Technical Report No. 12

A EUROPEAN DROUGHT REFERENCE (EDR) DATABASE: DESIGN AND ONLINE IMPLEMENTATION

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Photos: Lena Tallaksen
Acknowledgement/Preface

The European Drought Reference (EDR) database is a key deliverable of Work Package 1 (WP1). It contains consolidated information on major large-scale droughts in Europe, their characteristics, climatological course and major impacts building upon common data sources. Currently, the database contains information for 12 major European events. The physical characteristics (including both climatological and hydrological drought indices) were derived as part of WP1. The impacts have been obtained from the European Drought Impact Report Inventory (EDII; developed as part of WP3) and the authors would like to thank all contributors to EDII for making this information available through the impact database (see DROUGHT-R&SPI Technical Report no. 3 for further details).

The design and structure of the EDR database was developed and implemented by James H. Stagge, whereas other co-authors have contributed with methodology, derivation of indices and gathering of information for specific drought events. A synthesis of information from EDII for each event was facilitated by Irene Kohn.

This first version of the EDR database provides the basis for a comprehensive and unique European reference database for major historical drought events that is not limited by national boundaries. The database is a dynamic site that will be continuously improved and updated until the end of the project (and hopefully thereafter), including standard assessments for a more complete set of events and other information of interest for the drought community as it is generated within the project. The EDR database will become available to the public at the end of the project, providing a valuable tool and source of information for the user against which existing (observational as well as model based) studies can be compared. Hopefully, it will also inspire new studies and raise the awareness of the drought hazard to the larger science and user community, including water managers and policy makers.

Lena M. Tallaksen
(Work Package 1 leader), Oslo, 27 September 2013
Abstract

This report presents the structure and status of the online European Drought Reference (EDR) database. This website provides detailed historical information regarding major historical European drought events. Each drought event is summarized using climatological drought indices, hydrological drought indices, and user-generated drought impacts. The database currently highlights 11 drought events, from 1959 to 2007. In addition, an online tool is provided to query and view climatological drought indices for any day in the available historical record. The EDR database is tool designed to compile drought statistics in a usable manner and will continually improve as more data becomes available. It is our hope that the EDR database can become a standard reference tool which improve public awareness of drought issues and stimulate data collection, sharing, and analysis.
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1. Introduction

Drought is an extreme, but temporary water shortage relative to the average (natural) condition of a region. It can be defined as a “a sustained and regional extensive occurrence of below average natural water availability” (Tallaksen & van Lanen, 2004). Deviations or anomalies are part of the natural variability in the climatic system on various spatial and temporal scales. Accordingly, drought can occur in any hydroclimatological region and at any time of the year, and its characteristics and impacts may vary considerably between regions in Europe depending on climate as well as properties of the land surface.

The climate in the middle and north of Europe is influenced by the Westerlies of the mid-latitudes during the whole year, whereas the Mediterranean region lies in a transitional climate zone, influenced by the Subtropical High Pressure Belt during summer and the mid-latitude Westerlies during winter. Hence, three main climate regions can be distinguished: a temperate climate with a dry summer season in the Mediterranean, and a temperate and a cold climate without any dry season in the middle and north of Europe, respectively. The climate of these regions is further modified by numerous other factors such as soil moisture content, oceanic currents and topography. In the Mediterranean region, with its seasonal climate, severe droughts can for instance be caused by longer than usual influence of the subtropical high-pressure belt. Droughts can accordingly last several weeks or even months. In the more humid mid-latitudes of western and northern Europe, “atmospheric blockings” are the major atmospheric anomalies causing extended dry weather periods. Here already a few weeks or months with low rainfall may constitute a severe drought. The blocking high-pressure system (anticyclones) diverts the moisture bringing pressure systems of the Westerlies away from the affected region to either lower or higher latitudes.

The primary cause of a drought is the lack of precipitation over a large area and for an extensive period of time, called a meteorological drought (Tallaksen & van Lanen, 2004). The water deficit propagates through the hydrological cycle and gives rise to different types of drought. Combined with high evaporation rates a soil water deficiency may cause a soil moisture drought to develop. Subsequently, groundwater recharge and streamflow will be reduced and a hydrological drought may develop. A reduced recharge leads to lower groundwater heads and storage and finally to low river flows or even dried up river. Thus, drought has a wide range of impacts depending on the scale of the event and which components of the hydrological cycle are most severely affected. These include major social, economic and environmental impacts as listed by Stahl et al. (2012), who classify the impacts into nine categories and corresponding types.

A suite of drought indicators is normally recommended for drought studies given the diversity of the studied phenomenon. Commonly, the deviation from a long-term (hydroclimatological) statistics is being used, expressed as e.g. a value from the empirical (percentile-based index) or fitted distribution. This includes indices like the Standardized Precipitation Index (SPI), the SPEI, soil moisture percentiles or runoff anomalies for different time resolutions. As drought is a slowly developing phenomenon, both the onset and recovery of a drought event are considered, accounting for varying persistence (memory) in the natural system. Different parts of the terrestrial system will impacted by the drought depending on the duration of the drought event and the persistence of the system, e.g. agricultural drought (typically months) or hydropower drought (typically years).

