

Response Letter

Title: Panta Rhei benchmark dataset: socio-hydrological data of paired events of floods and droughts

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MS No.: essd-2022-330

Dear Referees,

We would like to thank you for the time and effort put into reviewing the manuscript. This response carefully addresses all your comments (our response is marked with an R). At the end of this response letter we provide the revised version of the data description with tracked changes for your information. The revised manuscript with tracked changes will be uploaded separately.

Best regards,

Heidi Kreibich on behalf of all authors

Referee #1

The presented database is the result of a large effort in collecting impact and risk management data of both flood and drought events, more specific: two floods or two droughts that occurred in the same area (Kreibich et al. 2017, 2019). The 45 paired events in the database occurred in 42 different study areas (there are three study areas for which there are two paired events). These basins have different socioeconomic and hydroclimatic contexts, and are spread across all continents. The dataset is unique in covering floods and droughts, in the number of cases assessed and in the amount of qualitative and quantitative socio-hydrological data contained. The dataset underlies the publication on multi flood-drought assessment by Kreibich et al. (2022)

In order to collect the data, templates were provided to structure the event characteristics using review style of reporting. In addition, semi-quantitative data was collected on: management, hazard, exposure, vulnerability and impacts. The main sources of the data vary from peer-reviewed papers to reports (by governments, NGOs, etc) to newspapers. The campaign started at the EGU General Assembly in April 2019 in Vienna.

The study and the database are unique and I am supporting the publication. The efforts to collect these data must have been a lot of work and the rigorous verification process is convincing. The database sets the scene for new scientific work on multi risk & hazards, for which empirical data is now lacking.

R: We thank the Referee for the positive feedback. Below, we have responded to all the comments point by point.

I only have some minor edits and suggestions:

The data base is guided by a document which describes the sampling methods and the data processing. This latter part is quite important, because it describes the quality assurance process, using peer review by a core group and cross checking. What I miss here a bit, is that the guiding document does not address the differences in the quality of the sources of the data. One may assume that a peer reviewed paper may provide data which has already undergone a review process, whether a newspaper article does not. I have checked the excel files, and the sources are mentioned. But there is no judgement on the resulting quality ?

R: We have tried to compile as detailed and complete data as possible on the events. As peer reviewed data sources were not available for all indicators of all events, we have also relied on reports, newspaper articles or expert knowledge. We agree that it is useful to provide some judgement about

*the quality of the various data sources. In the revised version of the manuscript as well as of the data description, we added a personal judgement on the quality of the sources of the data. For instance, in the manuscript in section “2.3.1 Compilation of key data” (lines 287-296): “Our aim was to compile as complete data as possible on the events, but not for all indicators of impacts, hazard, exposure, vulnerability and management shortcomings of all events peer-reviewed data sources were available. Thus, we also resorted to e.g. newspaper articles or expert knowledge. For transparency reasons, and to give data users the opportunity to judge the quality of the data themselves, data source information (citations, references) is also compiled in the key data table. **According to our personal assessment, the sources of the data are categorised in descending quality as follows:** scientific study (peer reviewed paper and PhD thesis), report (by governments, administrations, NGOs, research organisations, projects), own analysis by authors, based on database (e.g. official statistics, monitoring data such as weather, discharge data, etc.), newspaper article, and expert judgement.”*

The role of the references in the “reference tab” of the key data is not clear: these do not correspond with the references in the PairedEvents document. I assume it is for the key data? However, it misses a link between the key data tab. Using only the current notation of source (“report” or “scientific study”) is not enough to locate which of the references belong to which piece of information. It is also not notated if the source contains information on the first or second paired event. Therefore my recommendation for the authors is to make this link more clear, e.g., in the key data source columns refer to which source contains the data and to include in the references tab whether the reference contains information for the 1st / 2nd / 3rd or all events.

R: Indeed, the ‘reference tab’ of the Key data table contains all the references cited in the ‘key data tab’. Starting from the reference, you can find its citation (and as such the data for which it is the source) in the key data tab by using the ‘search’ within the excel document. This works very well, although it might appear not straightforward. However, our idea was the other way around: we expect that data users/readers start from the key data in the ‘key data tab’, which contain the citations of the data sources. For instance, Paired event with ID1, data column “Management: Problems with water management infrastructure”, event 2 (this is cell F3 in the key data tab) contains the citation: “(Zhang et al. 2017)”. To find the full reference to this citation, you go to the reference tab, look under ‘ID of Paired event: 1’ and find it in line 5 (last line of the ID1 block as the references are sorted alphabetically per paired event). This is described in section 3.2.2 Key data table of the manuscript; however, we realise that the header of the columns in the key data tab were misleading. We have now changed the header of every second column from “source of data” to “category of data source”. Also, the description of the key data table in the data description file has been improved accordingly. We refrain from adding the event year to the references tab because the listed references refer to particular event characteristics and thus are context specific. We are convinced that the access to references should start from the context information which is given in the key data tab. We will include a README tab into the Key data table, to even better inform the data user how to use the key data table.

The templates / attachments are missing in the index, and are not referred to in the document. Section 3.1 mentions that there are templates, but it would be useful to refer here to the templates in the document itself.

R: In the revised version of the data description, we have added the Appendix with the template to the “Table of contents”. Additionally, we refer to the Appendix in section 3.1 where the templates are mentioned. The provision of the templates in the Appendix of the data description is now also mentioned more clearly in the manuscript (section 2.2 Data acquisition, line 244 and in the conclusions lines 520-521)

Referee #2

This work provides a large database concerning a number of paired flood and drought events occurred worldwide across several decades. It is the result of significant efforts and commitment of a large community of experts working together within the framework of the Panta Rhei Research Initiative of the International Association of Hydrological Sciences (IAHS) (Working Groups “Changes in flood risk” and “Droughts in the Anthropocene”).

The result is a unique database that may sustain further investigations of the community and I certainly support its publication. The value of the work should also be recognized considering that it attempts to compare, across time and space, events that are, for their nature and for the different contexts/condition on which they occur, unavoidably different. This appears evident looking at the descriptions of the events (for example, events diverge in terms of the magnitude of the precipitation, initial basin conditions, extent of levee failure, tidal elevation, etc). In my opinion, this aspect represents both the strength and the limit of the database.

The attempt to provide a rational way to compare such events represents the most challenging part of the work. Although the applied approach (i.e., quality assurance procedures, etc.) is convincing and represents the best way of acting, I still be doubtful regarding the possibility to drive conclusions on risk and impact patterns, or on the effectiveness of management solutions, when boundary conditions and characteristics of the two compared events are different. Thus, my only request is to made an additional effort (perhaps on section 4?) in trying to emphasize this aspect, stressing the limit of the current database and thus promoting caution on the interpretations of the outcomes.

R: The following explanation is now included in Section 4 lines 453-460: “While the variables describing the first and second event of a pair are comparable, variables and data quality differ strongly between the paired events. The great heterogeneity of data and events represents both the strength and the weakness of the Panta Rhei dataset with regard to comparative analyses. As quantitative comparative analyses across all paired events are impossible, such analyses can only be undertaken on the basis of the indicators-of-change. Although these indicators were created with great care according to the quality assurance protocol, they are subject to uncertainties and caution is required when interpreting the results.”

Panta Rhei benchmark dataset: socio-hydrological data of paired events of floods and droughts

(<https://doi.org/10.5880/GFZ.4.4.2022.002>)

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1. Licence

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2. Citation

When using the data please cite:

Kreibich, Heidi; Schröter, Kai; Di Baldassarre, Giuliano; Van Loon, Anne; Mazzoleni, Maurizio; et al. (2022): Panta Rhei benchmark dataset: socio-hydrological data of paired events of floods and droughts. GFZ Data Services. <https://doi.org/10.5880/GFZ.4.4.2022.002>

The data are supplementary material to:

Kreibich, Heidi; Schröter, Kai; Di Baldassarre, Giuliano; Van Loon, Anne; Mazzoleni, Maurizio; et al. (20xx): Panta Rhei benchmark dataset: socio-hydrological data of paired events of floods and droughts. ESSD, doi....

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3. Data Description

As the negative impacts of hydrological extremes increase in large parts of the world, better understanding of the drivers of changes of risk and impacts is essential for effective flood and drought risk management and climate adaptation. However, there is a lack of comprehensive, empirical data about the processes and feedbacks in complex human-water systems leading to flood and drought impacts. To fill this gap, we present an IAHS Panta Rhei benchmark dataset containing socio-hydrological data of paired events, i.e. two floods or two droughts that occurred in the same area (Kreibich et al. 2017, 2019). The contained 45 paired events occurred in 42 different study areas (in three study areas we have data on two paired events), which cover different socioeconomic and hydroclimatic contexts across all continents. The dataset is unique in covering floods and droughts, in the number of cases assessed and the amount of socio-hydrological data contained.

References to the data sources are provided in **2022-002_Kreibich-et-al_Key_data_table.xlsx** where possible.

3.1. Sampling method

Based on templates ([see appendix of this document](#)), detailed, review-style reports (PairedEventReports.pdf) describing the events and key processes between the events in the case study areas were collected. The reports contain data that characterise impacts, hazard, exposure, vulnerability and management of the paired events in the case study areas.

The campaign to collect the review-style reports on paired events started at the EGU General Assembly in April 2019 in Vienna and was continued with talks promoting the paired event collection at various conferences. Communication with the IAHS Panta Rhei community and other flood and drought experts identified through snowballing techniques was important. Thus, data on paired events were provided by professionals with excellent local knowledge of the events and risk management practices.

