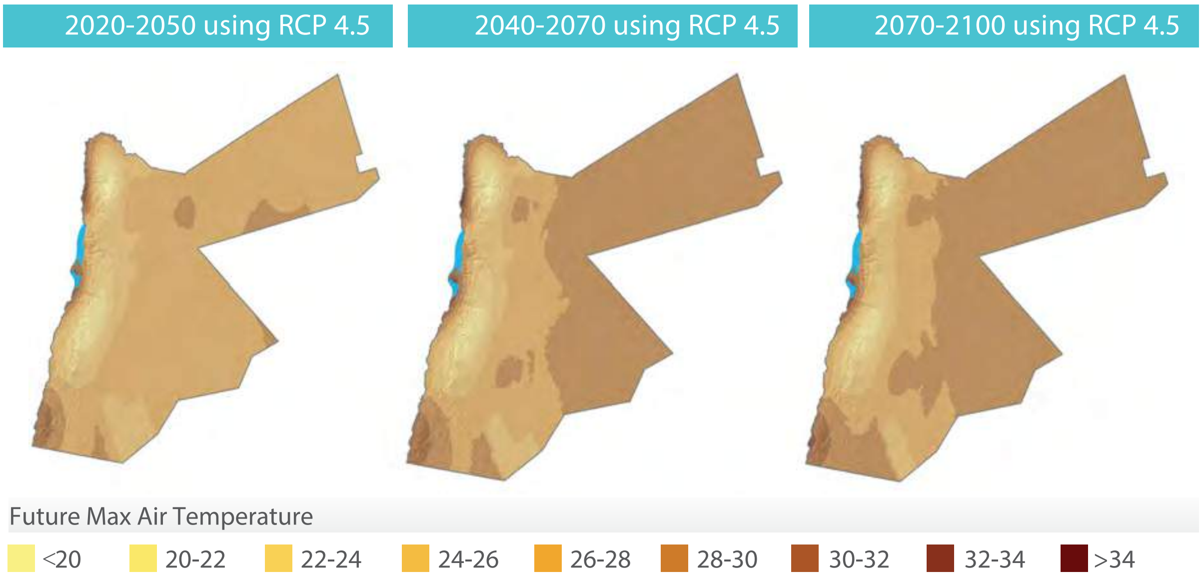


Figure 14: Project average maximum temperature for three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

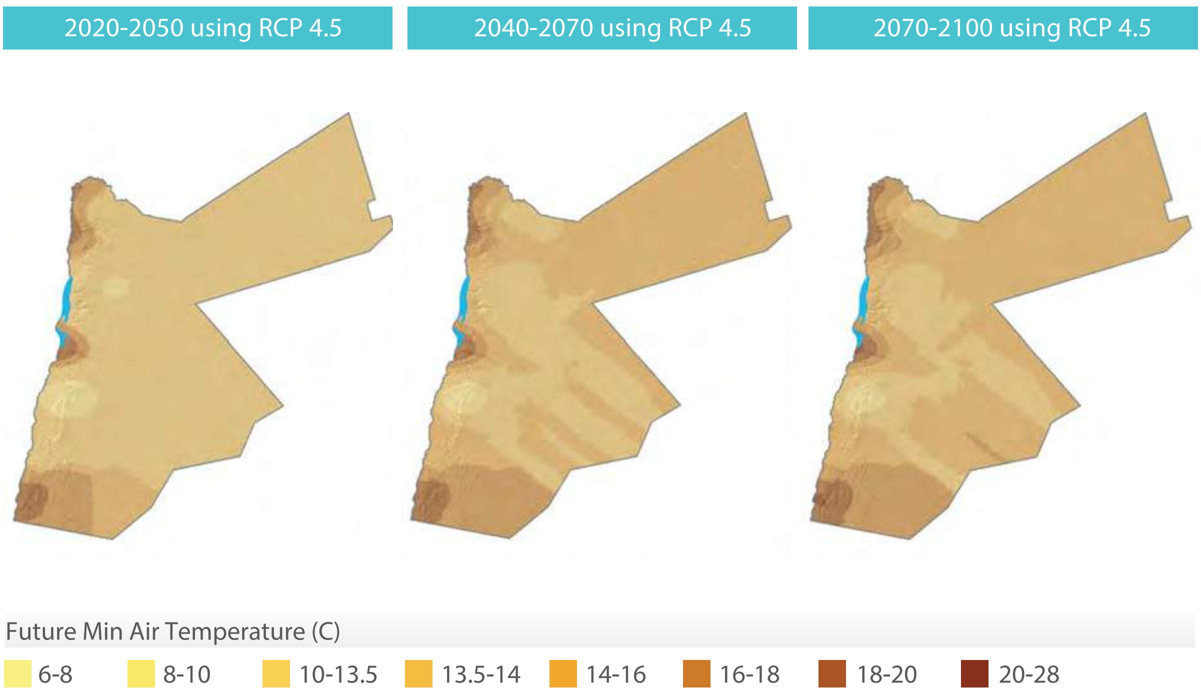


Figure 15: Projected average minimum air temperature for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

Future Precipitation Trends

According to the projections for future daily, monthly, and seasonal precipitation, the country will witness a significantly drier climate. By the end of the 21st century, the country is likely to experience a noticeable decline in precipitation. The projections suggest a decrease of 15.8% [-7.1% to -31.3%] under RCP 4.5, considering that certain areas are anticipated to receive increased precipitation, with a maximum increase of 19% under RCP 4.5. The projections highlight a pronounced likelihood of significant precipitation decrease, particularly in the western reaches of the country. Conversely, the southern arid zones where Petra is located emerge as potential beneficiaries of increased precipitation (Figure 16). To assess the spatial and temporal exposure risks, the projected differences in average precipitation for the three time horizons were mapped using RCP 4.5 (Figure 17).

2020-2050 using RCP 4.5 | 2040-2070 using RCP 4.5 | 2070-2100 using RCP 4.5

Future Precipitation (mm)

<50 | 50-100 | 100-150 | 150-200 | 200-250 | 250-250 | 250-300 | 300-350 | 350-400 | 400-450 | 450-500 | >500

Figure 16: Projected Annual Precipitation for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

2020-2050 using RCP 4.5 | 2040-2070 using RCP 4.5 | 2070-2100 using RCP 4.5

<-40 | -40 – -30 | -30 – -20 | -20 – -10 | -10 – -0 | 0 – 10 | 10 – 20 | 20 – 30 | 30 – 40 | >40

Figure 17: Projected Differences in Annual Precipitation for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

The northern part of the region, notably the Yarmouk Basin, faces a substantial maximum exposure risk. This projection carries significant implications for key sectors, particularly water and agriculture, thereby necessitating strategic planning and the implementation of adaptive measures to mitigate potential challenges.

In contrast to the challenges in the north, the Eastern and Southern Badia regions, including Petra, paint a different picture. Here, precipitation is anticipated to experience a surge, reaching a maximum of 40% compared to the historical baseline scenario by the year 2050. However, this upward trend is expected to reverse, leading to a reduction of 10% by the close of the century. Understanding and preparing for these distinct climatic trajectories in various regions is crucial for effective long-term planning and resilience building.

Future Evapotranspiration Projections

In the delicate balance between precipitation and temperature, potential evapotranspiration emerges as a linchpin, providing a perspective on the impending challenges in Jordan's water landscape. The reduction in precipitation and the increase in temperature forecast a substantial rise in potential evapotranspiration. According to the projections, a very likely increase of 5.8% [+4.7% to +6.9%] is anticipated under RCP 4.5. These figures underscore a discernible escalation in water demand, setting the stage for a critical juncture in resource management.

The short-term impacts are predicted to concentrate primarily on the southern region of the country. However, as time passes, these effects are likely to extend their reach, enveloping the western and northern Badia regions by the end of the 21st century (Figure 18). This spatial evolution is depicted in Figure 19, illustrating the projected differences in potential evapotranspiration across three pivotal time horizons for RCP 4.5.

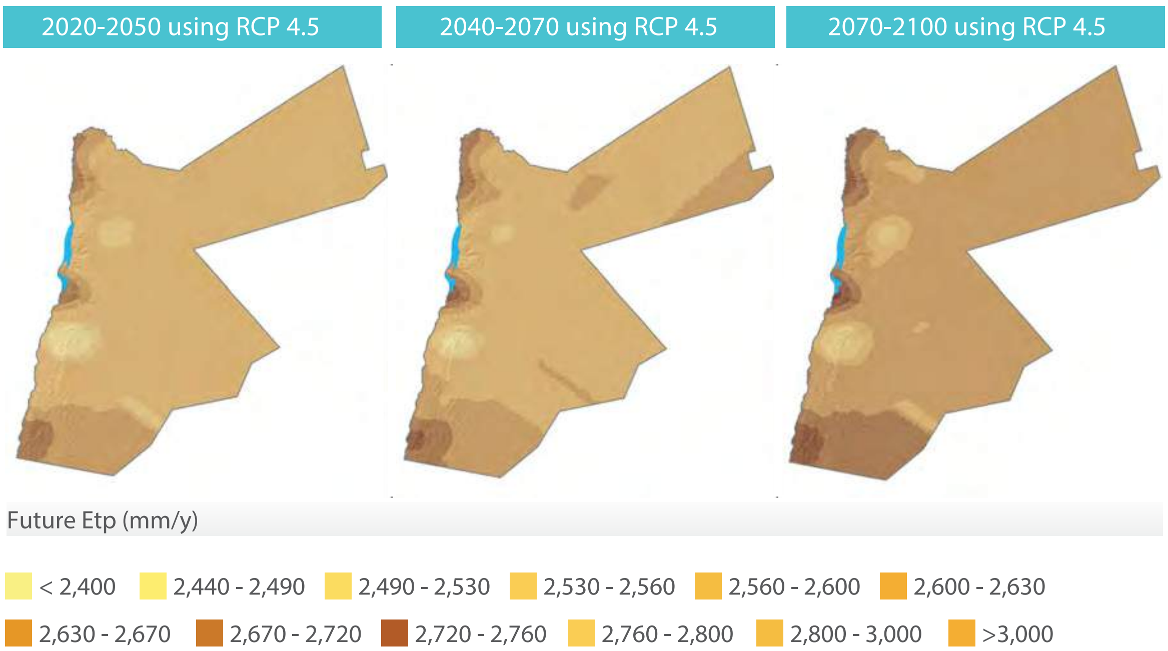


Figure 18: Projected Annual Etp for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

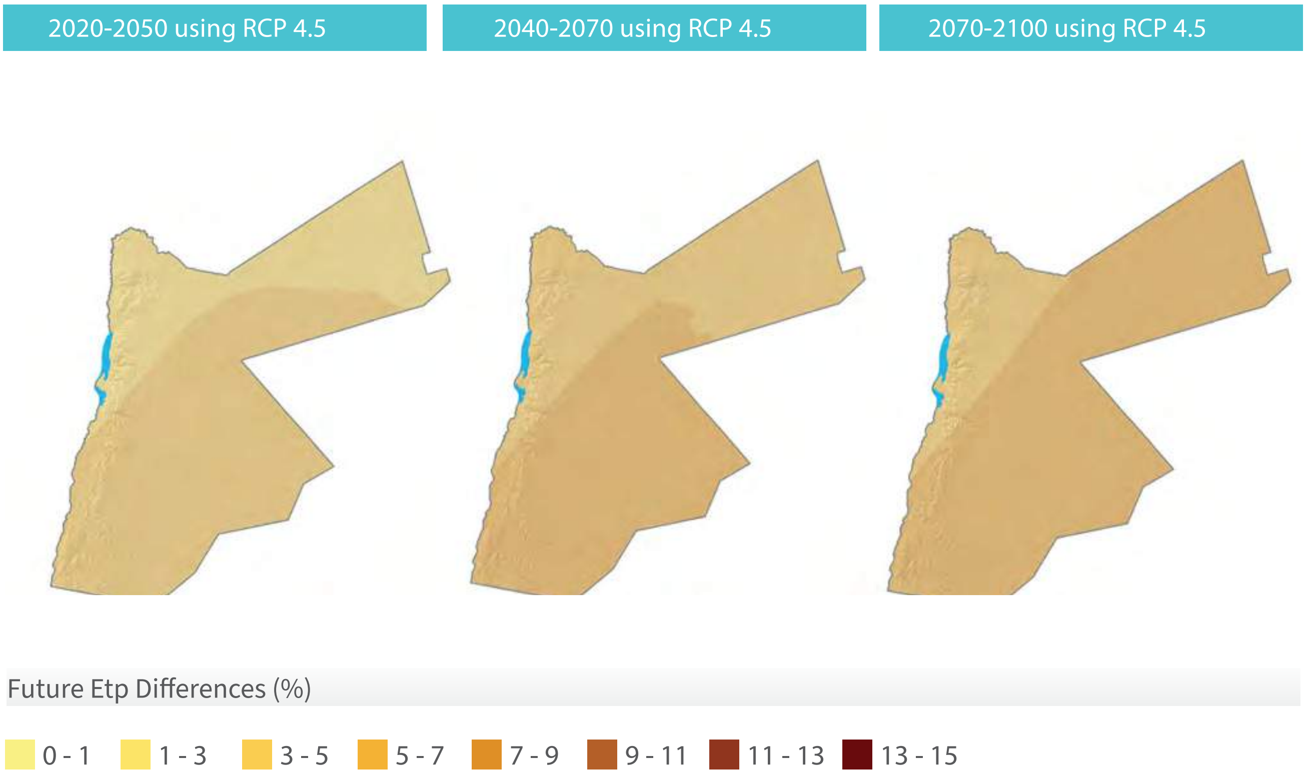


Figure 19: Projected Differences in Annual Etp for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

Future Drought Patterns

Drought was assessed using the Standardised Precipitation Index (SPI) methodology, pioneered by McKee et al. (1993). Standardised precipitation values were calculated by dividing the deviation between seasonal precipitation and the long-term seasonal mean precipitation by the standard deviation. According to the criteria proposed by McKee et al. (1993, 1995), a drought event is defined as any period where the SPI remains consistently negative, reaching an intensity of -1.0 or lower, and concludes when the SPI transitions to positive values. The severity of drought is categorised into seven classes: extremely wet (SPI > 2), very wet (1.5 to 1.99), moderately wet (1.0 to 1.49), near normal (-0.99 to 0.99), moderate drought (-1.49 to -1), severe drought (-1.99 to -1.5), and extreme drought (SPI < -2). According to the occurrence of drought events (SPI < -1), Figure 20 illustrates that throughout the historical period, the likelihood of droughts was notably minimal. The highest probability, reaching a maximum of 19%, was observed at the western border, with relatively elevated probabilities noted along the semi-arid stretch extending from the northern to the southern regions of the country.

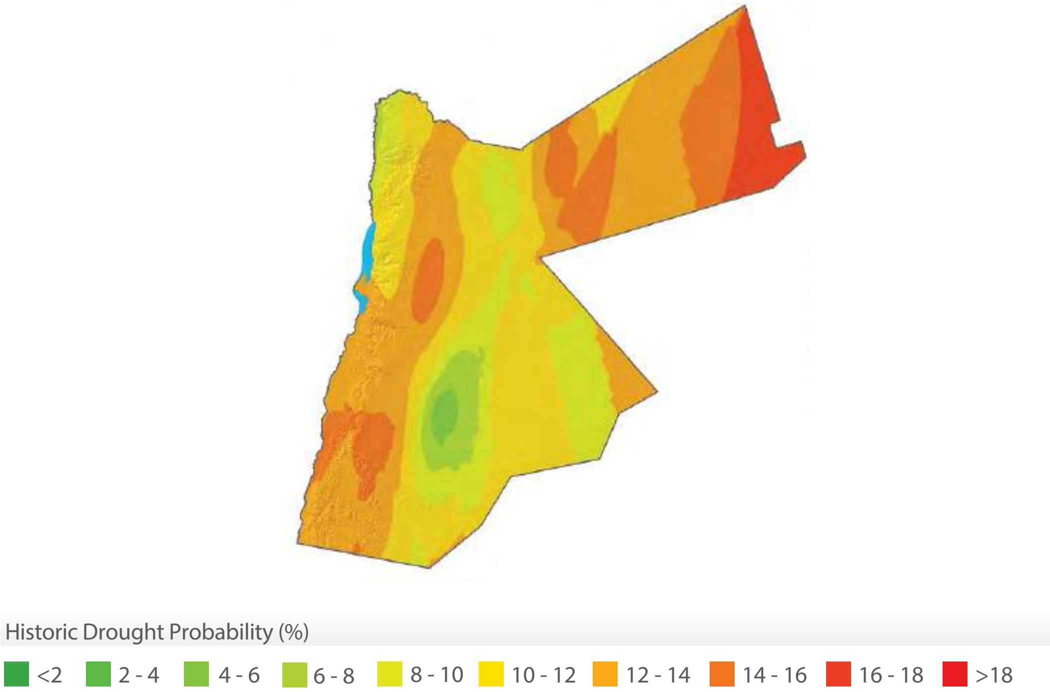


Figure 20: Historical SPI estimated by the number of drought events (The Hashemite Kingdom Of Jordan, 2015)

Figure 21 lays bare the future projections of drought probabilities under RCP 4.5. The narrative unfolds with a significant increase in drought probability until the end of the 21st century, particularly in the northern region of the country. By the end of the 21st century, the drought probability is likely to increase in magnitude reaching a maximum probability of 50% under RCP 4.5. Drought duration is likely to become longer, with more than 3 consecutive years using RCP 4.5. These projections paint a stark picture of the evolving climate landscape, urging a comprehensive understanding of the implications for water resources, agriculture, and societal resilience.