A prerequisite to mitigate the wide range of drought impacts is to establish a good understanding of the drought generating mechanisms from their initiation as a meteorological drought through to their development as agricultural (soil moisture) and hydrological drought. Droughts are regional by nature, typically covering large areas, and should preferably be studied at the pan-European scale to
consistently address the dynamic nature of drought (i.e. spatial and temporal characteristics) and drought-generating processes across Europe. In particular, potential links to climate drivers and studies of large-scale impacts such as heat waves, forest fires and vegetation stress, require a large-scale approach. On the other hand, the high spatial variability found within a drought-affected region is caused by a combination of catchment and land surface properties, together with small-scale climate variability, thus local-scale studies should be seen as a complementary and necessary part of any large-scale assessment for the purpose of local mitigation strategies and risk assessments.
2. Objective and Organization

The online European Drought Reference (EDR) database was created as part of the Drought RSPI Task 1.1, to create “a concise reference dataset of historical droughts, their climatological cause and major impacts...". The EDR database introduced in this document achieves this goal, consolidating information on major large-scale droughts in Europe in a single location available to the public online through the European Drought Centre (EDC) website. The EDC website is already an active European drought resource, with over 275 members representing 55 countries, and provides a useful platform to launch this new drought reference database.

The EDC website will also house the European Drought Impact Report Inventory (EDII), which is part of Deliverable 3.2 and is outlined in Stahl et al. (2012). Housing the EDR database and the EDII database within the same website provides the public with a simple, yet comprehensive location to learn about droughts. Additionally, it allows for direct links between the databases. Within each detailed drought event summary in the EDR database is a reported drought impact section, which presents all relevant impacts from the EDII. The summary of reported drought impacts is updated automatically, meaning that its data and coverage will improve throughout the course of the project as the EDII grows and improves.

European researchers have significant information and expertise regarding droughts; however, this expertise is distributed across many countries and too often is not combined. The EDR database has great potential to consolidate this knowledge on droughts into a single resource, analogous to the US Drought Monitor. It is our hope that the EDR database can become a standard reference tool which will grow with time and stimulate data collection, sharing, and analysis.
3. Data and Methods

3.1 Historical climate

All historical climate estimates in the EDR database were based on the Watch Forcing Dataset (WFD), a gridded historical climate dataset based on ERA-40 reanalysis with 0.5° x 0.5° resolution (Weedon et al., 2010). The WFD consists of subdaily forcing data spanning the time period 1/1/1958 to 12/31/2001 and employs bias-correction for temperature and precipitation based on CRU-TS2.1 and GPCCv4 observations. For the purpose of this research, the European extent is defined as the region between 34°-72° N latitude and -13°-32° E longitude, resulting in 3,950 land grid cells that follow the CRU land surface mask. Climate variables used for climatological drought indices include rainfall, snowfall, temperature, and wind speed. Climatic indices are always based on precipitation, calculated as the sum of rainfall and snowfall.

The Watch Forcing Dataset – ERA-Interim (WFDEI) was used to extend climatic coverage to include events which occurred after 2001. This climate set was prepared using nearly identical procedures as the WFD, although using an updated re-analysis model (ERA-Interim, Dee et al. 2011) and updated observations for bias-correction (CRU-TS3.1, Mitchell & Jones, 2005 and GPCCv5, Rudolf et al., 2011). For the purposes of the online EDR database, it is assumed that the WFDEI and WFD form a continuous time series, with no detectable bias between the two datasets. This is currently being confirmed by the creators of the climate data and initial results have shown that this is a reasonable assumption when compiling summary statistics over a large area, such as Europe (Weedon, personal communication).

3.2 Historical modelled runoff

Historical gridded runoff was simulated using a suite of nine large-scale models at the same 0.5° x 0.5° resolution and forced by the WFD to maintain consistency (Haddeland et al 2011a). Technical details of the hydrologic models are summarized in Table 1 and described in great detail by several methodology and validation studies (Haddeland et al. 2011a, Gudmundsson 2012a, Gudmundsson 2012b). Simulated runoff was available for the period 1963-2001, as the first 5 years of the WFD were used as a model spin-up period. Despite large differences in how runoff is calculated, all models simulate Qs (water leaving the surface of a grid cell) and Qsb (water leaving the grid cell below the surface), allowing Qtot, the total amount of water discharged by a cell to be calculated as Qs + Qsb. All models assume “naturalized” conditions, ignoring direct anthropogenic effects such as dams and water abstraction. The large-scale hydrological models have not simulated runoff using the WFDEI and therefore no hydrological drought statistics are available for major drought events after 2001.

Comparison of the nine large-scale models with observations suggests that the multi-model ensemble mean is a more consistent predictor of runoff than any single large-scale model (Gudmundsson 2012b). Given this finding, all estimates of hydrologic drought within the drought event database were based on the multi-model ensemble (MME). To calculate the MME, each model was processed and normalized individually and combined when calculating summary statistics. More detail is provided in Section 3.4 – Hydrological Drought Indices.
Table 1: Overview of the large-scale hydrological models, adapted from Haddeland et al. 2011a and Gudmundsson et al. 2012a.

