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A multidisciplinary drought catalogue for southwestern Germany dating back to 1801

Mathilde Erfurt et al.

Correspondence to: Mathilde Erfurt (mathilde.erfurt@geographie.uni-freiburg.de)

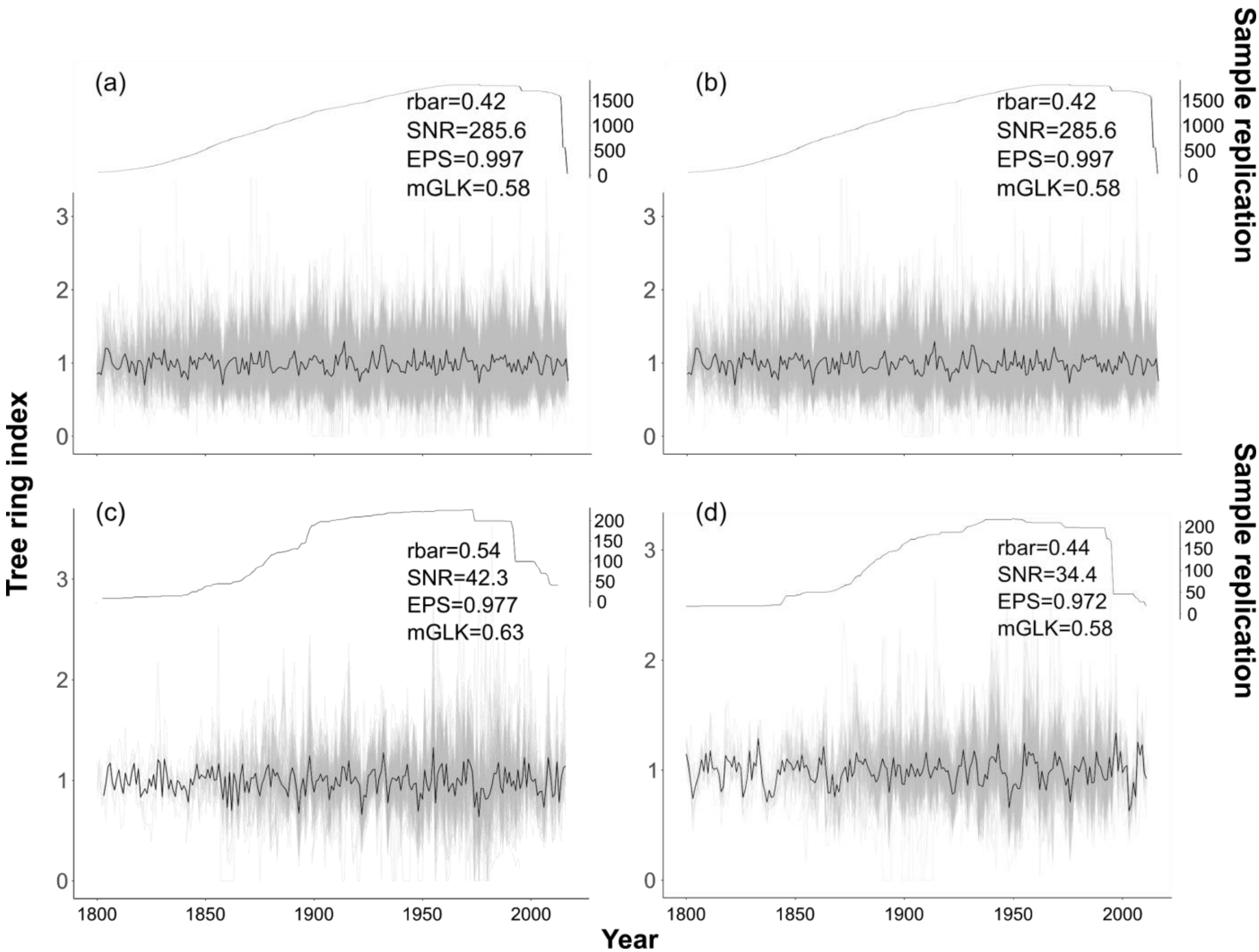

Figure S1: (a) The combined chronology, (b) the oak chronology, (c) the fir chronology and (d) the spruce chronology.