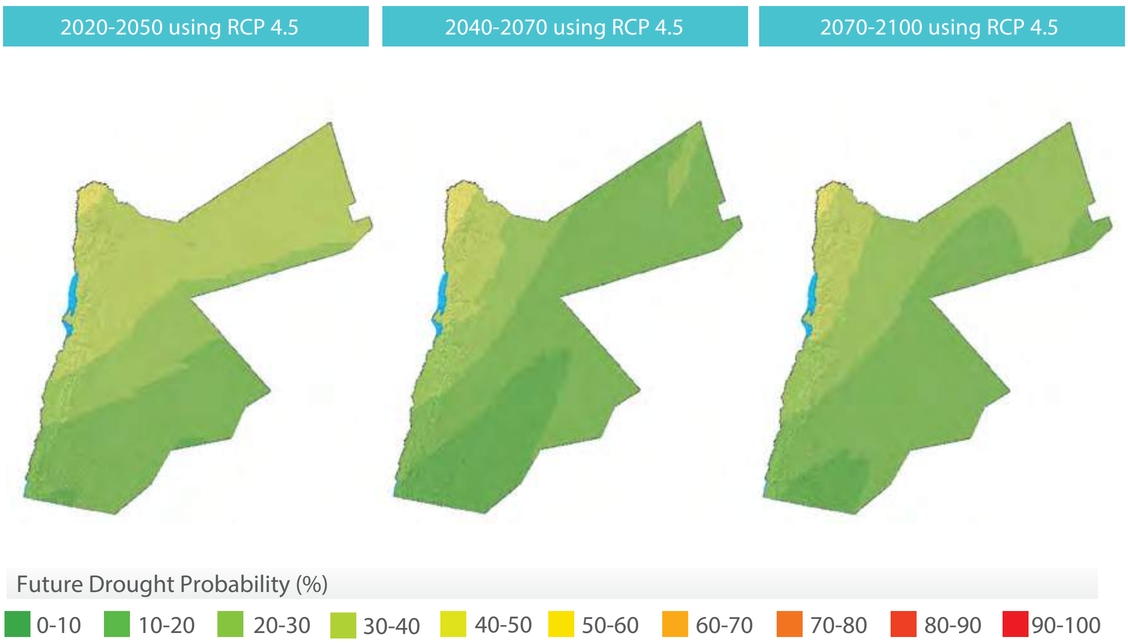


Figure 21: Projected Differences in drought probability, for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

Heatwaves: Historical Trends and Future Projections

In the realm of meteorology, the term "heatwave" conjures increasing temperatures, challenging the resilience of ecosystems and communities. Meteorologically, a heatwave manifests as a trio of scorching days, each surpassing the normal "long-term average" maximum temperature by 5°C or more. A meticulous calculation of the annual count of heatwave events unveils the changing face of this meteorological phenomenon.

Between 1990 to 2020, a significant increase ($P<0.0001$) in the number of heatwave events is observed. The linear trend analysis exposes a rise at a rate of 0.15 events per year, showcasing the intensifying impact of heatwaves. Noteworthy spatial disparities emerge, with highland regions like Madaba, Shoubak, and Queen Alia Airport experiencing heightened heatwave intensity compared to the Jordan Rift Valley and desert areas (Figure 22).

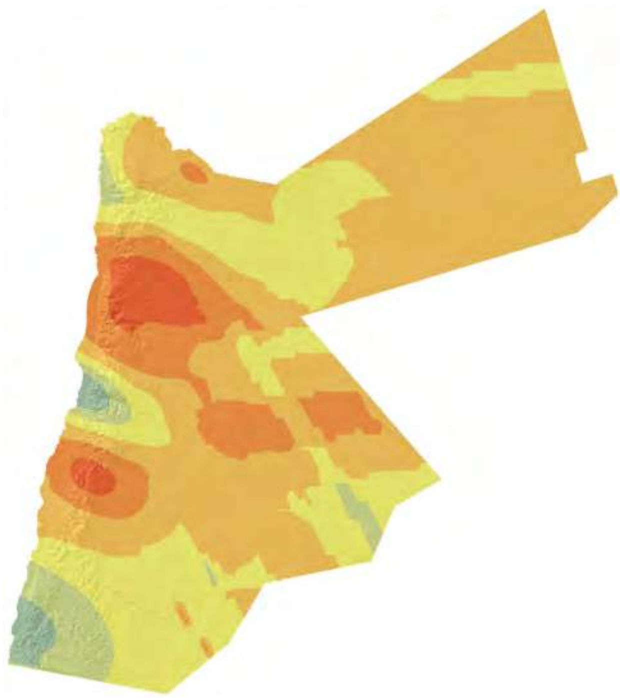


Figure 22: Historical heat waves spatial distribution in Jordan (The Hashemite Kingdom Of Jordan, 2015)

The temporal trends spotlight the prevalence of heatwave events, peaking during March, April, and May (Figure 23) which underscores the seasonality of heatwave occurrences. The future projections under RCP 4.5 predict more heatwaves, especially during the late period from 2070 to 2100. The future heatwave events are forecasted to be more severe in terms of duration and magnitude. Relative to the historical timeframe, projections for the future period (2070-2100) indicate a substantial surge in potential heat wave occurrence, with an anticipated rise of 120% under RCP 4.5. This increase varies spatially, ranging from 54% to 398% (Figure 24). The impending threat looms large, promising a landscape where heatwave exposure intensifies, and their duration becomes more formidable.

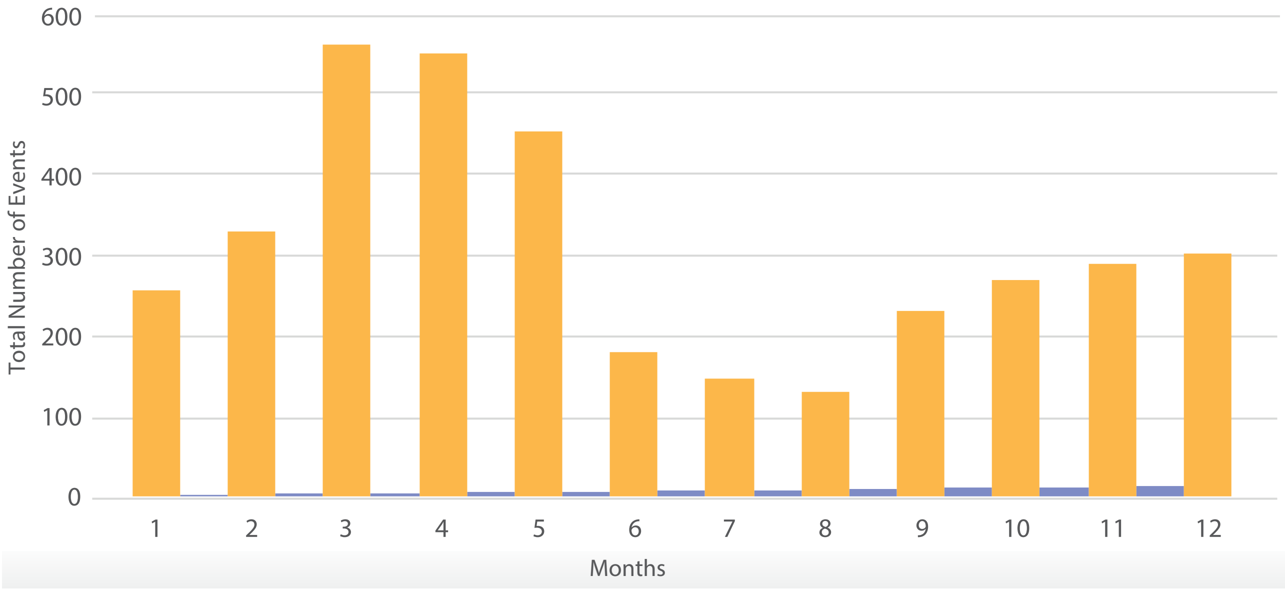


Figure 23: Historical heat waves events distribution by month in Jordan (The Hashemite Kingdom Of Jordan, 2015)

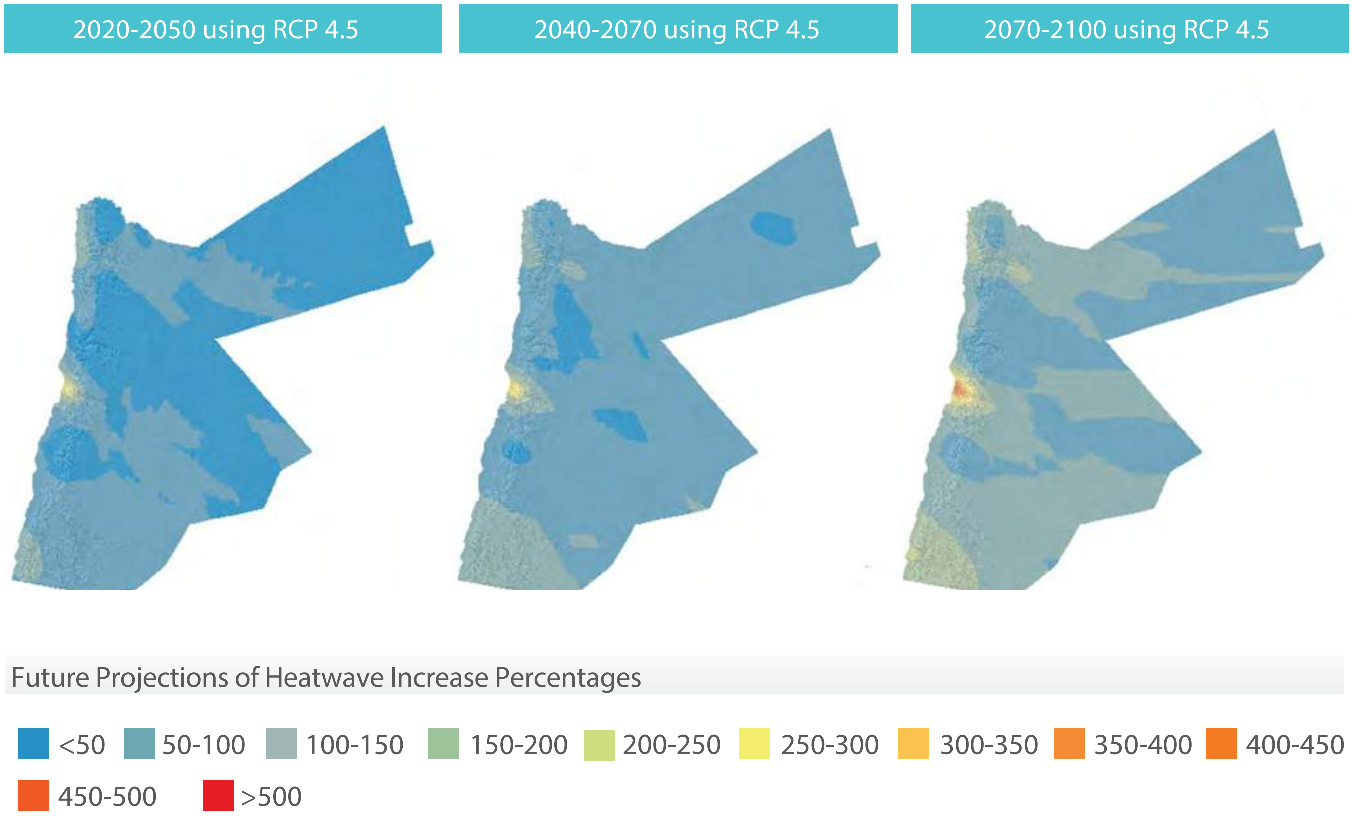


Figure 24: Spatial distribution of the potential future heatwaves projection using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

Future Projected Wind Speed: Temporal and Spatial Consistency

Under RCP 4.5 scenario, there is an appearance of stability, indicating no significant changes in wind speed both temporally and spatially, as illustrated in Figure 25. Based on the anticipated variances in wind speed across the three temporal phases, as delineated in Figure 25,the country is about as likely as not to be subjected to wind bloom events exceeding 12 m/s under RCP 4.5.

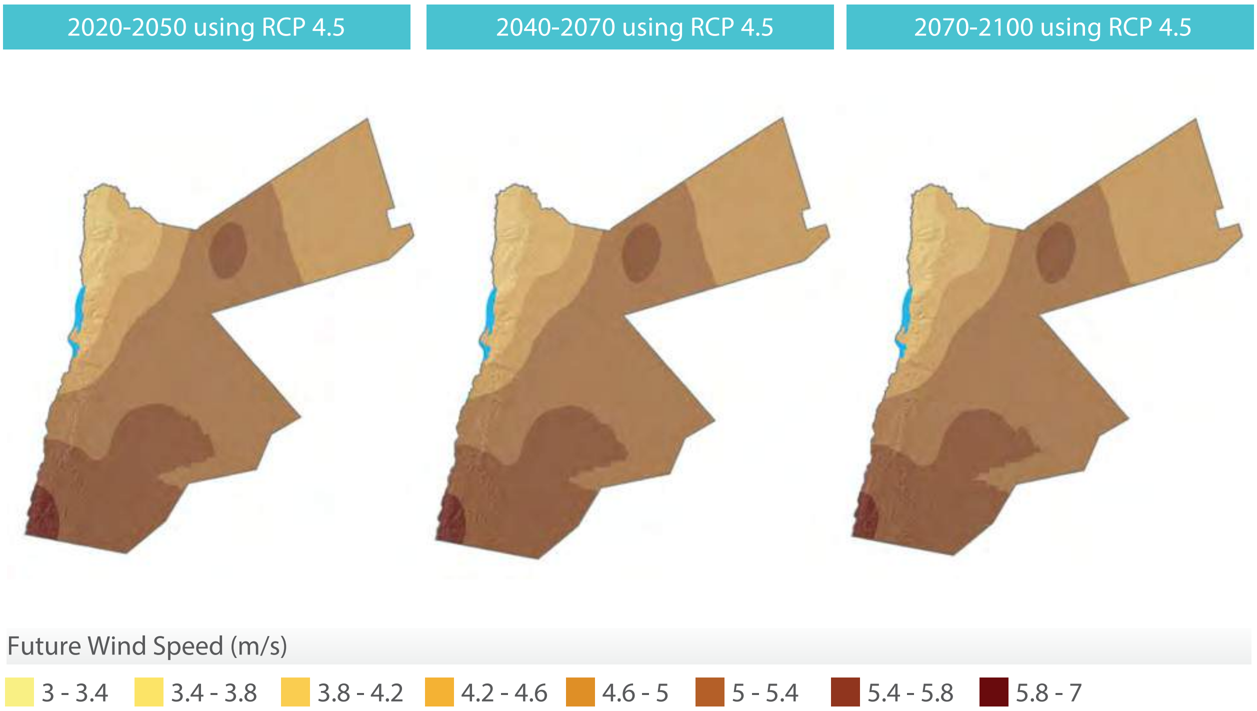


Figure 25: Projected average wind speed, for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

Figure 26: Projected Differences in Average Wind Speed, for the three time horizons using RCP 4.5 (The Hashemite Kingdom Of Jordan, 2015)

► A historical analysis of climate change in Petra (1979-2024)

Trends and Anomalies in Temperature and Precipitation

The broader Petra region has experienced a steady rise in temperature from 1979 to 2024, as depicted in Figure 27. Cold temperatures, compared to the 30-year climate mean of 1980-2010, were noted between 1980 and 2002, with only warmer temperatures observed from 2002 to 2024. The recorded temperature anomalies (Figure 26 and Table 7) and precipitation anomalies (Figure 27 and Table 8) in Petra, spanning from 1979 to 2023, provide a detailed chronicle of the region's thermal dynamics. Notable patterns emerge as we navigate through each month by examining the deviations from the long-term average. Across most regions, an increasing frequency of warmer months is observed over the years (Figure 27), indicative of the global warming trends associated with climate change.