<table>
<thead>
<tr>
<th>Model name</th>
<th>Runoff Scheme</th>
<th>Energy Balance</th>
<th>Evapo-Transpiration</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWAVA</td>
<td>Saturation excess/beta function</td>
<td>No</td>
<td>Penman-Monteith</td>
<td>Meigh et al. 1999</td>
</tr>
<tr>
<td>H08</td>
<td>Saturation excess/beta function</td>
<td>Yes</td>
<td>Bulk approach</td>
<td>Hanasaki et al. 2008</td>
</tr>
<tr>
<td>HTESSEL</td>
<td>Infiltration excess/Darcy</td>
<td>Yes</td>
<td>Penman-Monteith</td>
<td>Balsamo et al. 2009</td>
</tr>
<tr>
<td>JULES</td>
<td>Infiltration excess/Darcy</td>
<td>Yes</td>
<td>Penman-Monteith</td>
<td>Cox et al. 1999; Essery et al. 2003</td>
</tr>
<tr>
<td>LPJmL</td>
<td>Saturation excess</td>
<td>No</td>
<td>Preistley-Taylor</td>
<td>Bondeau et al. 2007; Rost et al. 2008</td>
</tr>
<tr>
<td>MATSIRO</td>
<td>Infiltration and saturation excess/groundwater</td>
<td>Yes</td>
<td>Bulk approach</td>
<td>Takata et al. 2003; Koirala 2010</td>
</tr>
<tr>
<td>MPI-HM</td>
<td>Saturation excess/beta function</td>
<td>No</td>
<td>Thornthwaite</td>
<td>Hagemann and Gates 2003; Hagemann and Dümennil 1998</td>
</tr>
<tr>
<td>ORCHIDEE</td>
<td>Saturation excess</td>
<td>Yes</td>
<td>Bulk approach</td>
<td>De Rosnay and Polcher 1998</td>
</tr>
<tr>
<td>WaterGAP</td>
<td>Beta function</td>
<td>No</td>
<td>Preistley-Taylor</td>
<td>Alcamo et al. 2003</td>
</tr>
</tbody>
</table>

3.3 Climatological Drought Indices – SPI and SPEI

Within the EDR database, the Standardized Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI) were used to objectively quantify and compare drought severity, duration, and extent across the varied climatic regions in Europe. SPI is recommended as a key meteorological drought indicator by the World Meteorological Organization (WMO, 2006) and the Lincoln Declaration on Drought (Hayes et al., 2011). The newer SPEI was developed to incorporate other climatic factors such as temperature and wind speed, which affect evapotranspiration and thereby water balance, while maintaining the same understandable statistical methodology as the SPI (Vicente-Serrano et al. 2010). Because SPEI includes climatological factors other than precipitation, the term “climatological drought” is used for the remainder of this study, rather than “meteorological drought”.

SPI is typically computed by summing precipitation over k months, termed accumulation periods, and fitting these accumulated precipitation values to a parametric statistical distribution from which non-exceedance probabilities are transformed to the standard normal distribution (µ=0, σ=1) (Guttman, 1999; Lloyd-Hughes & Saunders, 2002; McKee et al., 1993). SPEI is calculated in a similar fashion, but instead uses accumulated climatic water balance, defined as the difference between precipitation and PET (Vicente-Serrano et al. 2010). In this way, SPI and SPEI values are easily statistically interpretable, representing the number of standard deviations from typical accumulated precipitation, or climatic water balance, for a given location and time of year.

For the drought event database, SPI and SPEI were calculated at a daily temporal resolution. Accumulation periods considered in this study are the commonly used periods: 1, 2, 3, 6, 9, 12, and 24 months, which are considered equivalent to 31, 61, 91, 183, 274, 365, and 730 days, respectively. All normalization was performed relative to the reference period 1970-1999, in accordance with WMO standard reference periods. Selection of a common reference period allows for consistency with hydrological drought indices and provides a consistent baseline as new data becomes available in the future. SPI was normalized using the 2-parameter gamma distribution, while SPEI was normalized using the Generalized Extreme Value distribution, in accordance with recommendations from Stagge et al.
SPI and SPEI values were limited to the range between -3 and 3 to ensure reasonableness (Stagge et al. 2013a).

When calculating SPEI, potential evapotranspiration was calculated using the Penman-Montieth equation with the Hargreaves-Samani modification (Hargreaves and Samani, 1985) as described in the FAO-56 (Allen et al., 1998) and as recommended by Stagge et al. (2014). The Penman-Montieth equation is the standard for accurately calculating PET and is recommended by both the WMO (WMO, 2006) and the FAO-UN (Allen et al., 1998). The modified form of the Penman-Montieth equation uses the daily difference between Tmax and Tmin as a proxy to estimate net radiation (Hargreaves & Samani, 1985), which retains the physical foundation of the Penman-Montieth equation, while also largely avoiding concerns with mixing bias corrected WFD temperature and precipitation with non-bias corrected radiation (Haddeland et al., 2011b).

