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JRC Technical Report

Drought in Europe August 2023

GDO Analytical Report

Copernicus Europe's eyes on Earth

Emergency Management Service

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Drought in Europe - August 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – GDO/EDO data up to 20/08/2023

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Executive summary

- After a severe and prolonged drought impacting Europe for most of 2022 and the first months of 2023, drought conditions are still affecting large parts of north-eastern Europe, particularly in the Baltic Sea region and the Alpine region, especially on the north-western side of the Alps.
- Recent precipitation in the Mediterranean region has almost fully counterbalanced the effects of a persistent lack of precipitation and heatwaves over the spring and summer of 2023.
- Wildfire danger is moderate over most of the Mediterranean region, but ranges from high to extreme over central-southern Italy and southern Ukraine.
- Seasonal forecasts point to a warmer than average autumn in 2023. Precipitation is expected to be close to or higher than average.

Combined Drought Indicator (CDI)

After an extremely dry spring and a very hot summer in 2023, dry conditions are still affecting some parts of Europe, and are associated with severe impacts. In terms of the availability of water resources, the evolution is uncertain and variable across the different regions.

The Combined Drought Indicator (CDI) for mid-August 2023 (Fig. 1)[1] shows variable drought conditions across Europe. The Alpine region, south-eastern France, southern Germany, most of Poland, Estonia, Lithuania, northern Scandinavia, and eastern Romania are in warning drought conditions due to low rainfall and dry soil. In Scandinavia, Baltic Sea regions, eastern Romania only small areas are in alert drought conditions. In the Iberian Peninsula, a few scattered spots show watch-to-warning drought conditions.

Recovery or normal drought conditions are estimated in the UK, Ireland, central and northern France, Belgium, the Netherlands, northern Germany, and partially in central southern Scandinavia.

In the Iberian Peninsula, the persistent lack of precipitation in spring and warmer-than-average temperatures led to severe negative soil moisture anomalies and poor vegetation conditions, which have been almost fully counter-balanced by the summer 2023 precipitation. Since April-May 2023, heatwaves and lack of precipitation has been affecting northern and central Europe, particularly in the Baltic Sea area. More recently, dry conditions are hitting the Alpine region again.

The evolution of CDI (Fig. 2) shows that warning-to-alert drought conditions were observed in Iberian Peninsula and in western Alps, and scattered warning conditions in the Baltic region in April 2023, which worsened towards alert conditions over almost the whole Iberian Peninsula and widespread warning conditions in the Baltic region, by May 2023. During June and July 2023, a recovery phase developed in the Iberian Peninsula, but the drought further developed and expanded in central and northern Europe, with widespread warning conditions in June, and finally reaching a critical peak with widespread alert conditions, mainly in Germany and the Baltic region, by August.

[1] For more details on the CDI, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

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JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – GDO/EDO data up to 20/08/2023

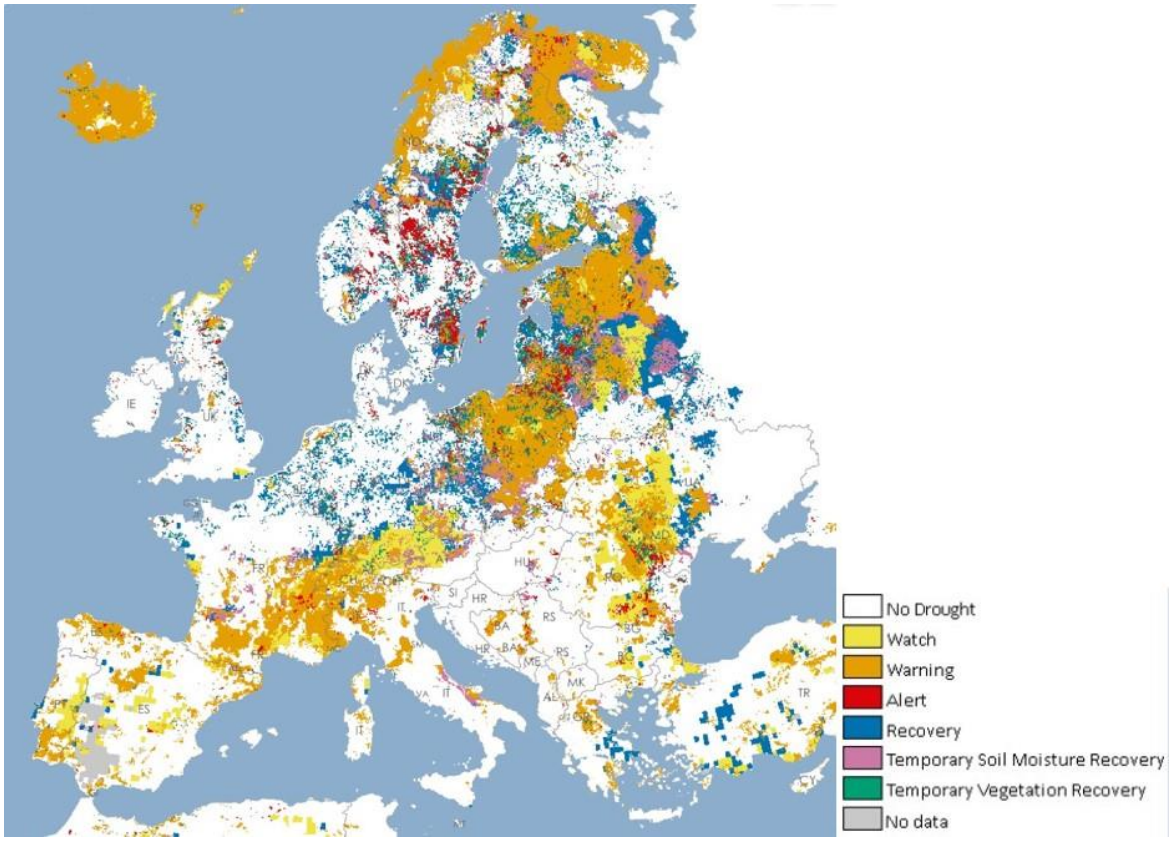

Figure 1: The Combined Drought Indicator (CDI), based on a combination of indicators of precipitation, soil moisture, and vegetation conditions, for mid-August 2023.[1]