The two meteorological drought indices (SPI and SPEI), calculated for different accumulation periods and for different months of the year, correlated strongly with each other (Figures S.5 and S.6). As expected, series of SPEI and SPI for the same accumulation periods (e.g. 3 months) and of the same months (e.g. June) showed nearly perfect correlations ($r > 0.9$). The relationship between the same meteorological drought indices for the same months but for different accumulation periods was weaker (e.g. between SPEI-3 of June and SPEI-6 of June). Similarly, strong correlations ($r > 0.7$) were found between streamflow percentiles of the two considered rivers in BW and for both accumulation periods examined (Mar-Nov and Jun-Nov). Less pronounced relationships were observed among the tree-ring chronologies, except for the strong correlation between the combined chronology and the oak chronology in both 40 year periods. The two conifer chronologies (spruce and fir) were strongly correlated in both periods (r=0.68 and 0.67 in the early and later period respectively).

Apart from the expected relationships between indicators belonging to the same groups, strong correlations were also observed between indices belonging to different groups. Streamflow percentiles correlated most strongly with long-term accumulation periods (12 and 24 months) of meteorological indices in both the early and later period ($r > 0.6$). Correlations between streamflow and SPI/ SPEI-6 were slightly weaker and even weaker for indices calculated for an accumulation period of three months. Tree-ring chronologies showed overall weak correlations with streamflow percentiles with the exception of the oak and the combined tree-ring chronologies which were significantly correlated with the two streamflow series from the Rhine River. However, the combined tree-ring chronology as well as the oak chronology showed the strongest correlations with short-term meteorological drought indicators in both periods. In the early period, high correlations were observed between these two chronologies and the series of SPEI/SPI-3 of August and SPEI/SPI-6 of September. In the later period, these correlations were weaker and even absent in the case of SPEI/SPI-3, while at the same time the strongest correlations were observed with SPI/SPEI-6 of June. A similar change, although weaker in strength, is observed for the spruce chronology for the two periods. Apart from a weak correlation with SPEI-24 of December, no relationship between the fir chronology and meteorological drought indicators was found. However, fir growth showed weak but significant correlation in the later period with short-term (3 and 6 months) SPI and SPEIs of June.

