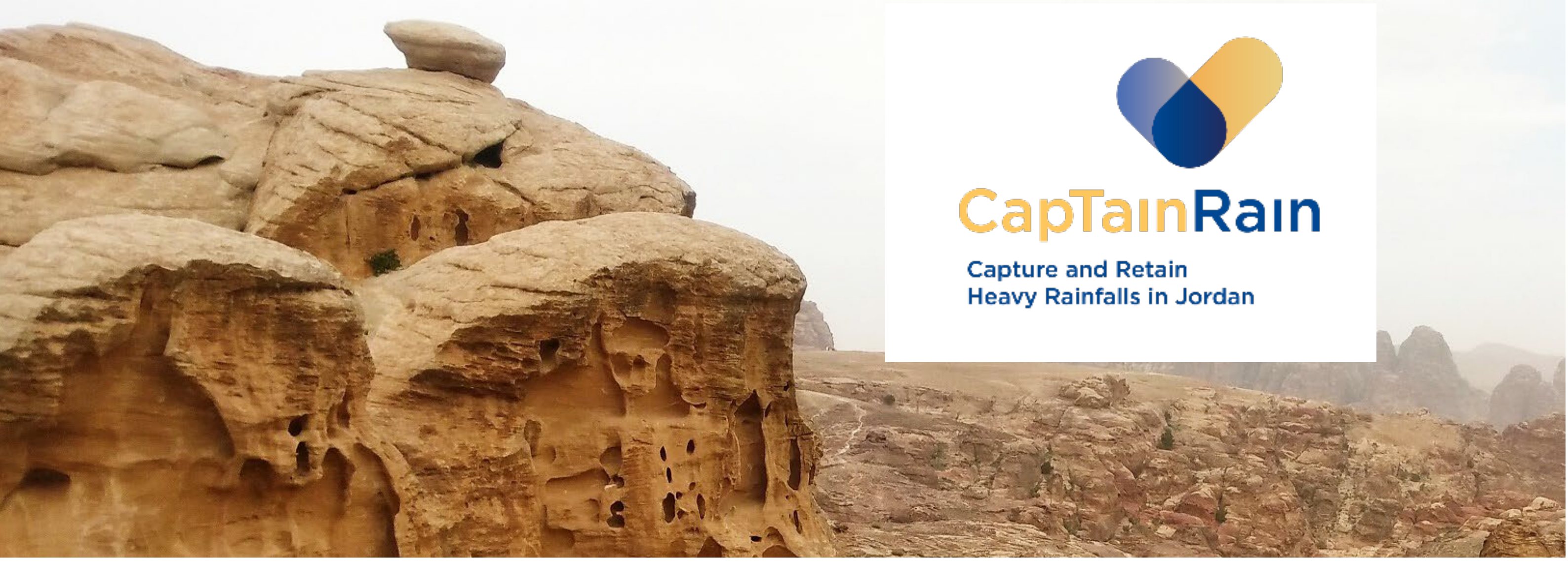

Capture and retain heavy rainfalls in Jordan (CapTain Rain)

Progress report 2022

(January 2022 – December 2022)

Presented by the CapTain Rain project team

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Number and type of project partners (updated list)

Partner from Germany (Abbreviation)	Type
Institute for Social-Ecological Research (ISOE)	Research Institute
Koblenz University of Applied Sciences (KU)	University
Potsdam Institute for Climate Impact Research (PIK)	Research Institute
HAMBURG WASSER (HW)	Company
KISTERS AG (KIS)	Company
Institute for Technical and Scientific Hydrology GmbH (ITWH)	Company
Partner from Jordan (Abbreviation)	
Ministry of Environment of Jordan (MoE)	Ministry
Ministry of Water and Irrigation of Jordan (MWI)	Ministry
Jordan Meterological Department (JMD)	Research Center
Greater Amman Municipality (GAM)	Administration
Royal Jordanian Geographic Center (RJGC)	Research Center

Further important associated partners: Petra Development and Tourism Region Authority (PDTRA), National Agricultural Research Center (NARC), German Jordanian University (GJU), Kyoto University, Swiss Development Cooperation (SDC) - National flood mapping program

CapTainRain

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Zusammenfassung

Der Nahe Osten ist in besonderem Maße vom Klimawandel und extremen Klimaereignissen wie Dürren und starken Regenfällen betroffen. In Jordanien haben die wiederholten Starkregenereignisse der letzten Jahre zu Sturzfluten mit enormen Schäden geführt. Zugleich ist Jordanien eines der wasserärmsten Länder der Welt und verfügt nur über wenige erneuerbare Wasserressourcen. Die Minimierung solcher Schäden, aber auch die Maximierung des Nutzens von Starkregenereignissen durch verbesserte Wasserrückhaltung in einem der wasserärmsten Länder der Welt, ist das Forschungsthema von CapTain Rain ("Capture and retain heavy rainfalls in Jordan"). Dazu werden die treibenden Faktoren von Sturzfluten in jordanischen Wadi-systemen analysiert und die komplexen Wechselwirkungen zwischen Klima- und Landnutzungsänderungen und wasserbaulichen Maßnahmen untersucht. Auf der Grundlage von Vulnerabilitätsanalysen und technischen Lösungen für die Wassersammlung und -ableitung bei Starkregenereignissen werden Maßnahmen zum Schutz der Bevölkerung identifiziert. Klimadienstleistungen (z.B. Sturzflutgefahrenkarten, Frühwarnsysteme, Empfehlungen zur Vorbeugung von Starkregenereignissen) werden in enger Zusammenarbeit mit jordanischen Akteuren und Praxispartnern unter Berücksichtigung wissenschaftlicher und lokaler praktischer Erkenntnisse entwickelt. Das Untersuchungsgebiet umfasst die Hauptstadt Amman mit ihren 4,3 Millionen Einwohnern in der Metropolregion und die eher ländlich geprägte Wadi Musa Region um das UNESCO-Weltkulturerbe Petra. Beide Regionen waren in der Vergangenheit stark von Sturzflutereignissen betroffen.

Nach dem erfolgreichen Start des CapTain Rain Projekts im Juni 2021 setzten alle Arbeitspakete (AP) ihre Forschungsarbeiten und die damit verbundenen empirischen Erhebungen im Jahr 2022 fort. Die Bestandsaufnahmen zum lokalen Wissen und den lokalen Bedingungen in AP 3-4 wurden abgeschlossen und die retrospektive Analyse von Starkregenereignissen in AP 2 ist weitgehend abgeschlossen. In AP 3 wurde das hydraulische und hydrologische Modell ausgewählt und mit der Simulation der aktuellen Situation begonnen. Außerdem wurden die zielgruppenorientierte Disseminationsstrategie und der Publikationsplan entworfen.

Um die kollaborative und transdisziplinäre Arbeit zu fördern, wurde besonderes Augenmerk auf die interne Kommunikation innerhalb des Netzwerks gelegt. Dazu gehörten regelmäßige Telefon-konferenzen des CapTain Rain Koordinierungsteams, monatliche Treffen und Videokonferenzen der Teams der verschiedenen Arbeitspakete sowie regelmäßige Projekttreffen. Insgesamt fanden im Berichtszeitraum vier größere Projekttreffen mit den deutschen Partnern (zwei online und zwei in Anwesenheit), zwei große Projekttreffen mit den deutschen und jordanischen Partnern (online) sowie zwei Sitzungen des Steering Committee (online) statt.

Zu den Höhepunkten des Jahres 2022 zählten insbesondere der erfolgreiche Abschluss der Kooperationsvereinbarungen mit den jordanischen Partnern, der Beitrag zum Capacity Building durch insgesamt fünf vom CapTain Rain-Team durchgeführten Online-Trainings (Webinare), Feldaufenthalte in Jordanien im Mai, September, November und Dezember und die Fertigstellung von elf Publikationen und Konferenzbeiträgen.

Summary

The Middle East is particularly affected by climate change and extreme climatic events such as droughts and heavy rainfall. In Jordan, repeated heavy rainfall events in recent years have led to flash floods with enormous damage. At the same time, Jordan is one of the most water-scarce countries in the world and has few renewable water resources. Minimising such damage while maximising the benefits of heavy rainfall through improved water retention is the research topic of CapTain Rain ("Capture and retain heavy rainfalls in Jordan (webpage: www.captain-rain.de)". Within the transdisciplinary research project CapTain Rain, the German and Jordanian project partners aim to help improve current methods and tools for flash flood prediction and prevention. For this purpose, the driving factors of flash floods in Jordan's wadi systems will be analysed and the complex interactions between climate and land use changes and hydraulic engineering measures will be unravelled. Based on vulnerability analyses and engineering solutions for water collection and drainage during heavy rainfall events, measures to protect the population will be identified. Climate services (e.g., flash flood risk maps, early warning systems, recommendations for heavy rainfall risk prevention) will be developed in close collaboration with Jordanian stakeholders and practice partners, considering scientific as well as local practical knowledge. The study areas include the capital Amman with its 4.3 million inhabitants in the metropolitan region and the more rural region Wadi Musa around the UNESCO World Heritage Site Petra. Both regions have been heavily affected by flash flood events in the past.

After a successful start of the CapTain Rain project in June 2021, all work packages continued their investigations and related empirical work in 2022. Inventories on the local knowledge and local conditions in WP 3-4 were finalized and the retrospective analysis of heavy rainfall events in WP 2 has been largely completed. In WP 3, the hydraulic and hydrological model were selected and simulations of the current situation started. Furthermore, the target group-oriented dissemination strategy and the publication plan have been drafted.

To foster collaborative and transdisciplinary work, special attention was paid to internal communication within the network. This included regular teleconferences of the CapTain Rain coordination team, monthly meetings and video conferences of the different work packages' teams, and regular project meetings. In total, four major project meetings with the German partners (two online and two in presence), two major project meetings with the German and Jordanian partners (online) and two meetings of the steering committee (online) took place during the reporting period.

Highlights for the year 2022 included in particular the successful finalization of the collaboration agreements with Jordanian Partners, the contribution to capacity building by altogether five webinars conducted by the CapTain Rain team, travels to Jordan of some German partners in May, September, November and December and the finalization of eleven publications and conference contributions.

Topics and objectives of the project

Background

The Middle East is particularly affected by climate change and extreme weather events. Over the past 50 years, heavy rainfall events in Jordan have caused many flash floods that lead to significant property damage and fatalities. At the same time, Jordan is one of the most water-scarce countries in the world and has few renewable water resources. Maximizing the benefits of heavy rainfall events in terms of water harvesting and minimizing flash flood damages is therefore one of the most important tasks when it comes to climate change adaptation in Jordan.

One prerequisite for minimizing disaster losses is the ability to accurately predict disaster events so that precautionary measures can be taken. Such “climate services” for risk prevention are a high political priority in Jordan, but have not yet been sufficiently put into practice. Despite recent scientific findings, there is a lack of basic hydrological and meteorological knowledge which is needed to better predict the occurrence and intensity of flash floods in Jordan’s wadi systems. A successful development and implementation of climate services also requires that it is done in cooperation with future users and decision makers. Here, transdisciplinary research methods enable a holistic analysis of flash flood hazards and hazard prevention and facilitate the transfer of scientific knowledge into practical measures for climate change adaptation.

Objectives

CapTain Rain aims to help improve current methods and tools for flash flood prediction and prevention in Jordan. For this purpose, the driving factors of flash floods in Jordan’s wadi systems are analysed and the complex interactions between climate and land use changes and hydraulic engineering measures are deciphered. Based on vulnerability analyses and engineering solutions for water collection and drainage during heavy rainfall events, measures to protect the population are identified.

Climate services (e.g. flash flood risk maps, early warning systems, recommendations for heavy rainfall risk prevention) are developed in close collaboration with Jordanian stakeholders and practice partners, considering scientific as well as local practical knowledge. The transdisciplinary research methods of CapTain Rain enable a holistic analysis of flash flood hazards together with hazard prevention and facilitate the transfer of scientific knowledge into practical measures for climate change adaptation.

For this, CapTain Rain will:

(1) analyse the social-ecological drivers of flash floods in Jordan's wadi systems and entangle the complex interactions between climate and land use change to enable a better simulation and prognosis of flash flood events;

(2) assess the social-ecological risk of flash floods using an integrated vulnerability analysis, taking into account the spatial exposure of flash floods, sensitivity and adaptive capacity;

(3) develop climate services for flood-related decision making based on stakeholder dialogues and participatory approaches;

(4) and identify promising measures to improve the adaptive capacity of local communities, including methods and technologies to capture and retain water from heavy rainfall, but also to prevent damages.

The study areas include the capital Amman with its 4.3 million inhabitants in the metropolitan region and the more rural region around Wadi Musa, including the UNESCO World Heritage Site Petra (Figure 1). Both regions have been heavily affected by flash flood events in the past.