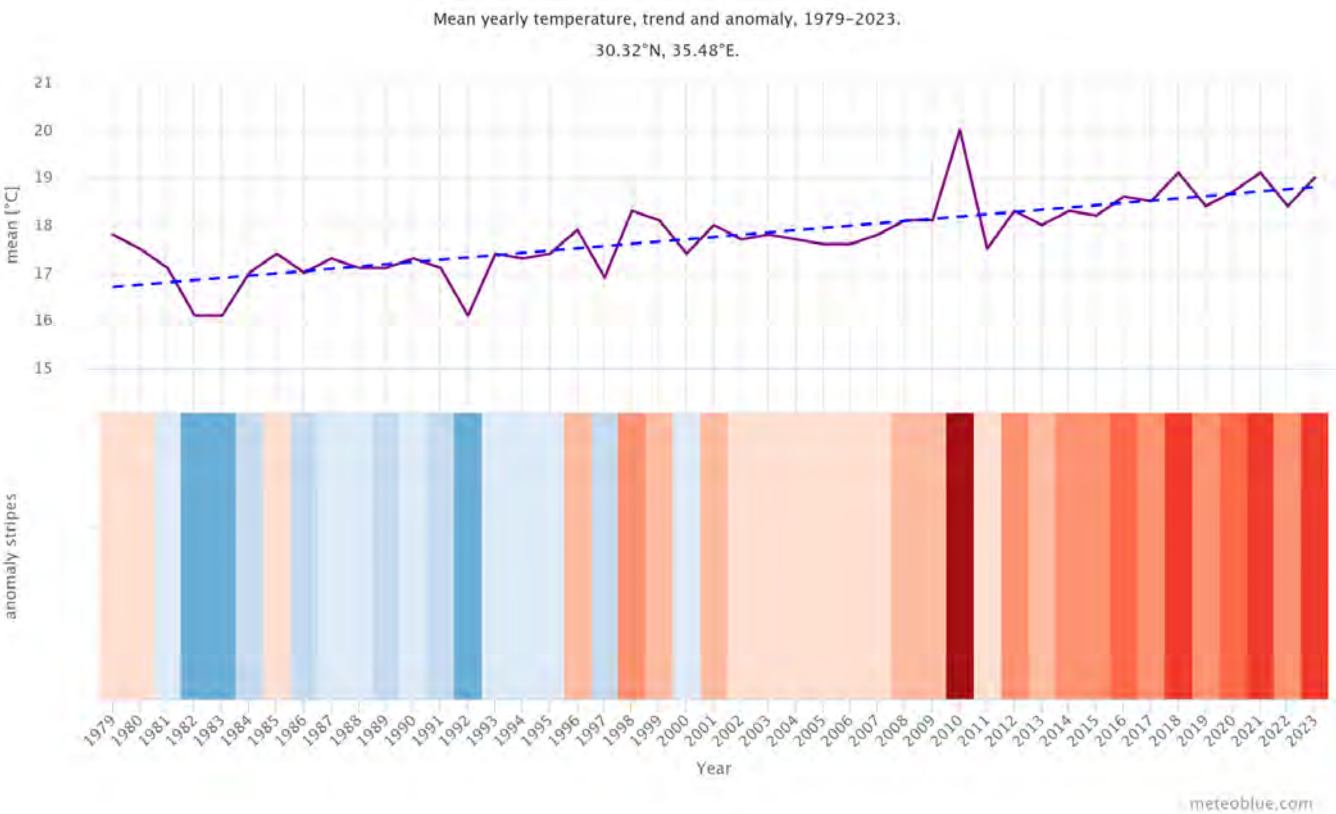


Figure 27: Mean yearly temperature, trend and anomaly 1979-2023 in Petra, Jordan. The dashed blue line represents the linear trend in climate change. A positive incline from left to right indicates a warming trend in Petra due to climate change, while a horizontal line suggests no discernible trend, and a downward slope implies cooling conditions over time. In the lower section of the graph, warming stripes are depicted. Each coloured stripe corresponds to the average temperature for a year, with blue indicating colder years and red representing warmer ones (MeteoBlue, 2024)

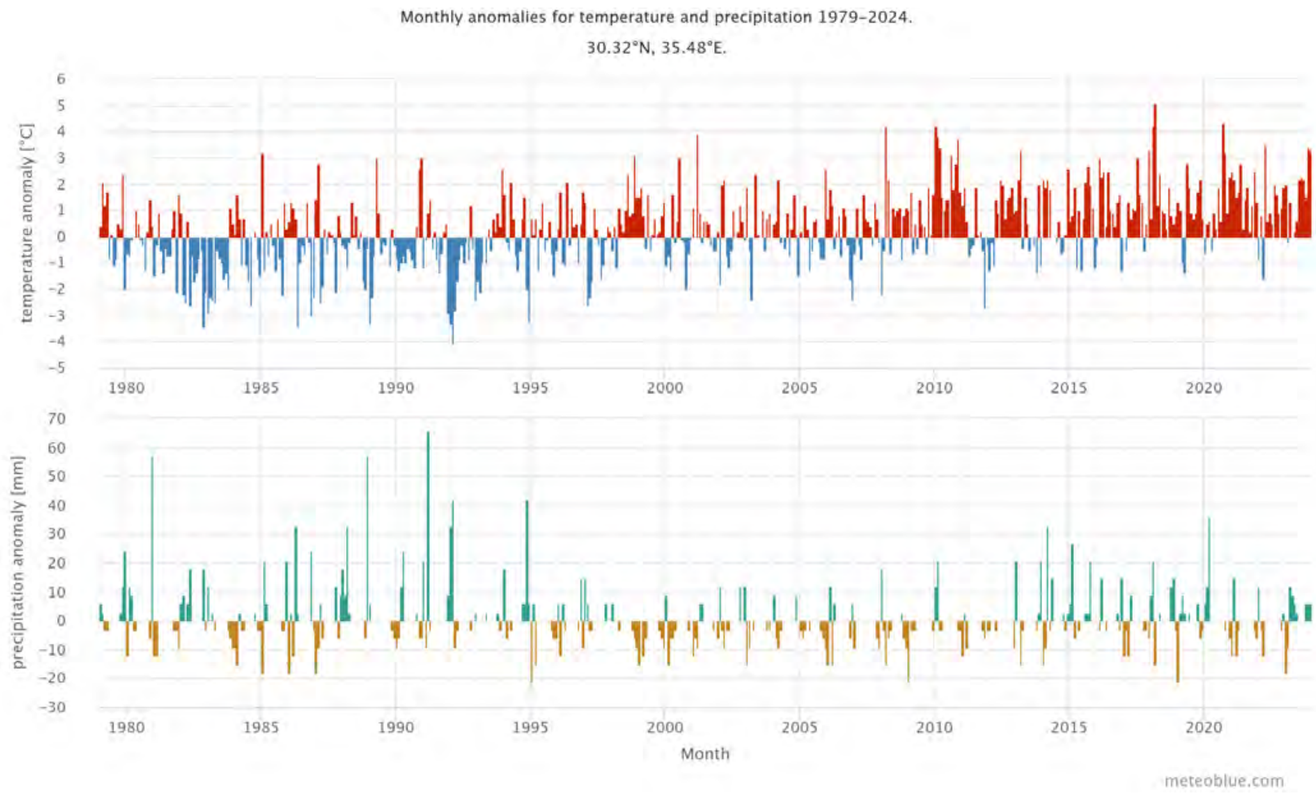


Figure 28: The upper graph presents the temperature anomaly for each month spanning from 1979 to the present. This anomaly quantifies the deviation from the 30-year climate mean of 1980-2010, showcasing warmer months in red and colder ones in blue. The lower graph delves into precipitation anomalies for every month since 1979. This anomaly measures variations from the 30-year climate mean of 1980-2010, with green indicating wetter months and brown representing drier conditions than the norm (MeteoBlue, 2024)

Table 7: Monthly temperature deviations from the 30-year climate mean of 1980-2010 for 1979 and 2023 in Petra (MeteoBlue, 2024)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	0.4	2.1	1.2	1.7	-0.8	0.1	-1.1	-0.9	0.5	0.3	2.4	-2
2023	2	-0.2	1.3	-	0.2	0.6	2.2	2.3	2.2	1.5	3.4	3.3

Table 8: Monthly precipitation anomalies (in millimetres) from the 30-year climate mean of 1980-2010 observed in Petra in 1979 and 2023. The values represent the amount of rainfall or snowfall during each respective month (MeteoBlue, 2024)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	6	3	-3	-3				3	12	24		
2023	-18	-9	12	9	6	3	6	6		6	6	6

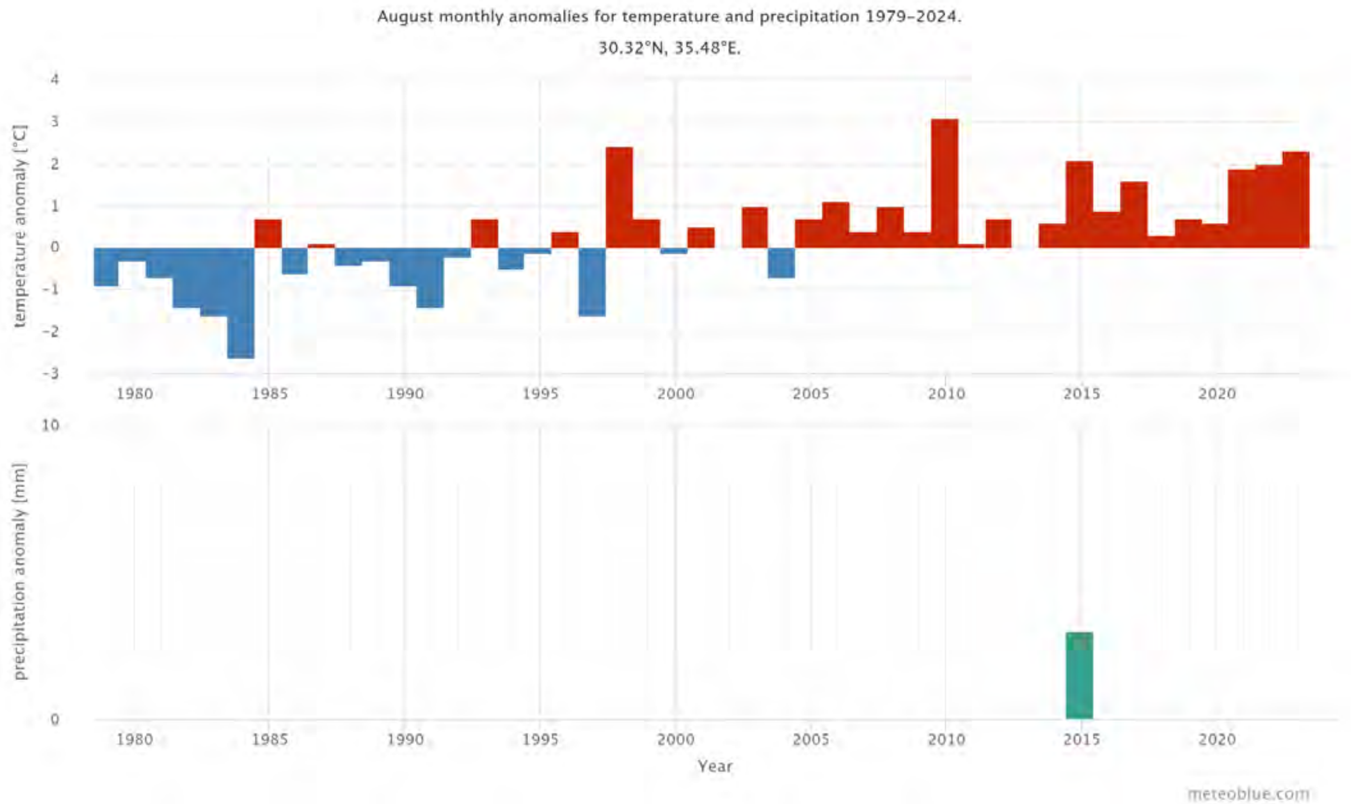
Seasonal Temperature Patterns

This section offers an in-depth seasonal analysis of the temperature dynamics influencing Petra's climate. Petra's climate dynamics manifest distinct seasonal patterns throughout the year, reflecting seasonal fluctuations that define each quarter of the annual cycle and contribute to dynamic environmental conditions. During the winter months, spanning from January to March, a mix of positive and negative anomalies underscores the inherent variability intrinsic to Petra's winter climate. March stands out with above-average temperatures, suggesting a shift towards warmer conditions. During the spring season, encompassing April to June, the temperature landscape undergoes significant fluctuations, exhibiting both positive and negative anomalies. Specifically, in the period from 1979 to 2024, April showcases a combination of negative and positive anomalies. However, May and June consistently manifest positive anomalies observed from 2012 and 2016, respectively. This trend signifies a transition towards warmer weather and underscores the discernible impacts of climate change on the temperatures recorded during these months. The subsequent summer months, extending from July to September, are characterised by a sustained elevation in temperatures. While the preceding three months demonstrated a combination of positive and negative anomalies historically, they exclusively registered positive anomalies commencing in 2015. Transitioning into autumn, spanning from October to December, Petra experiences variability in October, with a mix of positive and negative anomalies. November and December often lean towards cooler temperatures, indicating the commencement of winter. In the historical context, the three preceding months displayed a mix of positive and negative anomalies, but from 2017 onward, they consistently exhibited positive anomalies exclusively.

Seasonal Precipitation Patterns

Petra's precipitation patterns reveal an interplay between seasonal shifts and climatic variations. Monthly data from January to March highlights the gradual progression of seasons, with January initiating the winter season through moderate precipitation. March is a crucial month with increased rainfall or snowfall, contributing significantly to vital water reserves. Transitioning to spring from April to June introduces variability, showcasing diverse years with varying levels of rainfall. June marks a noticeable shift toward drier conditions, marking the arrival of summer. The summer months of July and August consistently exhibit dry spells, marked by minimal recorded rainfall. While it has never rained in June and August historically, the 2 months have recorded precipitation anomalies in 2019 and 2023, and 2015 respectively. September, however, presents a potential resurgence in precipitation, offering a balanced conclusion to the preceding dry summer period. The month recorded 2 precipitation anomalies in 1994 and 2015. As autumn unfolds from October to December, varied precipitation patterns serve as a transitional phase from the dry summer to the wetter winter. Notably, November and December are pivotal in water replenishment, emphasising their critical importance for sustaining Petra's ecosystem.

This in-depth analysis underscores the intricate dynamics of Petra's precipitation, emphasising the need for a comprehensive understanding to implement effective climate change adaptation and water resource management strategies.



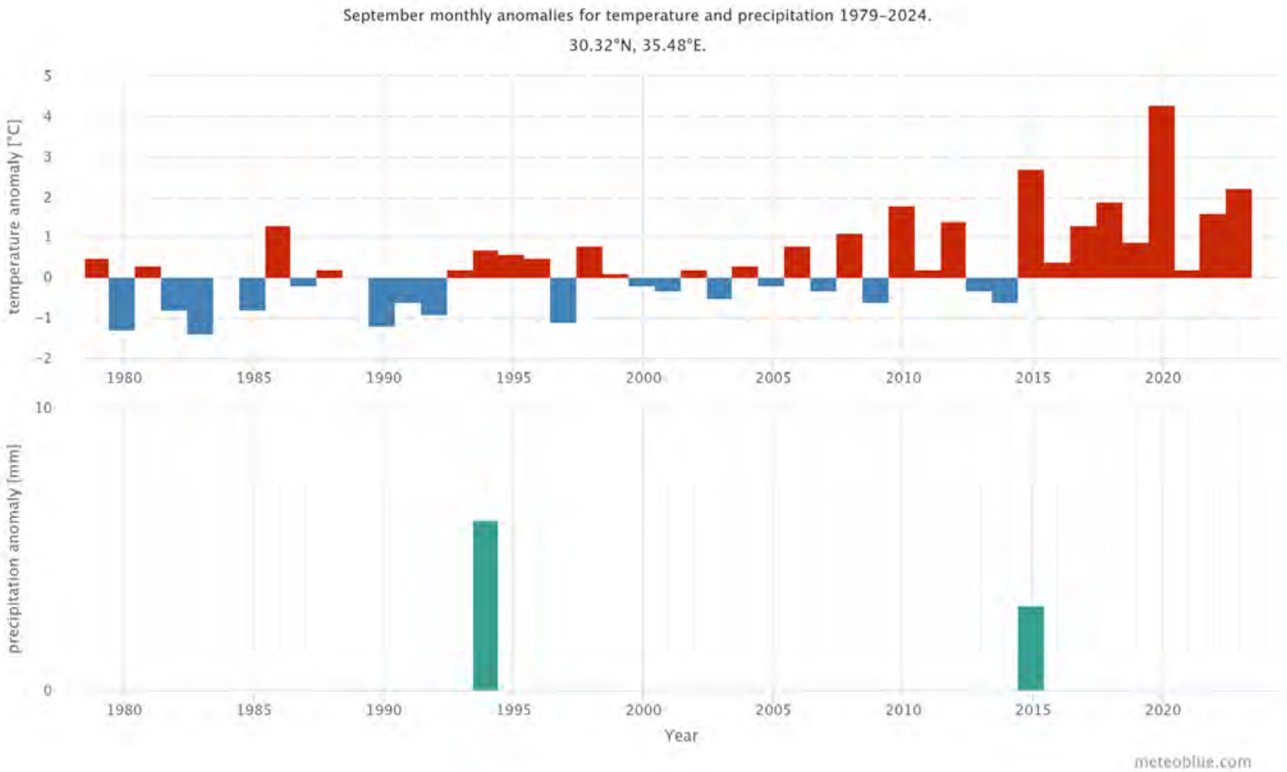


Figure 29: Monthly anomalies for temperature and precipitation for the months of June, August and September between 1979-2024 (MeteoBlue, 2024)

Climate Hazards in Petra

Petra faces various climate hazards, posing a threat to its cultural heritage assets, values, and communities. The site is vulnerable to sudden flash floods, which can be exacerbated by urbanisation, such as asphalt roads and buildings replacing natural soil (Alhasanat, 2017; Akasheh, 2019). Flash floods in Petra pose a significant threat to both the cultural heritage and the safety of communities and visitors (Delmonaco, 2013). In December 2022, severe flooding forced around 1,700 people to evacuate the archaeological site (Harris, 2022); the city was flooded after experiencing an estimated six months' worth of rain in a single day. In 2018, flash floods in Petra forced the evacuation of approximately 4,000 people, with no reported fatalities. The floodwaters rose to 4 meters, sweeping away more than a dozen individuals (Van Ruymbek, 2018). The last fatal flash flood in Petra occurred in 1963, resulting in the tragic deaths of 22 French tourists and a local guide (Van Ruymbek, 2018). The potential for flash floods in the region is exacerbated by the presence of sandstone canyons and the impact of intense rainfall (Al-Weshah and El-Khoury, 2017). The use of flood analysis models and mitigation measures, such as afforestation and construction of check dams, can help reduce the impact of these floods (Al-Weshah and El-Khoury, 2017). However, the specific rainfall thresholds that trigger flash floods in Petra are not clearly defined, highlighting the need for further research in this area (Papagiannaki, 2015).