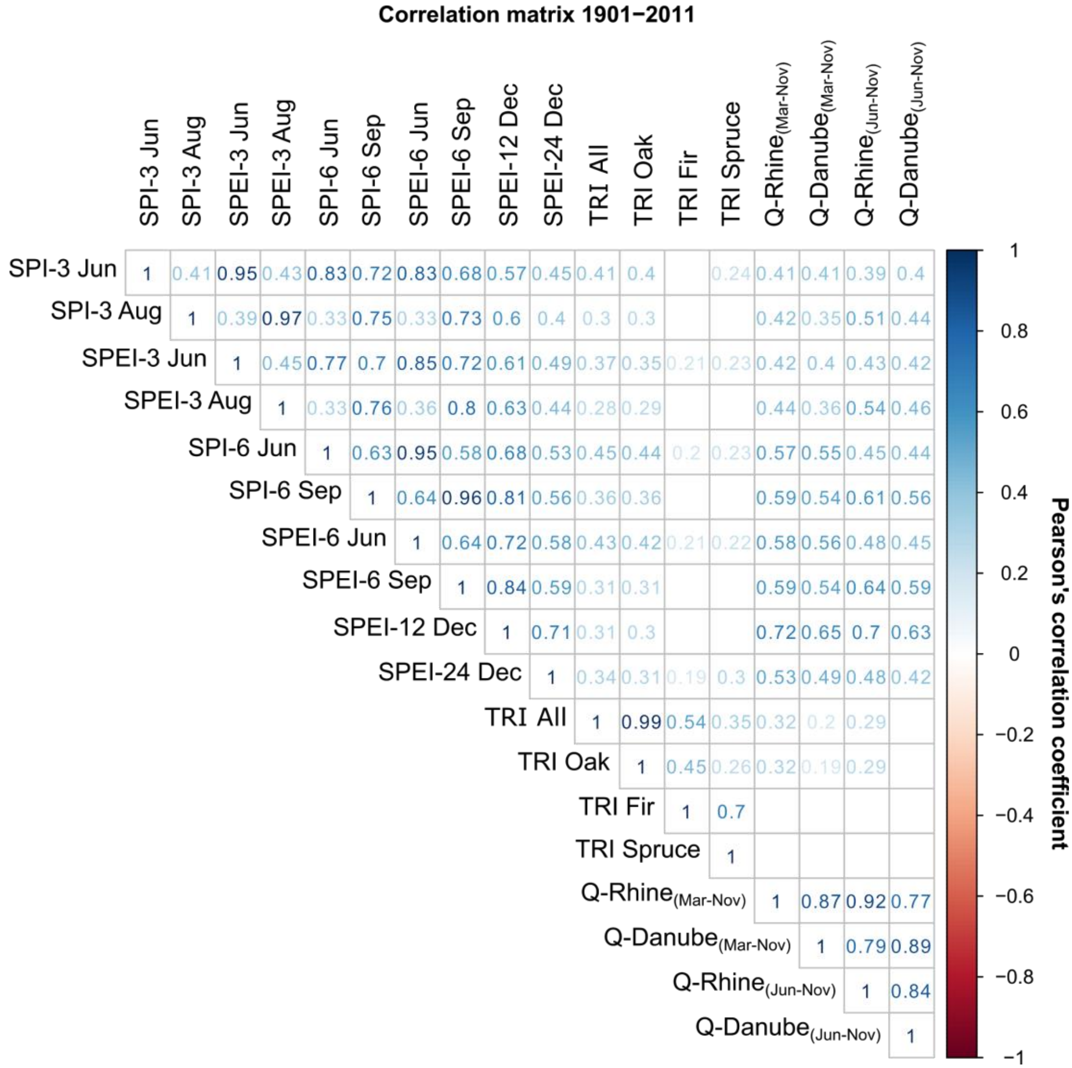

Figure S2: Correlations between the different indices over their common period (1901-2011).