In the past ten years, Amman has experienced a total of six flash floods (Nov 14, Nov 15, Jan 18, Apr 18, Oct 18, and Feb 19). The November 2014 flood was particularly severe, killing three people in Amman, as was the November 2015 flood, which killed four people and caused extensive property damage. Overall, the risk of flash flood events in Amman has increased dramatically due to rapid urbanization in recent decades.

In Petra, in particular, there was a very severe flash flood in 1963, when large parts of the UNESCO World Heritage Site were flooded and about 20 tourists died. In the 1991, 1995, and 1996 flash floods, several tourists had to be evacuated (Al-Weshah/El-Khoury 1999). The most recent severe flash flood in Petra occurred in November 2018 with a total of 12 fatalities, according to media reports.

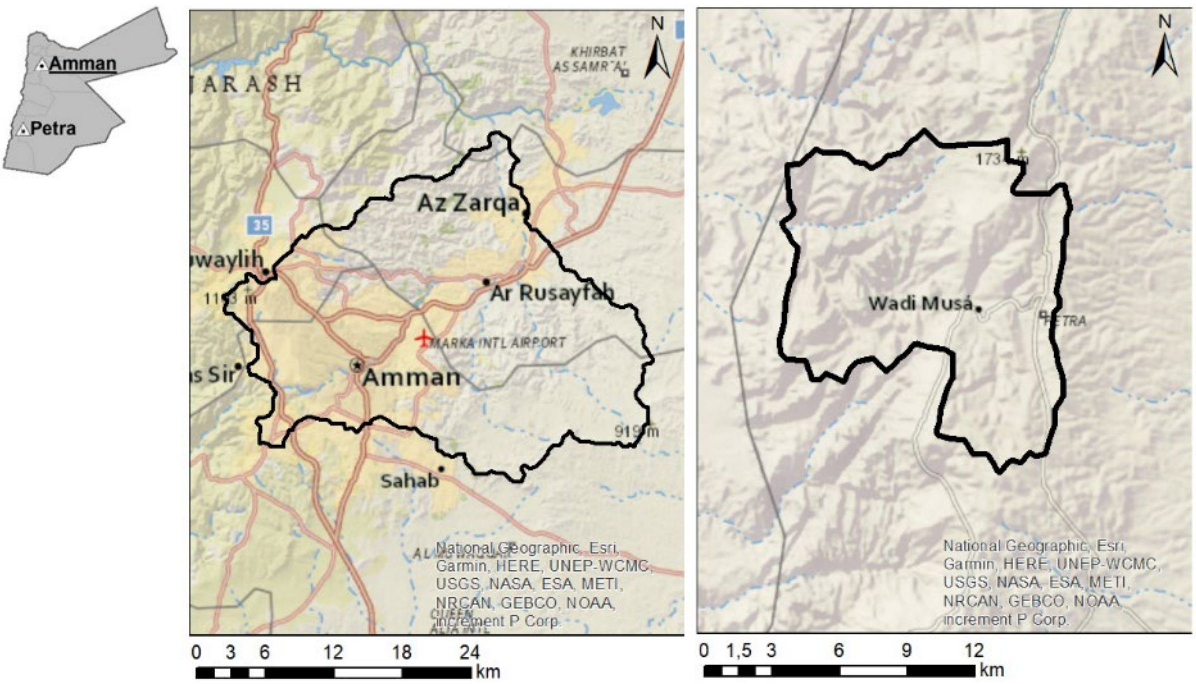


Figure 1. Overview of the selected study areas: The capital Amman as urban region (left) and the more rural region of Wadi Musa (right), Jordan (satellite image scene in the background: Sentinel-2B, April 2019).

Project structure

An integrated vulnerability analysis of flash floods is carried out in close collaboration with relevant stakeholders, which includes the analysis of the socio-ecological causes of flash floods and the identification, mapping and assessment of flash flood risks (exposure and sensitivity). In addition, risk perceptions are investigated from the perspective of the local population and strategies for adaptation to heavy rainfall events are developed. Model-based scenarios are used to develop and evaluate measures to improve risk preparedness, including technologies to divert and use water from heavy rainfall events. Climate services for the prevention of heavy rainfall risks are prepared and made available in a participatory manner.

Altogether, six work-packages (WP) with researchers from Germany and Jordan contribute to the analysis of flash floods including the integrated vulnerability analysis and provide a revision of the current methods for flash flood prediction and prevention. Each WP is subdivided in two sub-work packages, expect of WP 3, which comprises three sub-work packages (Figure 2).

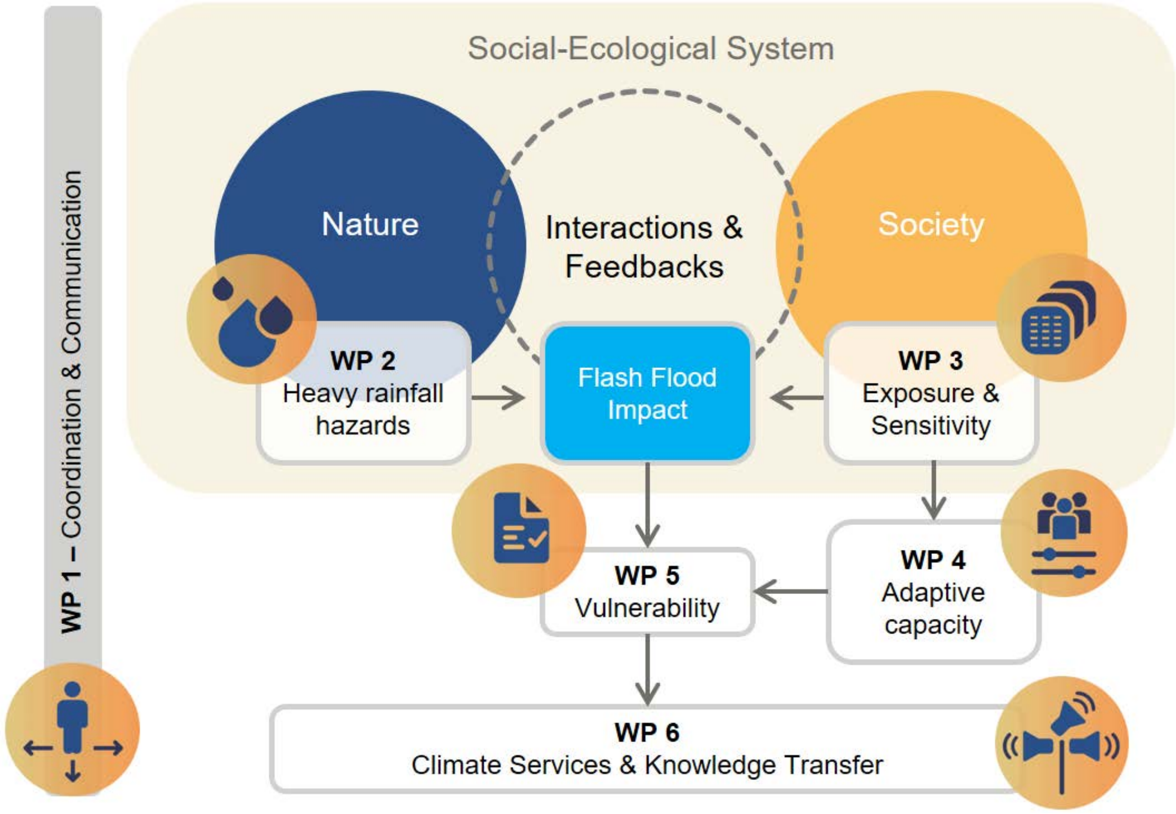


Figure 2. Conceptional framework of the integrated vulnerability analysis of flash floods and associated work packages.

All WPs are closely linked to each other in a network that allows synergistic interactions. WP 1 "Coordination & Communication" encompasses the central project management including the scientific and technical coordination as well as the stakeholder integration and communication. WP 2 "Heavy rainfall hazard" focusses on an improved understanding of flash flood hazards in wadi-systems and investigates how heavy rainfall events have changed in the past and may continue to change in the future due to climate change effects. The spatial and temporal impacts of flash floods on people, infrastructure, and ecosystem services along an urban-rural gradient are analysed in WP 3 "Exposure & Sensitivity". WP 4 "Adaptive Capacity" investigates the local knowledge of severe flash flooding and adaptation strategies, as well as potentials to improve methods and technologies to capture and retain heavy rainfall events through assessment of different water adaptation technologies. The results of WP 2-4 are synthesized to conduct an integrated vulnerability assessment and a scenario analysis of different adaptation strategies in WP 5 "Vulnerability". WP 6 "Climate Services & Knowledge Transfer" focusses on the provision of climate services for climate and flood related decision-making and communication of flash flood risks and impacts.

Status quo of the project and achievements in comparison to the milestones set in the proposal

The interdisciplinary cooperation between the different work packages is made possible in CapTain Rain through an overarching research design (Fig. 2). At the same time, a transdisciplinary approach is taken to ensure early stakeholder integration and the alignment of the project with the on-ground problem and need situation. The work of the individual WPs is closely interlinked and, in some cases, must be carried out in parallel, which is why one project partner is responsible for coordinating and combining the results for each WP. The tracking and follow-up of coordination and agreements is carried out along the SWP/topic responsibilities.

In the year 2022, the different work packages continued their research activities with literature research, data acquisition and processing and the choice of modelling approaches. These steps also comprised a fine-tuning of activities and corresponding scientific products to better adapt them to the specific stakeholder needs. Numerous internal project events were carried out (online project meetings, meetings of work packages' teams, etc.). In total, four major project meetings with the German partners (two online and two in presence), two major project meetings with the German and Jordanian partners (online) and two meetings of the steering committee (online) took place during the reporting period. In addition, numerous bilateral meetings have taken place with Jordanian partners, online and in presence during field trips to Amman and Wadi Musa.

The planning-organizational milestone M1 was successfully reached at the end of 2021. The scientific-technical milestone M2 was finalized until the end of 2022 (Table 1). This milestone included preliminary investigations and related empirical work in all work packages. Inventories on the local knowledge and local conditions in WP 3-4 have been finalized; the retrospective analysis of natural hazards in WP 2 has been largely completed, model-based simulations started in WP 2 and 3 and the target group-oriented dissemination strategy and the publication plan have been drafted.

Table 1. Overview of milestone status:

	Description of Milestone	**Date of completion**	**Status**
M1	Planning-organizational milestone; Inventory completed	11/2021	fullfilled
M2	Scientific-technical milestone; Preliminary investigations carried out	11/2022	fullfilled
M3	Scientific-technical milestone; Models implemented and simulations completed	05/2023	partly fullfilled
M4	Assessment-related milestone; Integrated scenario and vulnerability analysis conducted	11/2023	pending
M5	Utilization-related milestone; Dissemination of climate services successfully carried out	12/2024	pending

Highlights and difficulties

The beginning of the CapTain Rain project was unfortunately heavily overshadowed by the Covid-19 pandemic situation. Travel restrictions and the lack of local presence made the integration of and cooperation with Jordanian stakeholders difficult and hindered trust building among German and Jordanian partners. This led to delays in the provision of baseline data, as well as for the establishment of collaboration agreements among German and Jordanian Partners, which were still noticeable in 2022. The successful finalization of the collaboration agreements with all Jordanian partners took much more time than expected, due to the administrative work involved in concluding the contracts on the German and Jordanian sides. The reasons for this were mainly personnel changes within the leadership positions of the partner institutions, which necessitated further negotiations, and a lengthy signing procedure (the Jordanian institutions had to request the signing at a higher level including several Ministries). This also caused delays in the work of other work packages, especially since much of the data delivery by the Jordanian partners did not begin until after the cooperative agreements were finalized.

Despite these delays, 2022 was a successful project year. Two new key Jordanian partners were identified and included in the consortium: The Jordan Meteorological Department (JMD) and the Royal Jordanian Geographic Center (RJGC). Further highlights of the year 2022 included in particular the successful finalization of the collaboration agreements with Jordanian partners despite the already mentioned difficulties, the contribution to capacity development by conducting altogether five CapTain Rain webinars on different research topics, travels to Jordan to conduct field inventories and bilateral meetings with Jordanian partners to strengthen collaboration and jointly working on research tasks and identifying synergies. This also included a meeting with the Mayor in Amman at GAM, as well as official signing ceremonies of the collaboration agreements (Figure 3).

Numerous cross-association administrative and coordinative measures were carried out to foster collaborative and transdisciplinary work. Special attention was paid to internal communication within the network. This included regular teleconferences of the CapTain Rain coordination team, monthly meetings and video conferences of the different work package' teams, and regular project meetings. Regular online meetings with the Jordanian partners should also be emphasized here, as they enabled good cooperation despite the lack of on-site visits. We experienced a good participation of Jordanian stakeholders in such online events. Parts of the German CapTain Rain team conducted field trips to Jordan in May, September and November 2022. Beside many meetings and expert interviews with Jordanian project partners and further local stakeholders, the study sites in Amman and Wadi Musa have been visited to conduct on-site measurements and ground truthing. This data is used for empirical analysis and to improve input data for models and.