Additionally, the area is prone to rapid onset natural phenomena like earthquakes, landslides, and rock falls, which pose a significant risk to the heritage site, the local communities and visitors. The Siq of Petra is susceptible to rock-fall hazards due to its geological structure and tectonic activity (Delmonaco, 2013). This is further exacerbated by the presence of unstable volumes, which can pose a threat to visitors (Delmonaco, 2014).

Climate change impacts, including gradual changes in temperature, precipitation, and wind intensity, also affect the site. The environmental impacts, including weathering factors and mechanisms affecting the stone decaying in Petra, have also been studied, highlighting the long-term effects of climatic conditions on the site's preservation.

▶ Unveiling Dynamics and Navigating Climate Change: Narratives from Local Communities Focus Groups

> *"Yes, a change in the climate has been observed. The impact of climate change was observed in the lack of availability of agricultural crops compared to previous years."*
>
> Sana'a Al-Rawajfeh, Workshop Participant

In recent years, the locals of Petra have meticulously documented a myriad of climate observations, shedding light on the profound impacts of climate change at the local level. Notably, there has been a discernible shift in the types and species of plants, with citrus trees struggling to thrive in the Petra Region. In response, the community has adopted the cultivation of lemon, orange, and guava, which are better suited to the prevailing warmer conditions. However, a once-thriving species of apple faces challenges, failing to flourish as it once did. The scientific explanation lies in the concept of "chilling requirements," where each fruit tree requires a minimum of cold weather for successful blossoming.

Another noteworthy revelation made by the locals pertains to the increasing frequency of flash floods over the past two decades. Despite a rise in rainfall, the duration of these events has decreased significantly. What was once a day-long occurrence now transpires within a mere hour, reshaping the traditional patterns of precipitation.

Figure 30: Haifa Abdalhaleem from PNT presenting future climate scenarios to workshop attendees (Photo: Michael O. Snyder, 2023)

Recollections of abundant snow events in the past evoke nostalgia among the residents. Not only was the amount of snow more substantial, but the frequency of these events was also higher. Memories of snow during the barley and wheat harvests in April and May underscore a noticeable change in land temperatures, with the colder conditions of the past allowing the snow to linger longer in the Petra Region.

Summer in Petra was once characterised by acceptable temperature degrees, eliminating the need for air conditioners in local homes. In response to seasonal temperature variations, residents engaged in biannual migrations. During the summer, they sought refuge in higher areas in the northern part of Petra, known for their cooler temperatures. Conversely, in the winter, they migrated to lower areas like Baidah, seeking warmth during the coldest times of the year.

The architectural landscape of Petra reflects the community's adaptive strategies to climate change. Local buildings, constructed with locally-sourced rocks and mud, feature thick walls that serve as effective temperature barriers. Older buildings, a testament to these climate adaptation techniques, exhibit a superior ability to retain warmth in winter and provide a cooler haven in the summertime. Overall observations are presented below.

Changes in temperature, specifically:

- The planting of new species of trees including citrus trees like lemon, orange and guava which have not traditionally grown in the landscape. Conversely, some species like apples which have traditionally grown in and around Petra are no longer productive. In some extreme cases, they are dying. Local knowledge suggested that this was due to the lack of a “chilling requirement” which is the minimum period of cold weather after which that fruit-bearing tree will blossom.

- Similarly, there was a local memory of harvesting wheat and barley in April and May in the late 1980s due to the cooler temperatures.

- A drastic reduction in snowfall in winter months. Locals recalled that both the amount and frequency of snowfall events were both greater in the past. This was attributed to warmer temperatures.
- The increase in temperatures in the summer months have changed how the local community lives. There has been an increase in the use of air conditioners and people no longer travel to higher areas during warm periods as these are no longer cooler.

Changes in precipitation, specifically:

- It was particularly noted that while the overall quantity of rain had decreased, the intensity of shorter rainfall events had increased significantly resulting in an increase in flash floods in the last two decades

The community's historical wisdom and resourcefulness in dealing with climate events are evident in their water harvesting techniques and the design of old buildings. However, as recent climate change events trigger growing concerns, the residents anticipate the onset of more extreme occurrences in the future. They emphasise the urgency of developing necessary actions to mitigate climate change's impact on the local community and the broader Petra area. In this chapter, we delve into the intricacies of Petra's evolving climate and witness the community's resilience in the face of unprecedented environmental changes.

► Key Hazards and Likely Impacts from the Workshop

> *"Yes, there was a noticeable change in summer rains and delayed winter. As a member of society, we must adapt and know the extent of the impact of climate change and provide advice and guidance."*
>
> Etedal Al-Hasanat, PhD, Workshop Participant

During the focus groups and workshops, participants were presented with the future climate scenarios and worked together to identify the three main climate hazards from a longer list. The community agreed that the three main climatic hazards were:

1. Increased precipitation (rainfall) leading to flash flooding in and around the Petra Archaeological Park. These are exacerbated by drier weather making the soils less absorbent and more resistant to water.
2. Warmer weather leading to drought events, especially during the summer period. These events are exacerbated by less regular rainfall and the inability of drier soils to absorb moisture.
3. Wind and increased storminess including erratic weather conditions can cause sandstorms. These events are exacerbated by drier weather and drought events.

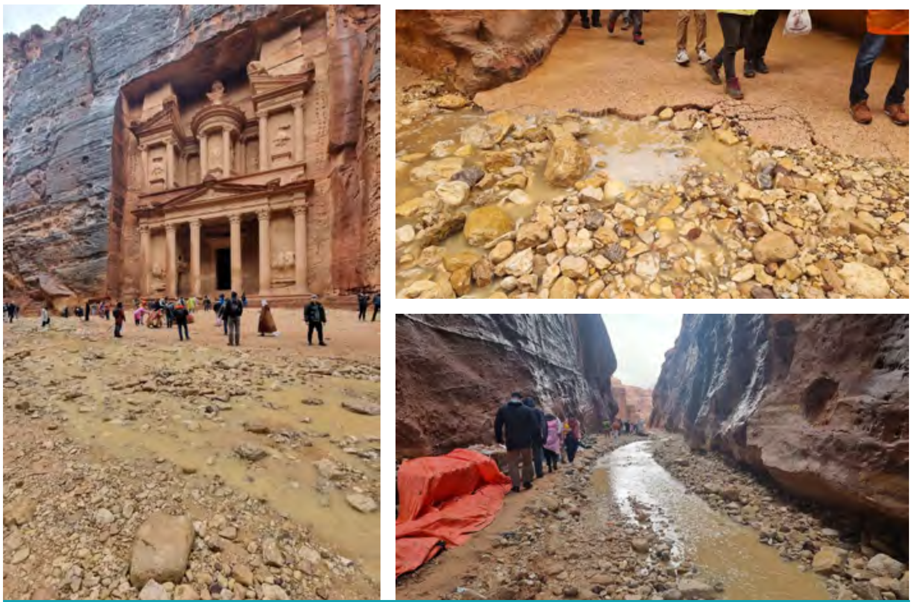


Figure 31: Images showing the impacts of recent flooding on the Petra archaeological site (Photos: Taher Falahat 2022

Table 9: Stakeholder observations on potential impacts from the workshop

Values	Attribute	Hazards	Workshop observations on Impacts
Heritage	The sandstone carved historic buildings, the Siq and the cultural and natural landscape which people come from all over the world to visit. Loss of these attributes would result in damage to the economic value of the site.	Floods Drought Winds/ Storms	*'The nature of the archaeological site is made of sandstone, and **heavy rains** may cause erosions and cracks that change the archaeological and historical landmarks'* *'Dust and the disappearance of part of the plant and animal diversity… **Drought** affects the archaeological site, plants, and animal diversity in the area'* *'Erosion of inscriptions may lead to the disappearance of archaeological landmarks… leads to burying of archaeological landmarks caused by* **increased storminess** *('including windstorms and sandstorms)'* *Winds cause chemical processes of **abrasion and erosion**, affecting the authenticity of the carved archaeological structure*
Tourism	Field systems, terraces, wells and hydrological element used to facilitate agriculture in and around the Petra site. The medical knowhow: Special plants with historical and contemporary medicinal use within the community.		*'People visit from all over the world. **Flooding** will people reluctant to visit the site and impact on revenue'* *The archaeological site is affected by **heavy rains**, thus impacting local traditional industries by reducing effective marketing and sales processes* *'**[Drought]** affects the material components of the site, reducing its historical significance for visitors'* *'**Flooding** will lead to a loss of human lives, which is an important element in the archaeological site, loss of rock facades and features*
Nature	The sandstone carved historic buildings and the cultural landscape. Also the built structures (temples, roads, bathhouses, etc.). This includes the different historic layers including Nabatean, Roman, etc.		*'**[Drought]**... leads to the disappearance of many rainfed plants'* *'Breaking and reduction of trees like Pistacia and Juniper. Damage and destruction of the fragile infrastructure. Appearance of plants not native to the area. **Abrasion and erosion** remove the surface layer and reveal lower sedimentary layers.* *'**Drought** leads to the destruction of natural plants'* *'Leads to the disappearance of some plants and animals'* *Repeated **drought** years lead to desertification and disappearance of plant cover and animal species*
Agriculture	The environment and biodiversity (fauna and flora) of the site including plants, trees and animals and their ecosystems. Also, geological formations, mountains, gorges and natural water systems		*'Heavy rains cause **soil erosion**, leading to the disappearance and reduction of vegetation cover…Impact on agricultural terraces and their destruction. Burying of wells in case of floods'* *'**Erosion** of agricultural and residential areas due to the geographical location of the area'* *'[Need for] diversity in agricultural crop production and **lack of rain** and non-absorbent soil nature.* *[**Flooding and storminess]** leads to crop destruction, breaking of trees, and migration of animals to suitable and safe environments*

(Icons from Flaticon.com)

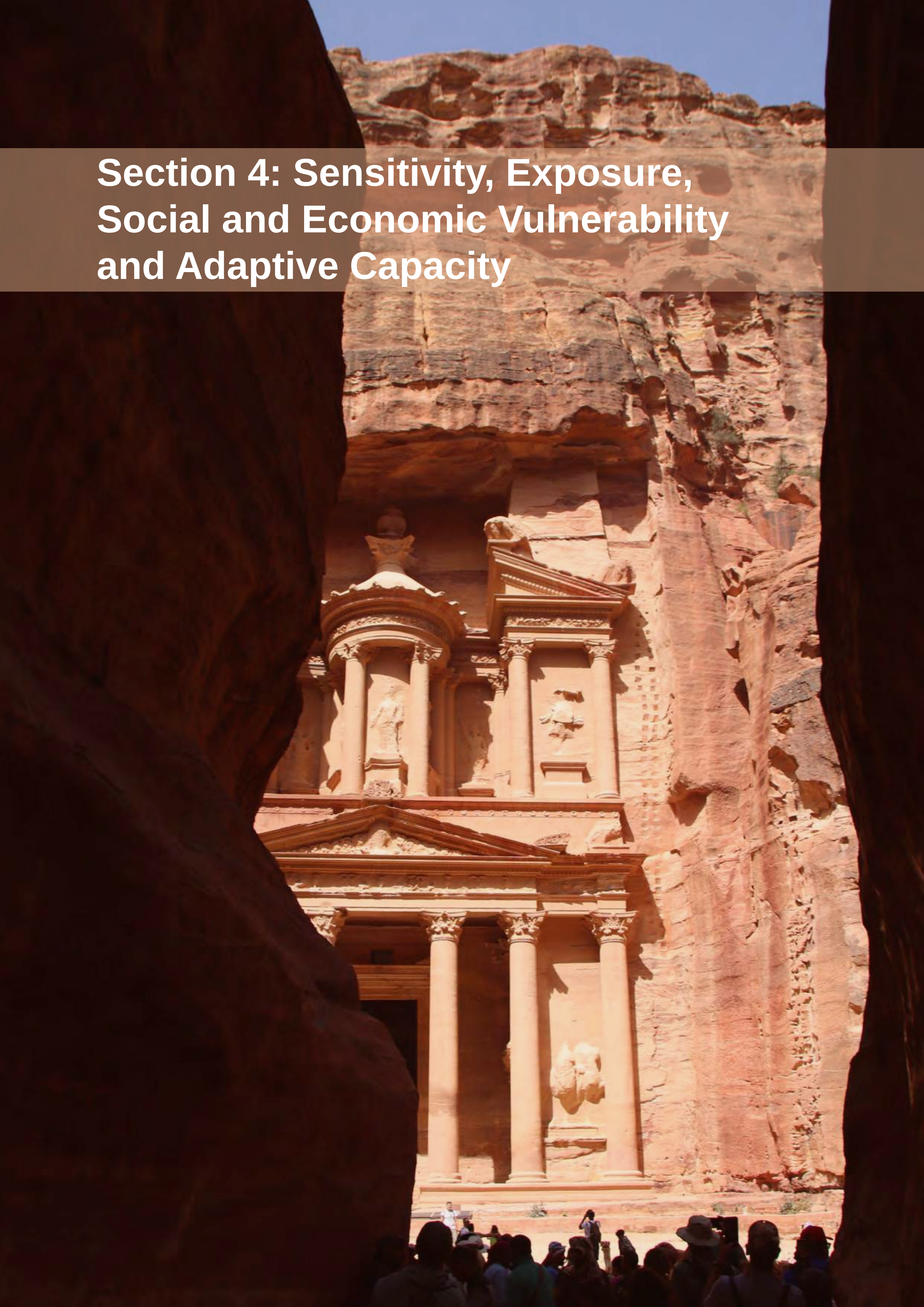
Participants were also asked to assess the degree of potential impact and what the impact to date had been and what they felt the potential impact to the attributes and their associated values by 2060 under the selected emissions scenario. These are presented in Table 7 and suggest that, in the minds of the local community, there have already been moderate impacts to site values due to climate change and that these impacts are likely to continue and in most cases become more extreme unless measures are taken. While the perceived current impacts are already moderate, these observations are not surprising as flash floods and wind storms were both identified as management concerns in the WH sites statement of OUV. Climate change is clearly exacerbating and accelerating these hazards. The emergence of drought as a new threat, and the comparatively lower impacts this has and may have on the values reflects a new hazard. The proceeding sections will explore wider factors which may further multiply these impacts as well as local adaptive capacities which may decrease them.