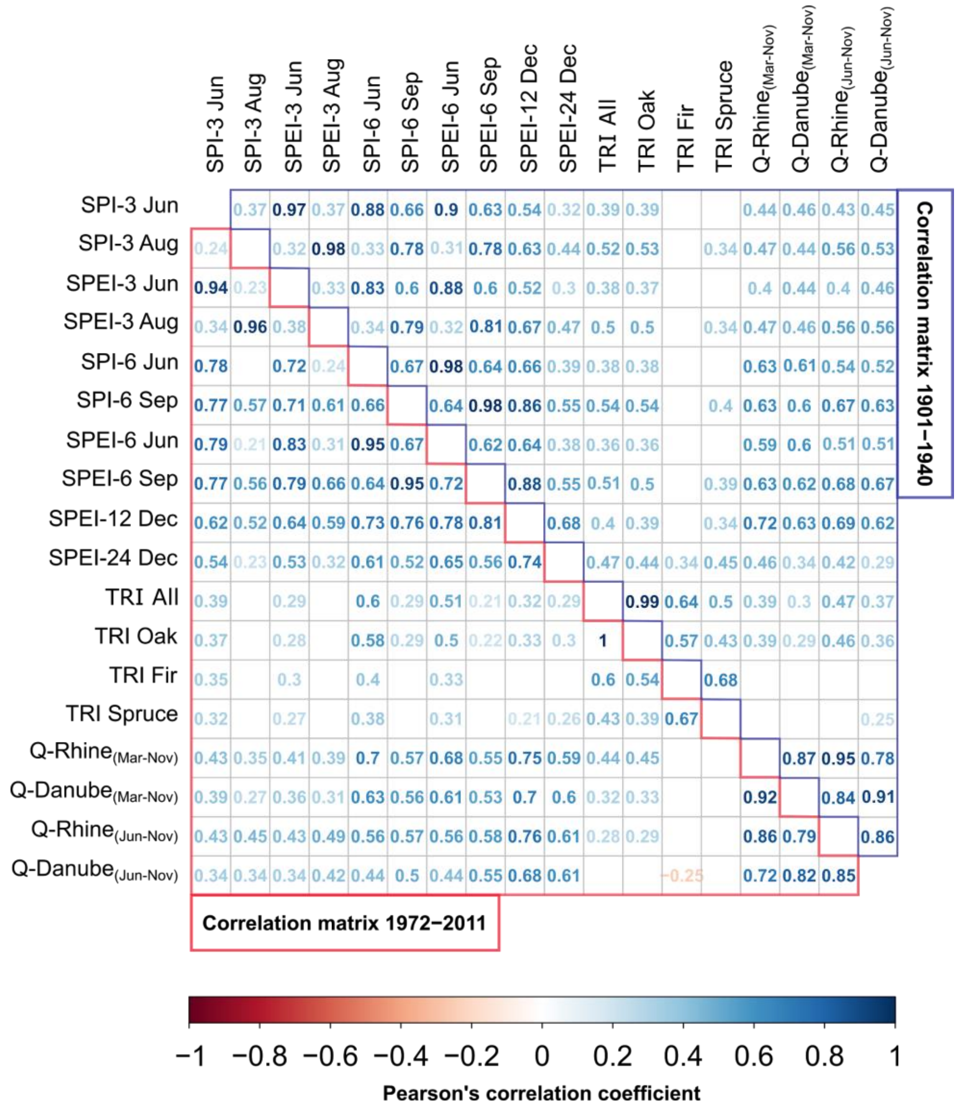

Figure S3: Correlations between the different indices and for two different time periods (1901 to1940 and 1972 to 2011).