So far, the team of the CapTain Rain project has successfully finalized eleven publications and conference contributions and also contributed to capacity development at the university level by supervising two Bachelor and one Master thesis.


Figure 3. Signing ceremony of the memorandum of understanding with RJGC (left); Meeting with the Mayor in Amman to present the benefits of the CapTain Rain project (right), September 2022.

Status quo of the workpackages

WP 1 „Coordination & Communication“

WP 1 "Coordination & Communication" encompasses the central project management including the scientific-technical coordination, the internal and external communication as well as the transdisciplinary integration. The sub-work package (SWP) 1.1 “**Stakeholder dialogue and transdisciplinary integration”** serves as an interface for external communication between science and society. As such, it includes a stakeholder analysis at the beginning of the project complemented by expert interviews in Jordan. The stakeholder dialogue aims to anchor and consider opinions, relevant practical knowledge and experience, and needs of societal (practical) actors in the project. The communication of knowledge and the active involvement in the findings and techniques for the prediction and prevention of flash flood risks takes place via annually coordinated stakeholder workshops. This will lay the foundation for the transfer of knowledge into practice in WP 6 and enables the early dissemination of the project results. The sub-work package 1.2 “**Scientific and internal project coordination”** coordinates the project activities of the consortium and is responsible for the scientific and internal communication in order to coordinate the different research activities during the project duration in a way that ensures the development of methods and tools (e.g. integrated vulnerability and scenario analysis). In addition to the project website, tools for web-based research data management are delivered to facilitate inter- and transdisciplinary collaboration through a common and transparent data basis. To ensure the involvement of the Jordanian partners and the utilization of the result, a steering committee is established.

Achievements in relation to milestones/work plan and intermediate scientific results

In 2022, the focus was placed in particular on strengthening the stakeholder network including the acquisition of new partners and the organizing and implementation of meetings and workshops. In total, four major **project meetings** with the German partners (two online and two in presence), two major project meetings with the German and Jordanian partners (online) and two meetings of the steering committee took place during the reporting period. In the steering committee all Jordanian and German partners that are closely committed to the project’s objectives and results are involved. In addition, numerous bilateral meetings have taken place with Jordanian partners, online and in presence during field trips to Amman and Wadi Musa. On 23th of June 2022 all German project partners met in Koblenz at the University of Applied Sciences. Beside the status quo reports of the different work packages, the integrated vulnerability analysis in work package 5 was one main topic. On the 15th and 16th of December 2022, the German project partners met at the offices of Hamburg Wasser. The organization of the upcoming stakeholder workshop in Amman was the main topic. In addition, the networking of the different work packages and how the disciplinary results will be incorporated into the integrated modelling and vulnerability assessment were discussed.

One of the main tasks of WP 1 in 2022, was the administrative work in finalization the **collaboration agreements** with all Jordanian partners, which comprised several meetings (online and in presence) and the bi-lingual (English, Arabic) drafting and adaptations of the contract documents to the needs of the partners.

For the **stakeholder analysis**, in total 15 interviews were conducted, transcribed and analysed through qualitative content analysis by coding the transcripts in MAXQDA. The interview results on the communication between the project and the stakeholders helped to initiate the steering committee and was used for the refinement of the dissemination plan (WP 6). For the stakeholder mapping, the mentioned stakeholders by the respondents were categorized into groups and their influence and interest towards CapTain Rain research outreach was estimated. The results of the stakeholder analysis (see Fig. 4) showed that state entities are the biggest group (22 actors). International organizations and international cooperation entities are the second biggest group (20 actors) and donor funding is always mentioned as key for measures and actions regarding flash floods. Consulting companies and scientific entities are small groups (each four actors) but are mentioned as important for measures and projects. Local citizens (six actor groups) are divided regarding their area (urban, camps, rural & flood prone areas) and function (shop owners, residents, local leaders). Only very few NGOs (three actors) were mentioned of which the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) is given an important role.

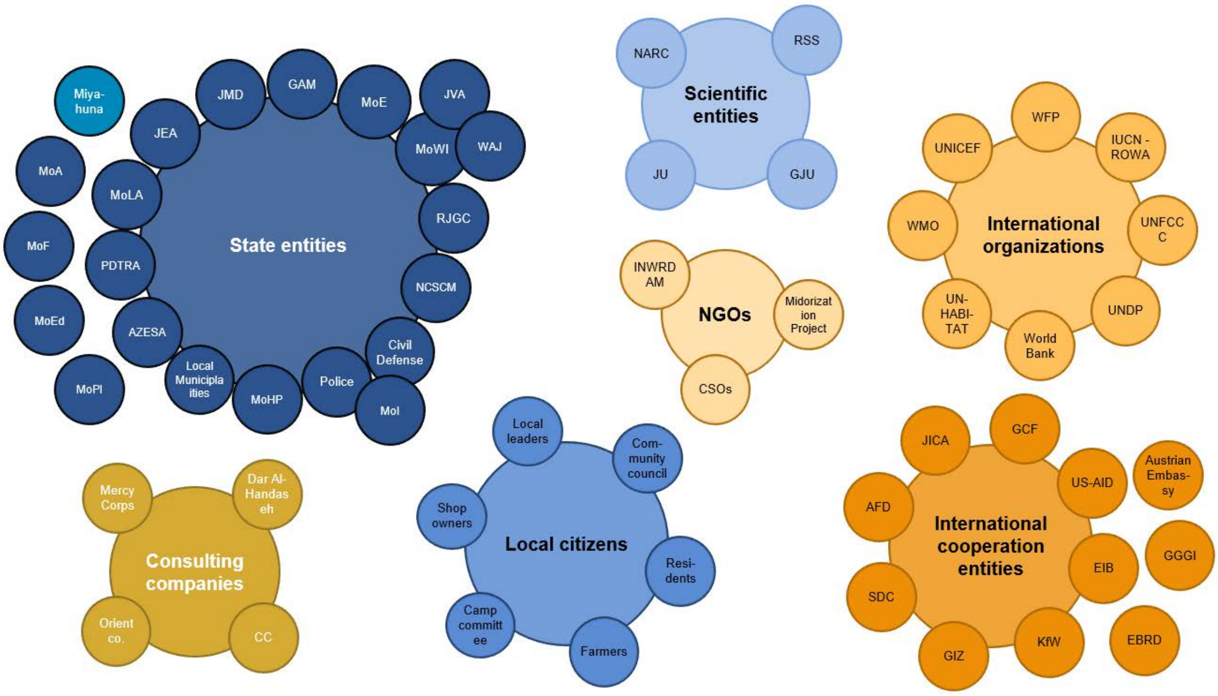


Figure 4. Results of the stakeholder mapping: Stakeholders mentioned in the interviews that play a role in CapTain Rain's research topics and their assignment to stakeholder groups.

The interview analysis revealed that the answers of respondents contain valuable information for the different work packages that can be also used for further WP-specific analysis as follows: Information on the local perception on flash floods and its drivers is integrated in WP 5. Interview respondents on the (traditional-) knowledge and measures is further analysed in WP 4. The technical and operational information on early warning systems enabled to depict a graphical representation of the emergency response chain in WP 6 (see Figure 17). The information on land use planning is used for further analysis in WP 3.

Another important task included the preparation of the second **Stakeholder Workshop** scheduled for January 2023 ("Validation and scenario development": presentation and discussion of first intermediate results related to modelling and assessment of flash flood risk and measures to prevent flash flood damages). The main objectives of this planned workshop comprise participatory validation of interim results and subsequent fine-tuning of model results, as well as a joint identification of promising adaptation strategies for scenario development in WP 5. A **second formative evaluation** of the work processes and quality control outcomes was prepared to be conducted during January 2023.

Public relation works in 2022 mainly included the regular upload of news and publications to the webpage (www.captain-rain.de) and the participation in Client II events, which also comprises an interview with CapTain Rain project administrator.

Inter- and transdisciplinary cooperation, highlights and difficulties

The overall coordination work of the joint project CapTain Rain is equally shared between ISOE and Koblenz University of Applied Sciences (KU). Internally, ISOE and KU coordinate the network in the form of a shared management. In consultation with the partners, they assume all coordination tasks between the network partners and share the content-related tasks according to their respective competences.

Based on the stakeholder analysis at the beginning of the project, as well as the implementation of regular stakeholder workshops, this WP provides the basis for stakeholder integration for all WPs and the transfer of knowledge into practice. The scientific coordination and internal communication ensure the coordination of all WP activities among each other to pave the way for the integrative vulnerability analysis in WP 5.

WP 1 was in particular involved in the successful finalization of the collaboration agreements with all Jordanian partners, which included meetings and negotiations due to personal changes within the partner institutions, adaptations of the contract documents to the needs of the partners and the bi-lingual preparation of the collaboration agreements in English and Arabic. Due to the administrative work involved in concluding the contracts on the German and Jordanian sides, there were delays in other activities in WP 1 (e.g. stakeholder analysis). This also caused delays in the work of other WPs, especially since much of the data delivery by the Jordanian partners did not begin until after the cooperative agreements were finalized.

Overall, the consortium has changed from the original application. Two new key Jordanian partners were identified and included in the consortium: The Jordan Meteorological Department (JMD) and the Royal Jordanian Geographic Center (RJGC). The JMD is a very important partner for CapTain Rain, especially for work packages 2 and 6 with regard to the interpretation of climate data and precipitation patterns and the supply of high-resolution, not publicly available climate data. This is of particular relevance for the modelling of heavy rainfall events (WP 2) and the preparation of an early warning system (WP 6). Among other things, the JMD operates the only rainfall radar in Jordan and a total of 30 weather stations. RJGC's inclusion in the consortium will facilitate access to remote sensing and GIS data that are urgently needed for hydraulic and hydrologic modelling and analysis of land use and land cover change (WP 3 and 5). In addition, the RJGC will contribute to research activities in WP 3 and 5

Future prospects/outlook 2023

The work of WP 1 will continue with regular online meetings to coordinate the CapTain Rain project. In 2023, the stakeholder analysis and mapping (analysis of interviews on stakeholder interests, overall challenges, knowledge on and experience with adaptation measures, ways of participation) will be finalized and the results published. Stakeholder dialogues and communication will continue on a regular basis. In January 2023, the second Stakeholder Workshop as well as the second internal project evaluation will be conducted with the Jordanian partners. The third Stakeholder Workshop on the joint assessment of the scenario results is planned for the end of 2023. Furthermore, the WP1-team will continue with the organization of joint project meetings according to the established communication plan as well as with the planning and coordination of field trips to Jordan. Another task will be the regular maintenance of the project webpage and the cloud-based management of research data.

WP 2 „Heavy rainfall hazards”

This work package aims to identify meteorological drivers of heavy rainfall in Jordan in the context of climate change. For this purpose, we analyse long-term local rainfall data provided by the Jordanian partners, global and regional reanalyses, high resolution satellite rainfall estimates as well as weather forecasts and climate scenarios. The research question to answer is, how heavy rainfall events and patterns in Jordan will change in frequency and intensity under different global warming levels. A diagnostic approach to detect critical circulation patterns is one relevant aspect to bring local extreme events in a larger context for reasons of causality. Thus, the work package is divided into two sub work packages focusing in a retrospective/diagnostic part (2.1) and a prognostic part (2.2). The overarching goal is an evaluation of the climate sensitivity on heavy rainfall events in Jordan. These results are the basis for early warning, climate services and flash flood mitigation actions provided in the other work packages.

Achievements in relation to milestones/work plan and intermediate scientific results

Table 2. Overview of the current status of the work package tasks.

	Task	**Time**	**Status**	**% fulfilled**
WP 2.1	Retrospective analysis of heavy rainfall events:			
2.1.a:	Data acquisition and processing	Jun21-Aug21	ongoing	75%
2.1.b:	Climate analysis and monitoring	Sep21-Feb22	ongoing	75%
2.1.c:	Classification of circulation patterns	Mar22-May22	almost finished	75%
2.1.d:	Qualitative prediction of heavy rainfall	Jun22-Aug22	testing	50%
2.1.e:	Data integration finished	Sep22-Nov22	ongoing	50%
WP 2.2:	Modelling of heavy rainfall:			
2.2.a:	Predictors for heavy rainfall	Dec22-May23	identified	50%
2.2.b:	Climate sensitivity of heavy rainfall	Jun23-Nov23	preliminary results	50%
2.2.c:	Limitation of predictability	Dec23-May24	ongoing	50%

SWP 2.1: Retrospective analysis of heavy rainfall events

2.1.a: Data acquisition and processing

Local meteorological data collection continued in 2022, but is not yet complete. Especially, station data provided by the Jordanian Meteorological Department (JMD) and the Ministry of Water and Irrigation (MWI) are still missing. However, a substantial improvement of the data situation is expected in 2023. Other open source data (reanalyses, satellite) were collected, processed, analysed and integrated into developed services. The most challenging task was to address the different stakeholder needs in the design of the research products. For reasons of transparency, the software and results are organized as notebooks in a static site generator application.