For the purpose of the EDR database, a grid cell was considered to be in climatological drought when the given index (SPI or SPEI) for the cell was below the 20% nonexceedance percentile, calculated from the reference period (1970-1999). In the context of SPI and SPEI, this percentile is equivalent to an SPI/SPEI of -0.842. Climatological drought extent was estimated using the SPI-6, a normalized measure of accumulated precipitation during the previous 6 months. This accumulation period was chosen as a reasonable measure of medium-duration, seasonal drought typical of Europe (Van Loon and Van Lanen 2012) and is correlated with hydrological droughts in both headwaters and downstream reaches (López-Moreno et al. 2013). Drought extent was calculated as the percent area with SPI-6 below -0.842, or the 20th percentile.

### 3.4 Hydrological Drought Indices

Hydrological droughts were defined using a threshold method (Zelenhasic and Salvai 1987), similar to that used for SPI and SPEI. For each grid cell and each of the nine hydrologic models, total runoff was derived as the sum of subsurface and surface runoff. Flows were then smoothed, using a five day moving average, to remove the effect of transient storm events and focus on baseflow as recommended by Tallaksen et al. (1997). Using the five day smoothed flows, daily varying drought thresholds were calculated using the 20% nonexceedance frequency, as in the SPI and SPEI analysis. For consistency, these thresholds were calculated using the same 30 year reference period (1970-1999).

Thresholds and daily percentiles were calculated separately for each of the hydrologic models and then combined to determine the daily mean ensemble flow percentile. Droughts were then defined as any day when this mean ensemble percentile fell below the 20th percentile. Hydrological drought index availability is limited to the period 1963-2001 because these models were not run for the WFDEI climate forcing data.

### 3.5 Selection of Major Drought Events

In total, 11 major European drought events within the European region were chosen to be detailed in the EDR database. Dates and location of these events are summarized in Table 2. Selection of these events was primarily based on those years with the highest mean annual hydrological drought extents. This preliminary list was updated based on meteorological drought indices to include drought events outside the hydrological data range (prior to 1963 and after 2001). Major drought events were then confirmed through drought impact reports submitted to the drought impact inventory.
Table 2: Major European drought events during the period 1958-2009.

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Duration (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>Central Europe</td>
<td>1/1973 - 7/1973</td>
</tr>
</tbody>
</table>
4. Structure and Status

The online drought event database is organized into three sections: an overview of major drought events, individual drought event pages with greater detail, and an application that allows the user to query drought conditions (SPI-6) on any day in the available historical record. Each of these sections are outlined in this report, using the 1975-1976 drought event as an example. Individual drought event pages for all 11 events are provided in Annex 1.

4.1 Major Drought Event Overview

The drought event overview page (Figure 1) is the starting page for investigating the major drought events included in the drought event database. This page provides a short outline of the purpose and content of the drought event database, while also providing a link to this document for additional detail regarding the underlying data and calculation methods.

The primary feature of the drought event overview page is a sortable table with summary statistics of the 11 major drought events identified in Table 2. Apart from the year and a subjective description of the region affected, the table provides an approximate duration for each event. Start and end dates for the drought duration are determined based on the date when total area in drought exceeds 30% and remains as such. A 2 month buffer is applied to both the start and end dates in this definition to account for drought development and decline.
In addition, the date of peak drought extent and the associated maximum drought area (percent and absolute area) are presented for both climatological and hydrological drought. As described in Sections 3.3 and 3.4, measures of meteorological and hydrological drought extent are based on the 20% nonexceedance percentile for SPI-6 and the multi-model ensemble mean, respectively. Hydrological drought statistics are not provided for the 1959 (Northern Europe), 2003 (Europe), 2004-2007 (Iberian Peninsula), and 2007 (Europe) events because output is not available from the nine hydrological models outside the original WFD timescale.

The drought event overview table is completely sortable, allowing the online user to easily rank drought events by maximum areal extent, either based on climatological or hydrological droughts. The table also allows a quick comparison within each event with regard to hydrological and climatological drought. Each event in the table is clickable and the hyperlink connects directly to the detailed individual drought event page described in Section 4.2.

4.2 Individual Drought Event Details

The individual drought event pages are accessible via the drought event overview page and provide greater detail and context for each of the 11 major drought events. Each drought event page contains...
an event summary, climatological drought data, hydrological drought data, and information regarding available drought impact reports.

4.2.1 Drought Event Summary and Background

The drought event summary (Figure 2) consists of a text overview, describing in detail how the drought event began, developed, and eventually returned to normal climatic conditions. Within this summary is information regarding large-scale climatic drivers, drought impacts, mitigation efforts, and all other pertinent data. Wherever applicable, these statements are cited, with a list of references provided at the bottom of the web page. Each drought event also includes a summary box, mirroring the information provided in the drought overview page.

![Figure 2: Screenshot of the drought event summary and background section for the 1975-1976 drought event.](image)

4.2.2 Climatological Droughts

The climatological drought section (Figure 3) displays details regarding the progression, location and severity of the particularly drought event with respect to the climatological drought index, SPI-6. Each climatological drought section contains a text overview, highlighting important climatological features of the drought event and briefly describing large-scale climatic drivers that control the drought when this information is available.