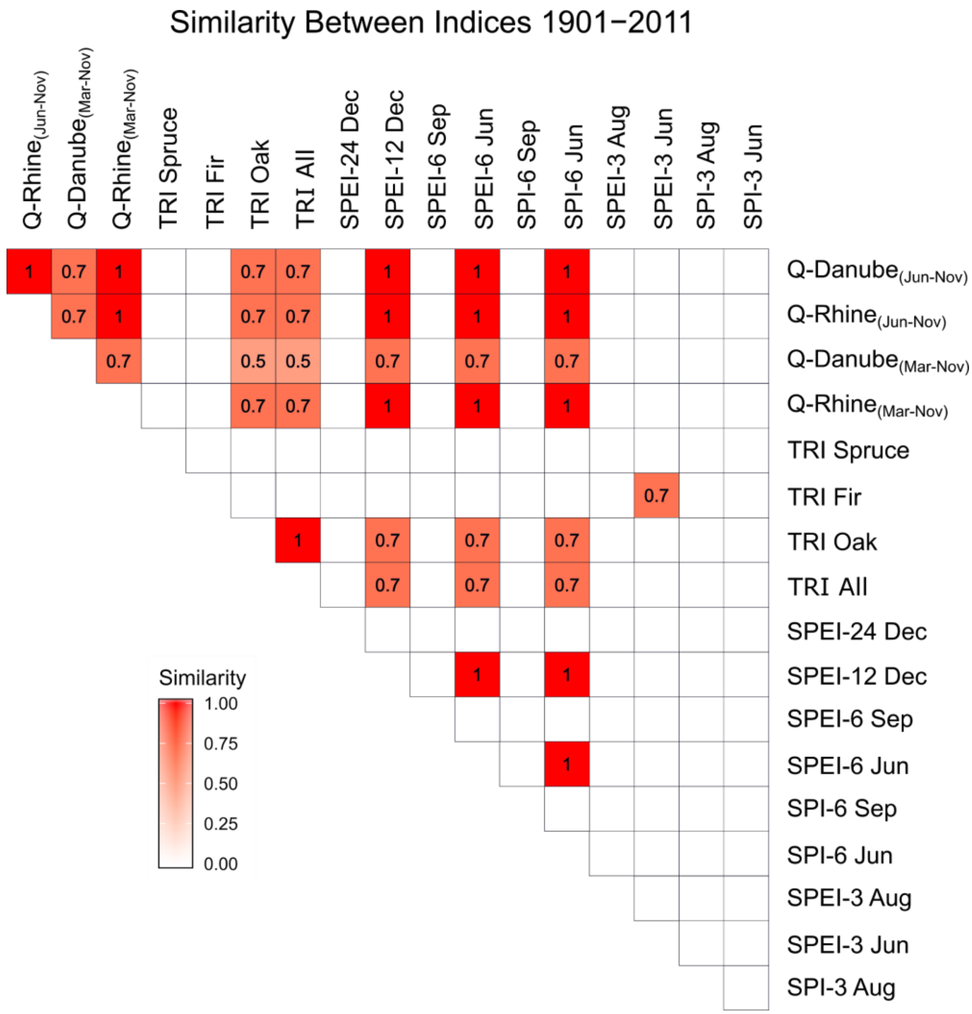

Figure S4: Quantification of similarities in extreme drought event occurrence between the different pairs of indices (Eq. 1) over their common period (1901-2011).

Table S1: The tree-ring datasets used in this study. Information on the location, species, elevation, sources and basic descriptive statistics.

Site Code	Lat	Lon	Species	Elevation (m)	Online source	N series	eps	snr	first	last	N years
BAME	49.49	9.78	Quercus spp.	220.6	no	210	0.98	46.96	1731	2014	284
B-W_ABI	48.7	9.03	Abies alba Mill.	-	no	115	0.77	3.27	1029	1952	924

B-W_QUE	48.7	9.03	Quercus spp.	-	no	404	0.94	15	1242	2014	773
ECO	48.11	7.89	Quercus spp.	250	no	40	0.88	7.03	1921	2016	96
EEM	48.09	7.85	Quercus spp.	212	no	42	0.95	19.1	1941	2016	76
EEO	48.09	7.85	Quercus spp.	212	no	40	0.92	11.37	1896	2016	121
EPPI	49.13	8.92	Quercus spp.	200	no	88	0.94	15.01	1770	2014	245
EWM	48.09	7.84	Quercus spp.	197	no	40	0.95	19.73	1956	2016	61
EWO	48.11	7.8	Quercus spp.	197	no	39	0.95	18.58	1915	2017	103
FEM	48.04	7.85	Quercus spp.	237	no	41	0.98	57.7	1923	2016	94
FEO	48.04	7.84	Quercus spp.	237	no	40	0.94	16.63	1813	2016	204
Fir_Schwatz	48.02	7.95	Abies alba Mill.	-	no	60	0.89	7.76	1900	2016	117
Fir_ Schwatz	47.97	8.88	Abies alba Mill.	-	no	60	0.97	30.37	1848	2012	165
FNM	48.04	7.89	Quercus spp.	291	no	40	0.94	15.66	1926	2016	91
FNO	48.05	7.88	Quercus spp.	291	no	40	0.93	13.25	1783	2016	234
FORS	49.16	8.58	Quercus spp.	112	no	44	0.92	10.79	1811	2014	204
FWO	48.05	7.83	Quercus spp.	226	no	40	0.95	19.6	1836	2016	181
germ041w	47.8	8.08	Picea abies (L.) H. Karst.	1200	https://www.ncdc.noaa.gov/paleo-search/study/4631	13	0.97	27.89	1932	1992	61
germ042w	48.08	7.68	Picea abies (L.) H. Karst.	440	https://www.ncdc.noaa.gov/paleo-search/study/4452	16	0.89	8.33	1903	1995	93
germ043w	48.09	7.68	Abies alba Mill.	440	https://www.ncdc.noaa.gov/paleo-search/study/4451	16	0.9	9.37	1926	1995	70
germ044w	47.83	7.7	Picea abies (L.) H. Karst.	390	https://www.ncdc.noaa.gov/paleo-search/	20	0.93	13.52	1890	1995	106