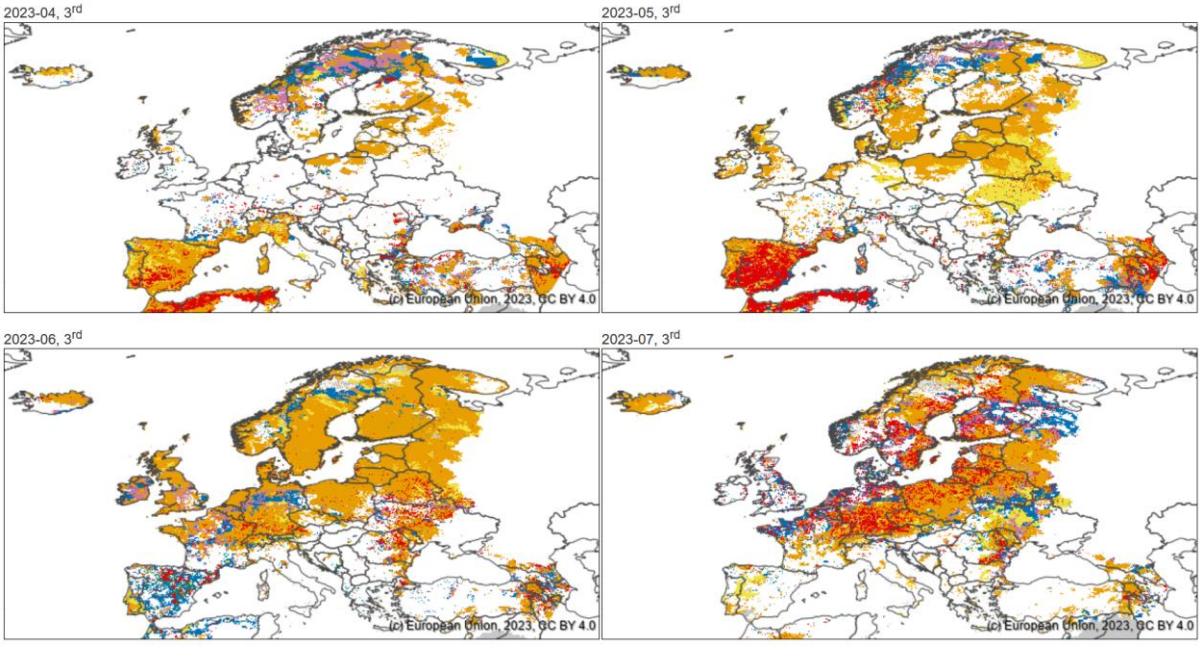

Figure 2: The Combined Drought Indicator (CDI), based on a combination of indicators of precipitation, soil moisture, and vegetation conditions, from April to July 2023.[1]

Standardized Precipitation Index (SPI)

In the middle of August 2023, the SPI-3 (i.e. computed for an accumulation period of 3 months) shows normal or wetter-than normal conditions in southern Europe, while dry anomalies are visible around the Baltic Sea region, over the Alps, and in eastern countries (Fig. 3)[2].

Until spring 2023, persistent negative anomalies of precipitation had been affecting many parts of western Europe and the western Mediterranean for over a year. In April 2023, precipitation conditions changed to normal or wetter-than-normal for most of central and eastern Europe (based on SPI-3), with dry anomalies concentrated in the Iberian Peninsula (Fig. 4, top-left). In May 2023, the drought in the Iberian Peninsula started to recede slowly, and a new event developed in the northern countries, particularly around the Baltic Sea (Fig. 4, top-right). In June 2023, the meteorological drought over northern and eastern Europe, and in particular around the Baltic Sea, reached its maximum extent (Fig. 4, bottom-left), and in July 2023 it started to recede, but dry conditions developed again over the Alpine region (Fig. 4, bottom-right).

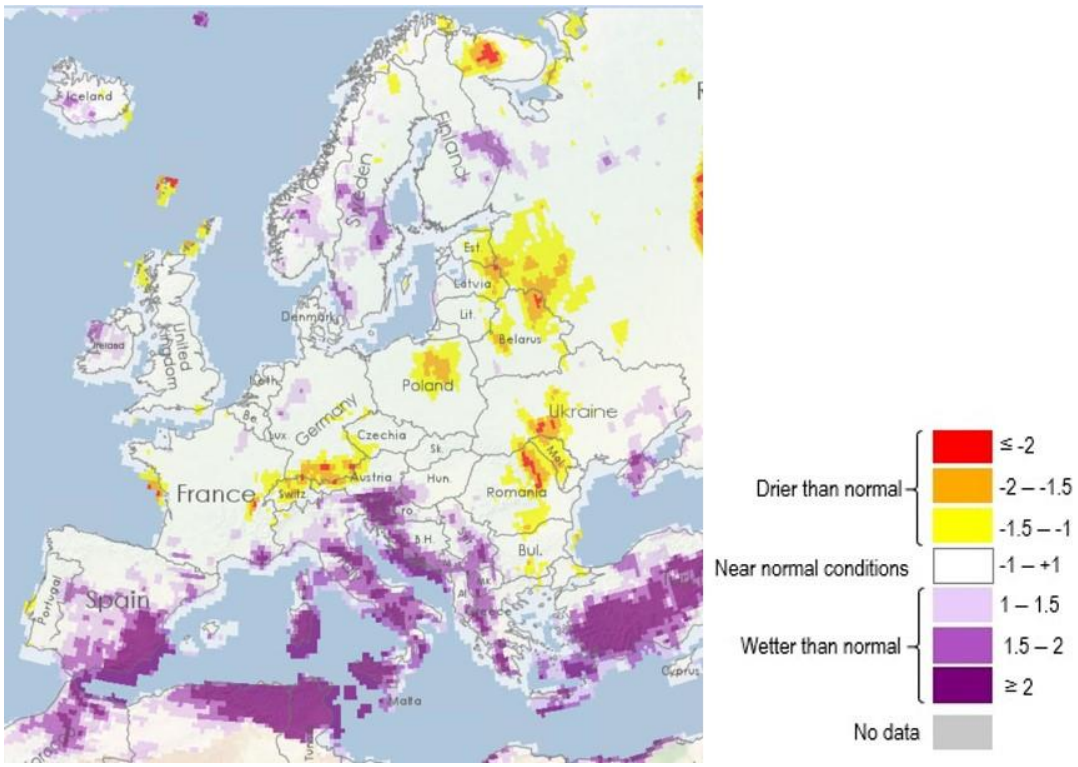

Figure 3: Standardized Precipitation Index (SPI-3), for the 3-month accumulation period ending in mid-August 2023.[2]

[2] For more details on the SPI, and the other GDO and EDO indicators of drought-related information used in this report, see the Appendix at the end of the document.

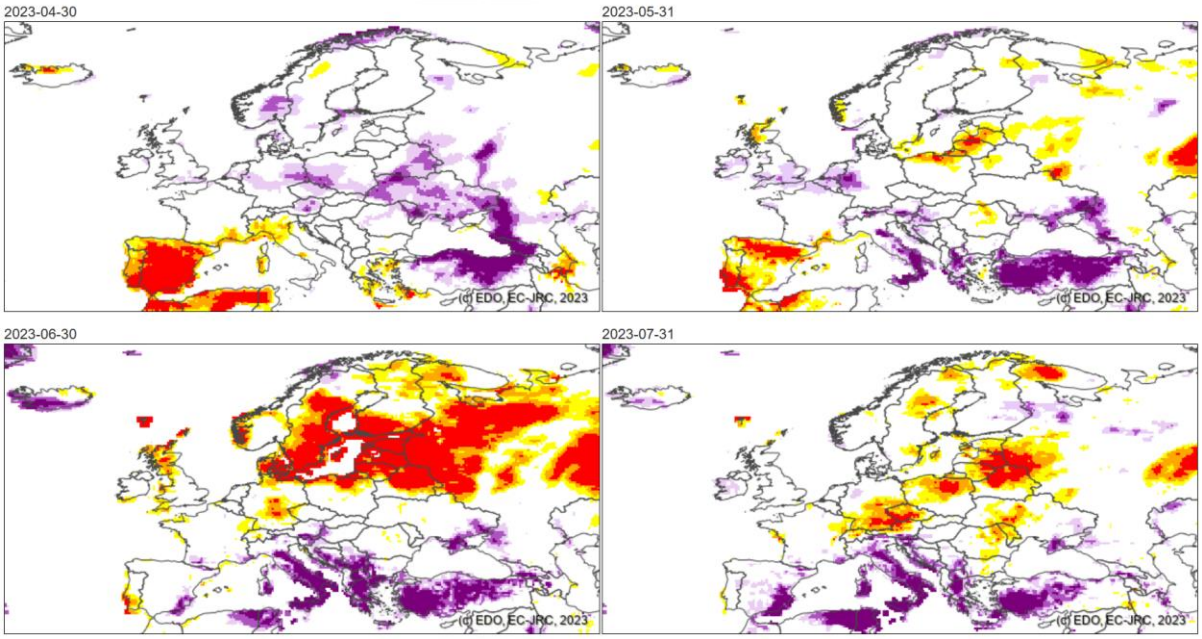

Figure 4: Standardized Precipitation Index (SPI-3) for the 3-month accumulation period, from April to July 2023.[2]