3.2. Data processing

From the detailed review-style reports (PairedEventReports.pdf), key data characterising management shortcomings, hazard, exposure, vulnerability and impacts of the paired events in the case study areas was extracted and organised in the key data table (Key_data_table.xlsx). Definitions of impacts, hazard, exposure, vulnerability and management shortcomings indicators and examples of description or measurement of variables for their assessment are provided in Table 1. [For transparency reasons, and to give data users the opportunity to judge the quality of the data themselves, data source information \(citations, references\) is also compiled in the key data table.](#) [According to the authors personal assessment, sources of the information and data as given in the reports were categorised ~~classified~~ in descending quality](#) as follows: scientific study (peer reviewed paper and PhD thesis), report (by governments, administrations, NGOs, research organisations, projects), own analysis by authors, based on database (e.g. official statistics, monitoring data such as weather, discharge data, etc.), newspaper article, and expert judgement.

Table 1 Definitions of indicators and examples of how to describe or measure variables to assess these indicators of flood and drought impacts, hazard, exposure, vulnerability and management shortcomings.

Indicator	Definitions	Example description or measurement for floods	Example description or measurement for droughts
Impacts			
Number of fatalities (only floods)	Number of fatalities due to the direct impact of a hazard.	Number of fatalities, e.g. reported in newspapers	<i>Not relevant</i>
Direct economic impacts	Direct economic impacts are due to the direct physical effect of a hazard on economic assets ¹⁴	Flood damage to buildings expressed in Euros, e.g. recorded by insurance companies	Drought damage to crops expressed in Euros, e.g. quantified by compensation programmes
Indirect impacts	Indirect impacts occur inside or outside the hazard area, often with a time lag. They are commonly induced by direct impacts ¹⁴	Disturbance of supply chains, e.g. described in economic reports	Loss of livelihoods, job loss in agriculture, e.g. described in governmental reports
Intangible impacts	Intangible impacts refer to damage to people, goods and services that are not easily measurable in monetary terms because they are not traded on a market (these can be direct or indirect impacts) ¹⁴	Damage to cultural heritage, e.g. described by authorities	Damage to ecosystems, e.g. described by authorities
Drivers of impact			
Hazard			

Severity of flood/drought	Severity of the event in terms of hydro-meteorological processes, i.e. hazard	Maximum discharge measured at gauging station	Standardized Precipitation Evapotranspiration Index (SPEI), estimated based on the water balance
Duration of drought (only droughts)	Number of months in drought conditions ⁵⁴	<i>Not relevant</i>	Drought starts in the month when Standardized Precipitation Index falls below -1 and it ends when SPI returns to positive values
Precipitation / weather severity (only floods)	Heavy precipitation or severe weather that triggered the flood	Precipitation measured at weather stations	<i>Not relevant</i>
Antecedent conditions (only pluvial and riverine floods)	Conditions at the onset of an event that may exacerbate or mitigate the event ⁵⁵	Antecedent precipitation index, which is the weighted sum of past daily precipitation amounts, used as a proxy for soil moisture or: as an indicator for catchment wetness	<i>Not relevant</i>
Tidal level (only coastal floods)	Tidal water level at the time of coastal flood occurrence	Tidal water level measured at tide gauges	<i>Not relevant</i>
Storm surge (only coastal floods)	Rise in sea or estuary water level caused by the passage of a low pressure centre ⁵⁵	Sea water level measured at tide gauges	<i>Not relevant</i>
Exposure			
People/area/assets exposed	Number of people, size of area (e.g. settlement area, agricultural area) or number/value of assets located in affected areas ⁹	Number of buildings in inundated area, e.g. estimated from satellite imagery	Number of inhabitants in drought affected area, e.g. from population statistics
Exposure hotspots	Areas of particularly high exposure affected during an event	Large scale industrial facility affected by flood	Hydraulic energy production affected by drought
Vulnerability			
Lack of awareness and precaution	Lack of understanding of the risk (e.g. sources, hazards, potential consequences, etc.) and implementation of suitable precautionary measures. Depends e.g. on experience, risk communication campaigns, incentives to implement precautionary measures	Ineffective risk communication, lack of guidelines and incentives for private precaution	Lack of drought experience
Lack of preparedness	Lack of knowledge and capacities developed by communities and individuals to effectively anticipate and respond to an event, e.g. via private emergency measures	Late early warning, insufficient resources like pumps, shutters, sandbags	Lack of water shortage response plans
Insufficient official emergency/crisis management	Organisational emergency or crisis management before or during an event was insufficient to optimally mitigate impacts	Lack of emergency plans, non-effective governance	Ineffective water demand management
Insufficient coping capacity	Coping capacity, which is the ability of communities using available skills and resources, to manage an event was insufficient due to a lack of funding (insurance, risk transfer), resources or skills	Low or lacking public flood compensation to individuals and businesses	Insufficient governmental aid or compensation
Management shortcomings that influence the drivers of impact			

Problems with water management infrastructure	Water management infrastructures such as levees, reservoirs, sewage systems, etc. failed or did not work optimally during an event due to deficits in maintenance, sub-optimal design, etc.	Number of levee breaches	Lack of water in reservoirs, insufficient storage capacity
Non-structural risk management shortcomings	Non-structural risk management measures, e.g. spatial planning that avoids increase of exposure in hazard-prone areas and private property level risk mitigation measures were not optimally implemented	Lack of hazard and risk maps	Ineffective water use restrictions

On basis of this key data (in Key_data_table.xlsx), indicators-of-change that represent the differences between the first event used as baseline, and the second event were developed (Indicators_of_change.csv). The indicators-of-change are categorised as large decreases/increases (-2/2), small decreases/increases (-1/1) and no change (0). Additionally, five summary indicators-of-change for management shortcomings, hazard, exposure, vulnerability and impacts were derived by qualitatively comparing and integrating the values of the respective associated indicators-of-change (see Indicators_of_change.csv).

To minimise subjectivity and uncertainty in assigning values for the indicators-of-change, a quality assurance protocol was implemented. The quality assurance was driven by a core group (authors of this data publication: HK, AvL, KS, PW, GdB) and was undertaken in the following steps: (a) on the basis of the detailed report a core group member suggested values for all indicators-of-change for a paired event; (b) a second member of the core group reviewed these suggestions. In case of doubt, both core group members rechecked the paired event report, and provided a joint suggestion; (c) all suggestions for the indicators-of-change for all paired events were discussed in the core group to improve consistency across paired events; (d) the suggested values of the indicators-of-change were reviewed by the paired event report authors; (e) finally, the complete table of indicators-of-change was reviewed by all authors to ensure consistency across paired events. Representative examples of qualitative and quantitative indicator values from flood and drought paired events corresponding to the five classes of the indicators-of-change are provided in Table 2.

Table 2 Representative examples of quantitative and qualitative variables from flood and drought paired events corresponding to the five classes of the indicators-of-change, i.e. large decreases/increases (-2/2), small decreases/increases (-1/1) and no change (0). Examples are taken from the key data table (Key_data_table.xlsx) (ID = paired event ID).

Impacts					
Impact indicators for floods					
Indicators of change		Number of fatalities	Direct economic impacts	Indirect impacts	Intangible impacts
Large decrease (-2)	1 st flood	Dead and missing: 4407 (ERD, 2008) (ID 20)	1,158 million USD (ERD, 2008) in 2007 values. Re-estimated as 1,329 million USD in the year 2009 and converted to 930 million EUR (ID 20)	Indirect damage of the flood event is estimated at USD 1,287 million for 2007 (Bappenas, 2007) (ID 4)	NA*
	2 nd flood	Dead and missing: 190 (UNDP, 2010) (ID 20)	269.28 million USD (Xinhua, 2009) (converted to 188 million EUR) (ID 20)	Indirect damage of the flood event is estimated at USD 130 million for 2013 (Lurah Galur et al.,	NA

				2013; Lurah Karet Tengsin et al., 2013; Lurah Petamburan et al., 2013) (ID 4)	
Small decrease (-1)	1 st flood	9 fatalities (ID 15)	4 billion Euro (ID 15)	Some cascading effects due to damage to the gas network (ID 12)	Mercè festival events cancelled; damage to the Romanesque church of Sant Pere (ID 12)
	2 nd flood	5 fatalities (ID 15)	2.32 billion Euro (ID 15)	no relevant indirect impacts (ID 12)	Damage to the Filmoteca (film library) and the Maritime Museum (ID 12)
No change (0)	1 st flood	2 (indirect) fatalities in Saint-Anne-des-Monts, Quebec (IBC, 2019a; Peritz, Perreaux, & Stone, 2017) (ID 41)	[Total monetary damage unknown] CAD \$223 million in insured damages (in 2017 value) (IBC, 2017). This is equivalent to CAD \$230.06 million in 2019 value when adjusted for inflation (using Bank of Canada Inflation Calculator) (ID 41)	Common problems post-flooding include mould, contamination, debris. Other possible indirect economic impacts due to road closures; supply, use, and disposal of sandbags; costs associated with dispatching Canadian Armed Forces and supplies. However, specific numbers or problems have not been reported as of April, 2020 (ID 41)	Water-borne diseases at informal residential areas along flooded canals in rainy seasons (HCM People's Committee, 2019; Huynh et al, 2020; Nguyen et al, 2017) (ID 28)
	2 nd flood	1 (indirect) fatality in Pontiac, Quebec (CBC, 2019a) (ID 41)	[Total monetary damage unknown] Insured losses reported to be CAD \$208 million (in 2019 value) (IBC, 2019a). The estimate for financial assistance paid for 2019 flooding by Quebec is CAD \$25.9 million as of June 2019 (Montreal Gazette, 2019) (ID 41)	Common problems post-flooding include mould, contamination, debris. Other possible indirect economic impacts due to road closures (Silcoff, 2019); supply, use, and disposal of sandbags; costs associated with dispatching Canadian Armed Forces and supplies. However, specific numbers or problems have not been reported as of April, 2020 (ID 41)	Water-borne diseases (Huynh et al, 2020; Nguyen et al, 2017) (ID 28)
Small increase (+1)	1 st flood	0 fatalities (DRBC, 2006) (ID 42)	3.5 billion USD (at national level) (INDECI, 1998; CAF, 2000) (ID 13)	Comparatively small indirect loss due to the suspension of the tourist activities in the late holiday season in September, roads and railroads were temporarily interrupted (ID 40)	The Ontario portion of the Ottawa River was designated as a Canadian Heritage River in July 2016 to acknowledge its recreational and cultural value to Indigenous Peoples and its history as a transportation route (Government of Canada, 2016). The Ottawa River runs through the Algonquin Indigenous territories in Ontario that comprises ten Indigenous communities in Ontario (Water Canada, 2017).