germ045w	47.86	7.7	Abies alba Mill.	390	https://www.ncdc.noaa.gov/paleo-search/	20	0.94	16.37	1894	1995	102
germ046w	47.8	7.75	Picea abies (L.) H. Karst.	930	https://www.ncdc.noaa.gov/paleo-search/?dataTypeId=18	20	0.95	17.06	1844	1995	152
germ047w	47.85	7.75	Abies alba Mill.	930	https://www.ncdc.noaa.gov/paleo-search/?dataTypeId=18	20	0.91	9.61	1844	1995	152
germ048w	47.8	7.98	Picea abies (L.) H. Karst.	1320	https://www.ncdc.noaa.gov/paleo-search/study/4645	20	0.97	34.78	1871	1995	125
germ050w	48.03	8.35	Picea abies (L.) H. Karst.	880	https://www.ncdc.noaa.gov/paleo-search/study/4721	20	0.95	20.48	1897	1994	98
germ051w	48	8.35	Abies alba Mill.	880	https://www.ncdc.noaa.gov/paleo-search/study/4720	20	0.98	54.45	1898	1994	97
germ052w	47.8	8.03	Picea abies (L.) H. Karst.	1250	https://www.ncdc.noaa.gov/paleo-search/study/4632	20	0.92	11.39	1756	1995	240
germ053	47.85	7.78	Picea abies (L.) H. Karst.	490	https://www.ncdc.noaa.gov/paleo-	20	0.96	23.08	1881	1995	115

					search/study/4545						
germ054	47.86	7.78	Abies alba Mill.	490	https://www.ncdc.noaa.gov/paleo-search/study/4544	20	0.9	8.97	1864	1995	132
germ055w	47.69	7.75	Picea abies (L.) H. Karst.	940	https://www.ncdc.noaa.gov/paleo-search/study/4652	20	0.95	18.63	1867	1995	129
germ056w	47.78	7.75	Abies alba Mill.	940	https://www.ncdc.noaa.gov/paleo-search/study/4651	20	0.86	6.17	1841	1995	155
germ16	50.25	10.25	Picea abies (L.) H. Karst.	550	https://www.ncdc.noaa.gov/paleo-search/	16	0.97	27.88	1830	1955	126
germ17	49.48	10.58	Picea abies (L.) H. Karst.	410	https://www.ncdc.noaa.gov/paleo-search/	10	0.79	3.66	1841	1972	132
germ18	48.02	8.5	Picea abies (L.) H. Karst.	770	https://www.ncdc.noaa.gov/paleo-search/	10	0.77	3.35	1906	1973	68
germ3	47.82	7.77	Abies alba Mill.	910	https://www.ncdc.noaa.gov/paleo/study/2703	31	0.97	37.85	1868	1976	109
LCM	49.64	8.65	Quercus spp.	293	no	40	0.9	8.5	1818	2016	199
LCO	49.65	8.68	Quercus spp.	293	no	40	0.96	23.28	1873	2016	144
LCY	49.65	8.67	Quercus spp.	293	no	40	0.96	22.71	1976	2016	41
LNM	49.72	8.52	Quercus spp.	96	no	40	0.97	31.39	1948	2016	69
LNO	49.72	8.52	Quercus spp.	96	no	40	0.97	32.44	1861	2016	156
LSM	49.59	8.56	Quercus spp.	100	no	40	0.95	20.22	1909	2016	108
LSO	49.58	8.58	Quercus spp.	100	no	40	0.96	23.63	1823	2016	194
LWM	49.71	8.53	Quercus spp.	93	no	40	0.95	20.76	1904	2016	113