Two figures are also presented for each drought event, showing: (1) daily snapshots of SPI-6 severity and (2) the percent area in climatological drought by date. The first figure, presenting the daily spatial distribution of SPI-6 indices, shows abnormally dry regions (negative SPI-6) in progressive shades of red and abnormally wet regions (positive SPI-6) in shades of blue. This figure is interactive, allowing the
user to view the progression of climatological drought as a movie, to select individual dates within the
drought event, or to scroll through the event manually. The second figure shows the progression of the
entire drought event, plotting percent area in drought against time. This figure clearly shows the speed
of onset, progression, and end of the event, while also highlighting the maximum drought extent. The
1975-1976 drought event (Fig. 3) was a distinct, singular event, but this figure is also useful for
identifying secondary peaks or temporary recover periods, which could otherwise be overlooked in
summary statistics.

Currently the climatological drought section only presents information regarding the SPI-6 for ease of
understanding and readability. However, data and figures have been generated for all major
accumulation periods (1, 2, 3, 6, 9, 12, and 24 months) of the SPI and SPEI, but have not been
uploaded to the site. This information may be added to the climatological drought section in the future if
it improves understanding of each event.

Figure 3: Screenshot of the climatological drought section for the 1975-1976 drought event.

4.2.3 Hydrological Droughts

The hydrological drought section of the online EDR database (Figure 4) focuses entirely on hydrological
drought as estimated by the nine large-scale hydrological models. Each hydrological drought section
contains a text summary of low flow patterns in addition to two figures showing the spatial pattern of
drought at the hydrological drought peak and the corresponding location of the drought centre for each
of the hydrological models. The hydrological drought section is not available for drought events outside

The spatial figure showing hydrological drought is based on the MME mean flow percentile, as
described in Section 3.4. All grid cells with runoff (surface + subsurface) below the 20% non-
The exceedance percentile is shaded as a location in drought. Conditions at the hydrological drought peak are shown as a static figure, but may be improved to an interactive figure, similar to the climatological drought section as the website is improved. The second, drought centre figure displays the drought centroid and indicates the drought area by a circle scaled to the total area covered on the particular day. This allows plotting all models and the ensemble median (grey colour) in one map for comparison.

Figure 4: Screenshot of the hydrological drought section for the 1975-1976 drought event.

4.2.4 Reported Drought Impacts

For all major droughts, the drought impact section (Figure 5) lists those drought impacts reported in the European Drought Impact Report Inventory (EDII) outlined in Stahl et al. (2012). This database is housed online and is queried automatically each time the page is loaded. Therefore, the reported drought impact section will improve throughout the course of this project and following its completion as the EDII increases in scope and detail. Currently, the EDII has differing levels of coverage, both spatially throughout Europe and temporally, with more attention focussed on the most recent drought events. The drought impact section consists of a text summary, an interactive map showing the location of all relevant drought impact reports, and a sortable table listing all pertinent details for the drought reports.

The drought impact map shows all drought impacts at the country level, with increasingly darker colors representing greater numbers of reported drought impacts in the EDII. Drought impact reports with exact locations (latitude/longitude) are shown as unique points. Online users can scroll over each country to access a short summary, showing the name of the country, number of impacts, and description of impact in the case of point reports. The map can also be zoomed and moved to show greater detail.
**Drought Impacts**

In parts of Northwestern Europe already the growing season (May to September) of 1975 was characterized by markedly below average rainfall. By June 1975 reservoirs were had been lowered throughout South West England and were extended to substantial parts of England and Wales during the following months (Rodda & Marsh, 2011). Newspaper also reported on record number of fires, heat and field fires in Denmark and adjacent Northern Germany as well as shortage of fodder in Eastern parts of Norway leading to slaughtering of cattle and transport of milk from the west.

Then, the drought conditions in 1976 combined with a heat wave in June/July particularly in France and the UK but resulted in widespread socio-economic and environmental impacts throughout Western Europe. Agriculture was extensively affected. Due to insufficient grazing availability and low hay and fodder crop yields livestock and especially dairy farming severely suffered from feed shortages during the hot summer period. This caused early slaughter of livestock as well as a severe reduction of milk production. In parts of Great Britain and the Netherlands water intonances contributed to agricultural damage (Rodda & Marsh, 2011; Massaut, et al., 2012). Households were impacted through sharply increased prices especially for potatoes and fresh vegetables together with the loss of their own garden produce (Caughey et al., 1977; Domschke et al., 1988; Rodda & Marsh, 2011).

The impact on public water supply services varied spatially. In England and Wales the seriousness of the water supply situation due to prolonged drought was a major problem: despite diverse mitigation measures for a period from beginning of August daily supplies had to be applied which finally affected over one million consumers (Rodda & Marsh, 2011; Domschke et al., 1988). In France initiatives in water supply affected urban and rural areas.

**Figure 5:** Screenshot of the reported drought impacts section, showing the text summary and impact locations for the 1975-1976 drought event.