					Flooding events along the river disrupt their traditional lifestyles and recreational activities (ID 41)
	2 nd flood	4 fatalities (Suro et al., 2009) (ID 42=)	3-9 billion USD (at national level) (Venkateswaran et al., 2017; INDECI, 2017) (ID 13)	High indirect loss due to the early suspension of the tourist activities at the peak of the holiday season in August, roads and railroads were temporarily interrupted (ID 40)	Similar disruptions as during the previous event due to flooding at the Ontario portion of the Ottawa River, a Canadian Heritage River (Government of Canada, 2016; Water Canada, 2017); Other long-term impacts comprise psychological impacts due to flooding fatigue caused by repeated flood events in similar regions or trauma due to emergency relocation and loss of belongings (Payne 2019, CBC, 2019b) (ID 41)
Large increase (+2)	1 st flood	NA	SEK 60 million (GP, 2010) (ID 45)	NA	In post cyclone period, there was a rise in mental health related problems (Kabir et al., 2016). Sidr caused severe damage to the Sundarbans, which is a World heritage site (ERD, 2008). However, the regeneration capacity of Sundarbans was high (Kumar Bhowmik and Cabral, 2013) (ID 20)
	2 nd flood	NA	SEK 600 million in total; of this SEK 440 million paid by insurance (SOU 2017:42) (ID 45)	NA	A large number of people were displaced or migrated. In several areas, people could not return for 3-4 years due to continued tidal flooding. A large number of people changed their livelihoods to daily labor or fishing to cope (Kumar Paul, 2013; Abdullah et al., 2016). This change in livelihood had extreme impacts on their culture, standard of living and social status (ID 20)
Impact indicators for droughts					
			Direct economic impacts	Indirect impacts	Intangible impacts
Large decrease (-2)	1 st drought		17,134 billion Euro (EEA, 2019a) (ID 9)	NA	NA
	2 nd drought		2,172 billion Euro (EEA, 2019a) (ID 9)	NA	NA

Small decrease (-1)	1 st drought
	2 nd drought
No change (0)	1 st drought
	2 nd drought
Small increase (+1)	1 st drought
	2 nd drought
Large increase (+2)	1 st drought

12% decrease in energy GDP regional contribution to the national energy GDP; 4% decrease in agriculture GDP regional contribution to the national agriculture GDP (computed as the difference between 1999 and 1998 GDP values from Banco Central de Chile, 2020) (ID 6)	Explosion of spruce and fir bark beetle (Geiger 1951) (ID 8)	Famine (Fegert, 2017), fish death (Deutscher Wetterdienst in der US-Zone 1947) (ID 8)
13% increase in energy GDP regional contribution to the national energy GDP; 12% decrease in agriculture GDP regional contribution to the national agriculture GDP (computed as the difference between 2014 and 2013 GDP values from Banco Central de Chile, 2020) (ID 6)	Similar indirect impacts as in 1947 event, but easier to cope with. (ID 8)	Fish death (less than 1947) (ID 8)
USD 50 million (EM-DAT (2019) (ID 10)	alga proliferation, 5% drop in electrical voltage, drought tax (ID 7)	Fish mortality and tree mortality (young plants) (ID 7)
USD 70 million due to agricultural losses (Choudhary et al. 2015) (ID 10)	bar beetle epidemic, increase in climate multi-risk insurance (ID 7)	Significant and unusual tree mortality (Département de la santé des forêts, 2019) (ID 7)
10 to 12 billion US Dollars (recalculated as at 2010) (ID 25)	Conflicts between different sectors of water uses (hydraulic, tourism, irrigation, drinking water) (Ricart and Pavon, 2014) (ID 34)	Damage to the environment, soil erosion (Gibbs, 1984; Heathcote, 1988) (ID 35)
15 billion US Dollars (ID 25)	Political conflicts between the party that was in the Government of Spain, the opposition and the Government of Catalonia, mainly because of the proposed transfer of water from Segre River to Internal Basins of Catalonia. Conflicts between hydroelectric, Water Catalan Agency, AGBAR for the overexploitation of water wells. (Llasat et al, 2009), newspaper La Vanguardia (2021) (ID 34)	Depression, exhaustion, drop in tourism, damaged aquatic and terrestrial ecosystems (Sherval et al., 2014, Bond et al. 2008; LeBlanc et al. 2012) (ID 35)
The estimated agricultural damage for 2003 is around 520,000 euros, the total	Limited indirect impact (ID 44)	NA

			agricultural damage is about 3% of the total crop value in the area. (ID 38)		
	2 nd drought		The estimated agricultural damage for 2018 is about 4 times as high as in 2003: 2,200,000 euros, which is about 11% of the total crop value in the area (ID 38)	About 35,000 job losses in agriculture, estimated 50,000 people pushed below poverty line due to job losses and food price inflation, drop in tourism (Ziervogel 2019; City of Cape Town 2019; WWF 2018) (ID 44)	NA
Drivers of impact					
Hazard indicators for floods					
		Antecedent conditions	Precipitation/weather severity	Severity of flood	
Large decrease (-2)	1 st flood	Before the rains from Ivan arrived, the Delaware River at Montague and Trenton, New Jersey was flowing at 298 percent and 265 percent of normal, respectively, for the first half of September (DRBC, 2004, 2006) (ID 42)	Average precipitation in the southern part of basin was 595 mm; average precipitation in the northern part of basin was 410 mm (Wu 2006) (ID 3)	Total runoff of the southern part of basin was 5,995 billion m ³ ; total runoff of the northern part of basin was 1,539 billion m ³ (Wu 2006) (ID 3)	
	2 nd flood	Normal to dry streamflow condition (Suro et al., 2009) (ID 42)	Areal mean rainfall in the north branch of Daqinghe river was 125 mm; areal mean rainfall in the south branch of Daqinghe river was 123 mm (Wu 2006) (ID 3)	Total volume into Baiyandian from north and south branch was 1,536 billion m ³ (Wu 2006) (ID 3)	
Small decrease (-1)	1 st flood	Above-normal (150-200% of average) fall precipitation and saturated soils. High winter snowpack (90-130% of normal) with high snow water equivalent. Low winter temperatures and significant frost penetration (Manitoba Infrastructure, 2013; Blais et al. 2016) (ID 31)	327mm/6 days (Bappenas, 2007), 50 year RP (Bappenas, 2010) (ID 4)	Maximum recorded peak flow in Piura river ever (3367 m ³ s ⁻¹) (ENFEN, 2017) (ID 13)	
	2 nd flood	Normal antecedent fall and winter conditions. Late spring melt and wet soils (Szeto et al. 2015; Ahmari et al. 2016) (ID 31)	250-300mm/15 days (Pertiwi, 2013), 30 year RP (Budiyono et al., 2016) (ID 4)	Peak flow of 2754.5 m ³ s ⁻¹ (ID 13) (ENFEN, 2017)	
No change (0)	1 st flood	No rainfall in the last previous 3 days. Numerous inlets clogged by leaves (CLABSA, 1995) (ID 12)	Areal average April-May precipitation over the basin for period 1981-2010 was recorded to be 150 mm. In 2017, it was 257 mm (174% of average) (ORRPB, 2018). (ID 41)	4.16m surge (Adnan et al. 2019) plus low tide (ERD, 2008) (ID 20)	