LWO	49.72	8.54	Quercus spp.	93	no	42	0.92	12.02	1845	2016	172
MUND	49	9.21	Quercus spp.	222.8	no	90	0.94	15.66	1797	2014	218
OFFE	48.48	7.95	Quercus spp.	156.9	no	52	0.94	15.36	1826	2014	189
rapp	49.24	9.1	Quercus spp.	240.8	no	17	0.58	1.38	1789	2018	230
REUT	48.51	9.2	Quercus spp.	404.4	no	130	0.93	12.26	1608	2014	407
sins	49.25	8.89	Quercus spp.	156.5	no	13	0.64	1.78	1815	2014	200
Spruce_ Schwatz	48.43	8.23	Picea abies (L.) H. Karst.	-	no	44	0.93	12.98	1848	2012	165
UNTE	48.77	9.57	Quercus spp.	473	no	23	0.76	3.23	1820	2014	195
URBA	48.81	9.58	Quercus spp.	268.3	no	138	0.94	16.56	1703	2014	312
WIDD	49.33	9.43	Quercus spp.	311.8	no	61	0.93	12.74	1784	2014	231
WITT	49.61	9.84	Quercus spp.	264.9	no	233	0.98	54.58	1769	2014	246

Table S2 lists which impact types from EDII categorisation scheme were used in this study. A list of the complete EDII Impact categories and type subcategories can be found at Stahl et al. (2016).

Table S2: Impact types from the European Drought Impact Report Inventory used in this study (see column Recategorization)

Impact category	Impact type		Recategorization
Agriculture and livestock farming	1.1	Reduced productivity of annual crop cultivation: crop losses, damage to crop quality or crop failure due to dieback, premature ripening, drought-induced pest infestations or diseases etc.	Agriculture
	1.2	Reduced productivity of permanent crop cultivation	Agriculture
	1.3	Agricultural yield losses >= 30% of normal production (EU compensation treshold)	Agriculture
	1.5	Reduced productivity of livestock farming (e.g. reduced yields or quality of milk, reduced stock weights)	Agriculture
	1.6	Forced reduction of stock(early selling/slaughtering)	Agriculture
	1.7	Regional shortage of feed/water for livestock	Agriculture
Forestry	2.1	Reduced tree growth and vitality	Ecology
	2.2	Decrease in annual non-timber products from forest trees (e.g. cork, pine nuts, mushrooms, berries, etc) (please specify which kind of product)	Ecology
	2.3	Increased occurrence of water stress indicators and damage symptoms (e.g. premature ripening, seasoning checks, defoliation, worsened crown conditions etc.) (please specify forest type/tree species in the description field!)	Ecology
	2.4	Increase of pest/disease attacks on trees (please specify species in the description field!)	Ecology
	2.5	Increased dieback of trees (please specify tree species in the description field!)	Ecology
	2.6	Increased dieback of planted tree seedlings (in nurseries or afforested area)	Ecology
	2.7	Damage to short rotation forestry plantations (energy forestry)	Ecology
Freshwater ecosystems	9.1	Increased mortality of aquatic species (specify species (latin term) and state whether a rare/endangered/protected species is concerned in the description field)	Ecology
	9.2	Increased species concentration near water	Ecology
	9.3	Migration and concentration (loss of wildlife in some areas and too many in others)	Ecology
Terrestrial ecosystems	10.1	Increased species mortality (specify species (latin term) and state whether a rare/endangered/protected species is concerned)	Ecology
	10.2	Changes in species biology/ecology	Ecology
	10.3	Loss of biodiversity (decrease in species diversity)	Ecology
	10.4	Shift in species composition	Ecology
	10.5	Reduced plant growth	Ecology
	10.8	Lack of feed/water for terrestrial wildlife	Ecology
	10.9	Increased attacks of pests and diseases	Ecology