Temperature

Most of Europe experienced above-average temperatures during summer 2023. In June (Fig. 5, left), positive average temperature anomalies affected northern and central western Europe with spots above 3°C in southern Scandinavia, northern Germany, northern France, and the northern part of the UK; while in south-eastern Europe close to average temperatures have been observed. In July (Fig. 5, right), the pattern was the opposite with normal or even colder than average temperatures in western and northern Europe and hotter than average temperatures in the Mediterranean region. The highest anomalies were observed in central and southern Italy and Greece.

In late August 2023, a widespread heatwave hit most of central and southern Europe. According to the Heat and Cold Wave Index (HCWI)[3] computed on 21 August, the heatwave lasted longer than 5-7 days in some regions of the Iberian Peninsula, the Alpine mountain range, central France, and northern Italy (Fig. 6).

[3] For more details on the Heat and Cold Wave Index (HCWI), and the other GDO and EDO indicators of drought-related information used in this report, see the Appendix at the end of the document.

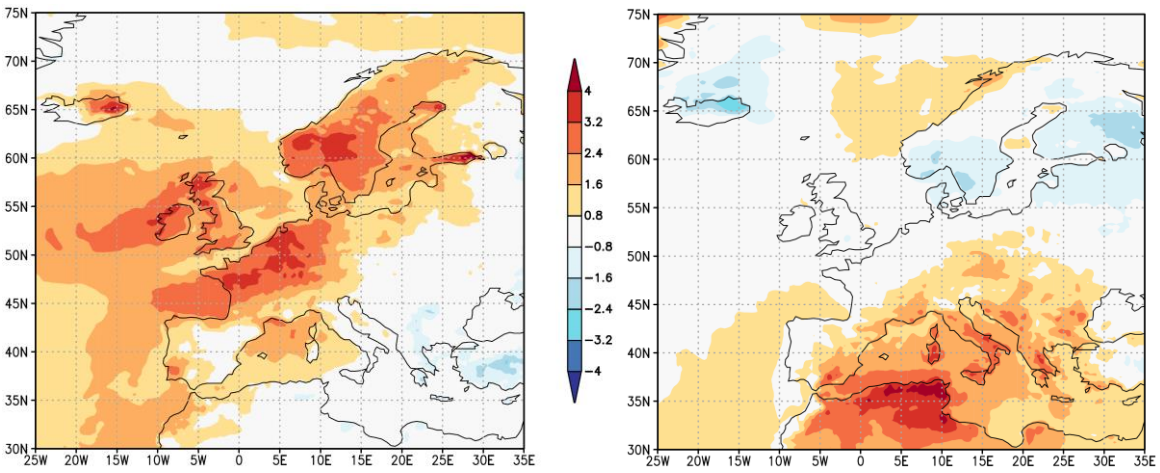

Figure 5: Average temperature anomaly (ERA5, baseline 1991-2020) computed for June 2023 (left panel) and July 2023 (right panel). Source: The KNMI Climate Explorer.[4]

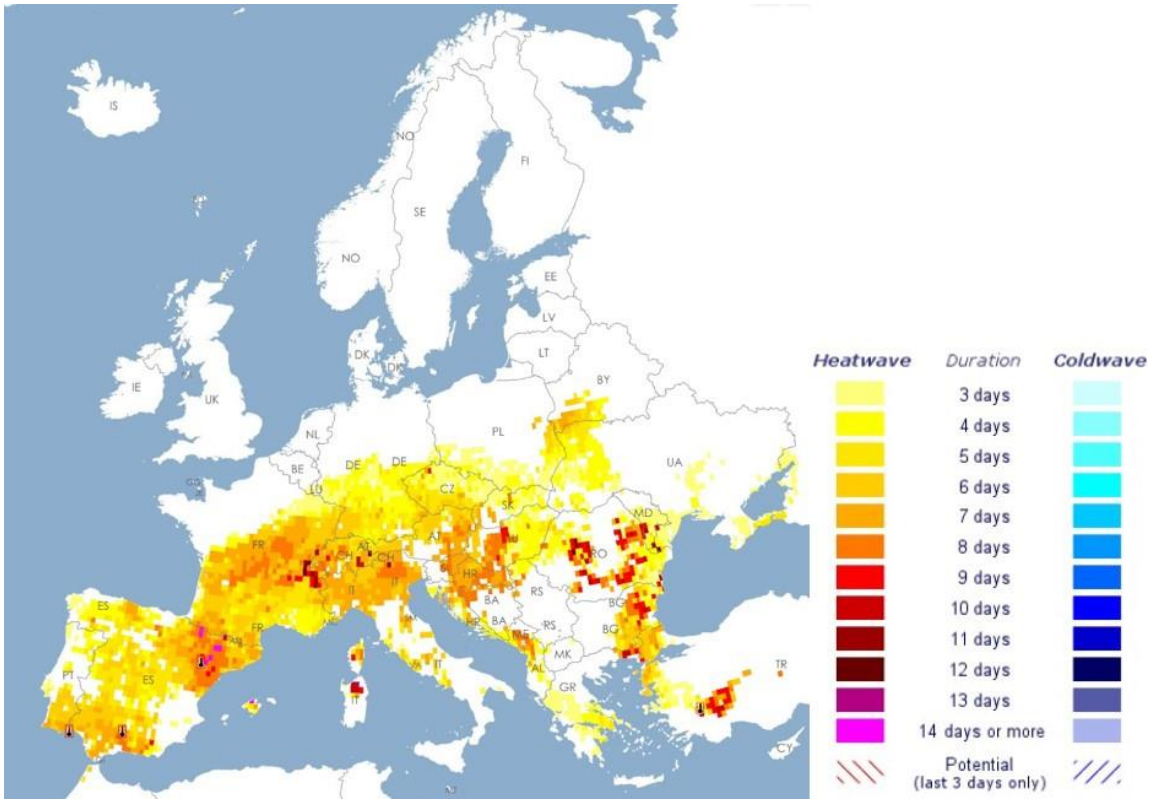

Figure 6: Duration (in days) of the heatwave computed on 21 August 2023, based on the Heat and Cold Wave Index (HCWI). The yellow to purple colour scheme represent increasing duration.[3]