	2 nd flood	No rainfall in the last previous 5 days. Some inlets clogged by leaves (BCASA, 2018) (ID 12)	April-May accumulated precipitation between 240-300 mm (preliminary data, Agriculture and Agri-Food Canada, n.d.) (ID 41)	4.10 m surge (Adnan et al. 2019) plus high tide (UNDP, 2010) (ID 20)
Small increase (+1)	1 st flood	Late winter conditions and snowpack were considered average for the basin for May-April. Heavy localized rainfall events happening at the same time as snowmelt led to high soil saturation and river flows in early April. However, the primary driver of flooding was rainfall runoff (McNeil, 2019; ORRPB, 2018). (ID 41)	62.5 mm (Areal average of 3-day precipitation maxima for German part of the Upper Danube catchment) (Schröter et al., 2015) (ID 15)	7,700 m ³ /s peak discharge at gauge Achleiten (~HQ50) (HND 2021); 1,081 cm water level at gauge Passau; 10,250 m ³ /s peak discharge at Korneuburg/Vienna (Blöschl et al., 2013) (ID 15)
	2 nd flood	Snow-cover did not reduce much till late April due to prolonged winter conditions. Snowpack/snow water equivalent in 2019 was considered to be 150-188% of average at peak amount. This led to increased freshet in late April. 2019 rainfall was above-average for the basin but less than that of 2017 and was more distributed over the basin. Hence, primary driver of flooding was a combination of above-average rainfall and snowmelt (McNeil, 2019 ; ORRPB, 2019).(ID 41)	75.7 mm (Areal average of 3-day precipitation maxima for German part of the Upper Danube catchment) (Schröter et al., 2015) (ID 15)	10,100 m ³ /s peak discharge at gauge Achleiten (~HQ150) (HND 2021); 1,289 cm water level at gauge Passau, i.e. highest water level in Passau since 1,501 flood; 11,055 m ³ /s peak discharge at Korneuburg/Vienna (Blöschl et al., 2013) (ID 15)
Large increase (+2)	1 st flood	NA	Max precipitation: 175.26 mm, 50-to-100-year recurrence interval for a 24-hour storm (Brooks, 2005) (ID 42)	< 25 years return period of precipitation for 6-hour duration (Sørensen & Mobini, 2017) (ID 45)
	2 nd flood	NA	Max Precipitation: 339.34 mm in 24 hours at Walton New York (Suro et al., 2009) (ID 42)	> 130 years return period of precipitation for 6-hour duration (Sørensen & Mobini, 2017) (ID 45)
Hazard indicators for droughts				
Large decrease (-2)	1 st drought		Duration of drought SPI6: 23 months, SPI12: 59 months (Cavus 2019; Cavus and Aksoy, 2019, 2020) (ID 26)	Severity of drought Average values for Maule region: SPI12 = -2.63; SPEI12 = -2.01 (ID 6)
	2 nd drought		SPI6: 9 months, SPI12: 13 months (Cavus 2019; Cavus and	Average values for Maule region: SPI12 = -0.95; SPEI12 = -1.06 (ID 6)

		Aksoy, 2019, 2020) (ID 26)	
Small decrease (-1)	1 st drought	Hydrological drought duration: 3.4 years (ID 22)	The core of the 2003 drought event (12°W-30°E; 35°N-55°N) recorded an extreme value of August SPEI3 = - 1.62 (Schär et al., 2004) (ID 9)
	2 nd drought	Hydrological drought duration: 2.1 years (ID 22)	The core of the 2015 drought event (0°E-45°E; 40°N-60°N) recorded an extreme value of August SPEI3 = - 1.18 (Ionita et al., 2017) (ID 9)
No change (0)	1 st drought	May to September 2003, based on SPEI3 drought index (EDC, 2003a) (ID 9)	SPEI extremely dry (SPEI <-2) (ID 21)
	2 nd drought	Late May to September 2015 based on the SPEI3 drought index (Ionita et al., 2017) (ID 9)	SPEI extremely dry (SPEI <-2) (ID 21)
Small increase (+1)	1 st drought	24 months (NDMC 2020c ; NC DMAC 2020b) (ID 33)	Average inflow into reservoir system 57% lower than the long-term average (Araújo 1986) (ID 37)
	2 nd drought	27 months (NDMC 2020c ; NC DMAC 2020b) (ID 33)	Average inflow into reservoir system 77% lower than the long term average (Nobre et al. 2016) (ID 37)
Large increase (+2)	1 st drought	2 years annual rainfall below threshold (Jacobs et al. 2007) (ID 44)	At peak intensity, over 30% of area affected by exceptional drought (D4) (NDMC 2020b; NC DMAC 2020b) (ID 33)
	2 nd drought	4 years annual rainfall below threshold (Otto et al. 2018, Wolski 2018) (ID 44)	At peak intensity, over 60% of area affected by exceptional drought (D4) (NDMC 2020b; NC DMAC 2020b) (ID 33)

Exposure indicators for floods			
		People/area/assets exposed	Exposure hotspots
Large decrease (-2)	1 st flood	More than 175,000 people exposed in South Carolina; at least 800,000 homes and businesses lost power access in South Carolina (Stewart, 2017) (ID 19)	NA
	2 nd flood	About 40,000 people exposed in South Carolina; about 250,000 homes and businesses lost power access in South Carolina (Stewart, 2017) (ID 19)	NA

Small decrease (-1)	1 st flood	8000 people and 4800 buildings exposed (Vologda regional government 2005) (ID 17)	50 flooded locations in the city (SCFC, 2011) (ID 28)
	2 nd flood	7400 people and 2900 buildings exposed (Vologda regional government (2016) (ID 17)	31 flooded locations in the city, including the landing zone of Tan Son Nhat Airport (SCFC, 2016) (ID 28)
No change (0)	1 st flood	Specifics around overall exposure of assets not well known (Westdal et al. 2015), but approximately similar between events. 3 million acres of cultivated farmland were exposed (MIT, 2013) (ID 31)	Flooding impacted primarily residential and city areas, including regions in Ontario (Dundas, Hamilton, Ottawa, Cumberland) and Quebec (Pontiac, Gatineau, Montreal island, Rigaud Saint-Jean sur Richelieu, Secteur Île Bizard, Île Mercier, Maniwaki, Mansfield-et-Pontrefact Shawinigan, Laval) (ORRPB, 2018; Floodlist, 2017) (ID 41)
	2 nd flood	Specifics around overall exposure of assets not well known (Westdal et al. 2015), but approximately similar between events. About 2.5-3.5 million acres of cultivated farmland were exposed (AAFC, 2014) (ID 31)	Flooding impacted primarily residential and city areas, including regions in Ontario (Ottawa, Constance Bay, Fitzroy Harbour, Cumberland) and Quebec (Gatineau, Pontiac, Montreal, Sainte-Marthe-sur-le-Lac, Pointe-Calumet, Laurentians and the Chaudière Appalaches region) (Statistics Canada, 2019) (ID 41)
Small increase (+1)	1 st flood	60,000 people exposed in Austria (EM-DAT, 2019) (ID 15)	Oldest part of the city, city center and cultural heritage (medieval walls and churches) exposed (ID 12)
	2 nd flood	80,000 people exposed in Bavaria (likely not all of them in the Danube basin); 16697 residential houses in Bavaria and Baden-Württemberg exposed (likely not all of them in the Danube basin) (Thieken et al., 2016a) (ID 15)	Oldest part of the city, city center, with great commercial and touristic activity and cultural heritage (medieval walls, churches, new Filmoteca (film museum and library)) exposed (ID 12)
Large increase (+2)	1 st flood	>350 buildings exposed, estimated on basis of flood claims to LF Skåne and (insurance company) and VA SYD (water utility company) (Sörensen & Mobini, 2017) (ID 45)	28 cities exposed, 2257 industrial, mining and railway enterprises in cities of Bao Ding, Xing Tai, Han Dan Shi Jia Zhuang and 116.4 km railway affected (Xiao et al. 1998) (ID 3)

	2 nd flood	>4700 buildings exposed, estimated on basis of flood claims to LF Skåne and (insurance company) and VA SYD (water utility company) (Sørensen & Mobini, 2017) (ID 45)	91 cities exposed, 94,000 township enterprises, 15 national roads, 76 provincial roads and 396 bridges affected (Xiao et al. 1998) (ID 3)
Exposure indicators for droughts			
		People/area/assets exposed	Exposure hotspots
Large decrease (-2)	1 st drought	NA	NA
	2 nd drought	NA	NA
Small decrease (-1)	1 st drought	Farmers across the UK exposed to soil moisture drought. No hosepipe bans so limited exposure to hydrological drought (Marsh, 2014; EA, 2017); Some local water supply difficulties in North West Scotland (Marsh, 2004) (ID 23)	In 1976 the drinking water supply was an exposure hotspot to drought especially in rural and industrial area because of insufficient drinking water network to satisfy the water demand (Mission interministérielle de l'eau 1977; Agence de l'Eau Rhin-Meuse 1977) (ID 7)
	2 nd drought	Farmers in Eastern and Southern England exposed to soil moisture drought. Localised impact of hydro drought in the South and East of the UK (Marsh et al, 2014; EA, 2017) (ID 23)	Agricultural land (Chambre d'agriculture) and few rural villages exposed (decline of industry) (ID 7)
No change (0)	1 st drought	Sown area: 1,488.2 thousand Ha; persons employed in agriculture: 205,275 (ID 21)	Drought hotspot at the Central Valley (urban and hydropower users) (ID 36)
	2 nd drought	Sown area: 1,463.5 thousand Ha; persons employed in agriculture: 209,160 (ID 21)	Drought hotspot at the Central Valley (urban and hydropower users) (ID 36)
Small increase (+1)	1 st drought	Large part of central Europe, ~3,700,000 km ² (ID 9)	Cape Town domestic and industrial water users (Steenkamp, 2005) (ID 44)
	2 nd drought	Whole Europe (Ionita et al., 2017), ~5,400,000 km ² (ID 9)	Cape Town domestic and industrial water users & Western Cape Agricultural Users (Muller, 2018; WWF 2018) (ID 44)
Large increase (+2)	1 st drought	1,035,377 of inhabitants in the Adana province were exposed together with more from the Seyhan River basin (DPT, 2008) (ID 26)	NA