	10.10	Increased contact of wild animals under stress (shortage/lack of feed and water) with humans/human settlements	Ecology
Wildfires	12.1	Increased burned area	Ecology
	12.2	Increased number of wildfires	Ecology
	12.3	Increased severity of wildfires	Ecology
Agriculture and livestock farming	1.4	Reduced availability of irrigation water	Hydrology
Freshwater aquaculture and fisheries	3.1	Reduced (freshwater) fishery production (please specify fish species in the description field)	Hydrology
	3.2	Reduced aquaculture production (please specify fish species in the description field)	Hydrology
	3.3	other	Hydrology
Energy and industry	4.1	Reduced hydropower production	Hydrology
	4.2	Impaired production/shut down of thermal/nuclear powerplants (due to a lack of cooling water and/or environmental legislation for discharges into streams)	Hydrology
	4.3	Restriction/disruption of industrial production process (due to a lack of process water and/or environmental legislation/restrictions for discharges into streams)	Hydrology
Waterborne transportation	5.1	Impaired navigability of streams (reduction of load, increased need of interim storage of goods at ports)	Hydrology
	5.2	Stream closed for navigation	Hydrology
	5.3	other	Hydrology
Tourism and recreation	6.3	Sport/recreation facilities affected by a lack of water	Hydrology
	6.4	Impaired use/navigability of surface waters for water sport activities (including bans)	Hydrology
Public water supply	7.1	Local water supply shortage / problems (drying up of springs/wells, reservoirs, streams)	Hydrology
	7.2	Regional/region-wide water supply shortage/problems (drying up of springs/wells, reservoirs, streams)	Hydrology
	7.3	Bans on domestic and public water use (e.g. car washing, watering the lawn/garden, irrigation of sport fields, filling of swimming pools)	Hydrology
	7.4	Limitations in water supply to households in rural areas (supply cuts, need to ensure water supply by emergency actions)	Hydrology
	7.5	Limitations in water supply to households in urban areas (supply cuts, need to ensure water supply by emergency actions)	Hydrology
Water quality	8.1	Increased temperature in surface waters (close to or exceeding critical values)	Hydrology

	8.2	(Temporary) water quality deterioration/problems of surface waters (natural & manmade); e.g. significant change of physio-chemical indicators, increased concentrations of pollutants, decreased oxygen saturation levels, eutrophication, algal bloom)	Hydrology
	8.3	(Temporary) impairment of ecological status of surface waters (according to EU Water Framework Directive)	Hydrology
	8.4	(Temporary) impairment of chemical status of surface waters (according to EU Water Framework Directive)	Hydrology
	8.5	Increased salinity of surface waters (saltwater intrusion and estuarine effects)	Hydrology
	8.6	Problems with groundwater quality	Hydrology
	8.7	Increased salinity of groundwater	Hydrology
	8.8	Problems with drinking water quality (e.g., increased treatment, violation of standards)	Hydrology
	8.9	Problems with bathing water quality	Hydrology
	8.10	Problems with irrigation water quality	Hydrology
	8.11	Problems with water quality for use in industrial production processes	Hydrology
Freshwater ecosystems	9.4	Increased populations of invasive (exotic) aquatic species	Hydrology
	9.8	Danger for or actual violation of minimum flow or environmental flow requirements	Hydrology
	9.9	Drying up of shallow water areas, weed growth or algae bloom	Hydrology
	9.10	Drying up of perennial stream sections	Hydrology
	9.11	Drying up of lakes and reservoirs (which have a habitat function)	Hydrology
Conflicts	15.1	Water allocation conflicts - international	Hydrology
	15.2	Regional/local user conflicts	Hydrology

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Stahl, K., Kohn, I., Blauhut, V., Urquijo, J., Stefano, L. de, Acácio, V., Dias, S. M.A., Stagge, J. H., Tallaksen, L. M., Kampragou, E., van Loon, A. F., Barker, L. J., Melsen, L. A., Bifulco, C., Musolino, D., Carli, A. de, Massarutto, A., Assimacopoulos, D., and Van Lanen, H. A. J.: Impacts of European drought events: Insights from an international database of text-based reports, Nat. Hazards Earth Syst. Sci. Discuss., 3, 801–819, https://doi.org/10.5194/nhessd-3-5453-2015, 2016.