2.1.b: Climate analysis and monitoring

Some of the nowcast data has been transferred to data products and operational services of approaching and predicting rainfall areas for Jordan in a design of a RADAR (see product list) and is available on a website (http://www.pik-potsdam.de/~peterh/s%c3%bcnoptik/jordan/#jordan). This enables the project partners to monitor accumulated rainfall over 12 hour near real-time. Furthermore, a risk map of heavy rainfall for a 50 year return period was integrated in this design. Another data product for event detection has been developed as a sortable table including local values of rainfall and regional patterns taken from different data sources. A next update of the table is planned in 2023, which also includes the integration of local station data for comparison.

2.1.c: Classification of circulation patterns

The detection of critical circulation patterns plays an important role with regard to the early warning of heavy rainfall events and their climate sensitivity. In this context we evaluated three approaches: (a) using an existing classification of weather-types for Europe to identify critical patterns; (b) filtering atmospheric fields at dates, where extreme rainfall occurred in Jordan; and (c) developing an objective approach of feature extraction in atmospheric fields. The latter is an ongoing work by a student assistant (Paula Dinse, student of mathematics). Approach (a) has been successfully implemented to detect critical circulation patterns in weather predictions. Observed causalities between circulation patterns and extreme rainfall in Jordan was used to assess operational forecasts: http://www.pik-potsdam.de/~peterh/s%c3%bcnoptik/jordan/#critical-circulation-patterns. How climate models project future developments of critical circulation patterns is done by filtering dates above the 99th percentile of daily precipitation in Jordan for a 30 year time period. The resulting composite patterns and long term changes can be attributed to climate change.

2.1.d: Qualitative prediction of heavy rainfall

Operational weather forecast ensembles provide possible developments of the weather for the next couple of days. However, they have no memory of historical events. Results of our retrospective analysis of the causal linkage between large-scale circulation patterns and local rainfall in Jordan provides experts additional information to better assess predicted forecast patterns in terms of heavy rainfall. Possible development paths are compared to critical ones in the past in order to qualitatively predict, whether a heavy rainfall event is likely. Whether such a diagnostic can be integrated in the early warning demonstrator developed by WP 6 has not yet been finally clarified.

2.1.e: Data integration finished

A number of data products and services have been developed and tested up to now. The optimal format and design of data integration is worked out and finished in 2023. This also includes the accessibility to the software for data processing and updating. Synergies with other projects help to find the best solution. The main infrastructure for cloud-based data integration is the Demonstrator. However, for research and software developing and testing also other local systems are used.

SWP 2.2: Modelling of heavy rainfall

The modelling of heavy rainfall addresses two branches. Firstly, how operational weather forecasts and existing climate models perform heavy rainfall in Jordan including uncertainties. Secondly, the analysis of the causal linkages between local rainfall patterns in Jordan to large scale circulation patterns derived from retrospective analysis to better predict critical events (short-term and long-term). Critical circulation patterns can trigger seasonally heavy rainfall events in Jordan. The analysis of long-term changes and climate sensitivity of the predictors started using large ensembles of global and regional climate scenarios.

2.2.a: Predictors for heavy rainfall

The understanding of existing causal effects between dynamical patterns and local extreme rainfall events in Jordan has increased by a retrospective data exploration. Predictors are more than a direct connection. Predictors also consider possible development paths before an extreme event occurs. This has been investigated by a systematic time lag analysis in long-term reanalysis data. Composite circulation patterns were identified ±5 days around significant extreme events in Jordan (Fig. 5). Such an approach estimates large scale conditions favouring extremes at an early stage. The finding can be used to assess weather forecasts. Applied to climate scenarios, the method can identify structural change with regard to the predictability of such extreme rainfall events in future.

2 days before events | one day before events | day of the events

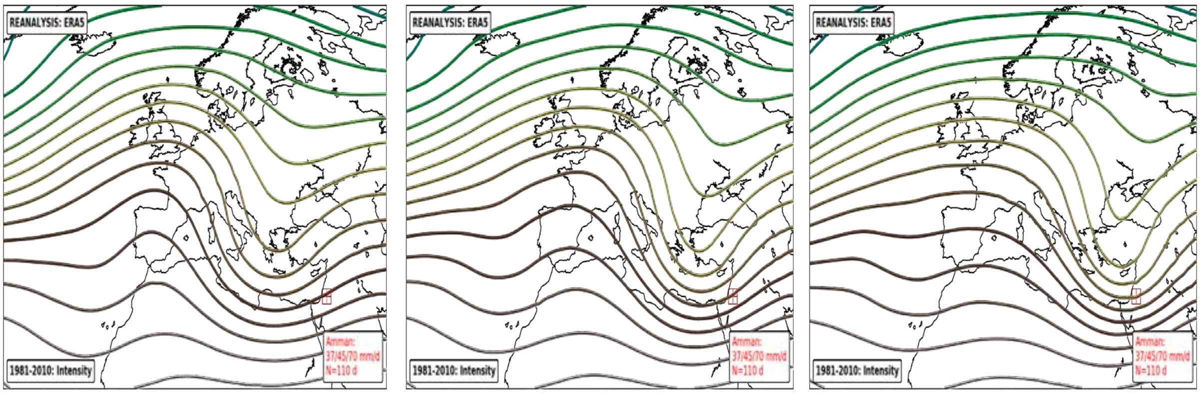
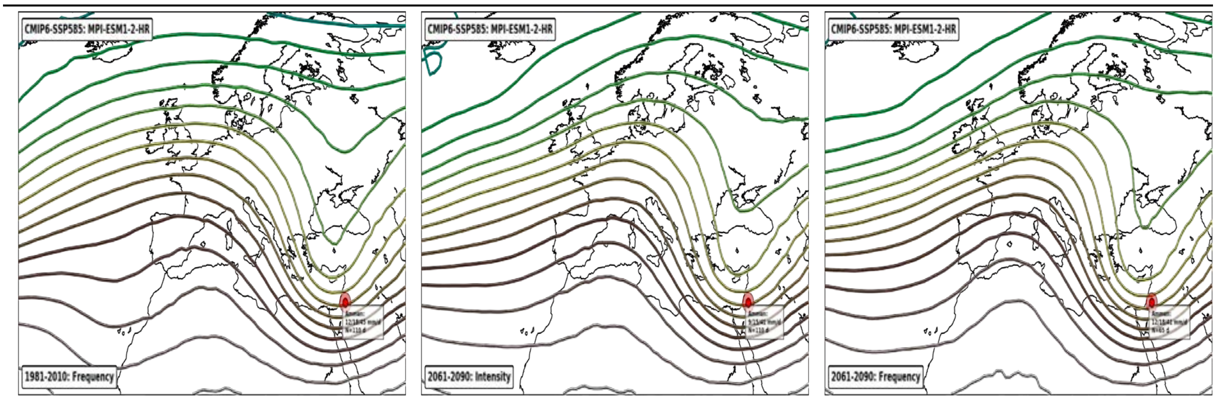


Figure 5. Composite circulations patterns of dates above the 99th percentile of daily precipitation in ERA5 reanalysis data for the time period 1981-2010: 2-days before, one day before an event occurs. It illustrates the mean trajectories of the development.

2.2.b: Climate sensitivity of heavy rainfall

The climate sensitivity analysis of heavy rainfall has been started in two different ways. First, by calculating return periods of annual daily maximum rainfall for different future or warming level periods by using available regional climate modal simulation for the CORDEX-MENA region by Christoph Menz. Second, we filter dates in available global and regional climate simulations with regard to high precipitation values over Jordan until 2100.

1981-2010: Baseline | 2061-2090: Intensity | 2061-2090: Frequency



99th: N=110d, pr=12-45 mm/d | 99th: N=110d, pr=9-41 mm/d | 99th: N=65d, pr=12-41 mm/d

Figure 6. Composite circulation patterns for dates above the 99th percentile of daily precipitation in the CMIP6 model MPI-ESM1-2-HR comparing intensity and frequency between 2061-2090 and 1981-2020. This model shows a deceasing number and magnitude of critical events in Jordan.

High precipitation values are determined by the 99th percentile of daily values within a 30-year period. For dates above the threshold we calculated composite patterns of the large scale circulation over North-Atlantic, Europe and the eastern Mediterranean. Preliminary results for comparing present and future periods 2061-2090 to 1981-2010 are shown in Fig. 6 and will be published and presented at two conferences in 2023. The selected CMIP6 models indicate a decrease of critical weather patterns with an increasing/decreasing magnitude of rainfall intensity. This is a challenge for the scenario building regarding climate change.

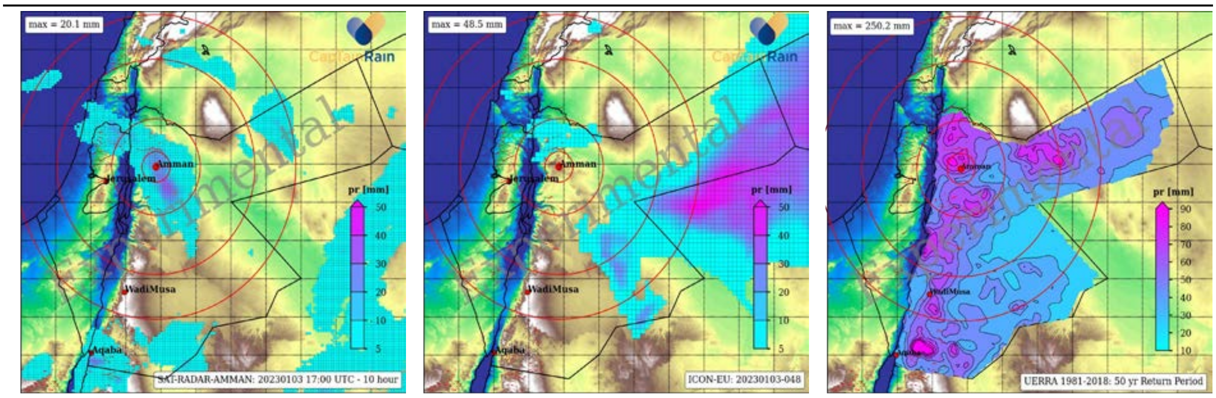
2.2.c: Limitation of predictability

Weather forecasts and climate models have limitations with regard to predict or project future developments of local heavy rainfall events. Free running climate models simulate its own weather variability. We found out, that critical patterns favouring heavy rainfall in Jordan are very similar to what is known from reanalysis data. Thus, large-scale critical patterns are much better predictable than the local rainfall patterns itself due to existing biases and the missing of small scale structures. One method we use to evaluate the limitation of the predictability of heavy rainfall in Jordan is to monitor hind- and forecast around the current condition. This enables experts to assess the predictability dependent on updated initial conditions. With regard to long-term climate projections of such extreme events we filter out dates in scenario runs and compare the frequency, the intensity, the seasonality and also preconditions with the observed behaviour.

Overview of products delivered by WP 2

SatRadar: In early 2022 we developed a data product with regard to the nowcast of approaching rainfall areas for Jordan in a design of a RADAR by processing rainfall estimates from satellites, weather forecasts and regional reanalysis data. Fig. 7 shows examples of the operational product. It gives information of the accumulated rainfall over the last 12 hours, the predicted rainfall for the next 24 to 72 hours using the ICON model and patterns of risks for heavy rainfall in Jordan represented by the 50 year return level. The development is finished. A possible recalculation of the total rainfall to a water level is an ongoing discussion with the project team.

Nowcast	Forecast	Return Level

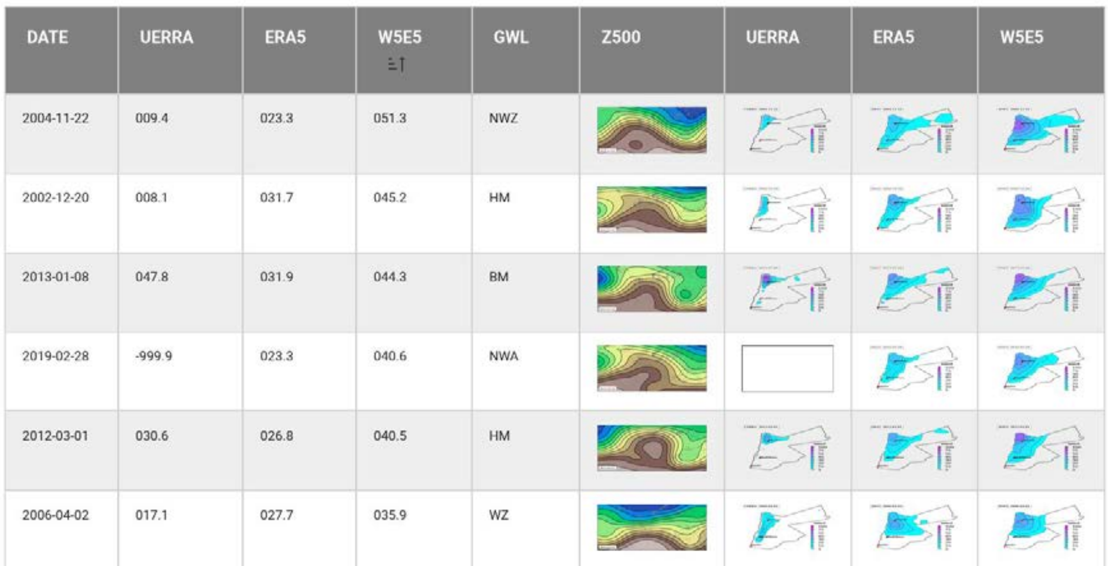


operational map of accumulated rainfall over 12 hours derived from rainfall estimates	operational map of predicted 48 hours total rainfall using ICON forecasts	risk map of heavy rainfall for return period of 50 year derived from regional reanalysis data UERRA

Figure 7. Operational nowcast product of approaching rainfall area in a design of a RADAR using rainfall estimates from satellite and weather forecasts. Accessibility under: *http://www.pik-potsdam.de/~peterh/s%c3%bcnoptik/jordan/#jordan.*

Event Table: Another product developed in this work package is a sortable table of historical events including local values and regional patterns. This helps to identify and assess historical events in a larger context and across different data sources. Station data provided by the local partners are integrated and updated in 2023. A recent extreme rainfall event on this list was in February 2019. The access to the table for Amman is preliminary available under: http://www.pik-potsdam.de/ ~peterh/restricted/CapTainRain/ results/events/#amman.