	2 nd droug ght	2,165,595 of inhabitants in the Adana province were exposed together with more from the Seyhan River basin (ID 26)	NA		
Vulnerability indicators for floods					
		Lack of awareness and precaution	Lack of preparedness	Insufficient official emergency/crisis management	Insufficient coping capacity
Large decrease (-2)	1 st flood	Flood risk awareness of the population as well as authorities was limited and only few precautionary measures were undertaken before the event (ID 13)	The SENAMHI river flow forecasts and flood alerts did not yet exist for the 1998 event. Although weather forecasts existed, it can be assumed that these were much less precise than for the 2017 event (ID 13)	Official emergency management activities were limited (ID 13)	The capacity to manage localized flooding was significantly reduced in the early 1990s subsequent to the privatisation of the water industry in the UK (Pitt, 2007); household flood insurance was in place (during both flood events) (ID 11)
	2 nd flood	NGOs such as 'Practical Action' have implemented disaster risk reduction activities such as evacuation exercises and awareness campaigns (French and Mechler; 2017); In 2011, the national Centre for the Estimation, Prevention, and Reduction of Disaster Risk (CENEPRED) was founded, which strongly improved risk awareness also among authorities (ID 13)	Around 2000, the national hydrometeorological service started issuing medium-range weather forecasts that allowed preparations months before the 2017 event. The national flood early warning system issued daily weather and river flow forecasts (SENAMHI, 2020) (ID 13)	The National Institute of Civil Defence (INDECI), and the national Centre for the Estimation, Prevention, and Reduction of Disaster Risk (CENEPRED), both founded in 2011, undertook and supported effective emergency management (ID 13)	Exposed communities formed networks and were able to effectively hold authorities to account. This means they were able to define their needs well and mobilise political support (e.g. the Pang Valley Flood Forum https://www.floodalleviation.uk/). This gave communities access to new funding for flood risk management, which requires evidence of effective local partnerships (ID 11)
Small decrease (-1)	1 st flood	Last severe floods in 1974 and 1976. Prior to these floods, the 1954 Hurricane Hazel's flash-flooding resulted in 81 fatalities, which prompted Ontario to develop more stringent rules on infrastructure development on areas close to water (Perreux, 2018) (ID 41)	Germany: penetration rate of early warning and actionable knowledge are low (Kreibich and Merz, 2007, DKKV, 2015, Kreibich et al. 2017) (ID 15)	In both, Germany and Austria, flood early warning was rather late and imprecise, coordination between the responsible authorities was limited (Thieken et al., 2016b, DKKV, 2015) (ID 15)	Economic compensations by state insurance "Consorcio de Compensación de Seguros" (CCS) helped to recover within several weeks (ID 12)
	2 nd flood	Increased awareness since 2017 with more information available at various government and NGO websites on flood management and recovery (City of Ottawa, n.d.; Ottawa Riverkeeper, 2019; Pfeffer, 2019; Ontario Ministry of Natural Resource and Forestry,	Penetration rate of early warning and actionable knowledge had increased significantly after 2002 event (Kreibich and Merz, 2007, DKKV, 2015, Kreibich et al. 2017) (ID 15)	In Germany and Austria: improved information and coordination capacities between the responsible authorities at federal, state and community levels (Thieken et al., 2016b, DKKV, 2015) (ID 15)	Economic compensations by state insurance "Consorcio de Compensación de Seguros" (CCS) helped to recover within some days; the metro was fully operational again within a few hours (ID 12)

		2019; ORRPB, 2019) (ID 41)			
No change (0)	1 st flood	Private precautionary measures implemented, such as storage of important items on higher level ground or upper floors of buildings, prepared door frames for shutters or dikes (Budiyono, 2018) (ID 4)	Happened Saturday evening, after rainfall all day (Sørensen & Mobini (2017); No official warnings or risk communication to the general public (ID 45)	Emergency management was supported by the military, as there were not enough emergency personnel available (MIT, 2013) (ID 31)	Main coping instruments include disaster recovery assistance (municipal, provincial, and federal when applicable) and private insurance (IBC, 2019b) (ID 41)
	2 nd flood	Similar level of private precautionary measures implemented (Budiyono, 2018) (ID 4)	Happened early Sunday morning (4.30–7.30) when few people were in office, many people were sleeping (Sørensen & Mobini 2017); no official warnings or risk communication to the general public (Bentzel 2019) (ID 45)	Emergency management was supported by the military, as there were not enough emergency personnel available (Westdal et al. 2015) (ID 31)	Main coping instruments include disaster recovery assistance (municipal, provincial, and federal when applicable) and private insurance (McNeil, 2019) (ID 41)
Small increase (+1)	1 st flood	High awareness and precaution - the Province recognized early in the fall of 2010 that there would be major flooding throughout Manitoba in the spring of 2011. Issued first spring flood outlook with high flood risk warning January 2011 (MIT, 2013). High knowledge and good operations of staff acknowledged as critical to successful management (MIT, 2013) (ID 31)	Manitoba Emergency Measures Organization began planning months ahead of flood event, including opening MB Emergency Coordination Centre (remained open for 103 days), purchasing 2 sandbag machines, etc. (MIT, 2013) (ID 31)	Responses to emergency calls were manageable (ID 45)	In 2011, Manitoba applied for Federal Disaster Financial Assistance Arrangements (\$780 M) to help with recovery (Kavanagh and Annable, 2017), and also launched a \$175 M compensation and mitigation program (Westdal et al. 2013) (ID 31)
	2 nd flood	Less awareness and precaution because spring melt was complete and the flood did not resemble typical floods for the region (Healy, 2014). In 2014, the spring flood outlook predicted only minor to moderate risk (Ahmari et al. 2016) (ID 31)	In 2014, the Province had much less time to prepare for the flash flooding that occurred rather unexpected as it was a non-typical event for the basin (Healy, 2014) (ID 31)	Collaboration between different departments was good during the 2014 event, however a central coordinator would have been good since the roles and responsibilities were unclear. The warning was late and the staff were not mentally prepared for such an extreme event (Lindher, 2015) (ID 45)	In 2014, Manitoba applied for Federal Disaster Financial Assistance Arrangements (\$180 M) to help with recovery (Kavanagh and Annable, 2017) (ID 31)
Large increase (+2)	1 st flood	NA	NA	NA	NA
	2 nd flood	NA	NA	NA	NA
Vulnerability indicators for droughts					
		Lack of awareness and precaution	Lack of preparedness	Insufficient official emergency/crisis management	Insufficient coping capacity

Large decrease (-2)	1 st drought	Low drought awareness, no precaution (ID 8)	No warning systems, no seasonal forecast available for people and farmers (Hydrometeorological Center 1973, 1976) (ID 25)	No special public management organisation for droughts, no emergency plans available, volume of water redirected to Don irrigation system 2,5 km ³ per year (ID 25)	No drought insurance available, the food trade on the black market was a strategy to get food (Fegert, 2017) (ID 8)
	2 nd drought	High drought awareness due to implemented monitoring systems and daily media reports (Erfurt et al. 2019) (ID 8)	Open-access 10-day and seasonal agro-meteorological forecast, warning system on Roshydromet website – MeteoAlarm service. For state water management company legislatively fixed critical water levels and early warning alarms when water levels are close to threshold (ID 25)	Public management organisation for droughts exists, drought emergency plans available, volume of water redirected to Don irrigation system 1,1 km ³ per year, no watering of streets from June till September (ID 25)	In the case of a disaster on a national scale (like in the case of the drought 2018), the federal government of Germany provides financial assistance for forestry and agriculture (BMEL, 2019). Private insurances (yield guarantee insurances and damage-based insurances) exist for agriculture and forestry (BMEL, 2017) (ID 8)
Small decrease (-1)	1 st drought	Mild awareness campaign to limit unnecessary water use (Jansen & Schulz 2006) (ID 44)	20% reduction in water allocation for domestic uses implemented by the City of Cape Town (Jacobs et al. 2007) (ID 44)	National and Local Water Demand Management; Level 3 or 4 Domestic Water Restriction in Cape Town Metropolitan Area up to 105 litres/per day (Jansen & Schulz 2006) (ID 44)	No insurance or governmental compensation (ID 7)
	2 nd drought	Aggressive awareness campaign (Day Zero) to considerably reduce domestic and agricultural water consumption (Ziervogel 2019, Robins 2019, Rodina 2019) (ID 44)	Water use restrictions up to 60% for agriculture and 45% for domestic water (Ziervogel 2019, Robins 2019, Rodina 2019) (ID 44)	National, Local and International task force with emergency plan; Level 6 Domestic Water Restriction in Cape Town Metropolitan Area up to 50 litres/per day, Sanction, Tariff increase and Water Management Devices (Ziervogel 2019, Robins 2019, Rodina 2019) (ID 44)	Since 1982, law on compensation for victims of natural disasters (Law n°82-600, July 13, 1982). Farmers are advised to take private insurance (ID 7)
No change (0)	1 st drought	High drought awareness in population (ID 6)	Early warning system did not exist (Aras et al., 2019) (ID 26)	No crisis management enacted (ID 23)	No drought insurance available (ID 37)
	2 nd drought	High drought awareness in population (ID 6)	Early warning system did not exist (Aras et al., 2019), it is within the future program of public organizations. (ID 26)	No crisis management enacted (ID 23)	Insurance mechanisms proposed for hydrologic drought insurance under water demand and climate change scenarios in a Brazilian context (Mohor & Mendiondo, 2017), but not yet implemented (ID 37)
Small increase (+1)	1 st drought	NA	NA	NA	Damage costs in agricultural and shipping sector mainly covered by higher prices: payed by consumer (Peters, 2003) (ID 38)