Table 10: Impact to date and potential future impacts to key values

Values	Attribute	Hazards	Impacts to Date
Heritage	The sandstone carved historic buildings and the cultural landscape. Also the built structures (temples, roads, bathhouses, etc.). This includes the different historic layers including Nabatean, Roman, etc.	Floods Drought Winds/ Storms	*Floods*
			Drought
			Wind/ Storms
Tourism	The sandstone carved historic buildings, the Siq and the cultural and natural landscape which people come from all over the world to visit. Loss of these attributes would result in damage to the economic value of the site.		*Floods*
			Drought
			Wind/ Storms
Nature	Field systems, terraces, wells and hydrological element used to facilitate agriculture in and around the Petra site. The medical knowhow: Special plants with historical and contemporary medicinal use within the community.		*Floods*
			Drought
			Wind/ Storms
Agriculture	The environment and biodiversity (fauna and flora) of the site including plants, trees and animals and their ecosystems. Also, geological formations, mountains, gorges and natural water systems		*Floods*
			Drought
			Wind/ Storms

(Icons from Flaticon.com)

Section 4: Sensitivity, Exposure, Social and Economic Vulnerability and Adaptive Capacity



Section 4: Sensitivity, exposure, social and economic vulnerability and Adaptive Capacity

Climate risk is different from climate impacts. The IPCC 2023 AR6 report notes that 'In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards' (IPCC 2023, 128). In this case, vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC 2023. It is necessary to evaluate these elements in order to correctly assign an assessment of risk. The following sections will explore three key elements which were presented to and discussed by workshop stakeholders. These are sensitivity and exposure and the capacity for the site and community to adapt.

► Sensitivity and Exposure

The potential impact and risk to key values depend on a range of factors including their exposure and their sensitivity to climate hazards. Exposure is a measure of the contact between a system (whether physical or social) and a stressor, while sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change.

Figure 32: The impact of sandblasting and wind erosion on the Royal Tombs (left) and Al Khazneh (right). Both sites are sensitive to erosion but have different sensitivities (Photos: Taher Falahat, 2022)

Previous Page Photo By: Khansa Bouaziz, 2023

Figure 33: The impact of sandblasting and wind erosion on stone carvings in Petra showing the sensitivity of some structures on the site (Photos: Khansa Bouaziz, 2023)

During the workshop, participants were asked to assign a degree of exposure and sensitivity to key attributes based on potential impacts by 2060 under the chosen emissions scenario. This is important as not all attributes have the same exposure to climate impacts as others. For example, the impacts of drought on attributes associated with heritage values of Petra's historic buildings are low; however, its impacts on agricultural and natural values and their attributes including flora and fauna can be extreme. Similarly - and in some cases conversely - some attributes are more sensitive to certain impacts than others. The soft sandstone is highly sensitive to water and wind erosion while natural attributes are more resilient. A good example of both exposure and sensitivity is the impact of sand erosion on the carved stone architecture. All structures are sensitive to this climate hazard yet not all are equally exposed. Figures 31 and 32 show the impact of erosion on the Royal Tombs and at Al Khazneh. The former is highly exposed to wind while the latter is more sheltered.

▶ Social and Economic Vulnerabilities

Climate impacts do not occur in isolation. They can be exacerbated by social and economic vulnerabilities, which can include past maladaptations. While considerable efforts have been made to boost the adaptive capacity of the site and community, some factors continue to exacerbate climate risk. During the workshop, the following examples were given by attendees that exacerbate climate impacts at Petra and its surrounding communities:

- Over tourism increases the number of people in the WH Site. This has an impact on the monuments and increases the risk to life from flash-flooding caused by increased precipitation. Camping and picnicking also increase risk to the archaeological site and wider landscape (Figure 33).
- Increasing numbers of tourists staying in Wadi Rum increases pressure on already stretched water resources, increasing the potential impacts of drought.
- Poor planning and infrastructure has had an impact on draining and traditional irrigation systems where a lack of maintenance has led to a decrease in the amount of water in traditional wells. This exacerbated the impact of drought on agriculture.
- The introduction of new agricultural methods, including ploughing techniques which have altered land use practices, and the replacing of traditional practices that were more resilient to changing climates exacerbate the impacts of drought on agriculture.
- The loss of flora and fauna due to hunting and the spread of livestock. This decreases the amount of space for wild animals and plants and increases risks to the natural landscape from drought. Wood cutting and deforestation also limit the capacity of the landscape to hold water, increasing risks from increased precipitation.
- Overgrazing of limited foliage has increased the risk from sandblasting and erosion caused by increased storminess.

Figure 34: Tourisms outside the Al Khazneh, Petra (Photo: Michael O. Snyder,2023)

It is worth noting that a number of these threats including over-tourism, overgrazing and the impacts of water and wind erosion on the site were included in the WH statement of OUV, which identified initiatives to address them. This will be discussed, within the context of climate risk, in the next section.

Adaptive Capacity

At a national level, adaptation to climate change is governed by the 2022 - 2050 National Climate Change Adaptation Plan of Jordan (Ministry of Environment and UNDP, 2022). This plan includes a specific adaptation goal for cultural heritage which notes both the lack of understanding of the causes of vulnerability at cultural heritage sites and the potential economic, social, and symbolic loss of the values resulting from climate change. Citically, it also notes the integration of traditional knowledge and technologies, alongside monitoring and capacity building initiatives within their evaluation indicators for success.

Preparatory work and stakeholder input from focus groups and workshop attendees outlined significant local adaptive capacity that reduces the impacts of some key hazards and protects site values. Investments in adaptive capacity have been led by the Petra Development and Tourism Regional Authority (PDTRA) in collaboration with a range of academic and research institutions. These approaches all rely heavily on public and stakeholder involvement and PDTRA actively promotes public awareness regarding climate change and its potential effects on the archaeological site. Educational campaigns are conducted to engage local communities and visitors, fostering a sense of responsibility and encouraging sustainable practices to preserve the cultural and natural heritage. Adaptation actions can be divided into two main actions: contemporary adaptations and learning from the past.

On another level, the Petra National Trust (PNT) is leading the development of a comprehensive Climate Heritage Programme aimed at protecting cultural heritage in the face of climate change challenges. This initiative focuses on collaboration and innovation, seeking to incorporate heritage considerations into national climate policies, advocate for climate solutions based on culture, and conduct thorough assessments of risks to heritage sites while developing effective strategies to mitigate these risks. The strategic approach of this programme also prioritises enhancing adaptation efforts, strengthening resilience, educating stakeholders, and aligning heritage initiatives with sustainable development goals. An essential aspect of the strategy is the strategic integration of technology to improve predictions and adaptive measures.

The programme includes a multi-faceted approach, which involves targeted research to address knowledge gaps, advocacy efforts to ensure policy integration, extensive education and awareness campaigns, and capacity-building initiatives.

Anticipated outcomes include highlighting the crucial role of heritage in responding to climate change, establishing robust networks of experts, securing essential funding for research, facilitating the exchange of knowledge, and establishing a geospatial platform for comprehensive assessment of climate risks.

Through these strategic efforts, PNT reaffirms its commitment to preserving cultural heritage for present and future generations amidst the complex challenges posed by climate change. By proactively addressing the connection between heritage and climate, the programme seeks to effectively protect our shared cultural legacy while promoting sustainable development practices for a resilient future.

Contemporary Adaptations

The construction of a wadi mousa reuse treatment water plant was a major undertaking to address water pressures due to tourism, easing water pressure on the community and reducing the impact on agriculture. There have been substantial hard adaptation projects to help channel water through the archaeological site and away from congestion points. Barriers have been placed in strategic locations to prevent water inundation (Figure 34). The maintenance of these initiatives is key to their ongoing utility and PDTRA conducts periodic cleaning and maintenance activities for water cisterns, dams, and water canals distributed throughout the archaeological site. The importance of regular maintenance is highlighted in the Statement of OUV and the routine is carried out annually before the onset of the winter season.

These adaptations also reduce the risk from flash flooding. PDTRA has been actively involved in the continuous development and updating of the early warning system initiated in 2014. Regular enhancements ensure the system's efficacy in providing timely alerts and mitigating potential climate-related risks. PDTRA has prioritised the training and qualification of its personnel in emergency evacuation operations from the archaeological site. Collaborative efforts with state agencies such as the Civil Defense Directorate and the Crisis and Risk Management Center have facilitated comprehensive training programs, enhancing the readiness of PDTRA cadres in responding to potential climate-related emergencies.

Figure 35: Retractable barrier at the entrance to the Siq, open (left) and closed (right)
(Photos: Muhannad Rawadieh, 2024)

The restoration of natural landscapes also reduces the potential risk from climate hazards. PDTRA has initiated afforestation projects within and around the archaeological site, contributing to enhanced ecological resilience. The planting of native vegetation not only aids in soil conservation but also helps mitigate the impacts of climate change, such as soil erosion and water runoff. By retaining more water, instances of flash flooding are greatly reduced. These efforts are an effective adaptation measure to reduce impacts from all three key hazards - increased precipitation, drought, and increased storminess and wind erosion.

Learning from the Past

The Petra Development and Tourism Region Authority (PDTRA) has undertaken several collaborative projects aimed at the rehabilitation and maintenance of the Nabataean water management system in and surrounding the archaeological site. This includes the rehabilitation of terraces and dams as well as clearing and maintaining cisterns and water channels (Figures 35 and 36). These efforts have significantly reduced the impact of recurrent instantaneous floods in the region. Similarly, efforts have been directed towards the rehabilitation of waterways traversing the archaeological site. This involves the construction of retaining walls on the sides and thorough cleaning to regulate and control sudden floods. The goal is to prevent deviations from the natural path, thus averting potential dangers to both human lives and the archaeological site.

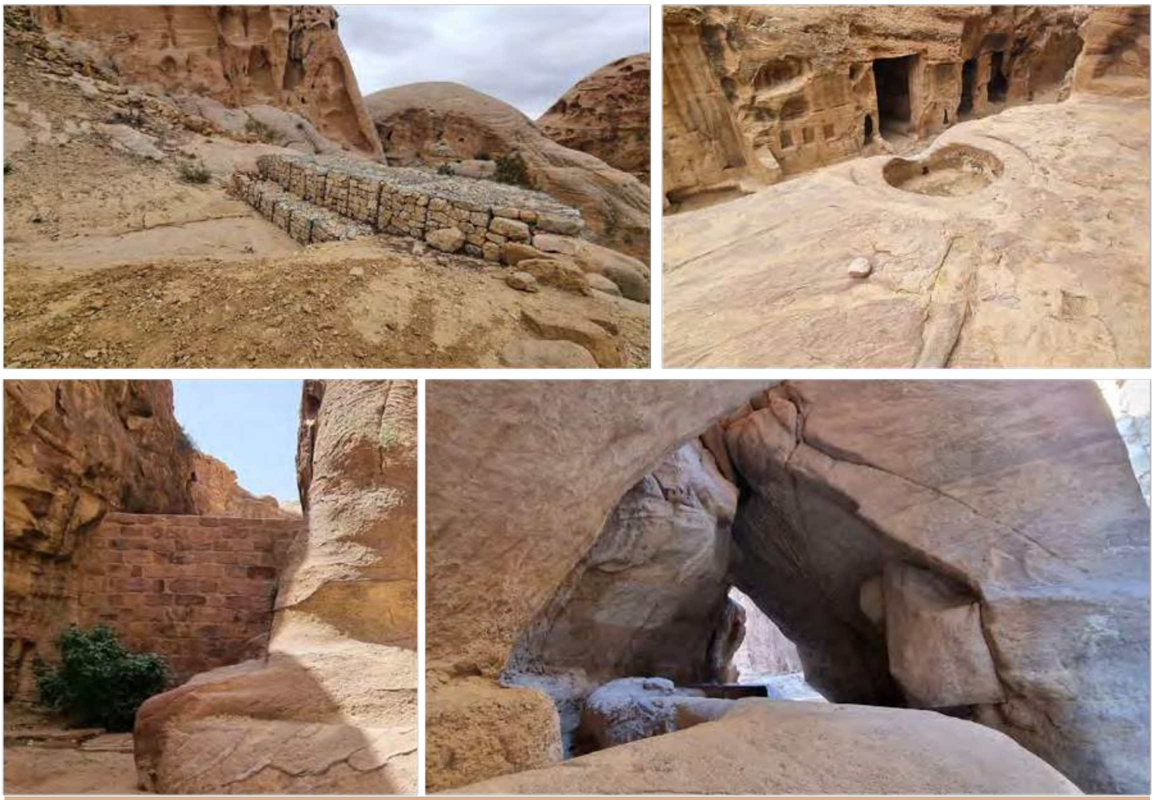


Figure 36: Photos showing traditional Nabatean water management strategies. Clockwise from top right: Renovated terrace above the WH site, water cistern at Little Petra, water channel and renovated dam in the Siq, Petra (Photos: Taher Falahat 2023 and Will Megarry 2023).

The value of Nabataean dam restoration (Figure 36) is supported by recent hydrological studies which used high-resolution surface models to model water flow (Abdelal et al. 2021). This showed that the restoration of multiple smaller dams delayed the flow of flash floods by up to 25 minutes compared to 15 minutes for one larger dam.

Dam 2 Before re-construction

Dam 2 After re-construction

Dam 4 Before re-construction

Dam 4 After re-construction

Dam 6 Before re-construction

Dam 6 After re-construction

Figure 37: Pictures of some dams before and after reconstruction (Source: Abdelal and al./,Hydrological assessment and management implications for the ancient Nabataean flood control system in Petra, Jordan, 2021, pp 9)

Local buildings were also suggested as another example of climate adaptation techniques. Homes built from local rocks and mud with very thick walls act as temperature barriers, making them warmer in wintertime and cooler in the summertime compared with more modern buildings. This local knowledge extends to agricultural practice, such as using the traditional donkey-cart instead of the modern farming tractor, which is unable to reach every corner of the farmland, resulting in less production ; however, there was concern amongst attendees that they may no longer be sufficient to adapt to more extreme climate change.

▶ Assessing Climate Risk at Petra - A Community Response

The sensitivity and exposure and the social and economic vulnerabilities of the site and its community were discussed in detail during the focus groups and workshop. The responses of participants were used to create an assessment of potential risk under the chosen emissions scenario by 2060. The results of these discussions are presented in Table 11. It was felt that while different attributes and values had varying degrees of exposure and sensitivity, the adaptation efforts of PDTRA were proving effective at reducing risk from flooding in particular. Other hazards were more challenging, including the impact of drought on the natural landscape.

Table 11: Risk of key values by 2060 under scenario RCP 4.5 including exposure, resilience and adaptive capacity

Values	Attribute	Hazards	Impacts to Date	Impact by 2060*	Adaptive Capacity	Climate Risk
Heritage	The sandstone carved historic buildings and the cultural landscape. Also the built structures (temples, roads, bathhouses, etc.). This includes the different historic layers including Nabatean, Roman, etc.	Floods	Floods	Floods	Medium	
		Drought	Drought	Drought	None	
		Winds/ Storms	Wind/ Storms	Wind/ Storms	Low	
Tourism	The sandstone carved historic buildings, the Siq and the cultural and natural landscape which people come from all over the world to visit. Loss of these attributes would result in damage to the economic value of the site.		Floods	Floods	Medium	
			Drought	Drought	None	
			Wind/ Storms	Wind/ Storms	Low	
Nature	The environment and biodiversity (fauna and flora) of the site including plants, trees and animals and their ecosystems. Also, geological formations, mountains, gorges and natural water systems		Floods	Floods	Low	
			Drought	Drought	None	
			Wind/ Storms	Wind/ Storms	Low	
Agriculture	Field systems, terraces, wells and hydrological element used to facilitate agriculture in and around the Petra site. The medical knowhow: Special plants with historical and contemporary medicinal use within the community.		Floods	Floods	Medium	
			Drought	Drought	None	
			Wind/ Storms	Wind/ Storms	Low	

* Under SSP 2 Taking exposure, sensitivity and social and economic vulnerabilities into account
(Icons from Flaticon.com)

RCP 4.5 2041 - 2060

Potential Impacts, Exposure and Vulnerability, and Social and Economic Vulnerabilities, Overall Risk		Adaptive Capacities	
	Not Discussed		Not Discussed
	None		None
	Low		Low
	Moderate		Medium
	Extreme		High

Section 5: Understanding Climate Risk at Petra - Key Areas for Concern and Opportunities

Section 5: Understanding Climate Risk at Petra - Key Areas for Concern and Opportunities

As outlined in the previous section, climate risk incorporates a wide range of elements. The Petra Climate Risk Assessment is a values-based and community-led exercise based around a series of focus groups and a workshop where a wide range of local stakeholders discussed key values, hazards, social, and economic vulnerabilities and adaptive capacities that may impact the site. They were asked to consider both current impacts and potential impacts by 2041-2060 based on a 'middle of the road' emissions scenario (RCP 4.5). Participants were asked to consider both climate science knowledge in the form of models, which outline likely changes to temperature and precipitation, as well as local knowledge and observations on changing traditions, community practices and agricultural activity due to climate change. The purpose of the Petra Climate Risk Assessment is to plan for this future by facilitating more effective adaptation actions while avoiding maladaptive initiatives. Climate risk to four key values and their attributes are presented in this section which will be followed by a final discussion of key messages and next steps.