Tables for WadiMusa and Aqaba are also available in a similar format.



Amman

DATE	UERRA	ERA5	W5E5	GWL	Z500	UERRA	ERA5	W5E5
2004-11-22	009.4	023.3	051.3	NWZ				
2002-12-20	008.1	031.7	045.2	HM				
2013-01-08	047.8	031.9	044.3	BM				
2019-02-28	-999.9	023.3	040.6	NWA				
2012-03-01	030.6	026.8	040.5	HM				
2006-04-02	017.1	027.7	035.9	WZ				

Figure 8. Event table of historical events including local values and regional patterns for Amman.

Hindcast: The Jordanian Meteorological Department (JMD) provides forecast reports for the whole country by mainly using the ECMWF ensemble. They often mentioned the benefit of hindcast evaluations. However, this task is out of the scope within this project and rather expensive. A more pragmatic approach is to monitor forecasts of the past two or three weeks compared to the actual forecast. The figure shows the operational monitor of hind- and forecast (± 20 days) of temperature and precipitation for Amman using the Climate Forecast System (CFS) model. The chart shows daily updated trajectories dependent on the initial conditions. The closer the bundle of lines in timing the more reliable the prediction. The sensitivity of the forecast with regard to the initial conditions.

The software used for data processing and integration is mainly based on *python* and a static site generator *mkdocs*. Both together enable to integrate source code in project documentation for reproducibility. Developed products within this work package can be easily collected and shared with project partners. A preliminary demonstration is available under: http://www.pik-potsdam.de/~peterh/restricted/CapTainRain/results/criticality/

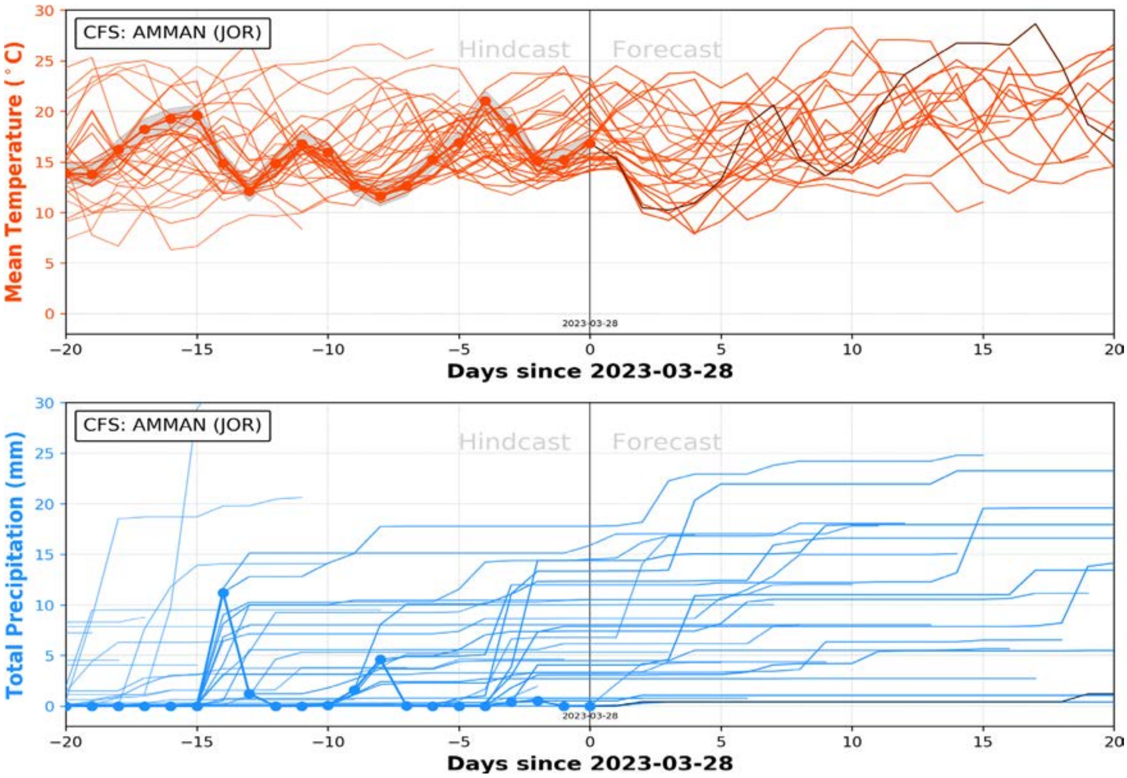


Figure 9. Operational monitor of hind- and forecast (± 20 days) of temperature and precipitation for Amman using the Climate Forecast System (CFS) model.

Inter- and transdisciplinary cooperation, highlights and difficulties

The available regional climate ensembles and precipitation events of WP 2 are used in WP 3 for the risk analysis of flash floods (SWP 3.1). The societal and climatological drivers of heavy rainfall risks will be determined and modelled in SWP 3.2 in the analysis of damage potentials and in SWP 3.3 in the risk assessment. All available climatological information is organized in a data management system for further processing. The data products and their processing used in SWP 2.1 flow directly into SWP 6.1 and provide the basis for the development of an EWS in the form of a demonstrator. Collaboration within the CapTain Rain project team (exchange on data and derived products on availability, quality, processing, integration, accessibility and interpretation of results) was conducted during monthly meetings.

Future prospects/outlook 2023

- Jan-Feb: Stakeholder Workshop in Amman and Petra
- Mar-Apr: Paper draft focusing on a contextualization of heavy rainfall events (case study Jordan)
- May-Jun: Contribution to the Flash Flood Symposium in Algeria (ISFF7)
- Sep-Oct: Contribution to the Annual Meeting of the European Meteorological Society in Bratislava (EMS)
- Nov-Dec: Stakeholder Workshop in Amman and Petra (trainings)
- Jan-Dec: Member of the organization and program committee of the next German Climate Conference in Potsdam 2024 organized by the German Meteorological Society (DMG)

WP 3 „Exposure & Sensitivity“

WP 3 analyses the spatial and temporal impacts of flash floods on humans, infrastructure, and ecosystem services. Exposure or spatial occurrence encompasses the hazard analysis due to flash floods. Sensitivity determines the potential for damage in areas affected by heavy rainfall. This WP is subdivided in three Sub-work packages. The hazard analysis and the analysis of damage potentials are combined for the preparation of risk maps and assessments. This will lay the foundation for the vulnerability analysis and the allocation and implementation of adaptation measures in WP 5. The risk maps will also be used as a basis for risk communication (WP 6).

Achievements in relation to milestones/work plan and intermediate scientific results

In the SWP 3.1 – Hazard analysis (“exposure”) we conducted a literature review on hydrological models used for flash flood analysis in arid regions and decided to setup the widely used HEC-HMS model for Amman and Wadi Musa as well as the Rainfall-Runoff-Inundation (RRI) model for Wadi Musa only. For both regions we also set up the hydraulic model HE2D/FOG2D for the whole catchment. To run the models, we mainly used open source data (e.g. SRTM DEM, OSM) resulting in simulations of inundated areas and runoff curves. Also, first simulations with possible adaptation measures (WP 4) to quantify their effects were carried out.

In SWP 3.2 – Damage potential (“sensitivity”) land cover and land use (LULC) maps for different time periods in the past were established using remote sensing methods. For the latter, a quantitative analysis of long-term LULC changes from 1968 to 2021 was conducted using an object-based classification of multi-temporal satellite images. Spatial and non-spatial metrics were further used to focus on the urban growth patterns. To analyse the drivers behind LULCC, multi linear regression analysis was performed to statistically analyse potential urbanization predictors. This was further complemented by semi-structured expert interviews with local stakeholders to identify the wider range of potential drivers and their interactions with key actors in the analysed LULCC system of Amman.

We conducted a literature research on the current state of the art of damage potential analysis in Germany and applied a classification approach based on the building usage for the two study regions. Also, here we used open source datasets like OSM.

As a combination of the hazard and damage potential maps we created first flash flood risk maps for the current state within SWP 3.3 – Identification and assessment of flash flood risk.

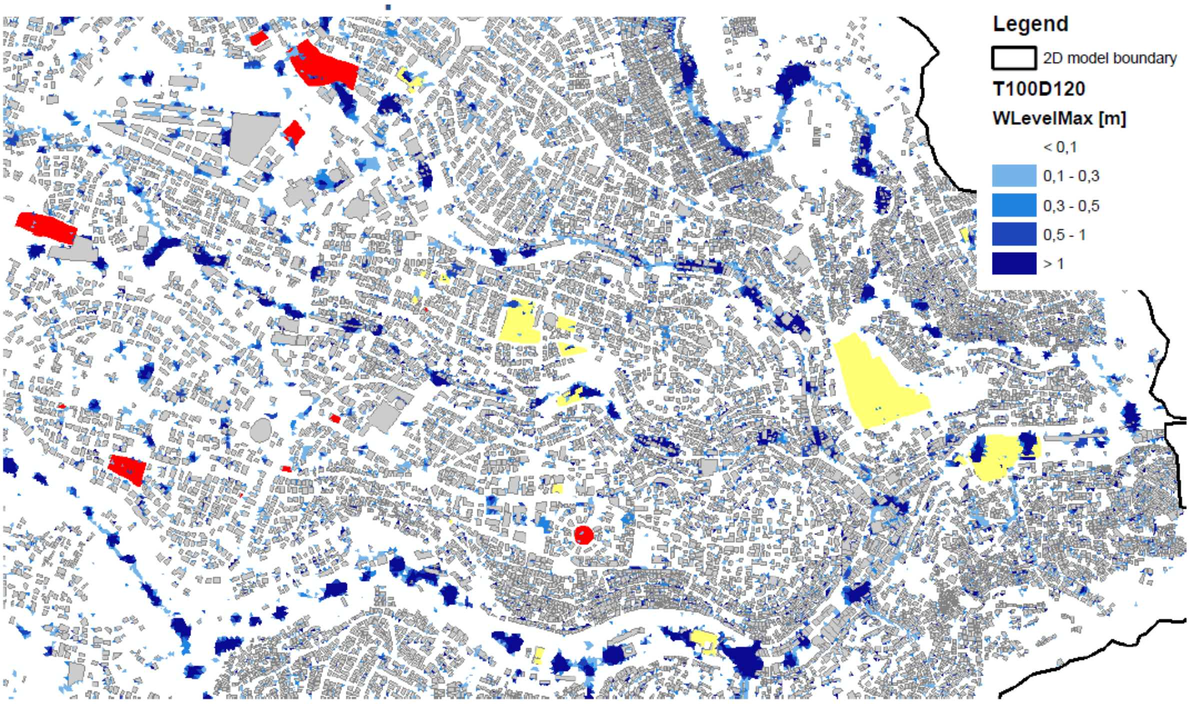


Figure 10. First risk map for Downtown Amman. Results of the hydro-dynamical 2D simulation with the model HE2D/FOG2D and building usages with a high (yellow) and a very high (red) damage potential are shown.