	2 nd drou ght	NA	NA	NA	Resources in agricultural sector were not sufficient to cope with the consequences (Ecorys, 2019) (ID 38)
Large increase (+2)	1 st drou ght	NA	NA	NA	NA
	2 nd drou ght	NA	NA	NA	NA
Management shortcomings					
Indicators of management shortcomings for floods					
		Problems with water management infrastructure	Insufficient risk management		
Large decrease (-2)	1 st flood	The design discharges of the levees were half the event discharges, all levees failed (Veatch, 1952) (ID 2)	Limited risk management activities and response capacity (French and Mechler 2017) (ID 13)		
	2 nd flood	No levee failures occurred, following upgrading based on 1951 event (Lovelace & Strauser, 1996; United States General Accounting Office, 1995) (ID 2)	Much improved risk management and response capacity, including newly established government institutes (CENEPRED, INDECI) (French and Mechler 2017) (ID 13)		
Small decrease (-1)	1 st flood	The combined capacity of the Portage Diversion (operated over design capacity during the flood event) and the dikes downstream of Portage La Prairie was not enough to contain peak flows, prompting the Province to construct an emergency controlled outlet at Hoop and Holler Bend (Blais et al. 2016; MIT, 2013) (ID 31)	No consistent large-scale flood hazard and risk mapping available before the event in 2002 (ID 15)		
	2 nd flood	Directly following 2011 flood, an emergency outlet channel on the end of Lake St. Martin was constructed and operated over the winter to prepare for spring runoff. The operating rules for the Fairford Water Control Structure were also modified to allow maximum possible discharge to lower lakes levels between 2011-2014 (Ahmari et al. 2016); During the 2014 flood, the Portage Diversion was again operated over capacity (Ahmari et al. 2016).	Flood hazard mapping initiated following the EU Flood Directive launched in 2007; Floodplain restoration at lowland Danube tributaries in Germany and Austria since 2004 increased storage capacity (e.g. storage capacities at Salzach near Niedernsill, Austria) (BLFUW, 2006) (ID 15)		

		The emergency outlet at Hoop and Holler Bend was not required (ID 31)	
No change (0)	1 st flood	Issues with combined sewage system, Spillepengen pumping station out of order due to overload (Sørensen & Mobini, 2017) (ID 45)	Limited access to floodplain and flood risk maps (Henstra et al., 2019; Henstra & Thistlethwaite, 2018). Ontario guidelines for hydrologic modelling, floodproofing standards and floodplain mapping based on approaches from the 1980s, now considered outdated (McNeil, 2019) (ID 41)
	2 nd flood	Issues with combined and separate sewage system, Turbinen pumping out of order due to flooding (Sørensen & Mobini, 2017) (ID 45)	Still limited access to floodplain and flood risk maps (Henstra et al., 2019; Henstra & Thistlethwaite, 2018); Federal Floodplain mapping Framework containing guidelines for mapping projects released by government as part of National Disaster Mitigation Program (NRCan & Public Safety Canada, 2018). Government of Quebec announced CAD \$24 million for updated flood zone maps after the 2017 event. Updated maps were released in June 2019, a month after the event (CTV Montreal, 2018; Anhoury, 2019). Federal Liberal government also earmarked CAD \$2 billion to be spent over 11 years on risk mitigation and disaster prevention, but none of the approved projects were completed by 2019 floods (Press, 2017; Press, 2019a) (ID 41)
Small increase (+1)	1 st flood	No dyke breaches (DKKV 2015) (ID 15)	NA
	2 nd flood	Dyke failure along the Bavarian Danube and Isar resulted in extensive inundation at Deggendorf (24 km ²) (DKKV 2015) (ID 15)	NA
Large increase (+2)	1 st flood	NA	NA

	2 nd flood	NA	NA
Indicators of management shortcomings for droughts			
		Problems with water management infrastructure	Insufficient risk management
Large decrease (-2)	1 st drought	System of reservoirs available to manage droughts (ID 35)	NA
	2 nd drought	In 1984 the Thomson Reservoir was completed, which increased the existing storage capacity by 250% (Low et al. 2015) (ID 35)	NA
Small decrease (-1)	1 st drought	The activation of stand-by sources and the granting of drought permits (EA 2004) to allow, for instance, additional abstraction to supplement dwindling reservoir stocks played an important role (Marsh, 2004) (ID 23)	Drought Monitoring Council Upgraded to Drought Management Advisory Council (NC DMAC 2020a) (ID 33)
	2 nd drought	Some reservoirs were temporarily switched to non-consumptive mode (Marsh, 2007). Reduced water demand in 2006 meant that the major-pumped storage reservoirs for London were well sufficient (Marsh, 2007) (ID 23)	Requirement of local water providers to have Water Shortage Response Plans (North Carolina General Assembly 2007) (ID 33)
No change (0)	1 st drought	Total retention capacity: 171,136 thousand m ³ ; usable capacity of water reservoirs for melioration is 57,782 thousand m ³ (ID 21)	Spray irrigation restrictions widely applied (Marsh, 2004). All the water companies in England and Wales revised their drought plans early in 2003 and the Environment Agency reported to Ministers on these in June 2003 (EA, 2004). Nearly all drought plans from companies were made public (EA, 2004). No hosepipe bans or restrictions on non-essential water use were applied (Marsh, 2004) (ID 23)
	2 nd drought	Total retention capacity: 189,881 thousand m ³ ; usable capacity of water reservoirs for melioration 53,878 thousand m ³ (ID 21)	Spray irrigation restrictions widely applied. Introduction of a range of drought mitigation measures (e.g. publicity campaigns to moderate demand, local water transfers, reductions in compensation flows). Hosepipe bans, as well

			as appeals to save water, have been assessed by water companies to have reduced customers' demand for water by 5–15 per cent in 2006 (ID 23)
Small increase (+1)	1 st drought	Well organised irrigation system (Hydrometeorological Center 1973, 1976; Dzhamalov et al. 2017) (ID 25)	NA
	2 nd drought	Old and damaged irrigation system, no investment during last 30 years (Dzhamalov et al. 2017) (ID 25)	NA
Large increase (+2)	1 st drought	NA	NA
	2 nd drought	NA	NA

* NA – not such example available in dataset of paired events (i.e. in Key_data_table.xlsx)

4. File description

4.1. File inventory

The dataset contains the following three files:

- **2022-002_Kreibich-et-al_PairedEventReports.pdf:** PDF document containing the paired event reports (346 pages). The paired event reports are between 3 and 18 pages long and are structured in the following sections: 1) short description of events with a focus on impacts; 2) descriptions of processes between events with a focus on risk management 3) event comparison in respect to hazard; 4) event comparison in respect to exposure; 5) event comparison in respect to vulnerability; 6) summary; 7) references. For each paired event report, 1-4 co-authors are responsible, they are the experts best placed to answer specific questions about the events. They are listed at the beginning of the individual paired event reports. All authors of reports are co-authors of this data publication.
- **2022-002_Kreibich-et-al_Key_data_table.xlsx:** Excel file containing the key data separated into the following 2 spreadsheets: 1) “key data”, which contains the data of the flood and drought paired events, [including citations leading to the source of the data where possible](#), 2) “references”, which contains the references cited in the key data [spreadsheet compilation](#), separated by paired events. [All references related to the same paired event \(indicated by the same paired event ID\) are sorted alphabetically.](#)
- **2022-002_Kreibich-et-al_Indicators_of_change.CSV:** CSV file containing the indicators-of-change for the flood and drought paired events. These indicators-of-change represent the differences between the first event used as baseline to the second event, categorised as large decreases/increases (-2/2), small decreases/increases (-1/1) and no change (0).

4.2. Description of data tables

4.2.1. 2022-002_Kreibich-et-al_Key_data_table.xlsx

Spreadsheet: key data

Always 2 rows belong to one paired event, i.e. the information in the first columns that identify and roughly characterise the paired event and study area “Paired event ID”, “Event type”, “Area: Catchment/region”, “Area: Country”, contain the same information. The first line contains the information of the first event in the then following columns, the second line contains the information of the second event.

Column header	Description
Paired event ID	ID of paired event
Event type	Text describing the event type of the paired event (e.g. pluvial flood, meteorological drought). Events of a pair are always of the same type.
Area: Catchment/region	Text describing the catchment or region of paired event occurrence
Area: Country	Text describing the country of paired event occurrence
Year of event	Year or multi-year period in which the event occurred. Usually one single year for floods, as floods are usually shorter than one year (e.g. 2012). Usually a multi-year period for droughts, as droughts usually last several years (e.g. 2003-2006).
<i>The columns with the following headers contain the key data <u>including citations of the sources of data where possible</u> (this is every second column)</i>	

<p>Management: Problems with water management infrastructure</p> <p>Management: Non-structural risk management shortcomings</p> <p>Hazard: Duration of meteo drought (only meteo droughts)</p> <p>Hazard: Severity of meteo drought (only meteo droughts)</p> <p>Hazard: Duration of soil moisture drought (only soil moisture droughts)</p> <p>Hazard: Severity of soil moisture drought (only soil moisture droughts)</p> <p>Hazard: Duration of hydro drought (only hydro droughts)</p> <p>Hazard: Severity of hydro drought (only hydro droughts)</p> <p>Hazard: Tidal level (only coastal floods)</p> <p>Hazard: Storm surge (only coastal floods)</p> <p>Hazard: Antecedent conditions (only pluvial & riverine floods)</p> <p>Hazard: Precipitation / weather severity (only floods)</p> <p>Hazard: Severity of flood (only floods)</p> <p>Exposure: People/area/assets exposed</p> <p>Exposure: Exposure hotspots</p> <p>Vulnerability: Lack of awareness and precaution</p> <p>Vulnerability: Lack of preparedness</p> <p>Vulnerability: Imperfect official emergency / crisis management</p> <p>Vulnerability: Imperfect coping capacity</p> <p>Impacts: Number of fatalities (only floods)</p> <p>Impacts: Direct economic impacts</p> <p>Impacts: Indirect impacts</p> <p>Impacts: Intangible impacts</p>	<p>Data i.e. variables and textual descriptions, characterizing the indicators for management shortcomings, hazard, exposure, vulnerability and impacts. Citations of the sources of data are provided where possible (mainly for scientific studies and reports).</p> <p>NA: not available (unknown, not measured)</p> <p>NR: not relevant (for the specific event type)</p>
<p><i>The columns with the following header contain the category of the data source, each related to the data in the column before (this is every second column). This shall give data users the opportunity to judge the quality of the data themselves.</i></p>	
<p>Category of data source of data (this is every second column)</p>	<p>Category of the source of data, according to personal assessment of the authors in descending quality: scientific study (peer reviewed paper and PhD thesis), report (by governments, administrations, NGOs, research organisations, projects), own analysis by authors, based on database (e.g. official statistics, monitoring data such as weather, discharge data, etc.), newspaper article, expert judgement</p>

Spreadsheet: references

Column header	Description
Paired event ID	ID of paired event (used to link the citations provided in the spreadsheet “key data” to the references).
DOI	If possible, DOIs are given, especially for scientific papers.
Web-link	For data sources for which there is no DOI, the web link is given if possible, this is often possible for reports.
Accessed (web-link)	Date on which the data source provided via a web-link was last accessed.
References	References for the citations provided in the spreadsheet “key data”.