Figure 38: Haifa Abdalhaleem from PNT hosting a focus group in advance of the workshop (Photo: Khansa Bouaziz, 2023)

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▶ Climate risk to key values

As a values-based exercise, the climate risk assessment starts with an assessment of key values according to the local community and WH Site stakeholders. Unsurprisingly, the heritage values of the site (as outlined in the WH statement of OUV) were deemed very important, but so were the economic values associated with tourism and agricultural production in the wider landscape. Finally, the natural value of the Petra landscape was identified as a key value. All four values were incorporated into the climate risk assessment and their potential impact by 2041-2060 explored.

Heritage Values

As an outstanding archaeological site, Petra's heritage values are world-renowned. These values are outlined in the WH statement of OUV that forms the basis of its inscription on the WH List. Local stakeholders, and especially those who work in heritage, were familiar with the values associated with OUV and were also cognisant of the importance of protecting them from impacts, including climate change. A summary of climate impacts on the heritage values of Petra can be seen in figure 38.

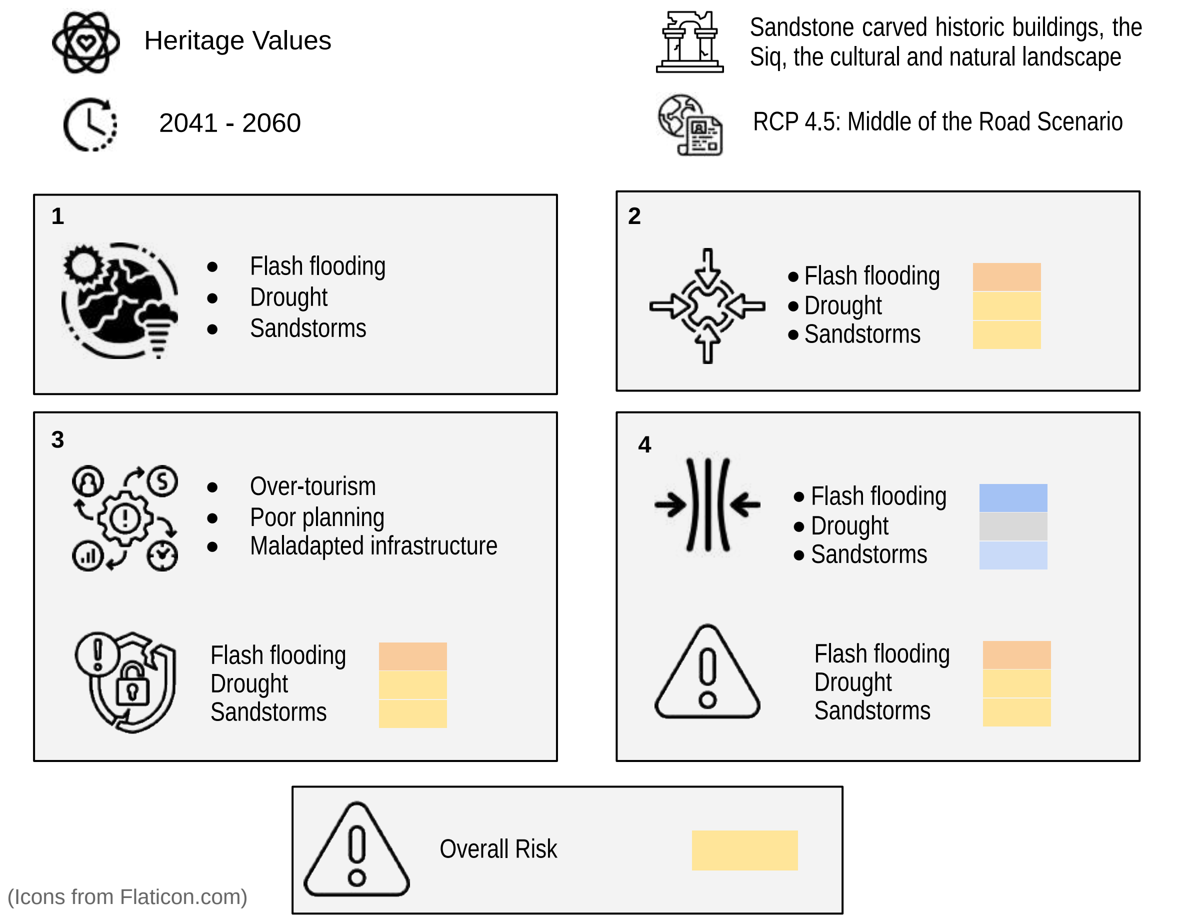


Figure 39: A graphical summary of the climate risk to heritage values at Petra including assessments of impacts to date, sensitivity, exposure and social and economic vulnerabilities, and the adaptive capacity of the WH site and its community. While each climate hazard is assessed separately, an aggregate risk is also provided. For heritage values, this risk is deemed to be low

Heritage values as attested to by a wide range of physical attributes. These include the rock-carved architecture, the historic buildings, and the interface between the natural and cultural landscape (especially the Siq). Climate models indicate that there will be an increase in heavy precipitation events, drought and sandstorms by 2060 and these changes were confirmed by local knowledge which has already noted increased risk to structures from wind erosion and to the wider landscape from flash flooding. Most of these attributes are sensitive to these changes; however, some are more exposed than others. These hazards are also likely to be exacerbated by social and economic factors including over-tourism, poor planning of tourist infrastructure and infrastructural works which are maladapted to these climatic changes. Overall risk is reduced by the considerable recent efforts of the PDRA, including a flash flood early warning system, water treatment facilities measures to protect attributes from water.. **Overall, the risk to the heritage values of Petra by 2060 in a middle of the road emissions scenario ranged from low to moderate with an average risk of low.**

Economic Values - Tourism

The economic value of Petra to both Jordan and the local economy cannot be overstated. Stakeholders repeatedly recounted the fiscal pressures experienced during covid when all international tourism stopped. The majority of businesses in Wadi Musa are associated with tourism and nearly everyone, from tour guides to PDTRA staff, are involved to some extent.

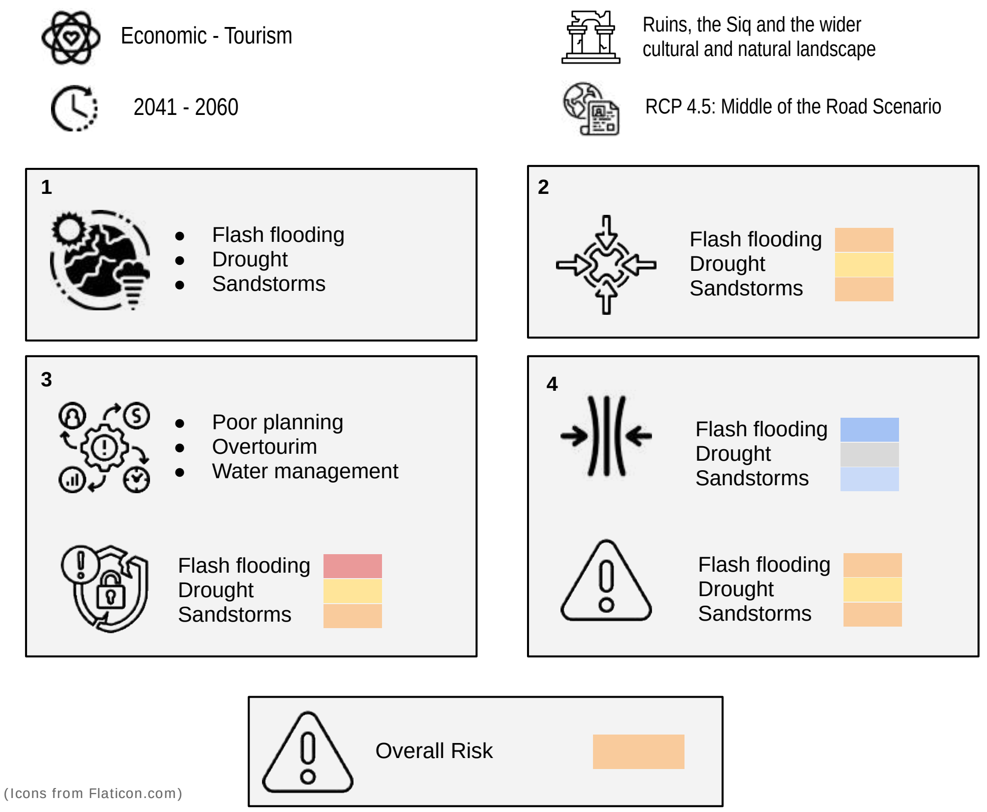


Figure 40: A graphical summary of the climate risk to economic values associated with tourism at Petra including assessments of impacts to date, sensitivity, exposure and social and economic vulnerabilities, and the adaptive capacity of the WH site and its community. While each climate hazard is assessed separately, an aggregate risk is also provided. For economic values associated with tourism, this risk is deemed to be moderate.

The attributes for economic values associated with tourism are similar to the heritage values attributes, which draw nearly 1 million visitors to the site every year. The loss of these attributes would result in a reduction of visitors and a reduction of economic value. Climate models indicate that there will be an increase in heavy precipitation events, drought, and sandstorms by 2060. These changes were confirmed by local knowledge, which has already noted increased risk to life from flash flooding, risk to structures from wind erosion, and to the wider landscape from flash flooding. Most of these attributes are sensitive to these changes; however, some are more exposed than others. These hazards are also likely to be exacerbated by social and economic factors including over-tourism, poor planning of tourist infrastructure, and infrastructural works that are maladapted to climatic change impacts. Overall risk is reduced by the considerable recent efforts of the PDRA, including a flash flood early warning system, the restoration and regular maintenance of hydrological systems at the site and education of those in the tourism sector to increased risks and responses. **Overall, the risk to the economic values associated with tourism of Petra by 2060 in a middle of the road emissions scenario ranged from low to moderate with an average risk of moderate.**

Economic Values - Agriculture

For a community so focused on tourism, it may seem odd that agriculture was identified as a key value; however, most members of the local community felt that it was a crucial part of their identity and an intrinsic part of the wider site. Specific activities included growing fruit and vegetables, keeping animals, and growing/ collecting herbs and ingredients for medicinal use.

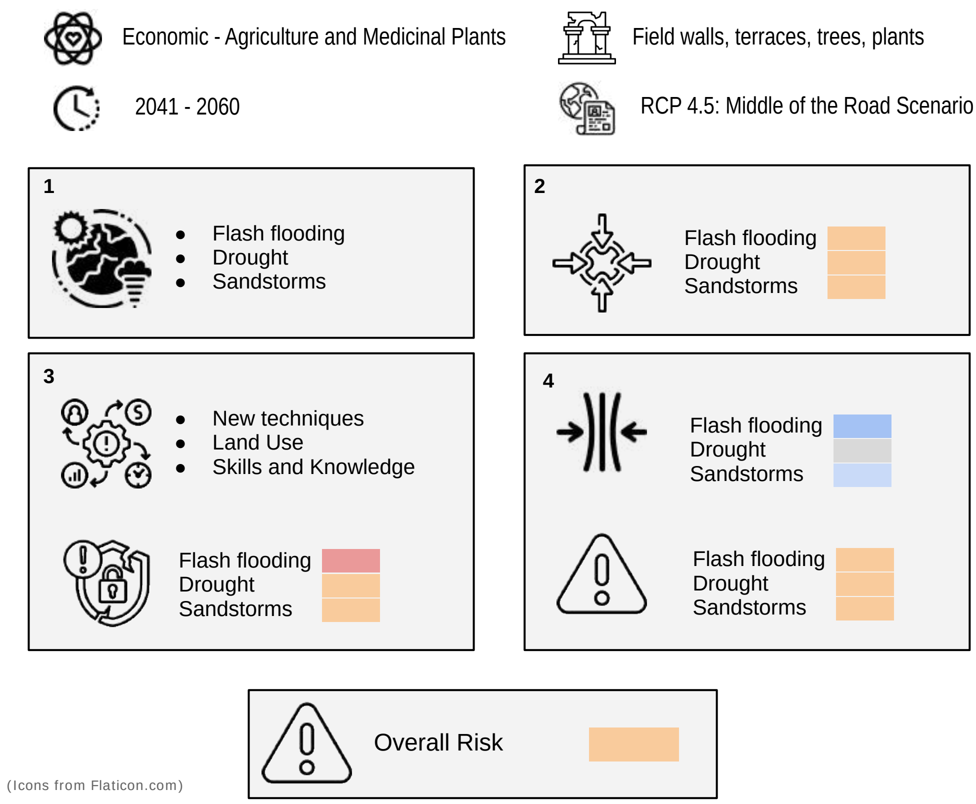


Figure 41: A graphical summary of the climate risk to economic values associated with agriculture at Petra including assessments of impacts to date, sensitivity, exposure and social and economic vulnerabilities, and the adaptive capacity of the WH site and its community. While each climate hazard is assessed separately, an aggregate risk is also provided. For economic values associated with agriculture, this risk is deemed to be moderate.

The attributes associated with agriculture are less tangible. They include local knowledge and processes as well as field walls and terraces, wells and the plants and trees. While a loss of these attributes would have significant economic impacts, it would also represent a loss of intangible traditions which link people with the landscape. While flash flooding, drought, and storms were all considered at moderate risk, it was felt that poor water management has exacerbated the issue of flooding, and that attributes were particularly vulnerable to heavy rains that damage crops. Thankfully, stakeholders also felt that more recent efforts to control and manage water in and around the WH site reduced these risks. Drought was discussed as a particular concern and participants noted current species and crop loss. Attempts to restore and maintain local wells were also presented as an adaptation strategy that participants felt could decrease some risk in the future. Even taking these factors into account, all three hazards pose a moderate risk to the economic values associated with agriculture. **Overall, the risk to the economic values associated with agriculture at Petra by 2060 in a middle of the road emissions scenario is moderate.**

Natural Values

While Petra was inscribed on the WH List as a cultural site, the wider landscape contains impressive natural attributes. These include the iconic geological formations so central to the visitor experience (like the Siq) and rich biodiversity, including a broad range of flora and fauna. Both visitors and locals avail of these attributes for experiences and for medicinal plants and food.