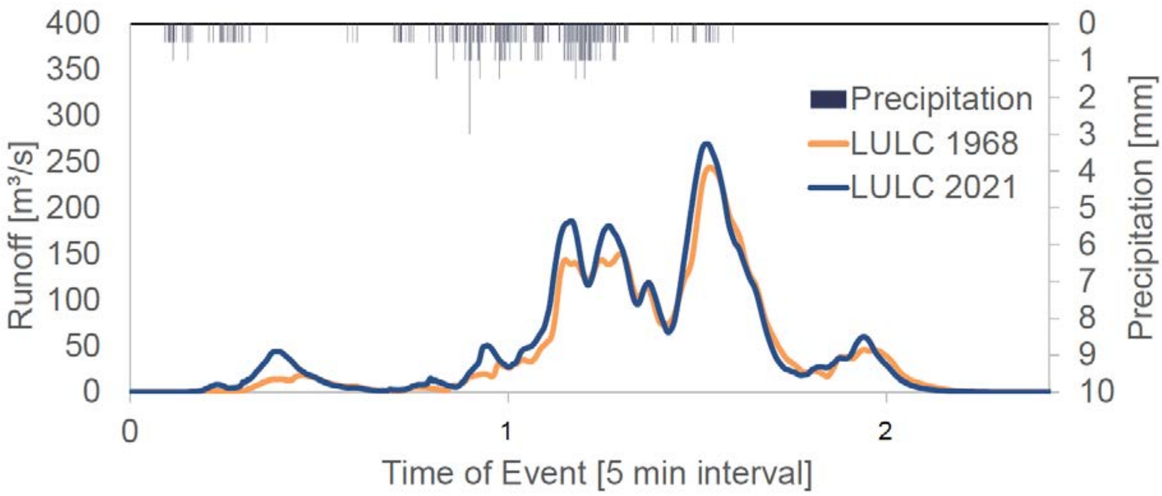


Figure 11. Modelled runoff of the hydrological model HEC-HMS. The two days rainfall event from February 2019 (5-minute resolution of rainfall series) was modelled with the LULC 1968 (yellow) and the LULC 2021 (blue).

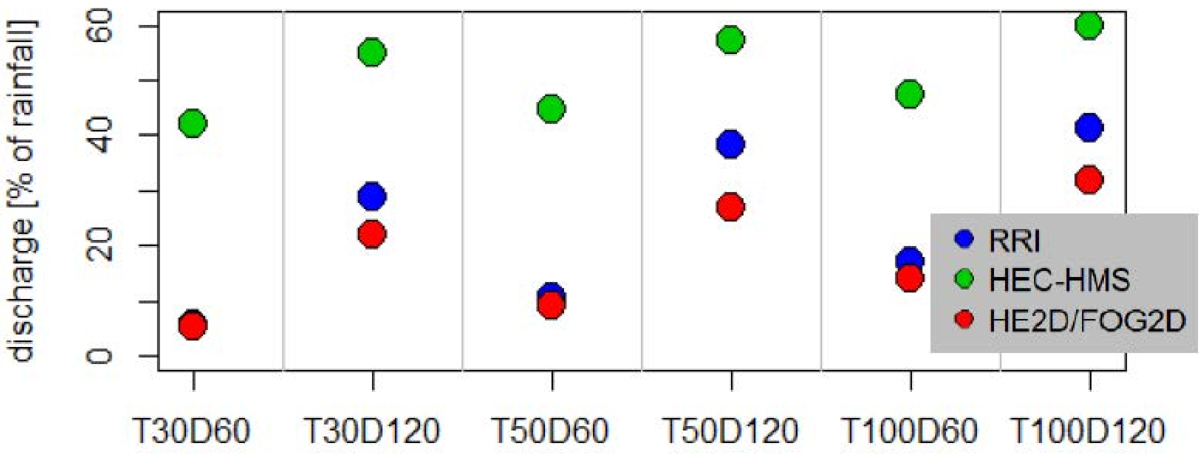


Figure 12. Total runoff volumes modelled with RRI, HEC-HMS and HE2D/FOG2D for design storm events with different return periods (T) and durations (D) for a subbasin of the Wadi Musa catchment (A_E = 18.5 km²).

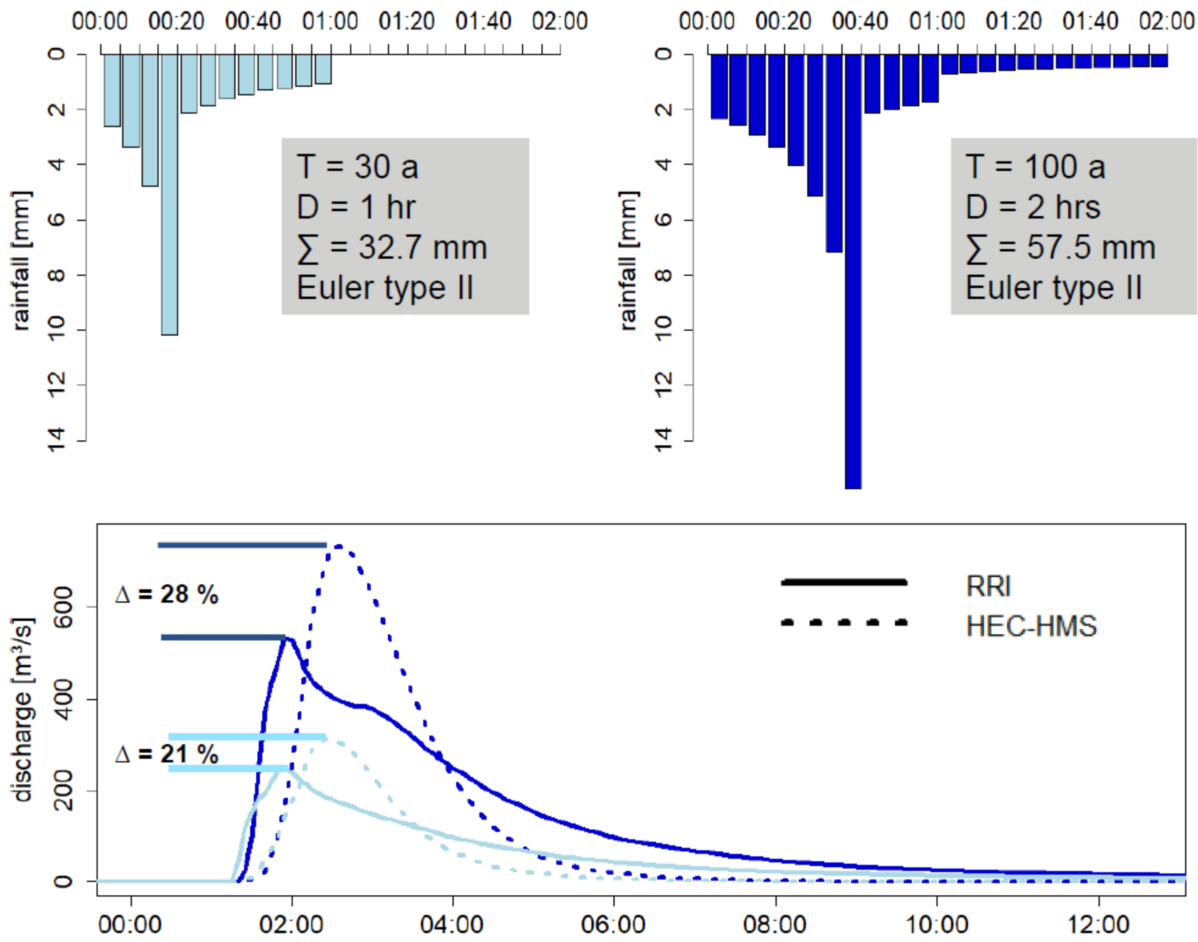


Figure 13. Runoff curves modelled with HEC-HMS (dotted) and RRI (solid) at the outlet of the Wadi Musa catchment (A_E = 130 km²) for two design storm events with different return periods (T) and durations (D).

Inter- and transdisciplinary cooperation, highlights and difficulties

The hydrologic and hydraulic models of WP 3 are used for the scenario analysis in WP 5. To guarantee that the climate input (WP 2) as well as the adaptation measures (WP 4) can be integrated and used for the simulations of the different models, WP 3 is closely collaborating with AP 2, 3, 4 and 5 and several joint meetings took place in 2022.

Since the potential of collaborative work with the Jordanian partners through online meetings is limited, members of WP 3 travelled to Jordan in May and in November/December 2022 to foster collaboration. Especially the collaboration with the MWI got closer due to a two-weeks stay at the GIZ water portfolio offices in Amman which are located at the MWI.

The cooperation with the Kyoto University (Dr. Sameh Kantoush) and the German-Jordanian University (Dr. Qasem Abdelal) for our focus area Wadi Musa/Petra continued successfully.

<u>Overview of supervised Master and Bachelor thesis in 2022:</u>

- Moritz Müller, Bachelor thesis "Hydraulische Analyse von Sturzfluten in Amman", Koblenz University of Applied Sciences, supervision: Prof. Dr. Dörte Ziegler and Dr. Clara Hohmann, external supervision: Stefanie Maßmann and Martin Schönfeld, itwh, 30.03.2022

- Ahmad Awad, Master thesis "Analysis of the spatial-temporal dynamics of land-use changes using a mixed-method approach: A case study from Amman, Jordan", Technical University of Munich, supervision: Dr. Isabel Augenstein, external supervision: Dr. habil Katja Brinkmann, 14.02.2023

- Felix Braun, Bachelor thesis "Analyse von Schadenspotenzialen bei Sturzfluten am Beispiel Downtown in Amman", Koblenz University of Applied Sciences, supervision: Prof. Dr. Dörte Ziegler, Dr. Clara Hohmann and Christina Maus, 06.02.2023

Future prospects/outlook 2023

In the beginning of 2023 we will receive new data sets from our partners MWI and GAM and PDTRA. As this additional information about the infrastructure of the two cities and rainfall events in a higher time resolution will improve our model results, we will integrate them to the already existing hydrological and hydraulic models. In addition, we plan to setup a third hydrological model for the Wadi Musa catchment to conduct a multi-model approach. With this approach we want to assess the uncertainties of our model results and hope to also reduce them which is especially important as we don't have sufficient reliable data to validate our models. This topic will also be discussed in a joint scientific publication with the University of Kyoto and further partners from Jordan. The hydrological and hydraulic models will be the core of the WP 5 quantifying the effects of climate and LULC changes as well as possible adaptation measures.

The newly acquired data from our Jordanian partners will also be of additional value for the damage potential analysis. Moreover, a bachelor thesis focusing on the damage potential analysis in Downtown Amman will be finished in February 2023. Based on these results the damage potential analysis will be improved and will then be discussed and adapted to the needs of the Jordanian stakeholders.

Based on the new results there will be also improved risk maps for the current state which will need a participatory validation. This validation will take place in 2023 but probably later than envisioned in the first time schedule of the project.

The cooperation with the Jordanian partners will hopefully be further strengthened as many members of WP 3 will travel to Jordan in January/February 2023. Beside the second stakeholder workshop we plan many meetings with the different Jordanian partners. We will also continue to invite employees from GAM and NARC to our online WP meetings and hope for a regular participation. Within these meetings we also want to discuss the planned English version of the DWA-M 119 and jointly adapt it to Jordan/the MENA-region. In the upcoming year we also plan regular joint meetings of WP 3 and 4 to finally merge into WP 5 starting in 2023.

WP 4 Adaptive capacity

WP 4 “Adaptive capacity” deals with the potential or capability of a system to adapt to the risk of flash floods. The perception and knowledge of the local population will be analyzed to identify knowledge gaps and recommend knowledge transfer. Appropriate and innovative measures to mitigate flash flood risks will be identified with the use of GIS-based participation methods. The measures and strategies of adaptive capacity of this project can be applied to other areas and therefore, with the help of technology, form an innovative foundation to reduce the risk of flash floods. The SWP 4.1 “**Local (practical) knowledge**” addresses the investigation and analysis of the perception of flash flood hazards by the residents as well as local (practical) knowledge including decision making for protective measures. Promising traditional adaptation measures of the past such as measures in the area of rainwater harvesting are identified and jointly assessed with local stakeholders. The aim is to identify existing practices and knowledge gaps, as well as recommendations for improved knowledge transfer to be incorporated in climate services (e.g. early warning systems). Innovative measures for the retention, safe discharge, storage and use of heavy rainfall are identified and evaluated in SWP 4.2 “**Prevention of (urban) flash flood damage**”. These measures can be related either to infrastructure, to the drainage system or to the catchment areas and they can be of technical, institutional or social nature. For areas with high land use pressure, the concept of multifunctional land use for heavy rainfall prevention serves as an interesting option. For the joint assessment of promising adaptation measures with local stakeholders and to provide tools for local decision-making, participatory GIS methods will be tested and implemented.