[4] The KNMI Climate Explorer: https://climexp.knmi.nl

Soil moisture

The Soil Moisture Anomaly in mid-August 2023 (Fig. 7) was negative in central-eastern Europe (particularly in the Baltic Sea regions), northern Scandinavia, the Alpine region, northern Italy, southern France, northern Spain, and southern Portugal. These conditions are a continuation of the severe drought that had hit Europe in the previous months, due to a combination of low precipitation and high temperatures. The drier-than-normal soil moisture pattern is consistent with the precipitation deficit of the previous months, as shown by the SPI-3 (see Fig. 3 and Fig. 4, last panel). Some of the regions with the strongest precipitation anomalies were also affected by high temperatures, which contributed to accelerating the water loss from the soil. Some areas in northern and eastern Europe show a Soil Moisture Anomaly below -2, corresponding to the driest class of this indicator.[5]

Figure 8 shows the evolution of the Soil Moisture Anomaly for late spring and early summer 2023. In April, the severely dry conditions during winter (not shown here) had slightly improved, but severe drought expanded to the Iberian Peninsula. From April to May, also the Baltic Sea regions became progressively drier. In June, most of southern Europe showed wetter-than-normal soil moisture, while central and northern Europe were extremely dry over wide areas. In July, the drought started to recede in the UK, Ireland, and southern Scandinavia, but remained severe mainly in central and eastern Europe, and particularly in the Baltic region.

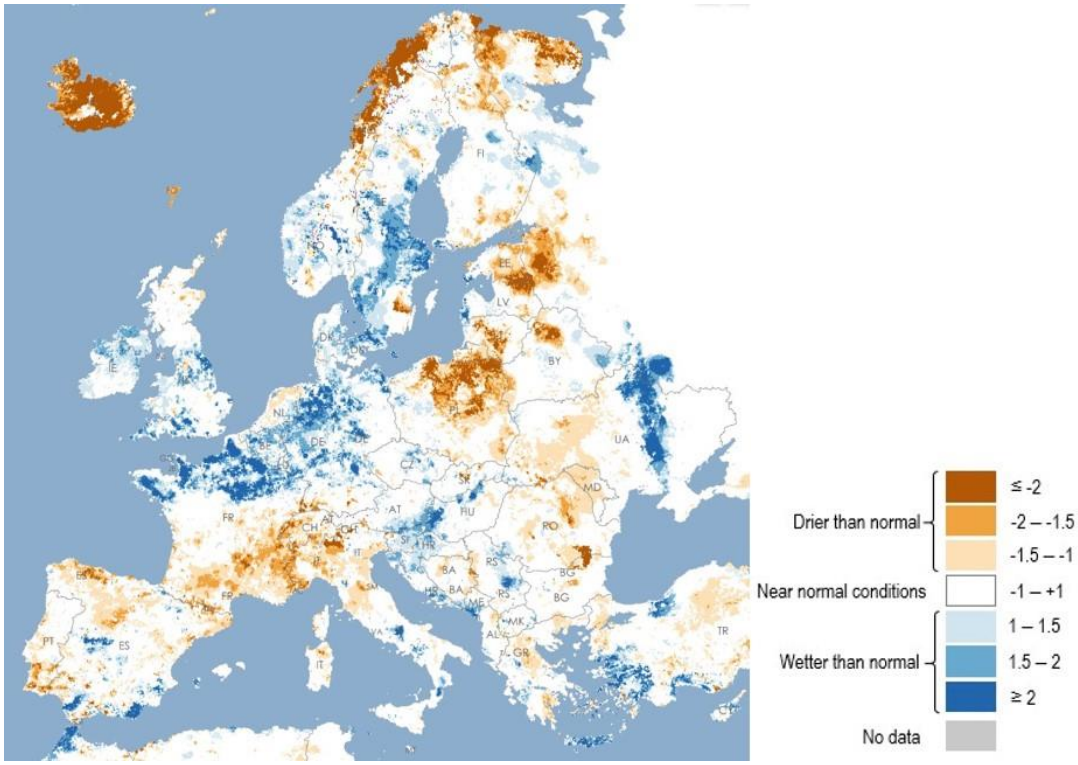

Figure 7: Soil Moisture Anomaly for mid-August 2023.[5]

[5] For more details on the Soil Moisture Anomaly, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

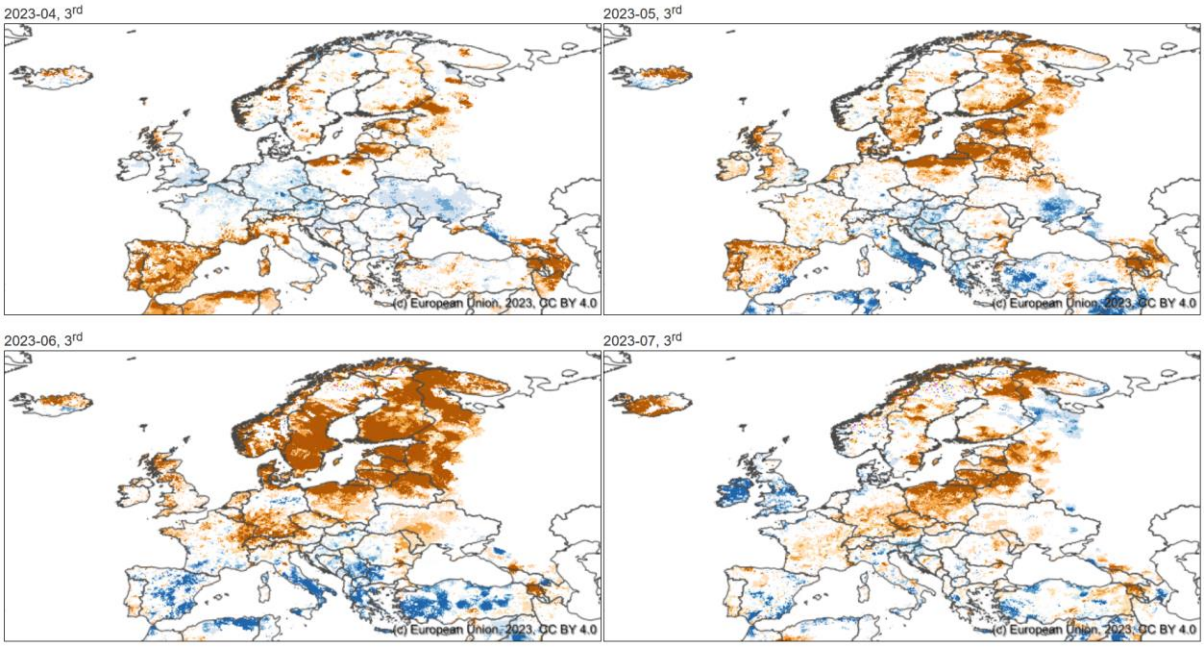

Figure 8: Soil Moisture Anomaly from April to July 2023.[5]

Vegetation biomass

In mid-August 2023, the satellite-derived fAPAR anomaly indicator showed vegetation stress over the southern Iberian Peninsula, the northern UK, Ireland, southern Scandinavia, and some scattered spots in eastern Europe and northern Italy (Fig. 9).[6]

The evolution of the fAPAR anomaly from April to August 2023, shown in Figure 10, indicates a progressive worsening of the vegetation stress, in the Iberian Peninsula and the Mediterranean region in April-May, then moving and expanding towards central and Northern Europe in June-July. The widespread critical conditions in July are due to the combined effects of a severe lack of precipitation and higher-than-normal temperatures.