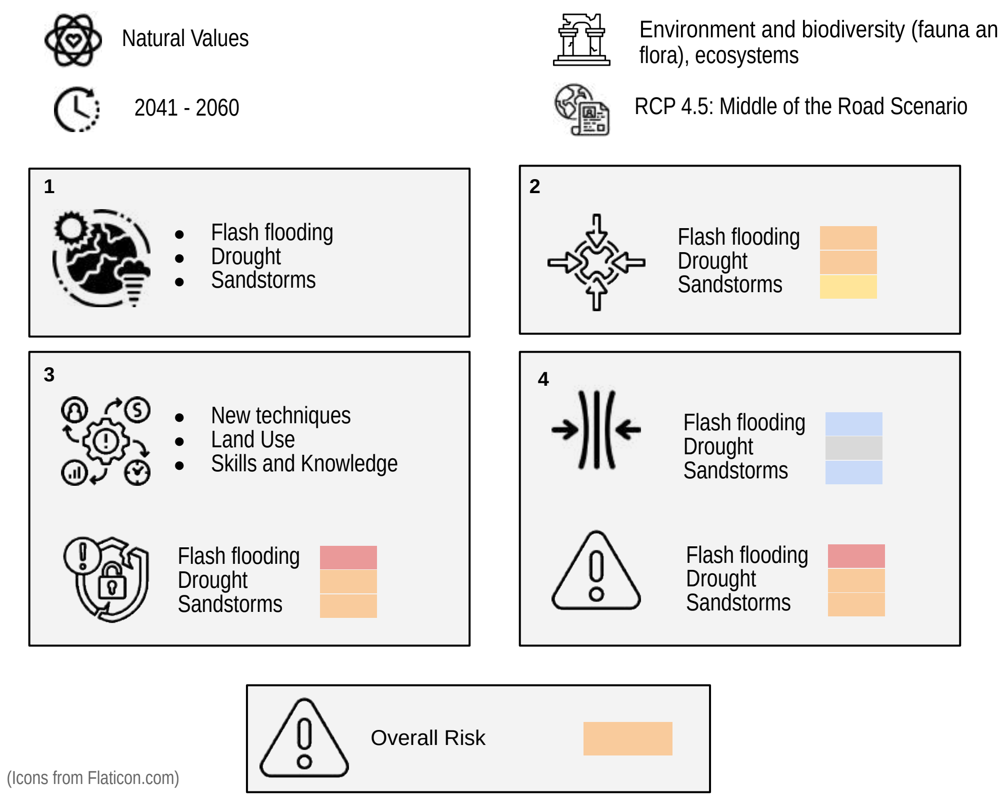
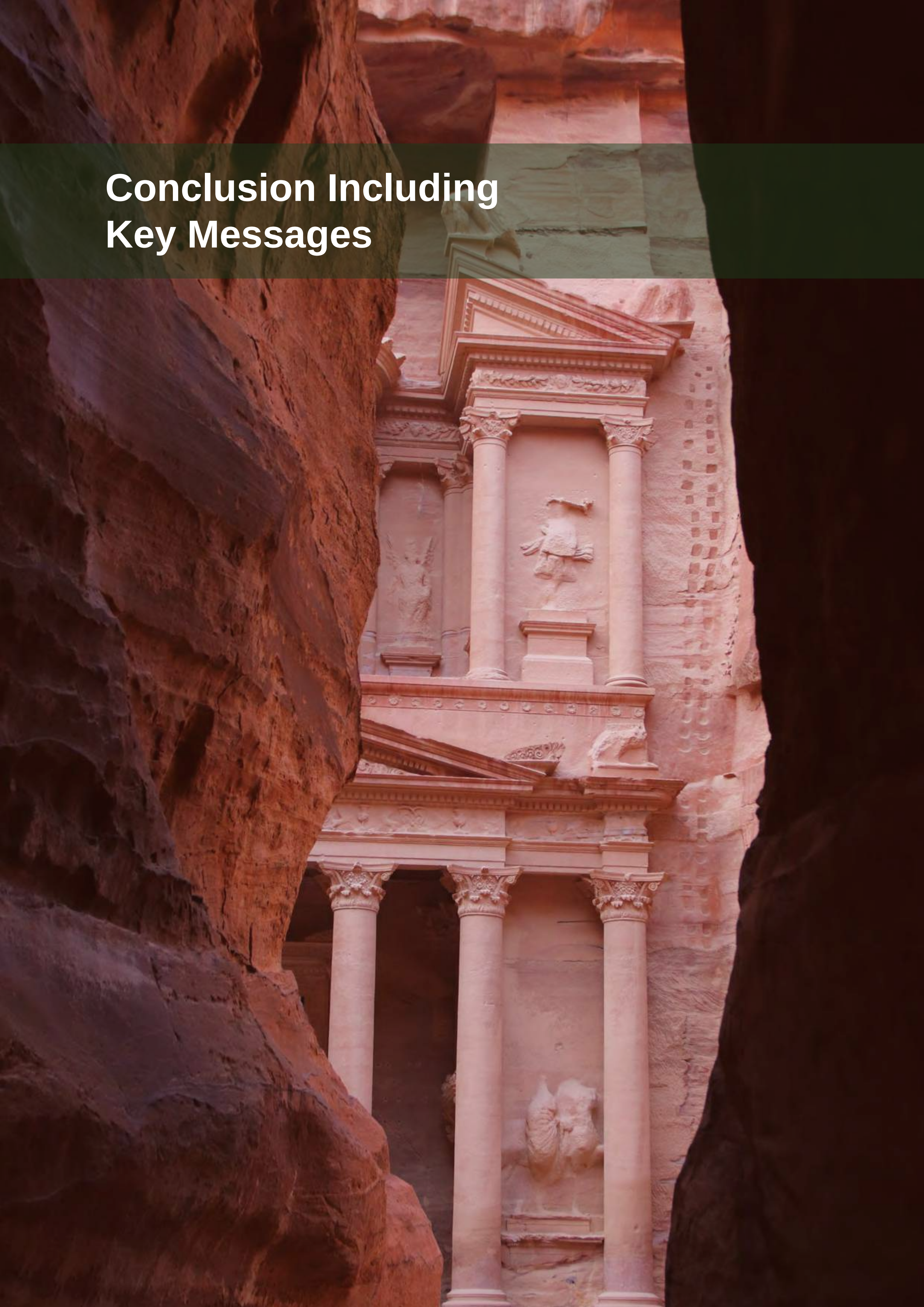


Figure 42: A graphical summary of the climate risk to natural values at Petra including assessments of impacts to date, sensitivity, exposure and social and economic vulnerabilities, and the adaptive capacity of the WH site and its community. While each climate hazard is assessed separately, an aggregate risk is also provided. For natural values, this risk is deemed to be moderate.

The attributes associated with the natural landscape are less cultural than other values. They include the natural environment, including flora and fauna, the geological formations in the landscape, and the overall biodiversity of the Petra landscape. Each attribute has very different levels of exposure and sensitivity and this makes evaluating risk more complex. Results here reflect the beliefs of local participants during the workshops. The natural environment is already suffering from species loss and participants note significant changes due to climate change. At present, all three hazards are having a low to moderate impact and participants felt that both flooding and drought will get worse by 2060. While adaptation efforts have had a significant impact on climate risk cultural values, it was felt that these efforts would be less effective on the natural environment. Taking these factors into account, the risk from the three hazards ranged from moderate to extreme. **Overall, the risk to the natural values of Petra by 2060 in a middle of the road emissions scenario ranged from moderate to extreme with an average risk of moderate.**

Conclusion Including Key Messages



Conclusion Including Key Messages

▶ Key Findings

The Petra climate risk assessment found that the overall risks to key values at the WH site by 2060 in a middle of the road scenario ranged from low to medium. Values directly associated with the WH site including heritage values and the economic value or tourism are less at risk. This is in no small part due to adaptation efforts in recent years to reduce the risk from rapid hazards including flash flooding which can have a major impact on both structure and tourist safety. Values associated with the wider landscape including nature and agriculture are at greater risk from climate change due to their sensitivity to slow onset hazards including drought. These are harder to adapt to, however, efforts to improve water security were noted by participants. Overall, the site showed a high adaptive capacity within the selected timeframe, however, existing vulnerabilities threaten to exacerbate impacts.

▶ Key Observations

The Preserving Legacies Risk Assessment methodology attempted to be as inclusive as possible, engaging with a wide range of experts and stakeholders to assess climate risk at Petra. This incorporated both top-down and bottom-up elements, ensuring that both current assessments and future adaptation actions will be undertaken in an inclusive and participatory manner as encouraged by the Paris Agreement. By listening to local knowledge and experiences, the process also attempted to overcome the outcome biases often present in assessing risk and vulnerability.

Key observations from this experience include:

1. The importance of **community engagement** to better understand the values of a place. While the heritage values of the WH site are understood and appreciated by the local community, other values including agricultural and natural values are also of great importance and must be considered when evaluating risk. Further workshops engaging a wider range of stakeholders would be important when considering next steps, including adaptation planning.

2. By taking a **values-based approach** to assessing risk, it was possible to explore wider community concerns. While heritage and tourism-based values are important at Petra, so too were agricultural values and values associated with the natural environment. Risk assessments should explore what matters to local communities.

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3. The value of **different knowledge systems** when considering climate hazards and impacts. Climate science models allowed the local community to visualise future change while local knowledge about changing weather, agriculture and society provided invaluable insight into how these changes will impact Petra and its community. Valuing both knowledge systems is key to understanding impacts and risk and further engagement with academic and research centres will provide valuable future insights.

- Existing **adaptation measures** - including learning from the past - are and will significantly decrease the risk from some climate hazards, especially rapid onset events like flooding. However, they are of less use for slow onset events like drought. In these cases, broader schemes addressing water security and policy changes are necessary.

- Many **key risk areas and impacts are preexisting** (including flash flooding and sandblasting) and were identified during the inscription process for WH site status. Climate change is and will make these impacts worse. Existing adaptation efforts and responses may continue to reduce these risks but must be considered alongside climate models and future changes in weather.

The results from this assessment can be used to inform future climate adaptation actions at Petra. Key values and climate hazards were identified and each value was assigned a risk assessment by 2060 based on a middle of the road emissions scenario. It has also identified key social and economic vulnerabilities which may exacerbate this risk as well as best-practice in adaptation which may reduce it. It is hoped that the results will be of value to both local management and national policy makers considering wider adaptation strategies across the country.

Glossary

▶ Glossary

Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
Anthropogenic	Resulting from or produced by human activities.
Climate	The composite or generally prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years.
Climate change	A change in the pattern of weather, and related changes in oceans and land surfaces, occurring over time scales of decades or longer.
Climate projection	A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models.
Exposure	A measure of the contact between a system (whether physical or social) and a stressor.
Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change.
Extreme weather event	A weather event that is rare at a particular place and time of year. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of the observed probability.
IPCC (Intergovernmental Panel on Climate Change)	The United Nations body, established in 1988, for assessing the science related to climate change; it was created to provide policymakers with regular scientific assessments on climate change, its implications, and potential future risks, as well as to put forward adaptation and mitigation options. The IPCC is the most authoritative international body on climate science and is an essential component of the world's response to climate change.

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Mitigation (of climate change)

A human intervention to reduce emissions or enhance the sinks of greenhouse gases (GHGs). Mitigation measures In climate policy are technologies, processes or practices that contribute to mitigation, for example renewable energy technologies, waste minimisation processes, public transport commuting practices, etc.

Restoration (in an environmental context)

Involves human interventions to assist the recovery of an ecosystem that has been previously degraded, damaged, or destroyed.

Weather

The state of the atmosphere—its temperature, humidity, wind, rainfall and so on—over hours to weeks.

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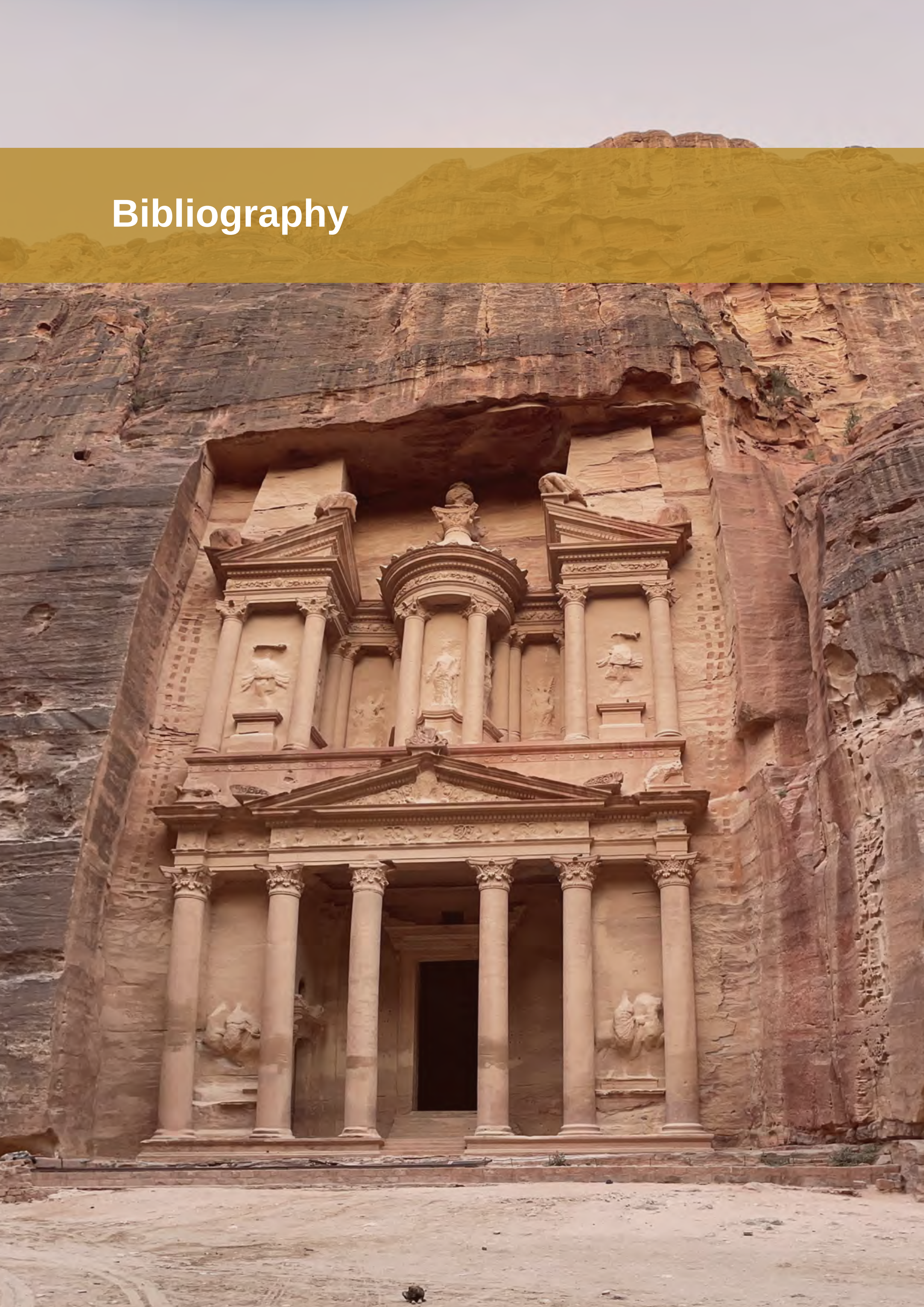

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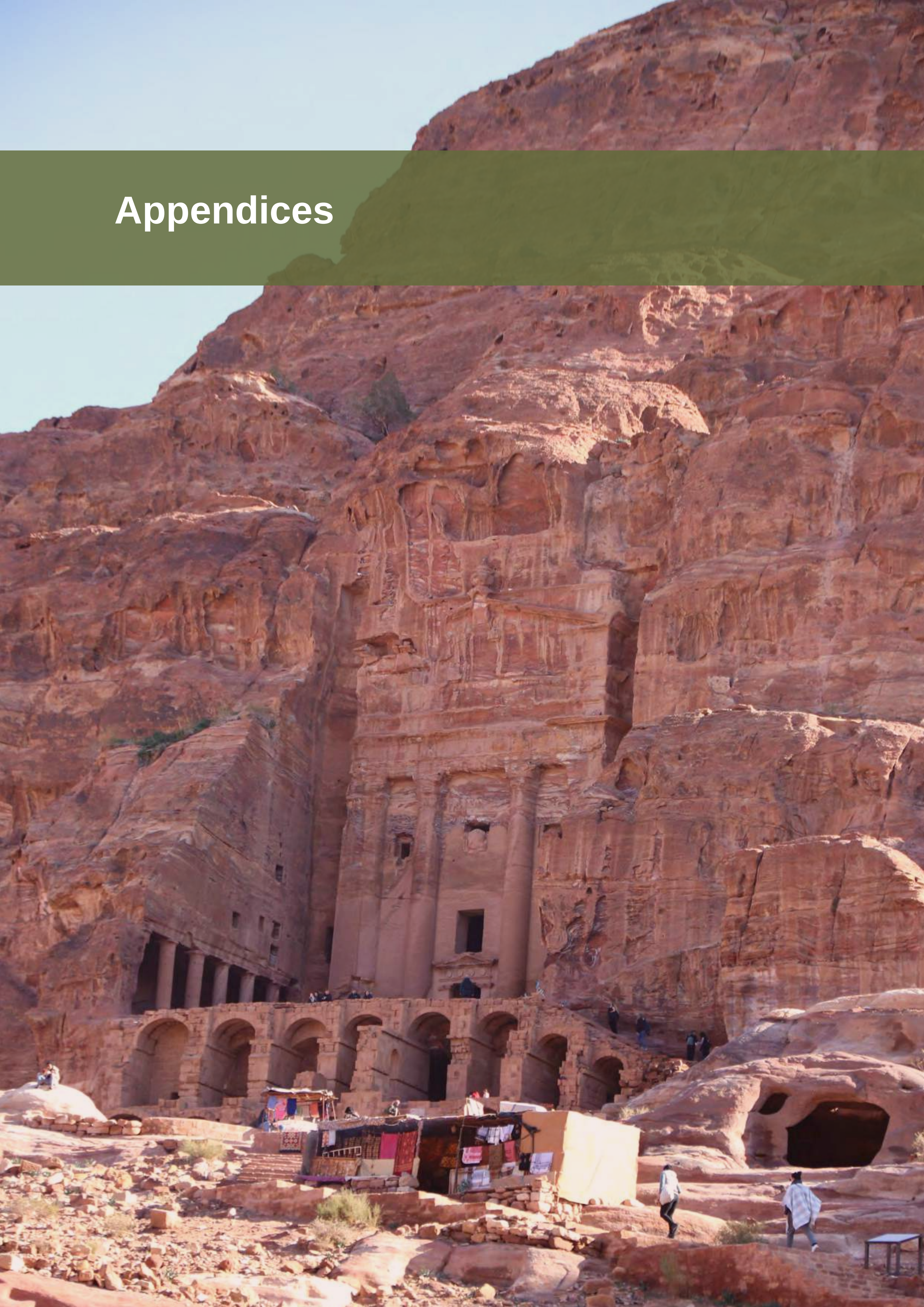
Appendices