Achievements in relation to milestones/work plan and intermediate scientific results

Regarding possible measures, a catalogue of different measures for flash flood prevention or mitigation was set up in 2021. This catalogue summarizes promising measures in arid and semi-arid region and was compiled based on literature analysis and expert interviews (data from stakeholder analysis). The main focus was on systems and strategies to prevent flash floods and reduce hazards, but also to ensure water supply during the dry season. Activities within the reporting period mainly focused on fine tuning of the established measure catalogue by additional literature research on ecosystem service provision of measures. Furthermore, the expert interviews conducted within in the scope of the stakeholder analysis in WP 1 were analysed to gather information on the overall challenges, knowledge on and experience with flash flood adaptation measures. The results were incorporated in the measures catalogue. To prioritize adaptation measures, the set of measures was discussed and sharpened with the Jordanian partners during several meetings. Based on the preliminary results of WP 3 (flash flood risk) and the report on flash flood adaptation strategies of the UN Habitat feasibility study for Downtown Amman (UN Habitat 2021: Developing a Preliminary Design for Flood Mitigation and Performing a Flood Risk Assessment and Flood Hazard Mapping), suitable locations and areas for implementing different measures according to the categories established in the catalogue were identified. The focus areas were chosen at different spatial scales (Figure 14) combining various functional properties to reflect the requirements of qualifying and quantifying the single types of measures and also the combination of those. The areas were divided in catchment or sub-catchment, districts, housing and neighbourhood and public space (park, parking lots, conversion area). A more detailed analysis of the focus areas with regard to their suitability for the allocation of measures in different scenarios within WP 5 already started at the end of 2022. For this, further risk assessments and points of interests through recommendations from the Jordan project partners will be incorporated.

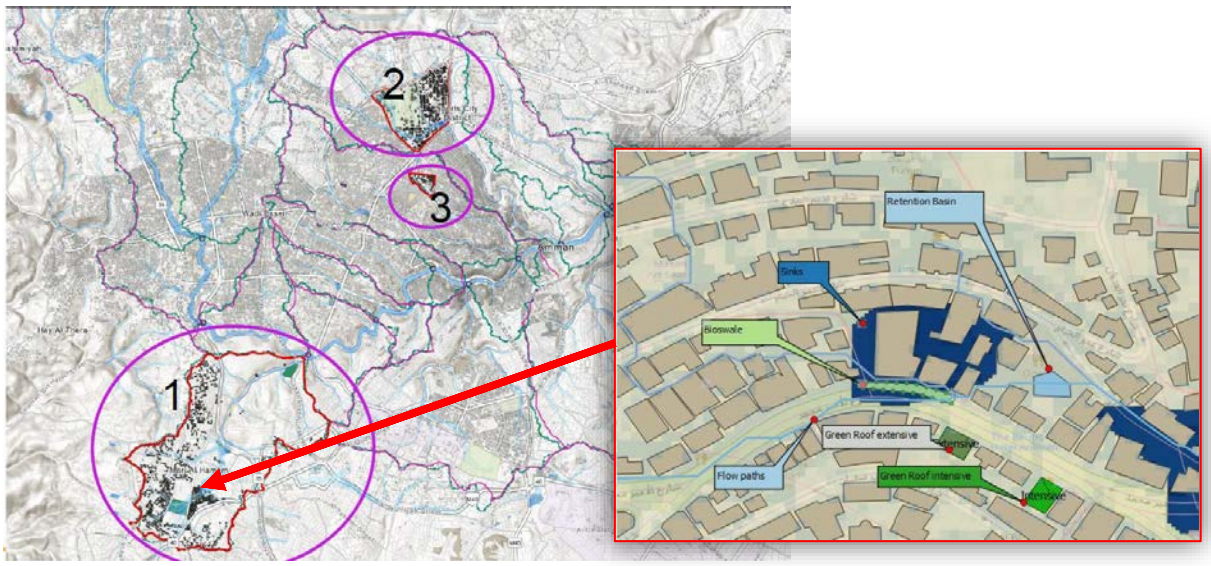


Figure 14. Map showing the three selected focus areas in Amman and an example how the allocation of measures is planned and visualized within the GIS environment.

The multi-touch table, which will be used in a participative manner for the presentation of the geographical data and results of AP 4 (measures) and WP 5 (scenarios and their assessment) was acquired and setup. This also included the installation of software and hardware requirements for the usage of the multi-touch table in Jordan. The geo-data has been compiled with the open source software application Quantum GIS. This allows an easy access for the different GIS data formats and it also includes an additional extension for web services and detailed geospatial analysis. To test the performance in terms of data visualisation and usability, the web application ESRI ArcGIS Online was used (Figure 15).

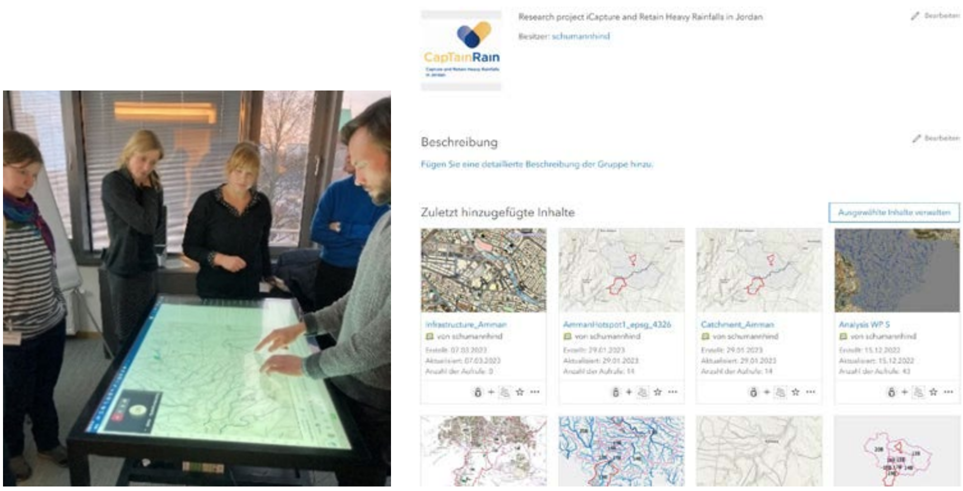


Figure 15. Multi-touch table equipped with software and geo-data. A first set-up of the system was presented by Hamburg Wasser during a project meeting in December and discussed in the team.

On-field surveys and semi-structured interviews with residents in Amman (n = 15) and Wadi Musa (n = 15) were conducted in 2022 to gather information on traditional adaptation measures and determine how local people perceive, understand and respond to flash floods. For this a structured questionnaire was prepared including questions on personal information, knowledge and local perception on flash floods events, drivers and causes of flash floods and knowledge and experience with flash flood adaptation strategies. The interviews were recorded, partly transcribed and analysed.

Inter- and transdisciplinary cooperation, highlights and difficulties

With the help of the rainfall-runoff simulations and flash flood risk mapping prepared in WP 3, suitable locations for the implementation of possible adaptation measures will be identified and located together with the local actors in WP 4. Participatory GIS methods will be used, which also allows to better communicate and discuss the results of WPs 3-5 with local stakeholders. The plausible adaptation strategies identified in WP 4 will be evaluated in the scenario analysis in WP 5. The analysis on risk perception in SWP 4.1 provides the basis for establishing user-friendly early warning systems in SWP 6.2. On the Jordanian side, this WP is supported in particular by GAM and PDTRA, which contribute their knowledge and experience in dealing with (traditional) adaptation strategies.

- Regular meetings between WP3 and WP5 to discuss results and further strategies
- Project meeting and workshop of the German partners in Hamburg. Overlay and integration of the preliminary results from hydrological and hydrodynamic simulations.
- Preparation of the stakeholder workshop in January 2023 in Amman.

Future prospects/outlook 2023

- Selection of adaptation measures, which will be used for the scenario and vulnerability assessment
- Services and interfaces will be installed on the multi-touch table to meet the requirements of the Jordanian partners
- Selection of possible promising adaptation measures within the selected focus areas. Those measures will be decided upon during the workshop and bilateral exchange with the project partners.
- Progress collaboration with the Jordanian Partners to e.g. find suitable focus areas
- Qualitative and quantitative evaluation of the different effects of the measures in relation to the planning and developing goals.
- Set up of the collaboration platform on the multi-touch table.
- Capacity building on interdisciplinary and integrated planning in terms of climate adaptation and infrastructure coordination.

WP 5 "Vulnerability"

WP 5 combines the results of the other work packages to perform an integrated vulnerability analysis for the selected study areas in Petra and Amman. Using a scenario analysis, promising adaptation strategies are simulated and assessed using indicators depicting the different social and ecological dimensions of vulnerability. Different options will be investigated with the aim of decreasing vulnerability. The resulting recommendations for action will be published as manuals, guidelines or policy briefs.

An integrated vulnerability analysis of flash floods is carried out in close collaboration with relevant stakeholders, which includes the analysis of the socio-ecological causes of flash floods and the identification, mapping and assessment of flash flood risks (exposure and sensitivity). In addition, risk perceptions are investigated from the perspective of the local population and strategies for adaptation to heavy rainfall events are developed. Model-based scenarios are used to develop and evaluate measures to improve risk preparedness, including technologies to divert and use water from heavy rainfall events. Climate services for the prevention of heavy rainfall risks are prepared and made available in a participatory manner. The study areas include the capital Amman with its 4.3 million inhabitants in the metropolitan region and the more rural region around the UNESCO World Heritage Site Petra. Both regions have been heavily affected by flash flood events in the past.

The simulated scenarios are discussed and assessed with local stakeholders. Promising adaptation strategies (traditional and improved methods and technologies) that can contribute to increasing resilience to flash floods and climate impacts are identified jointly. This will lay the foundation to develop recommendations for action, which are compiled via manuals, guidelines or policy briefs.

Achievements in relation to milestones/work plan and intermediate scientific results

Since the results of the other work packages are required for the implementation of the integrated vulnerability analysis of flash floods in WP 5, the work on this will start in 2023 according to the original planning. However, preliminary conceptual work has already been carried out based on literature research. Furthermore, the interdisciplinary collaboration within WP 5 and the interlinkage of the WP-specific results was discussed and identified during workshops and meetings. In a group work session of a project meeting in summer 2022, the participants jointly created a metaplan and identified the linkages of the different WP-related models and results that feed into the integrated vulnerability analysis. In addition, possible social, economic and biophysical vulnerability indicators for the integrated assessment were discussed and summarized.

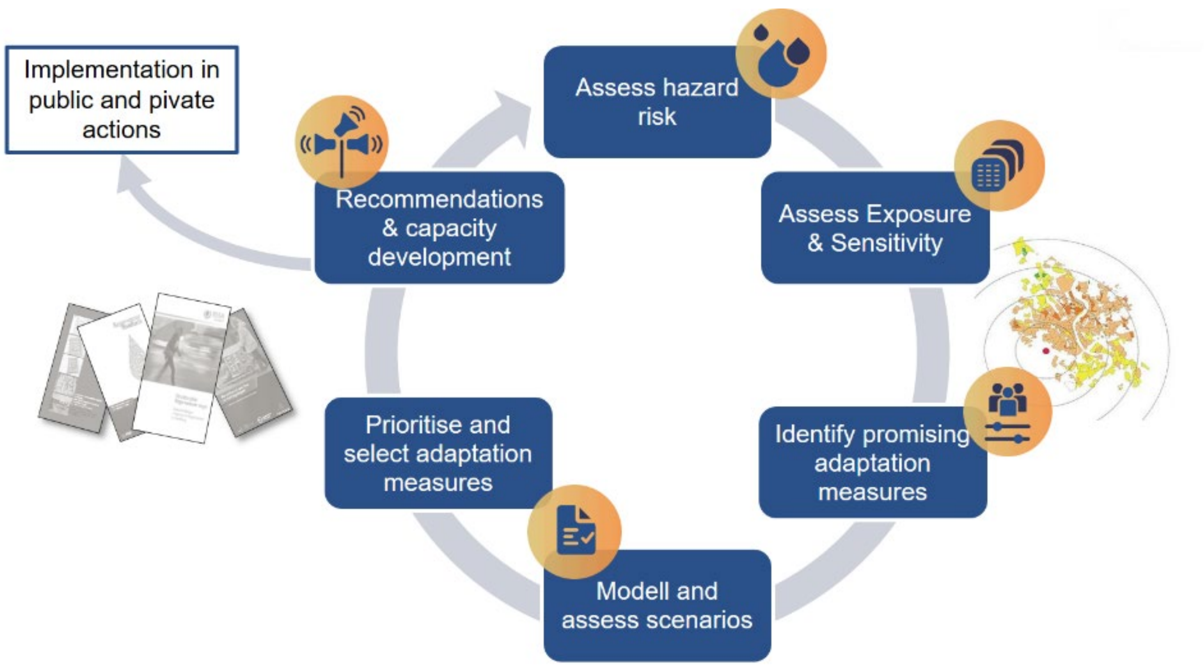


Figure 16. Overview of the integrated vulnerability assessment cycle.

Inter- and transdisciplinary cooperation, highlights and difficulties

The potentials of the promising adaptation strategies for urban and rural areas identified in WP 4 will be analysed in a scenario analysis in WP 5. The modelling tools required for this will be provided by WP 2 and WP 3. From the integrated assessment in WP 5, recommendations for action and measures will be derived and the results will be presented for integration into the dissemination strategy in WP 6.

In this WP, all partners are involved. In the framework of the planned stakeholder workshop "Validation and Scenario Development", the identification of promising adaptation strategies for the scenario analysis (scenario development) will take place jointly with Jordanian partners and stakeholders. The presentation and discussion of the vulnerability and scenario analysis along with the related recommendations for action will take place in the subsequent stakeholder workshop "Assessment and Recommendations for Action".