The drought impact table provides complete details on all drought impact reports shown in the impact map. This includes location (country and NUTS region), start and end dates, impact category and description, and the reference for the provided information. All information in this table follows the format provided in Stahl et al. (2013) including impact types and categories. The table is interactive, allowing the user to sort by any column, to increase the number of records shown per page or to do a text search within the records. The search function is particularly useful if the user wishes only to see a particular impact type or particular region. References with URLs are shown as clickable links, which will take the user directly to the drought impact reference.
4.3 Climatological Drought (SPI) By Date

In addition to information on the 11 major drought events, the EDR database allows the user to query the SPI database for any available date range (1959-2009) and view its progression as an interactive movie (Figure 7). Currently this page only provides data for SPI-6, as used in all major drought events, but the data exists to extend this functionality to any available drought index. The period from 2001 to 2009 is based on the WFDEI dataset and is considered experimental data subject to verification.

The generated SPI maps follow an identical format to those presented in the climatological drought section of the individual drought event pages and contain the same functionality. SPI figures may be viewed as a movie, scrolled frame-by-frame manually, or paused to view an individual date in the historical record.
**Figure 7:** Screenshot of the climatological drought query by date.
5. Availability and Proposed Improvements

The online EDR database is fully functional, but will continue to improve throughout the Drought R&SPI project. As of September 2013, it is only accessible to Drought R&SPI project members for internal testing and feedback. It will be made available to a larger test audience, i.e. the EDC members by November 2013, and made completely public in June 2014. The reason for this stepwise procedure is to insure ample testing with continual improvements to the site and its data. The content and formatting of the website will be continuously updated with additional tools and findings added as they become available.

One such anticipated improvement is the inclusion of a large-scale climate driver section for each drought event. Research on the climate drivers of drought is ongoing within the Drought R&SPI project (Kingston et al. 2013) and is tied to deliverable Task 1.3 (MS 15). As results from climate driver studies become available, summary statistics and figures will be included in this section. Figure 8 shows the mean geopotential height anomaly preceding the drought of 1976 and is typical of what would be included in this section.

Additionally, the WFDEI is being updated on a regular basis. The newest set of climate data will be released within the year and will include the years 2010-2012. This data will be incorporated into the EDR database to expand the temporal coverage. There is potential to add simulated runoff from future model runs (large-scale model ensemble forced by the WFDEI) once provided by the modelling community.

Technical improvements to the online EDR database are also proposed. Most notably, these improvements include expanding the SPI search functionality to include SPEI and hydrological drought snapshots. Similarly, the hydrological drought section will be improved to include an interactive daily drought progression, similar to those for climatological drought (SPI-6).

![Figure 8: Mean geopotential height anomaly prior to the drought of 1976. Reproduced from Kingston et al (2013).](image-url)
6. Conclusions

The EDR database was designed to provide a single, publically available site to disseminate detailed information about historical drought events in Europe. The current site provides the user with comparisons between events, in the form of an overview table, and detailed information about each of the 11 identified major European drought events in individual pages. In addition, an application is provided that allows the user to view meteorological drought conditions on any date in the available historical record.

This website is a first step towards creating a repository where drought information can be compiled and easily distributed throughout Europe. It has great potential to increase awareness of European droughts as well as provide a platform for future study. In its current state, the EDR database is an effective tool, but it is designed to be flexible, improving as new information is made available. Along with the EDII, this site will improve throughout the Drought R&SPI project and hopefully continue to provide important drought information after the project is complete.
References


Hargreaves GH & Samani ZA (1985) Reference crop evapotranspiration from ambient air temperature. *American Society of Agricultural Engineers*.


Annex 1 Major Drought Event Screenshots

1959 Drought Event
## Drought Impacts

Analysis of tree rings with samples of wood from Central Germany identified the summer of 1999 (June-Sept) to be one of the dryest on record. As a result, the summer was a severe drought for large areas of central Europe. Over the course of the summer, regions of Germany, Switzerland, and Austria experienced significant water shortages, affecting water supplies and irrigation needs.

### Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Event</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Impact Category</th>
<th>Impact Description</th>
<th>NAM</th>
<th>NET</th>
</tr>
</thead>
</table>

### References

1972 Drought Event

Drought of 1972
Northern and Eastern Europe

Drought Event Summary
The drought of 1972 was predominantly a summer and autumn event. Beginning with low accumulated precipitation from the previous fall, the drought intensified due to low precipitation during the spring. This winter deficit was enhanced in Germany. As the event intensified early spring, the drought was more pronounced, with the more severe drought conditions felt in March and April. By summer, western Europe had recovered, while eastern Europe and Scandinavia continued to have dry conditions.

Drought Statistics
- Area of hydrological drought: 6/6/1972

Affected regions: Northern and Eastern Europe

Climatological Drought
During February, a strong high pressure cell with its centre over central Mediterranean air moved to the north and east of central Europe, causing low precipitation in eastern and northern Europe, while an extreme low pressure centre caused floods in low-lying areas of the British Isles. In March, the reverse situation with high pressure over central Europe and low pressure over central Europe and Spain shifted the region affected by severe floods. Hardy weather was felt in France and the UK.