Dedicated information concerning the agricultural yield forecast for Europe can be found in the JRC MARS Bulletins[7].

[6] For more details on the satellite-derived fAPAR anomaly indicator, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.
[7] https://joint-research-centre.ec.europa.eu/monitoring-agricultural-resources-mars/jrc-mars-bulletin_en

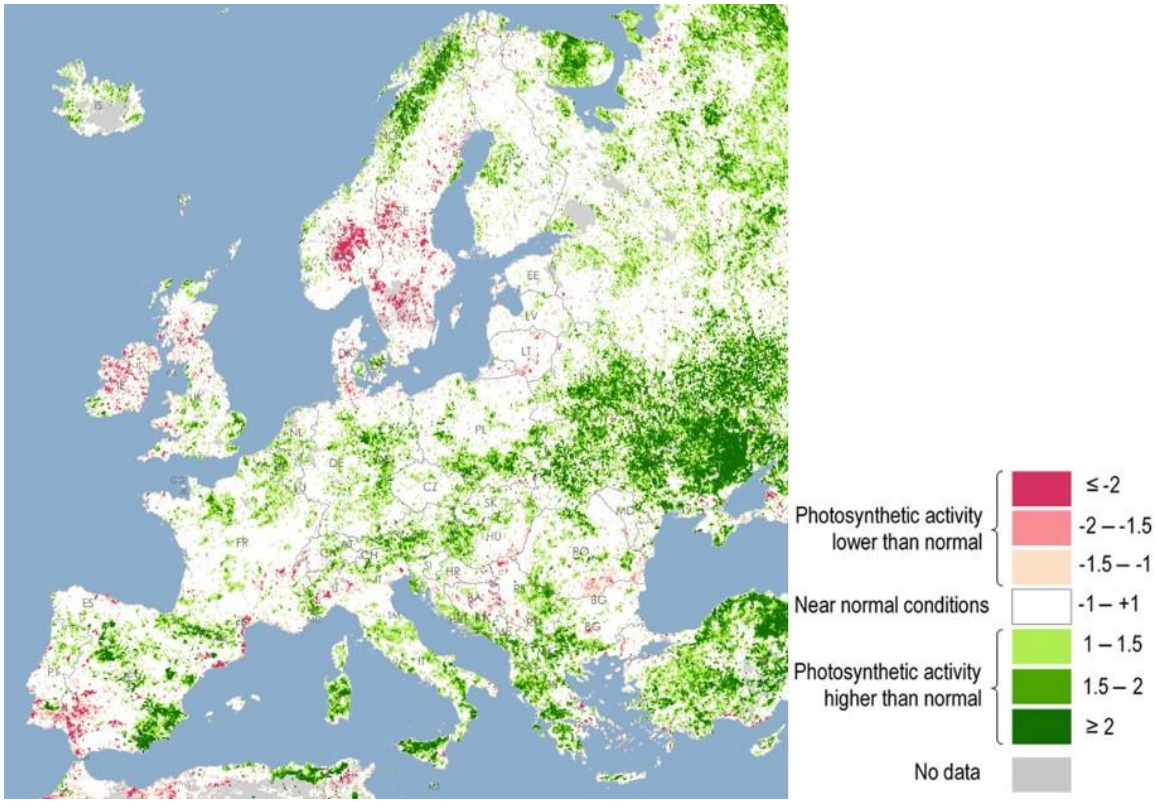

*Figure 9: Satellite-derived fAPAR anomaly indicator (*measuring photosynthetic activity of vegetation), for mid-August 2023.[6]

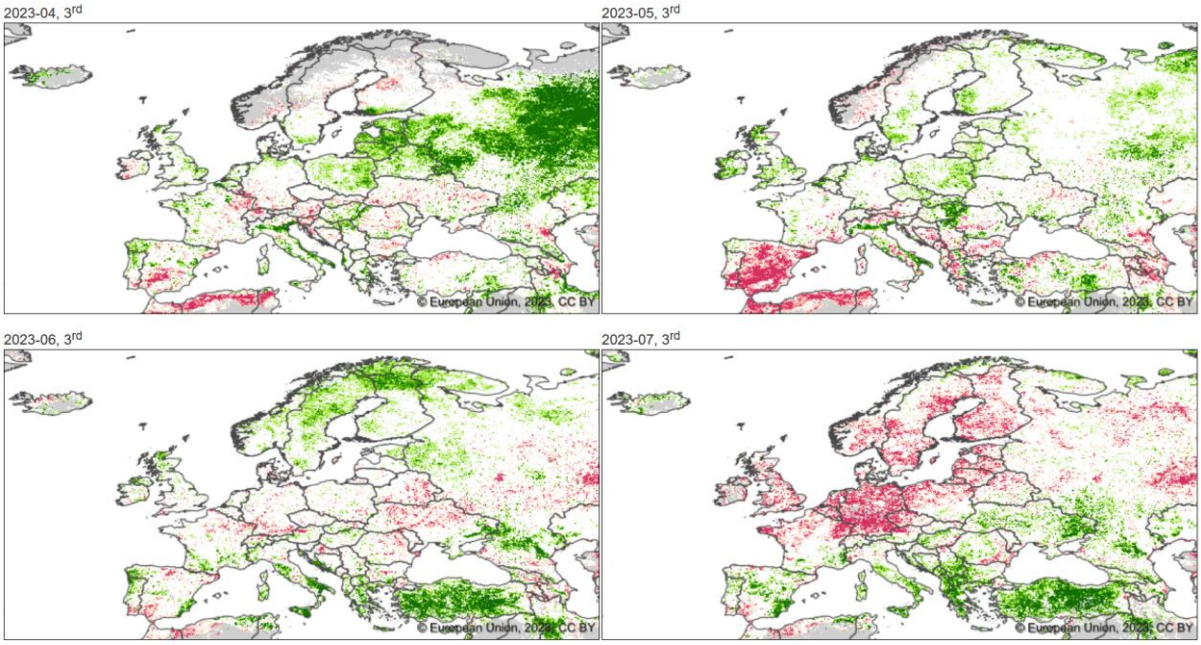

Figure 10: Satellite-derived fAPAR anomaly indicator (measuring photosynthetic activity of vegetation), for the end of each month from April to July 2023. [6]

River flow

In mid-August 2023, the Low-Flow Index (LFI) shows critical hazard values mainly over south-eastern Baltic Sea regions, western Alps, and locally in Iberian Peninsula. (Fig. 11). The flow reduction clearly correlates with the lack of precipitation over the last months, as shown by the SPI-3 (Figs. 3 and 4, last panel).[8]