Future prospects/outlook 2023

- Literature research and completion of the conceptual work.
- Choice of modelling approaches and methods of model coupling.
- Identification of possible scenarios for the integrated modelling within the project team.
- Scenario development in close collaboration with the other WPs and the Jordanian partners.

WP 6 “Climate Services & Knowledge Transfer”

WP 6 "Climate Services & Knowledge Transfer" focuses on providing recommendation for climate services (e.g. early warning systems) for climate and flash flood-related decision-making as well as the communication of risks and impacts of flash floods. The **SWP 6.1 “Recommendations for early warning systems and demonstrator”** analyses the weaknesses and strengths of existing early warning systems (EWS) including their underlying data sources, methodology and dissemination tools, and develops recommendations for an EWS adapted to the needs of the users. The user-friendliness of the existing early warning system in Petra is assessed and evaluated through expert interviews and focus group discussions with local stakeholders (What information should be included? What media channels should be used? Do warnings reach all people at risk? Are the risks and warnings understood? Are the warnings clear and usable?), in order to be able to work out recommendations for the development of early warning apps for the population. This will form the basis for the design and implementation of an appropriate service as a demonstrator. The transfer of scientific results and climate services into practice is conducted by means of target group-oriented dissemination strategies in **SWP 6.2 “Knowledge transfer into practice”.** Comprehensibility and user-friendliness form the basis for well-prepared results, which are needed by the individual actors and decision-makers to facilitate decision-making processes and to be able to initiate climate-relevant changes. In this context, capacity development is crucial for fostering individual competencies that enable stakeholders to act in a way that is both responsible and self-dependent. Capacity development is carried out at different levels with formats specifically tailored to stakeholders and supports the training of local decision-makers and users in scientific and technical competencies to use the climate services established in CapTain Rain (e.g. EWS and risk maps).

Achievements in relation to milestones/work plan and intermediate scientific results

In SWP 6.1, an initial demonstrator of an Early Warning System for climate data management including an interface for the visualization, analysis and extraction of operational data was created in 2021. The demonstrator was further developed in 2022. New historical and real-time data were integrated and made available to the collaborative partners and Jordanian stakeholders. These now include historical ground-based weather data from the Ministry of Water and Irrigation (MWI), Mutah University, and the U.S. National Center for Environmental Prediction (NCEP). Additionally integrated were real-time weather measurements from stations of the World Meteorological Organization, which were retrieved and made available several times a day. Furthermore, a series of satellite data from Eumetsat and the Japanese Meteorological Agency (JMA), as well as globally or regionally available weather forecasts from the German Wetterdienst (DWD), Meteo France, the European Centre for Medium-Range Weather Forecasts (ECMWF), the Finnish Meteorological Institute (FMI), the U.S. National Oceanic and Oceanic and Atmospheric Administration (NOAA) and the Canadian Meteorological Centre (CMC) were integrated and presented in a user-friendly way. This now provides Jordanian partners with access to historical data for analysis purposes and real-time data for the early detection of extreme rainfall events. In addition, preliminary work was done on recommendations for early warning systems in Jordan and an abstract was prepared and submitted to the 7th International Symposium on Flash Floods in Wadi Systems (Title: "Comparison Of Global And Regional Satellite Rainfall Products For Flood Event Detection In Jordan").

To better understand how local people perceive, understand and respond to flash floods and flash flood warnings, on-field surveys and semi-structured interviews (n = 30) with residents in Amman and Wadi Musa were conducted in 2022.

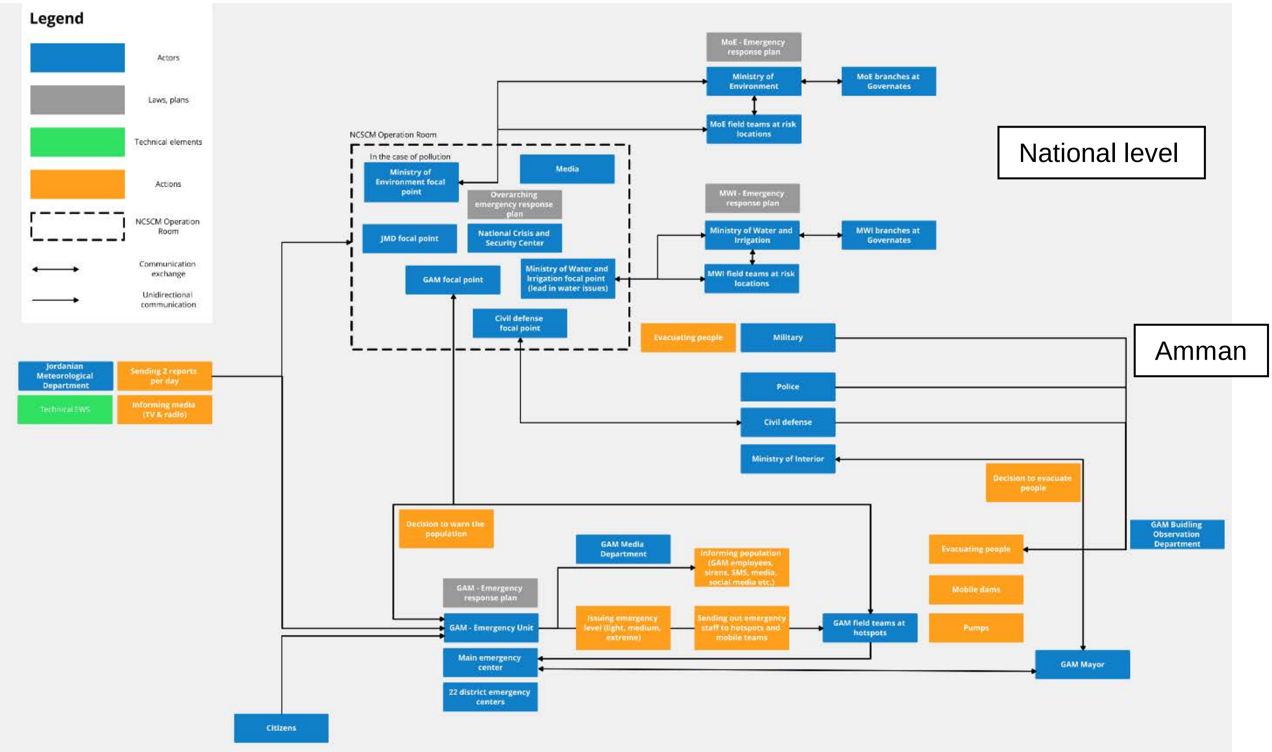


Figure 17. Communication flow in case of flash flood early warning (Emergency response chain) at the national level and for Amman.

The emergency response chain in the case of flash floods (Fig. 17) shows differences at the regional (Amman: Greater Amman Municipality GAM) and the national level (except PDTRA). The Jordan Meteorological Department (JMD) sends a climate report two times a day to different institutions. There is no early warning system for Jordan or Amman. The National Crisis and Security Centre brings together the main state institutions under its umbrella depending on the crisis to tackle. The Ministry of Water and Irrigation, Civil Defense, Police and Military act on the ground. In the case of GAM, the emergency unit with its main centre, 22 district centres and field teams as well as the Building Observation Department and the Media Department act also in case of emergencies such as flash floods. The emergency unit has pumps, mobile dams and other equipment to tackle flash floods. Remarkable are three different lines of decision for the emergency level (only GAM), the warning to the population (GAM and NCSCM) and evacuating people (GAM mayor and minister of interior).

The aim of SWP 6.2 is to disseminate the project results by involving Jordanian stakeholders and developing target group-specific formats for decision-makers and practitioners. This also includes contributions to capacity building. For this, **online seminars** (webinars) took place between the 17th March and 8th June 2022 (Table 3). The German project partners provided insights into their research activities and discussed possible approaches with the participants. Altogether, five research topics from different work packages were presented. The first seminar was held by the German company KISTERS AG, demonstrating a powerful data management tool for early warning systems. The itwh GmbH informed in the second seminar about data needs and possible approaches to analyze flood hazards. Together with the Koblenz University of Applied Sciences they also gave an overview of hydrological and hydraulic models for flash flood risk assessment in the third seminar. A highlight during this online seminar was the presentation of Dr. Qasem Abdelal from the German-Jordanian University who gave insights into his research in the Wadi Musa catchment. In the fourth seminar, the Potsdam Institute for Climate Impact Research (PIK) gave an introduction to predictors for heavy rainfall events in Jordan. The series ended with the fifth online seminar held by the German company Hamburg Wasser. They gave an overview on possible measures to reduce flash flood damages and presented the sponge city approach.

Table 3. Overview of online-Trainings (webinars) conducted in spring 2022 on WP-specific research topics.

Date	Topic	Presenter
17.03	Features of the state-of-the-art Demonstrator for climatic variables	KISTERS AG (Dirk & Marianne)
11.04	Flood hazard analysis tools – Data needed and possible approaches	itwh (Lothar)
16.05	Overview of hydrological and hydraulic models for flash flood risk assessment	Koblenz University (Clara & Christina), GJU (Qasem Abdelal), ITWH
30.05	Introduction to predictors for heavy rainfall events in Jordan under climate change	PIK (Peter & Christoph)
08.06	Measures to reduce flash flood risks and examples from the Sponge City Hamburg	Hamburg Wasser (Linnéa & Daniel)

Inter- and transdisciplinary cooperation, highlights and difficulties

The work on the integration of data in the demonstrator will continue in 2023 in close collaboration with AP 2 and the Jordanian partners (JMD, MWI and PDTRA). The dissemination of demonstrator has already been started through the creation of accounts that allow our German and Jordanian partners to access, visualize and extract it in order to integrate it with their own processes. Training and personal advice will be continuously offered to foster the use of the demonstrator.

For the dissemination of the project results, all relevant CapTain Rain results are included and processed in a target group-oriented manner based on the results of the stakeholder analysis and stakeholder workshops in SWP 1.1. Contributions are made here by all project partners.

Future prospects/outlook 2023

- In-person, hands-on workshops on the usage of the Early Warning System demonstrator in Jordan;
- Inclusion of desired features in the demonstrator according to the specific needs of the Jordanian partners;
- Analysis of the interviews to investigate the local perception and knowledge gaps concerning EWS;
- Development of recommendations for the establishment/improvement of EWS in Amman and Wadi Musa;
- Refinement of the dissemination plan.

List of publications and conference contributions in 2022

- Maus, C., Hohmann, C. and Ziegler, D., 2022: CapTain Rain – Capture and Retain Heavy Rainfalls in Jordan. Oral presentation held at the Tag der Forschung of the Koblenz University of Applied Sciences, online, 20.01.2022.
- Hohmann, C., 2022: CapTain Rain – Capture and retain heavy rainfalls in Jordan – A transdisciplinary German Jordanian research project. Poster presentation held at the DFG matchmaking fair, online, 15.02.2022.
- Hoffmann, P., Fallah, B., Menz, C., Wechsung, F. and Hattermann, F., 2022: Kumulierte Wetterextreme durch anhaltende Strömungsmuster: Ein bislang unterschätztes Risiko? Oral presentation held at the D-A-CH Meteorologie Tagung in Leipzig, 21.-25.03.2022.
- Hohmann, C., Maus, C., Ziegler, D., Brum, M. and Thiemann, M., 2022: Flash flood modelling and forecasting in data scarce regions like Jordan - A first step of an adequate model selection. Poster presentation held at the Tag der Hydrologie in Munich, Germany, 22.-23.03.2022.
- Hohmann, C., Maus, C., Ziegler, D., Kantoush, S. and Abdelal Q., 2022: Selection of flash flood models in data-scarce regions like Jordan. Oral presentation at European Geosciences Union (EGU) General Assembly in Vienna, Austria and online, 23.-27.05.2022, https://doi.org/10.5194/egusphere-egu22-3905.
- Awad, A., Brinkmann, K. and Hohmann, C., 2022: Spatial and Temporal Dynamics of Urbanization and its Impacts on Flash Flood Risk: A Case Study from Jordan's Wadi System. Poster presentation held at the Tropentag in Prague, Czech Republic and online, 14.-16.09.2022.
- Hohmann, C., 2022: BMBF – international project: CapTain Rain – Innovative climate services for better flash flood management in Jordan. Oral presentation held at the Young Hydrologic Society (YHS) Forum, online, 04.10.2022

CapTainRain

List of project meetings and workshops

- 14.02.2022, Meeting German project partners, online.
- 02.03.2022, Meeting Jordanian and German project partners, online.
- 23.06.2022, Meeting German project partners, Koblenz and online.
- 28.06.2022, Steering committee meeting, online.
- 19.07.2022, Steering committee meeting, online.
- 07.10.2022, Meeting German project partners, online.
- 05.12.2022, Meeting Jordanian and German project partners, online.
- 15.-16.12.2022, Meeting German project partners, Hamburg and online.