Progression of climatological DHI droughts:
Climatological drought is defined by the SPI-6, which shows precipitation over the previous 6 months and transforms this into a value on a standard normal distribution. Negative SPI values indicate more dry conditions, measured as standard deviations from optimal conditions. Percent area in drought is calculated by summing all cells less than the 25th percentile (SPI < -0.6).
Drought Impacts

According to Bradfield (2003), droughts in 1972 affected particularly the USSR, with severe losses in livestock and reduced yields in various crops. Although much of the eastern part of Russia was affected, large areas of the western portions of the USSR, as well as the Spanish, French, and Italian regions, were also affected. In Spain, the drought continued for almost four years, and livestock and agricultural production were severely affected. Similarly, the Argentine summer rains were highly uncertain. This document evidence of impacts could be found by Cole & Marsh.

Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Event</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Impact</th>
<th>Impact Category</th>
<th>Impact Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972 Drought</td>
<td>Russia</td>
<td>1/1/1972</td>
<td>12/31/1972</td>
<td>7.00</td>
<td>Drought</td>
<td>Drought resulted in reduced precipitation for months, water use restrictions for reservoirs, but also affecting other areas.</td>
</tr>
</tbody>
</table>

References

1973 Drought Event

Drought of 1973

Central Europe

Drought event summary

The 1973 drought event was a spring drought, related to low winter precipitation. It was not as severe when compared to other droughts in the region, but one occurrence, affecting much of central Europe and parts of the Iberian Peninsula.

The drought peak is not particularly well defined, but occurred between March and April of 1973, affecting the depressions and drought-prone areas of central Europe.

Climatological Drought

In central Europe, a high-pressure ridge extended from Russia to central Europe, causing low precipitation in central Europe. By March, the ridge had shifted over the British Isles, producing the most severe precipitation deficits there. This blocking effect continued, resulting in low rainfall across a wide area of central Europe by April 1973.

Drought Statistics

Approx. Duration: 1973-1975

Date of Drought: 03/1973

Region of Drought: Central Europe

Agricultural Impacts: Central Europe

(Spring and Summer)

Image of European Drought Centre

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Hydrological Drought

Peak hydrological drought, with hydrological drought based on output from large-scale hydrological models, is defined as an event where runoff falls below the 10th and 20th percentiles are shown in red, orange, and yellow, respectively. The lower curve (lighter area) is defined from each of the hydrological models during the drought period.

The hydrological drought peak occurred in November, significantly lower than the meteorological drought event. This fall hydrological drought was centered in Scandinavia and eastern Europe.

Drought Impacts

According to Bradshaw (2006), in 1975, some regions in France and Eastern Europe (UK, Austria, Germany, and Czechoslovakia) were affected by drought conditions. Most corn and other areas in France were affected by water use restrictions because of water shortages in 1975 (Hilare 1975-1977). According to Cole & Harms (2006), drought conditions from summer 1975 to late 1975 affected the most of England and Wales but became more serious in most areas, notable deficiencies were observed for spring fed lakes and aquifers and reservoirs in the Chelmer areas for summer rains were nearly non-existent. The documentary evidence of impact could be found by Cole & Harms.

Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Event</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Impact</th>
<th>Impact Category</th>
<th>Impact Description</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

References


© European Drought Centre 2012
1975-1976 Drought Event

Drought of 1975-1976
Central and Northern Europe

Drought Event Summary

The 1975-1976 event was brought about by a moderate to strong winter with below average precipitation. This precipitation deficiency developed during spring and summer over Western Europe centering in NW France to SE England. Only the Mediterranean and the north-western Iberian areas were unaffected. Throughout May and June, the drought spread northwards to the UK, Ireland and the Baltic region. Conditions in the UK were at their peak in July and Aug. Here, high clarity was seen among the wetter areas, suggesting a strong influence in the current. During a very wetter month, this is confirmed by Surface

Climatological Drought

Increase of drought was already present in the late fall and early winter of 1975 for Scandinavia and Eastern Europe. By the time the climatological drought peak in late July, nearly all areas of Europe except for the Mediterranean and coastal areas were experiencing moderate to severe drought conditions. The extent of this event was much felt in early winter of 1976.

Prognosis of climatological Drought

Drought is defined by the SPI, which sums precipitation over the previous 6 months and transfers this value to the standard normal distribution. Negative SPI values (shown in red) represent dry conditions, measured in standard deviations from typical conditions. Percentile dryness is calculated by summing all values less than the 25th percentile (SPI = -0.63).

Hydrological Drought

The hydrological drought peak occurred on July 11, 1976 and covered the majority of temperate Europe, extending from the UK and France to the east to Russia in the east. The Mediterranean region was largely unaffected.