4.2.2. 2022-002_Kreibich-et-al_Indicators_of_change.CSV

Column header	Description
Paired event ID	ID of paired event
Event type	Text describing the event type of the paired event (e.g. pluvial flood, meteorological drought). Events of a pair are always of the same type.
Area: Catchment/region	Text describing the catchment or region of paired event occurrence
Area: Country	Text describing the country of paired event occurrence
Years of events	Years or multi-year periods in which the two events occurred, separated by "and". Usually single years for floods, as floods are usually shorter than one year (e.g. 2012 and 2016). Usually multi-year periods for droughts, as droughts usually last several years (e.g. 2003-2006 and 2010-2012).
<i>The columns with the following headers contain the Indicators-of-change</i>	

<p>Management: Problems with water management infrastructure</p> <p>Management: Non-structural risk management shortcomings</p> <p>Management: Summary management shortcomings</p> <p>Hazard: Duration of drought (only droughts)</p> <p>Hazard: Severity of drought (only droughts)</p> <p>Hazard: Tidal level (only coastal floods)</p> <p>Hazard: Storm surge (only coastal floods)</p> <p>Hazard: Antecedent conditions (only pluvial & riverine floods)</p> <p>Hazard: Precipitation / weather severity (only floods)</p> <p>Hazard: Severity of flood (only floods)</p> <p>Hazard: Summary hazard</p> <p>Exposure: People/area/assets exposed</p> <p>Exposure: Exposure hotspots</p> <p>Exposure: Summary exposure</p> <p>Vulnerability: Lack of awareness and precaution</p> <p>Vulnerability: Lack of preparedness</p> <p>Vulnerability: Imperfect official emergency / crisis management</p> <p>Vulnerability: Imperfect coping capacity</p> <p>Vulnerability: Summary vulnerability</p> <p>Impacts: Number of fatalities (only floods)</p> <p>Impacts: Direct economic impacts</p> <p>Impacts: Indirect impacts</p> <p>Impacts: Intangible impacts</p> <p>Impacts: Summary impacts</p>	<p>Indicator-of-change:</p> <p>-2: large decrease</p> <p>-1: small decrease</p> <p>0: no change</p> <p>+1: small increase</p> <p>+2: large increase</p> <p>NA: not available (unknown, not measured)</p> <p>NR: not relevant (for the specific event type)</p>
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5. References

- Kreibich, H., Blauhut, V., Aerts, J. C. J. H., Bouwer, L. M., Van Lanen, H. A. J., Mejia, A., Mens, M., Van Loon, A. F. (2019): How to improve attribution of changes in drought and flood impacts. - Hydrological Sciences Journal - Journal des Sciences Hydrologiques, 64, 1, 1-18. <https://doi.org/10.1080/02626667.2018.1558367>
- Kreibich, H., Di Baldassarre, G., Vorogushyn, S., Aerts, J. C. J. H., Apel, H., Aronica, G. T., Arnbjerg-Nielsen, K., Bouwer, L. M., Bubeck, P., Caloiero, T., Do, T. C., Cortès, M., Gain, A.

K., Giampá, V., Kuhlicke, C., Kundzewicz, Z. W., Llasat, M. C., Mård, J., Matczak, P., Mazzoleni, M., Molinari, D., Nguyen, D., Petrucci, O., Schröter, K., Slager, K., Thieken, A. H., Ward, P. J., Merz, B. (2017): Adaptation to flood risk - results of international paired flood event studies. - *Earth's Future*, 5, 10, 953-965. <https://doi.org/10.1002/2017EF000606>

6. Attachment: Templates for the collection of socio-hydrological data on paired events of floods and droughts

Template for comprehensive paired event description

Event type: Floods¹

The comparison shall be about 2-3 pages plus 1-2 figures/tables plus references to scientific and grey literature (e.g. official reports, technical notes, newspapers)

Paired flood events: 0000 (event-year1) and 0000 (event-year2) floods² in the xx catchment, xx city, or xx (coastal) region³ in country

Authors and Affiliations

Short description of both events with a focus on impacts: *limited to hazard type, city/region affected and impacts, e.g. fatalities, affected people, destroyed houses, direct economic impacts/monetary damage, indirect and intangible damage (see Table 1) (Note that all other description will be in the event comparison on hazard, exposure and vulnerability aspects below)*

Description of processes between events with a focus on risk management⁴: *e.g. changes/improvements in risk management, deficits in infrastructure maintenance, changes in early warning systems, infrastructure projects, changes in the drainage system, risk communication campaigns, legal developments, land use change, changes in city planning/design, increase/decrease in population density or wealth, external drivers are for instance large scale events like the economic crisis in 2008 or ebola/birds flu, which may influence investments in adaptation*

¹ Types of floods may be coastal floods caused by storm surges, inland pluvial floods, riverine floods, and flash floods, which are usually caused by heavy precipitation, sometimes in combination with snowmelt, ice jams, high soil moisture, or high groundwater levels. In case of compound events, we attempt to isolate the direct effect of the floods from those of concurrent phenomena (e.g. windstorm) on hazard, exposure and impact, based on expert knowledge of the events. The two events of a pair must be comparable and thus belong to the same flood type.

² Specify the specific flood type of both events.

³ Appropriate area descriptions for the respective flood type shall be used.

⁴ In this section, processes/developments between the events shall be described, important are changes in risk management. In the sections "event comparison" below, event characteristics and facts (which might be consequences or manifestations of these processes) shall be described.

Event comparison in respect to pluvial flood hazard (key aspects): *information on antecedent conditions (e.g. water infrastructure down for maintenance, inlets clogged by leaves, saturated or frozen soils), precipitation/weather typology, severity (probability of precipitation, intensity, duration and extend of precipitation relative to assets), infrastructure failures, potentially with figure providing hazard overview of both events*

Event comparison in respect to exposure (key aspects): *e.g. number of people exposed, buildings/area/assets exposed, exposure hotspots (e.g. city center, critical infrastructure, cultural heritage)*

Event comparison in respect to vulnerability (key aspects): *e.g. awareness and precaution (experience, information campaigns, precautionary measures), preparedness (e.g. specific pluvial flood early warning system available, emergency/risk communication, private emergency measures), organisational emergency management (governmental crisis management), coping capacity (e.g. private/state insurance and risk transfer, duration to recover, fatigue, long-term impacts)*

Summary *including evaluation of important drivers of change and their interactions, phenomenon driving the general development, e.g. Adaptation effect (Frequent extreme events increase coping capacities thereby reducing social vulnerability, e.g. Kreibich et al. 2017, <http://doi.org/10.1002/2017EF000606>); Safe-development paradox (protection measures generate a false sense of security that reduce coping capacities (e.g. Di Baldassarre et al. 2018, <http://doi.org/10.5194/hess-22-5629-2018>))*

Table 1: Semi-quantitative comparison of the paired pluvial flood events

		Paired flood ⁵ events in the xx region) ⁶	
		0000 (event- year1)	0000 (event- year2)
Management aspects⁷	Problems with water management infrastructure		

⁵ Specify the specific flood type of both events

⁶ It is extremely important, that comparable information is provided for both events, i.e. the same variables or measurement results are provided! For all information provide the respective references.

⁷ Since management aspects may influence hazard, exposure and vulnerability, it is treated as a separate category.