► Appendix 1 - List of Workshop Participants

المؤسسة	الاسم
جمعية ينابيع البترا	عهد عبد المهدي الحسنات Ahed Abd El-Mahdi Al-Hassanet
	فاطمه هارون الحسنات Fatima Haroon Al-Hassanet
مديرية البيئة	اخلاص محمد سميحان Ekhlas Mohammad Samihat
PDAT	د.اعتدال موسى الحسنات Dr. Etidal Moussa Al-Hassanet
PAP	سناء مفضل الرواجفة Sanâa Mofadhel Al-Rawajfa
جمعية ارامل وادي موسى	عدله عيسى الطويسي Adla Eissa Al-Touwaissi
	علي رجا الخلايفة Ali Raja Al-Khalaifa
جمعية تعاونية وخيرية	سالم علي الرواجفه Salem Ali Al-Rawajfa
Artist in residence	خديجة ماجد الحسنات Khadija Majed Al-Hassanet
وحي الأردن للسياحة	احمد الهباهبه Ahmed Al-Habahba
	احمد الهلول Ahmad Al-Halloul
ICOMOS-JORDAN	أحمد مظهر بقيلة Ahmed Mazhar Bakila
	جهاد ابراهيم الهلالي Jihad Ibrahim Al-Hilali
	نور علي الخلايفة Nour Ali Al-Khalayfa
PNT	هيفاء عبد الحليم Haifa Abdalhaleem
PNT	غيث نوفل Ghaith Nawfel
	ماجد الحسنات Majed Al-Hassanet
PDTRA	طاهر الفلاحات Taher Al-Falahat
Site custodian	Carlos del Cairo
Site custodian	Chou Rudina

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المؤسسة	الاسم
Site custodian	Jasmine Remoket
Site custodian	Janni Albano
Site custodian	Marlon Martin
Site custodian	Vereniki Nalio
Site custodian	Lovely Yasmin
Preserving Legacies team member	Andrew Potts
	Dehora Treim
Preserving Legacies team member	Julianne Polanco
Preserving Legacies team member	Délie Ronsin
Preserving Legacies team member	Salma Sabour
Preserving Legacies team member	Will Megarry
Preserving Legacies Director	Victoria Herrmann
Preserving Legacies team member	Khansa Bouaziz
Preserving Legacies team member	Michael Snyoler
Site custodian	Connie Kelleher
Site custodian	Fergus Mc Cormrck

▶ Appendix 2 - Focus Groups Participants

Civil Society Group - 13th May 2023

1. Fawaziah Al Hassanat - Al Anbat Women Association - فوزية الحسنات - جمعية الأنباط للنساء
2. Zeinab Al Hlalat - Al Anbat Women Association - زينب الهلالات - جمعية الأنباط للنساء
3. Dr. Nadia Towaisi - Bayt Al Anbat Organization - د. نادية الطويسي - منظمة بيت الأنباط
4. Ahed Al Hassant - Petra Springs society (Yanabe' Al Patra) - عهد الحسنات - جمعية ينابيع البترا
5. Major General (Retired) - Salem Al Rawajfeh - اللواء المتقاعد سالم الرواجفة
6. Muyasser Khlaifat - Petra Pottery Association - ميسر خليفات - جمعية الفخار البترائي

7. Khalifah Al Hlalat - Anbat Capital Association - خليفة الهلالات - جمعية العاصمة الأنباطية
8. Mahmoud Towaisi - Bayt Al Anbat Organization - محمود الطويسي - منظمة بيت الأنباط
9. Jehad Al Hilali - Local community member - جهاد الهلالات - عضو في المجتمع المحلي
10. Radwan Al Salameen- Anbat Capital Association - رضوان السلامين - جمعية عاصمة الأنباطية
11. Adlah Alowaisi - Wadi Musa Widwos Association - عدلة العويسي - جمعية أرامل وادي موسى
12. Saleh Al Nusairat - Local Artist - صالح النسيرات - فنان محلي

PDTRA Staff - 14th May 2023:

1. Areej Mohammed Al Farjat - Petra Archeological Park (PAP) - أريج محمد الفرجات محمية البترا الأثرية
2. Ikhlas Abu Shattal - Ministry of Environment, Petra - إخلاص أبو شتال - وزارة البيئة، البترا
3. Donia Al Mashallah - Petra Archeological Park (PAP) - دنيا المشاعلة - محمية البترا الأثرية
4. Sana Al Rawajfeh - Petra Archeological Park (PAP) - سناء الرواجفة - محمية البترا الأثرية
5. Dr. Nesreen Abdulrahman Hasan - Petra Archeological Park (PAP) - د. نسرين عبدالرحمن حسن - محمية البترا الأثرية
6. Maha Ahmad- Petra Museum - مها أحمد - متحف البترا
7. Dr. Etdal Musa Al Hasanat - Petra Development Tourism Region Authority (PDTRA) - د. اعتدال موسى الحسنات - سلطة اقليم البترا التنموي السياحي
8. Firas Al Salmeen- Petra Archeological Park (PAP) - فراس السلمين - محمية البترا الأثرية
9. Hussam Al Hassant - Petra Development Tourism Region Authority (PDTRA) - حسام الحسنات - سلطة اقليم البترا التنموي السياحي
10. Salem Ismael Al Mashaleh - Petra Archeological Park (PAP) - سالم إسماعيل المشاعلة - محمية البترا الأثرية
11. Yehya Al Hasanat - Petra Archeological Park (PAP) - يحيى الحسنات - محمية البترا الأثرية
12. Hala Maher Al Farjat - Petra Archeological Park (PAP) - هالة ماهر الفرجات - محمية البترا الأثرية
13. Halemah Al Nawafleh - Petra Archeological Park (PAP) - حليمة النوافلة - محمية البترا الأثرية
14. Mohammed Al Samadi - Petra Development Tourism Region Authority (PDTRA), Environment - محمد الصمادي - سلطة اقليم البترا التنموي السياحي
15. Sameer Al Nawafleh- Department of Operations and Control - سمير النوافلة- دائرة العمليات والسيطرة
16. Mayson Al Hasanat- Petra Cultural Centre - ميسون الحسنات - مركز البترا الثقافي
17. Ahmad Al Nawafleh- Petra Cultural Centre - أحمد النوافلة - مركز البترا الثقافي

Tourism Services providers – 14th May 2023:

1. Ahmad Al Habahbeh- Wahi Al Ordon for Tourism - أحمد الهباهبه - واحة الأردن للسياحة
2. Ramzi Al Amareen - Wahi Al Ordon for Tourism - رمزي العمارين - واحة الأردن للسياحة
3. Eid Al Amareen - Tour guide - عيد العمارين - مرشد سياحي
4. Hani Masadeh - Tour Guides Association - هاني مساعدة - جمعية مرشدي السياحة

5. Zeid Halalt - Tour Guide -زيد هلالات - مرشد سياحي
6. Abdulaziz Ibrahim - Tour operator -عبد العزيز إبراهيم - مشغل سياحي
7. Tareq Al Towasi- Hotels Association - طارق الطويسي - جمعية الفنادق

► Appendix 3 - Petra Statement of Outstanding Universal Value

(From the UNESCO World Heritage Centre website)

Brief synthesis

Situated between the Red Sea and the Dead Sea and inhabited since prehistoric times, the rock-cut capital city of the Nabateans, became during Hellenistic and Roman times a major caravan centre for the incense of Arabia, the silks of China and the spices of India, a crossroads between Arabia, Egypt and Syria-Phoenicia. Petra is half-built, half-carved into the rock, and is surrounded by mountains riddled with passages and gorges. An ingenious water management system allowed extensive settlement of an essentially arid area during the Nabataean, Roman and Byzantine periods. It is one of the world's richest and largest archaeological sites set in a dominating red sandstone landscape.

The Outstanding Universal Value of Petra resides in the vast extent of elaborate tomb and temple architecture; religious high places; the remnant channels, tunnels and diversion dams that combined with a vast network of cisterns and reservoirs which controlled and conserved seasonal rains, and the extensive archaeological remains including of copper mining, temples, churches and other public buildings. The fusion of Hellenistic architectural facades with traditional Nabataean rock-cut temple/tombs including the Khasneh, the Urn Tomb, the Palace Tomb, the Corinthian Tomb and the Deir ("monastery") represents a unique artistic achievement and an outstanding architectural ensemble of the first centuries BC to AD. The varied archaeological remains and architectural monuments from prehistoric times to the mediaeval periods bear exceptional testimony to the now lost civilisations which succeeded each other at the site.

Criterion (i): The dramatic Nabataean/Hellenistic rock-cut temple/tombs approached via a natural winding rocky cleft (the Siq), which is the main entrance from the east to a once extensive trading city, represent a unique artistic achievement. They are masterpieces of a lost city that has fascinated visitors since the early 19th century. The entrance approach and the settlement itself were made possible by the creative genius of the extensive water distribution and storage system.

Criterion (iii): The serried rows of numerous rock-cut tombs reflecting architectural influences from the Assyrians through to monumental Hellenistic; the sacrificial and other religious high places including on Jebels Madbah, M'eisrah, Khubtha, Habis and Al Madras; the remains of the extensive water engineering system, city walls and freestanding temples; garden terraces; funerary stelae and inscriptions together with the outlying caravan staging posts on the approaches from the north (Barid or Little Petra) and south (Sabra) also containing tombs, temples, water cisterns and reservoirs are an outstanding testament to the now lost Nabataean civilization of the fourth century BC to the first century AD.

Remains of the Neolithic settlement at Beidha, the Iron Age settlement on Umm al Biyara, the Chalcolithic mining sites at Umm al Amad, the remains of Graeco-Roman civic planning including the colonnaded street, triple-arched entrance gate, theatre, Nymphaeum and baths; Byzantine remains including the triple-apses basilica church and the church created in the Urn Tomb; the remnant Crusader fortresses of Habis and Wueira; and the foundation of the mosque on Jebel Haroun, traditionally the burial place of the Prophet Aaron, all bear exceptional testimony to past civilizations in the Petra area.

Criterion (iv): The architectural ensemble comprising the so-called "royal tombs" in Petra (including the Khazneh, the Urn Tomb, the Palace Tomb and the Corinthian Tomb), and the Deir ("monastery") demonstrate an outstanding fusion of Hellenistic architecture with Eastern tradition, marking a significant meeting of East and West at the turn of the first millennium of our era.

The Umm al Amad copper mines and underground galleries are an outstanding example of mining structures dating from the fourth millennium BC.

The remnants of the diversion dam, Mudhlim tunnels (dark tunnels), water channels, aqueducts, reservoirs and cisterns are an outstanding example of water engineering dating from the first centuries BC to AD.

Integrity

All the main freestanding and rock-cut monuments and extensive archaeological remains within the arid landscape of red sandstone cliffs and gorges lie within the boundaries of the property that coincide with the boundaries of the Petra National Park. The monuments are subject to ongoing erosion due to wind and rain, exacerbated in the past by windblown sand due to grazing animals reducing ground cover. The resettlement more than twenty years ago of the Bdul (Bedouin) tribe and their livestock away from their former seasonal dwellings in the Petra basin to a new village at Umm Sayhun was aimed in part at arresting this process.

They are also vulnerable to flash flooding along Wadi Musa through the winding gorge (Siq) if the Nabataean diversion system is not continually monitored, repaired and maintained.

The property is under pressure from tourism, which has increased greatly since the time of inscription, particularly congestion points such as the Siq which is the main entrance to the city from the east.

The property is also vulnerable to the infrastructure needs of local communities and tourists. A new sewerage treatment plant has been provided within the property to the north with the recycled water being used for an adjacent drip irrigation farming project. Further infrastructure development proposed inside the boundary includes electricity supply and substation, a community/visitor centre, an outdoor theatre for community events, picnic areas, camping ground and a new restaurant near the Qasr al Bint temple, all of which have the potential to impact on the integrity of the property.

Authenticity

The attributes of temple/tomb monuments, and their location and setting clearly express the Outstanding Universal Value. The natural decay of the sandstone architecture threatens the authenticity of the property in the long-term. Stabilisation of freestanding monuments including the Qasr al Bint temple and the vaulted structure supporting the Byzantine forecourt to the Urn Tomb Church was carried out prior to inscription.

► Appendix 4 - Workshop Timetable

Time	**6 June 23**	**7 June 23**	**8 June 23**
Amman	*Tuesday*	*Wednesday*	*Thursday*
8:30:00 AM	**Registration and Arrival**		
9:00:00 AM	Presentation 1 Welcome from PNT/ PDTRA and Introduction to Project (*Victoria*)	Presentation 5: Introduction to Day 2 and Summary of Results from Days 1 *Tahir*	Presentation 8: Introduction to Day 3 and Summary of Results from Days 1 and 2 *Haifaa*
9:15:00 AM	Presentation 2: Workshop Introduction and introduction to values and attributes *Haifa*		
9:30:00 AM		Presentation 6 : Climate models and future climate scenarios *Haifaa*	Presentation 9: Introduction to the concepts of adaptive capacity and resilience with Q&A *Tahir and Haifaa*
9:45:00 AM	Presentation 3 : Overview of WH Values and Attributes Share Statement of OUV *Tahir*		
10:00:00 AM			Presentation 10: Overview of resilience and adaptive capacity discussed in focus groups *Majed*
10:15:00 AM	Q&A on WH Values and Attributes *Tahir*	Q&A on climate models and future climate scenarios and ranking hazards using table *Haifaa*	
10:30:00 AM	**Coffee**		
10:45:00 AM			
11:00:00 AM	Presentation 4: Overview of Values as discussed in focus groups *Majed*	Presentation 7 : Overview of climate impacts discussed in focus groups *Majed*	Introduction to Exercise
11:15:00 AM			Small groups and worksheet exercise to assess adaptive capacity 3 x Small Groups with Small Group Leader
11:30:00 AM	Introduction to Exercise	Introduction to Exercise (Key Terms Handout)	
11:45:00 AM	Small groups and worksheet exercise to rank values and confirm/ identify attributes 3 x Small Groups with Small Group Leader	Small groups and worksheet exercise to assess impacts to values and agree vulnerability 3 x Small Groups with Small Group Leader	
12:00:00 PM			
12:15:00 PM			
12:30:00 PM			Plenary discussion on small group exercise *Haifa and Tahir*
12:45:00 PM			
1:00:00 PM	Plenary discussion on small group exercise *Haifa and Tahir*	Plenary discussion on small group exercise *Haifa and Tahir*	Final group exercise to agree vulnerability assessment
1:15:00 PM			
1:30 PM	**Lunch**		

► Appendix 5 - Question list: Focus groups Jordan workshop

Participants need to start by understand the key terminology in their mother tongue:

- Values / attributes / OUV from the needed perspective of heritage science
- Hazards, impact, impact assessment, vulnerabilities
- Adaptation, adaptive capacity, mitigation, reducing impacts, mal-adaptation
- Climate, Weather, climate change,

1- Discussion on values:

1. Why is this site important for you as a member of the community? What's its importance for the community?
2. From your perspective, what are the key attributes of the site? They may be key physical places (like the treasury), or specific flora or fauna?
3. From your perspective, what are the key values of the site?
4. Are there any conflicts between different values?

=> Identify key values and attributes for FG stakeholders

2- Present climate report:

1. Have you ever heard about climate change? And do you think that this is happening only in your region or is it a global issue?
2. Have you ever noticed a change in the climate of your region over recent years?
3. From your perspective, what are the reasons behind climate change? And is it possible to live normally with the new environmental reality?
4. Did you mention any impacts on your personal lifestyle caused by a climate hazard or the climate change?
5. What are the hazards that you think would be the most impactful on the heritage values of the site? For example, how might climate change impact your activities at the site? Over what time frames might this happen?

=> Prepare a list of key hazards

3- Identify Impacts:

1. Present Impacts: How vulnerable do you think the site is from climate change?
2. Do you think that the climate could have a considerable impact on the heritage attributes of your site? the values? (especially that most of the attributes of the site resisted for many long centuries)
3. Past Impacts: Are there any values or attributes which we have already lost at the site?
4. Future Impacts: What are the most vulnerable/fragile values towards climate change that we may lose soon? In a decade? By 2050? By 2100?
5. What are the possible impacts that could affect the property? 6. Do you feel/think that the impacts on heritage would affect your families and your communities? how?

=> Come up with a list of key impacts

4- Stakeholder responses:

1. Is it possible to adapt to the impacts of climate change??
2. Do you feel like yo have a say in climate change adaptations at the site
3. Who is supposed to do the impact assessment of climate on heritage attributes and values?
4. How could the impact assessment become a participatory/inclusive action in the property?

=> Ideas on how to mitigate the impacts of climate change from different perspectives.

PETRA NATIONAL TRUST
الجمعية الوطنية للمحافظة على البترا

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Petra
Petra Development & Tourism Region Authority
سلطة إقليم البترا التنموي السياحي

Wadi Mousa, Petra - Jordan
www.pdtra.gov.jo

PRESERVING LEGACIES
www.heritageadapts.org

ICOMOS
international council on monuments and sites
www.icomos.org

Climate Heritage NETWORK
www.climateheritage.org