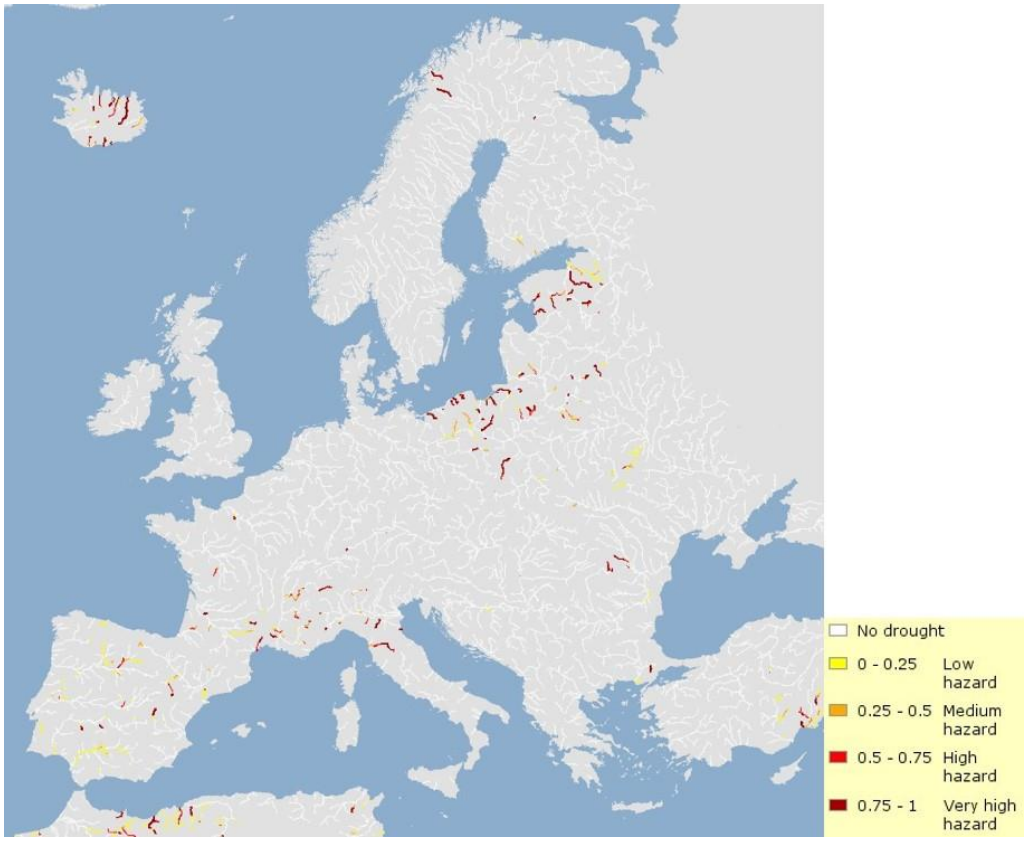

Figure 11: Low-Flow Index (LFI) for mid-August 2023. LFI ranges from 0 (no drought) to 1 (very high drought hazard).[8]

Large-scale atmospheric conditions

Large scale atmospheric conditions in June 2023 were characterized by anomalous anticyclonic circulation centred between Scotland and Norway (Fig. 12, left). This circulation pattern caused the below-average precipitation and higher-than-average temperatures experienced in the northern parts of the continent (Figs. 4 and 5). In contrast, July 2023 displayed a dipole of geopotential anomalies, with cyclonic (negative) conditions in the north and anticyclonic (positive) conditions in the south (Fig. 12, right). The cyclonic conditions in the North brought rains, moderating temperatures and improving drought conditions (Figs. 4 and 5). The anticyclonic anomalies in the south raised temperatures, leading to above average temperatures (Fig. 5, left and Fig. 6). Much of the Mediterranean region experienced a heat wave during the second half of July.

[8] For more details on the Low-Flow Index (LFI), and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

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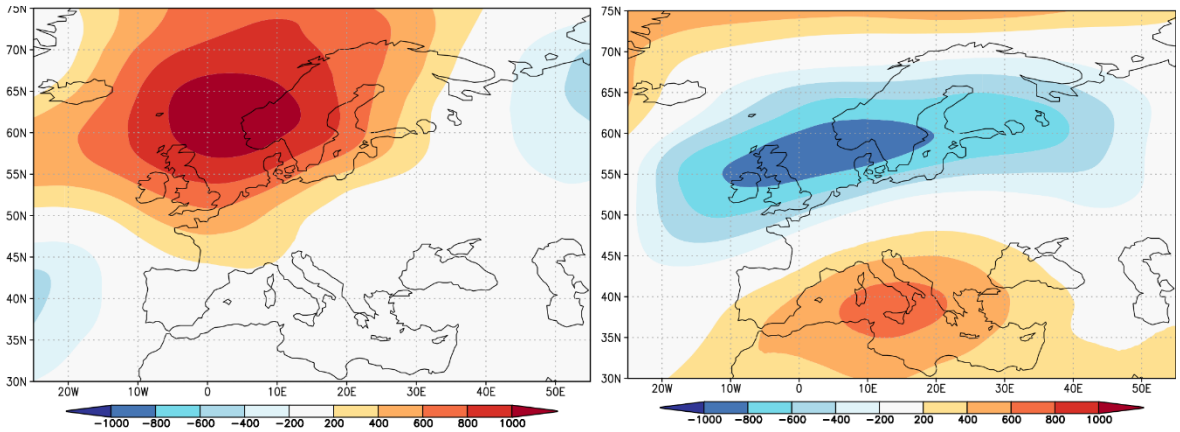

Figure 12: 500hPa geopotential anomalies (ERA5, baseline 1991-2020) in June (left panel) and July (right panel) 2023. Source: The KNMI Climate Explorer.[4]

Fire danger forecast

The wildfire hazard is a direct result of the elevated temperature anomalies and surface dryness, combined with the availability of fuel (dry litter and wood). The CEMS European Forest Fire Information System (EFFIS) provides mapping services of the fire danger forecast all over Europe[9]. High to extreme danger is shown in central-southern Italy and main islands, and southern Ukraine. Moderate danger is shown in south-eastern Spain, France, southern UK, Mediterranean regions, and eastern Europe, up to 7 September 2023 (Fig. 13).

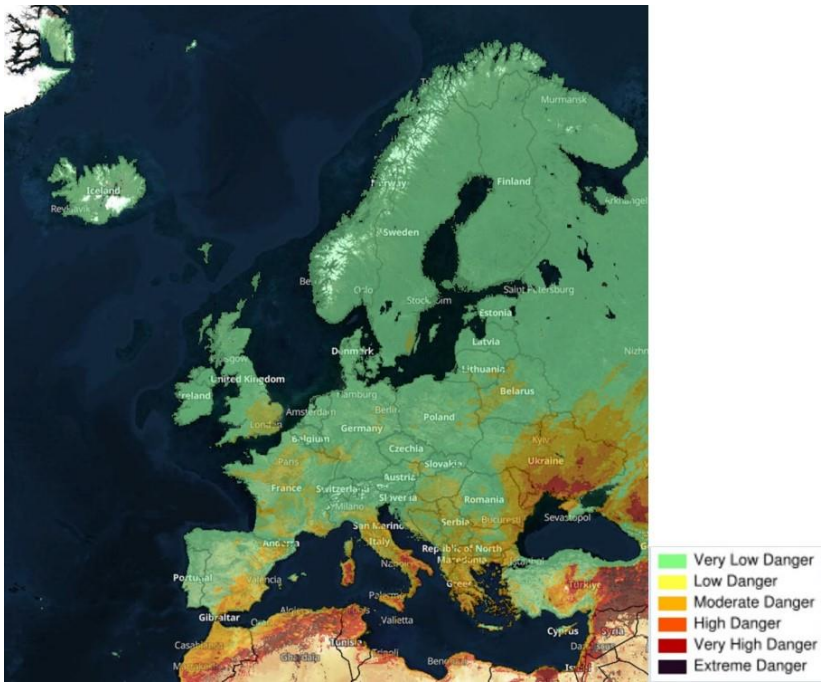

Figure 13: Fire danger forecast expressed by the Fire Weather Index up to 7 September 2023. Data source: European Forest Fire Information System (EFFIS).[9]

[9] The European Forest Fire Information System of CEMS: https://effis.jrc.ec.europa.eu/

Seasonal forecast

From August to October 2023, as shown in Figure 14, drier than average conditions (compared with the 1981-2016 baseline) are predicted for the northern Pyrenees, south-western Alps, and eastern Romania and Bulgaria, while wetter conditions are predicted for the Baltic Sea and Mediterranean regions.