	Non-structural risk management shortcomings <i>(e.g. risk assessment, recovery aspects)</i>		
Hazard	Tidal level (only coastal floods)		
	Storm surge (only coastal floods)		
	Antecedent conditions (only pluvial & riverine floods) <i>(e.g. water infrastructure down for maintenance, inlets clogged by leaves, saturated or frozen soils)</i>		
	Precipitation / weather severity		
	Severity of flood <i>(e.g. probability of precipitation, intensity, duration and extend of precipitation relative to assets)</i>		
Exposure	People/area/assets exposed <i>(Number of buildings exposed, Settlement area exposed, amount of assets exposed)</i>		
	Exposure hotspots <i>(e.g. city center, critical infrastructure, cultural heritage)</i>		
Vulnerability	Lack of awareness and precaution <i>(e.g. flood experience, information campaigns, precautionary measures)</i>		
	Lack of preparedness <i>(e.g. early warning, lead times, risk communication, private emergency measures)</i>		
	Imperfect official emergency management <i>(e.g. disaster management, civil protection)</i>		
	Imperfect coping capacity <i>(e.g. private/state insurance and risk transfer, duration to recover, fatigue, long-term impacts)</i>		
Impacts	Number of fatalities		
	Direct economic impacts <i>(monetary damage)</i>		
	Indirect impacts <i>(e.g. disruption of supply chains, interruption of infrastructure (electricity, water, road or train network)</i>		
	Intangible impacts <i>(e.g. health/psychological aspects, damage to cultural heritage, damage to the environment)</i>		

References

Template for comprehensive paired event description

Event type: Droughts⁸

The comparison shall be about 2-3 pages plus 3 tables (and possibly 1-2 figures) and references to scientific papers and/or grey literature (e.g. official reports, technical notes, newspapers)

Paired drought events: 0000(-0000) (event-year(s)1) and 0000(-0000) (event-year(s)2) droughts in the xx catchment (or xx region) in country/continent

Authors and Affiliations

Short description of both events with a focus on impacts: *limited to event type (meteorological, soil moisture and/or hydrological drought), catchment/region affected and impacts, e.g. negative impacts for agriculture, direct economic impacts/monetary damage, water shortages in cities, indirect and intangible damage (see Table 1). (Note that all other description will be in the event comparison on hazard, exposure and vulnerability aspects below.)*

Description of processes between events with a focus on risk management⁹: *e.g. changes/improvements in risk management, water conservation measures, changes in water/reservoir management, water infrastructure projects, deficits in infrastructure maintenance, introduction/changes of early warning systems for droughts, risk communication campaigns, water awareness campaigns, legal developments, land use change, changes in agricultural systems*

Event comparison in respect to drought hazard (key aspects): *Indices for meteorological, soil moisture and/or hydrological droughts¹: threshold-based indices giving duration and severity of drought in precipitation, soil moisture, river discharge, groundwater, lakes, and/or reservoirs, or duration and severity from standardized precipitation index (SPI), standardized precipitation evaporation index (SPEI), soil moisture anomaly (SMA), standardized*

⁸ **Meteorological drought** refers to a precipitation deficiency, possibly combined with increased potential evapotranspiration, extending over a large area and spanning an extensive period of time. **Soil moisture drought** is a deficit of soil moisture (mostly in the root zone), reducing the supply of moisture to vegetation. **Hydrological drought** is a broad term related to negative anomalies in surface and subsurface water. Examples are below-normal groundwater levels or water levels in lakes, declining wetland area, and decreased river discharge. Groundwater drought and streamflow drought are sometimes defined separately as below-normal groundwater levels and below-normal river discharge, respectively. Definitions from *Van Loon (Wires Water, 2015)* available at <https://onlinelibrary.wiley.com/doi/pdf/10.1002/wat2.1085>. In case of compound events, we attempt to isolate the direct effect of the droughts from those of concurrent phenomena on hazard, exposure and impact, based on expert knowledge of the events. For instance, in case that fatalities during drought events were not caused by a lack of water, but by the concurrent heatwave, these are not considered to be drought impacts. The two events of a pair must be comparable and thus belong to the same drought types.

⁹ In this section, processes/developments between the events shall be described, important are changes in risk management. In the sections "event comparison" below, event characteristics and facts (which might be consequences or manifestations of these processes) shall be described.

groundwater index (SGI) and/or standardized runoff index (SRI) (potentially with a figure providing an overview of both events, in time and space)

Event comparison in respect to exposure (key aspects): *e.g. number of people exposed, area exposed, exposure hotspots (crop production hotspots, cities, industrial areas, critical infrastructure, water exploitation index), object characteristics (water users, crop types, drinking water supply system, building/household/company characteristics)*

Event comparison in respect to vulnerability (key aspects): *e.g. awareness (drought perception, private precaution undertaken by e.g. farmers); preparedness (drought early warning systems, use of seasonal forecasts, precautionary measures); crisis management (water-use restrictions, public management organization, emergency plans); coping capacity (private/state insurance and risk transfer, duration to recover, fatigue, long-term impacts).*

Summary *including evaluation of important drivers of change and their interactions, phenomenon driving the general development, e.g. Adaptation effect (Frequent extreme events increase coping capacities thereby reducing social vulnerability, e.g. Kreibich et al. 2017, <http://doi.org/10.1002/2017EF000606>); Rebound effect (Increasing the efficiency leads to higher consumptions. Dumont et al., 2013, <https://doi.org/10.1016/j.aqpro.2013.07.006>); Safe-development paradox (protection measures generate a false sense of security that reduce coping capacities (e.g. Di Baldassarre et al. 2018, <https://doi.org/10.1038/s41893-018-0159-0>))*

Please complete Table 1, 2 and/or 3, dependent on which of the drought types you wish to compare.

Table 1: Semi-quantitative comparison of the paired meteorological drought¹⁰ events

		Paired meteorological drought events in the xx catchment (or xx region) ¹¹	
		0000 (event-year1 or years)	0000 (event-year2 or years)

¹⁰ Since exposure, vulnerability and impacts differ in respect to the drought type, this table is provided 3 times, in case the drought events comprise meteorological, soil moisture and hydrological droughts. In these cases, please fill in all three tables.

¹¹ It is extremely important, that comparable information is provided for both events, i.e. the same variables or measurement results are provided! For all information provide the respective references.

Management ¹²	Aspects of water management infrastructure (e.g. reservoirs, reservoir management)		
	Non-structural risk management aspects (e.g. risk assessment, introduction/changes of early warning systems for droughts, risk communication campaigns, water awareness campaigns, recovery aspects)		
Hazard	Duration of meteorological drought (name the (or more) respective indicator(s) the duration estimate is based on)		
	Severity of meteorological drought (name the (or more) respective indicator(s) the severity estimate is based on)		
Exposure	People/area/assets exposed		
	Exposure hotspots (e.g. crop production hotspots, cities, industrial areas, critical infrastructure, water exploitation index)		
Vulnerability	Lack of awareness and precaution (e.g. drought perception, private precaution undertaken)		
	Lack of preparedness (e.g. drought early warning systems, use of seasonal forecasts, precautionary measures)		
	Imperfect official crisis management (e.g. public management organization, emergency plans)		
	Imperfect coping capacity (e.g. private/state insurance and risk transfer, duration to recover, fatigue, long-term impacts)		
Impacts	Direct economic impacts (Monetary damage e.g. agricultural losses)		
	Indirect impacts (e.g. disruption of agricultural supply chains, reduction of tourism)		
	Intangible impacts (e.g. health/psychological aspects, damage to the environment)		

Table 2: Semi-quantitative comparison of the paired soil moisture drought events

¹² Since management aspects may influence hazard, exposure and vulnerability, it is treated as a separate category.

		Paired soil moisture drought events in the xx catchment (or xx region)	
		0000 (event-year1 or years)	0000 (event-year2 or years)
Management	Problems with water management infrastructure (e.g. reservoirs, changes in irrigation management, irrigation infrastructure projects, deficits in irrigation infrastructure maintenance)		
	Non-structural risk management aspects (e.g. risk assessment, water conservation measures, introduction/changes of early warning systems for droughts, risk communication campaigns, water awareness campaigns, recovery aspects)		
Hazard	Duration of soil moisture drought (name the (or more) respective indicator(s) the duration estimate is based on)		
	Severity of soil moisture drought (name the (or more) respective indicator(s) the severity estimate is based on)		
Exposure	People/area/assets exposed		
	Exposure hotspots (e.g. crop production hotspots, critical infrastructure / ecosystems, water exploitation index)		
Vulnerability	Lack of awareness and precaution (e.g. drought perception, private precaution undertaken by e.g. farmers)		
	Lack of preparedness (e.g. drought early warning systems, use of seasonal forecasts, precautionary measures, e.g. changing crop type)		
	Imperfect official crisis management (e.g. water-use restrictions, public management organization, emergency plans, e.g. fallowing land)		

	Imperfect coping capacity (e.g. private/state insurance and risk transfer, duration to recover, fatigue, long-term impacts)		
Impacts	Direct economic impacts (Monetary damage e.g. to agriculture)		
	Indirect impacts (e.g. disruption of agricultural supply chains, reduction of tourism)		
	Intangible impacts (e.g. health/psychological aspects, damage to the environment)		

Table 3: Semi-quantitative comparison of the paired hydrological drought events

		Paired hydrological drought events in the xx catchment (or xx region)	
		0000 (event-year1 or years)	0000 (event-year2 or years)
Management	Problems with water management infrastructure (e.g. changes in water/reservoir management, water infrastructure projects, deficits in infrastructure maintenance)		
	Non-structural risk management shortcomings (e.g. risk assessment, water conservation measures, introduction/changes of early warning systems for droughts, risk communication campaigns, water awareness campaigns, recovery aspects)		
Hazard	Duration of hydrological drought (name the (or more) respective indicator(s) the duration estimate is based on)		
	Severity of hydrological drought (name the (or more) respective indicator(s) the severity estimate is based on)		
Exposure	People/area/assets exposed		
	Exposure hotspots (e.g. cities, industrial areas, critical infrastructure, water exploitation index)		

Vulnerability	Lack of awareness and precaution (e.g. drought perception, private precaution undertaken)		
	Lack of preparedness (e.g. drought early warning systems, use of seasonal forecasts, precautionary measures)		
	Imperfect official crisis management (e.g. water-use restrictions, public management organization, emergency plans)		
	Imperfect coping capacity (e.g. private/state insurance and risk transfer, duration to recover, fatigue, long-term impacts)		
Impacts	Direct economic impacts (Monetary damage e.g. due to water shortages in cities, navigation / electricity production)		
	Indirect impacts (e.g. lack of electricity, transportation problems due to interruption of navigation, reduction of tourism)		
	Intangible impacts (e.g. health/psychological aspects, damage to the environment)		

References