Based on Copernicus C3S seasonal forecasts[10] (not shown here), warmer than usual conditions are likely to occur in Europe up to November 2023, with larger positive anomalies in the Mediterranean region. Precipitation forecasts are close to average in central and northern Europe, and wetter in the Mediterranean region and Iberian Peninsula. However, some variability between models is evident.

During September-October 2023, as shown in Figure 15, low river flows are expected in the Baltic regions, central UK, the Loire and Rhone river Basins, Sardinia, Sicily, and eastern Türkiye (high probability), and in central-western Italy, the Sava river basin, and central-eastern Europe (low probability). In these regions, the prolonged lack of precipitation and incomplete recovery is still potentially affecting river flows, with direct impacts on agriculture, ecosystems and energy production. Water resource management should be planned cautiously, to limit impacts and identify adaptation strategies.

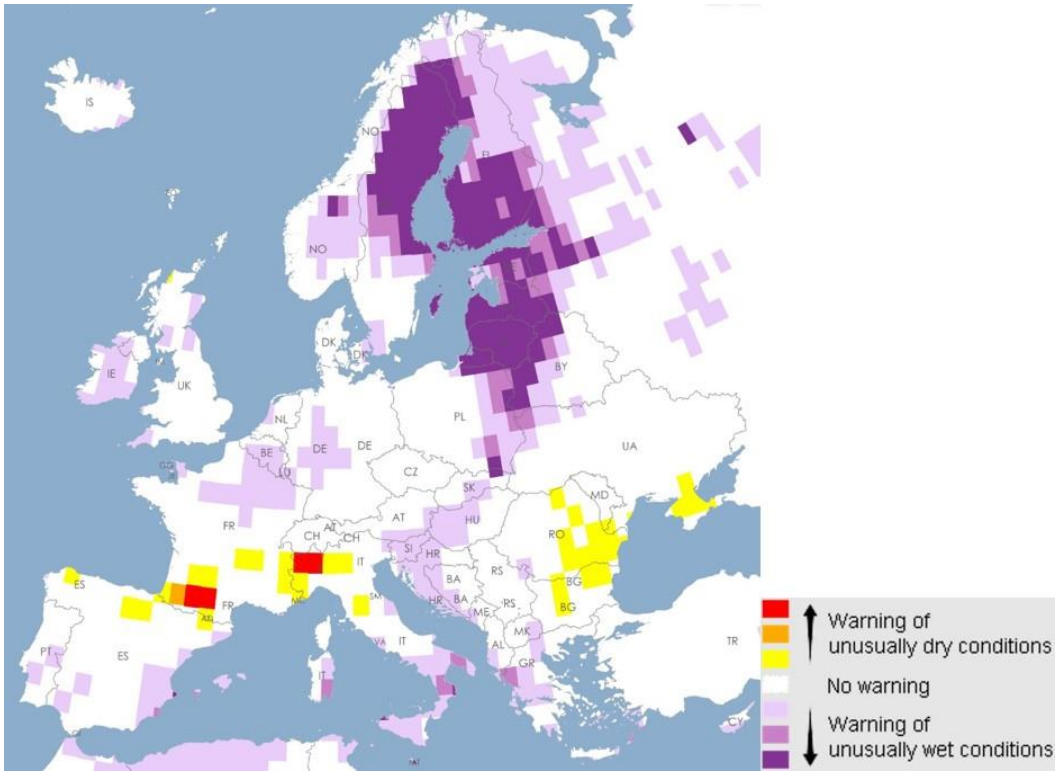

Figure 14: Indicator for Forecasting Unusually Wet and Dry Conditions, for August to October 2023 (based on ECMWF SEAS5).[11]

[10] https://climate.copernicus.eu/seasonal-forecasts

[11] For more details on the Indicator for Forecasting Unusually Wet and Dry Conditions, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

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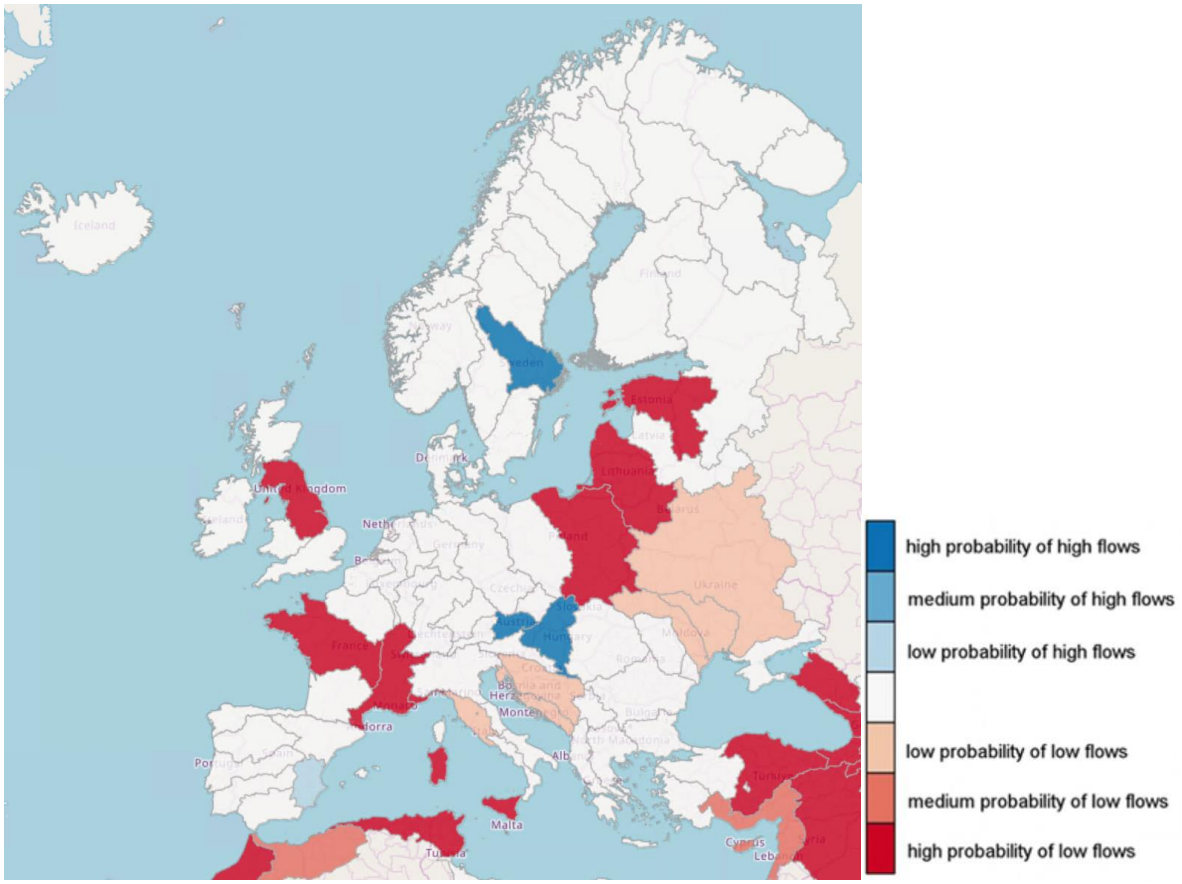

Figure 15: Probability of river flow anomalies for 8 weeks (September-October 2023). The high and low probability thresholds refer to the 90th and 10th percentiles of the simulated discharge from a 29-year model climatology run (1991 - 2019).[12] (See also Technical Note below).

Technical note:

- *The regions displayed in Fig. 15 were created by merging several basins together, respecting hydro-climatic boundaries. This allows large-scale variability in weather to be captured, and forecast information to be summarized. The map in Fig. 15 shows the forecast river flow anomaly per region over 8 weeks. The probability of a low and high flow anomaly is indicated by red and blue, respectively. The intensity of the colour represents the highest forecasted probability of falling below the low threshold, or exceeding the high threshold, within the forecast horizon.*

- *The analysis results shown in Fig. 15 are based on the LISFLOOD hydrological model outputs driven by 51 ensemble members of the ECMWF SEAS5 seasonal forecast. For more information on LISFLOOD: De Roo et al., 2000. "Physically based river basin modelling within a GIS: the LISFLOOD model". Hydrological Processes, 14, 1981–1992. Additional and updated information: Open Source Lisflood (https://ec-jrc.github.io/lisflood/)*

[12] Source: The CEMS European Flood Awareness System (EFAS): https://www.efas.eu

Reported impacts

The European JRC Mars Bulletin of August 2023[13] reported that the recent frequent precipitation in northern and central Europe, and heatwaves of southern Europe and Mediterranean, had only limited impacts on crops and yield. In the rainy regions, most damage and yield reduction are related to harvesting delays. Heatwaves and drought affected summer crops in Bulgaria, southern and eastern Romania, Czechia and central Poland.

Appendix: GDO and EDO indicators of drought-related information[14]

The Combined Drought Indicator (CDI) of the European Drought Observatory (EDO) is used to identify areas that may be affected by agricultural drought. The CDI is derived by combining the Standardized Precipitation Index (SPI), the Soil Moisture Index Anomaly (SMA), and the FAPAR anomaly. Areas are classified according to three primary drought classes: (1) "Watch", indicating less than normal precipitation; (2) "Warning", indicating that also soil moisture is in deficit; (3) "Alert", indicating that also vegetation shows signs of stress. Three additional classes – i.e. "Recovery", "Temporary Soil Moisture Recovery" and "Temporary FAPAR Recovery" – identify the stages of drought recovery processes in terms of impacts on soil moisture and vegetation.

The Standardized Precipitation Index (SPI) provides information on the intensity and duration of the precipitation deficit (or surplus). SPI is used to monitor the occurrence of drought. The lower (i.e., more negative) the SPI, the more intense is the drought. SPI can be computed for different accumulation periods: the 3-month period is often used to evaluate agricultural drought and the 12-month (or even 24-month) period for hydrological drought, when rivers fall dry and groundwater tables lower.

The Heat and Cold Wave Index (HCWI) is used to detect and monitor periods of extreme-temperature anomalies (i.e., heat and cold waves) that can have strong impacts on human activities, health and ecosystem services such as sprouting of crops. It is based on the persistence for at least three consecutive days of events with both daily minimum and maximum temperatures (Tmin and Tmax) above the 90th percentile daily threshold (for heat waves) or below the 10th percentile daily threshold (for cold waves). For each location, the daily threshold values for Tmin and Tmax are derived from a 30-year climatological baseline period (1991-2020), using the GloFAS/ERA5 derived temperature data.

Lack of precipitation induces a reduction of soil water content. The Soil Moisture Anomaly provides an assessment of the deviations from normal conditions of root zone water content. It is a direct measure of drought associated with the difficulty of plants in extracting water from the soil.

The satellite-based fraction of Absorbed Photosynthetically Active Radiation (fAPAR) monitors the fraction of solar energy absorbed by leaves. It is a measure of vegetation health and growth. Negative fAPAR anomalies with respect to the long-term average are associated with negative impacts on vegetation.

The Low-Flow Index (LFI) is based on daily river water discharge simulated by the LISFLOOD hydrological model. It captures consecutive periods of unusually low streamflow. It compares the consequent water deficit during those periods with historical climatological conditions.

The Indicator for Forecasting Unusually Wet and Dry Conditions provides early risk information for Europe. It is computed from forecasted SPI-1, SPI-3, and SPI-6 derived from the ECMWF seasonal forecast system SEAS5.

[13] https://publications.jrc.ec.europa.eu/repository/handle/JRC133188
[14] For more details on the GDO and EDO indicators: https://edo.jrc.ec.europa.eu/factsheets

Glossary of terms and acronyms

CDI	Combined Drought Indicator
CEMS	Copernicus Emergency Management Service
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
EDO	European Drought Observatory
EFFIS	European Forest Fire Information System
ERA5	ECMWF Reanalysis v5
ERCC	European Emergency Response Coordination Centre
EU	European Union
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GDO	Global Drought Observatory
GloFAS	Global Flood Awareness System
HCWI	Heat and Cold Wave Index
JRC	Joint Research Centre
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
LFI	Low-Flow Index
MARS	Monitoring Agricultural Resources
NCAR	National Center for Atmospheric Research (United States of America)
NCEP	National Centers for Environmental Prediction (United States of America)
SLF	Institute for Snow and Avalanche Research (Switzerland)
SMA	Soil Moisture Anomaly
SPI	Standardized Precipitation Index
SWE	Snow Water Equivalent
VIIRS	Visible Infrared Imaging Radiometer Suite
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research

GDO and EDO indicators versioning

The GDO and EDO indicators appear in this report with the following versions:

GDO, EDO indicator	*Version*
▪ Combined Drought Indicator (CDI)	*v.3.0.1*
▪ Low-Flow Index (LFI)	*v.2.1.2*
▪ Soil Moisture Index (SMI) Anomaly (SMA)	*v.2.1.2*
▪ fAPAR (fraction of Absorbed Photosynthetically Active Radiation) Anomaly (VIIRS)	*v.1.0.0*
▪ Indicator for Forecasting Unusually Wet and Dry Conditions	*v .1.1.0*
▪ Standardized Precipitation Index (SPI) (ERA5)	*v.1.0.0*
▪ Heat and Cold Wave Index (HCWI)	*v.1.0.0*

Check https://edo.jrc.ec.europa.eu/download for more details on GDO and EDO indicator versions.

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