Peak hydrological drought is defined as an exceedance in a large number of hydroclimatic models. Here, severity (SPI) decreases as the number of months below the 10, 20, and 50th percentiles are shown in red, orange and yellow, respectively. The cluster names (right) show the centile from each of the hydroclimatic models during the drought peak.
Drought Impacts

In parts of Northwestern Europe already during the growing season May in September 1975 characterized by relatively low average rainfall. By June 1975 meagre prices had been imposed throughout South West Europe and the continentally influenced part of Northern Europe, including agricultural activities such as raising cattle and transporting milk from the farm. The drought conditions in 1976 combined with a heat wave in June may have led to losses in crops. This resulted in widespread economic and environmental impacts throughout Europe. Agriculture was especially affected. Due to the scarcity of grassland and hay and fodder crop yield and harvesting were seriously affected from field burning during the heat wave period. The country that suffered from this heat wave and vegetation drought was France, particularly the wine regions of Bordeaux and St. Emilion. Half of the wine being destroyed as a result of the heat wave was of the highest quality, which caused a serious setback to the French wine industry. The other affected countries were Belgium, the Netherlands, and the United Kingdom, where the olive harvest was also affected.

The impact on public water supplies varied greatly. In England and Wales the severest impact of the water shortage was on the electricity supplies. In France, however, the impact was on the agricultural sector, as the crops had already been harvested.

Location of drought impact regions. Drought regions refer to more severe impacts in the table. Scroll over each country to see more details.

Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Category</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Impact</th>
<th>Impact Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% summer drought, European</td>
<td>Netherlands</td>
<td>6/1/1976</td>
<td>6/1/1976</td>
<td>Drought</td>
<td>Consequent effects on water supply and energy sector</td>
</tr>
<tr>
<td>100% summer drought, European</td>
<td>Germany</td>
<td>6/1/1976</td>
<td>6/1/1976</td>
<td>Drought</td>
<td>Consequent effects on water supply and energy sector</td>
</tr>
<tr>
<td>100% summer drought, European</td>
<td>Italy</td>
<td>6/1/1976</td>
<td>6/1/1976</td>
<td>Drought</td>
<td>Consequent effects on water supply and energy sector</td>
</tr>
<tr>
<td>100% summer drought, European</td>
<td>United Kingdom</td>
<td>6/1/1976</td>
<td>6/1/1976</td>
<td>Drought</td>
<td>Consequent effects on water supply and energy sector</td>
</tr>
</tbody>
</table>

References

Research Publications

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1989-1990 Drought Event
Drought Impacts

Two consecutive years of low precipitation impacted the eastern Mediterranean most severely. In Greece, there were reductions in agricultural production as well as shortages of ground and surface water. Water reservoirs which supplied Athens reached dangerously low levels in October 2009.

Impact Detail Table

<table>
<thead>
<tr>
<th>Location</th>
<th>Country</th>
<th>Start Year</th>
<th>End Year</th>
<th>Impact Category</th>
<th>Impact Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>Sicily</td>
<td>1999</td>
<td>1999</td>
<td>Summer drought</td>
<td>Summer drought has been a significant cause factor for tourism in southern Italy during the 1999 drought.</td>
</tr>
<tr>
<td>Greece</td>
<td>Athens</td>
<td>1999</td>
<td>1999</td>
<td>Reduced production of rice and olive cultivation</td>
<td>Reduction in agricultural production in irrigated areas.</td>
</tr>
<tr>
<td>Greece</td>
<td>Athens</td>
<td>1999</td>
<td>1999</td>
<td>Reduced of cultivated area due to use of irrigation water</td>
<td>Reduction in agricultural production in irrigated areas.</td>
</tr>
<tr>
<td>Greece</td>
<td>Athens</td>
<td>1999</td>
<td>1999</td>
<td>Storage of groundwater and surface water</td>
<td>Storage of groundwater and surface water.</td>
</tr>
</tbody>
</table>

References

© European Drought Centre 2010
1991-1995 Drought Event
Drought Impacts

The recent drought episode in the early 1990s (peaking in 1993) affected nearly the whole Siberian Peninsula but not by far the largest social impact in
the Southern part, i.e., in the Sakhalin basin in Hokkaido and in the
Primorsky-Kamchatka region. Millions of domestic consumers in the
Southern part of the country are left untreated or treated with very limited
treatment. The quality of the water is often poor, and the treatment facilities
are often not able to cope with the demand. The impact of the drought
in the Southern part is estimated to be about 40% of the total impact
in the country. The drought has also had a significant impact on the
agricultural sector, with a decrease in crop yields and the need for
emergency water supplies. The impact on the forestry sector has been
limited, but there have been some reports of forest fires due to the
drought and increased temperatures.

References

1. G. Karaman (2011). Widespread severe drought, food and water disruption, and amplified tree
1995-1996 Drought Event
### Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Event</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Impact</th>
<th>Impact Category</th>
</tr>
</thead>
</table>

**Impact Descriptions**

- Inflow to the hydropower system in the Nordic countries was 21.9% lower than normal in 2002. By comparison, the total inflow to the Nordic countries was 21.9% lower than normal in 1996. When normal 2002 and actual years can be compared, it is clear that inflow to the Nordic countries was 21.9% lower than normal in 2002. In 2002, total inflow to the Nordic countries was 21.9% of the average for the past 25 years. Historically, there has been a positive correlation between inflow to the Nordic countries and river discharges often being either partially or fully maintained. In some years, however, the inflow to the Nordic countries was 21.9% lower than normal in 1996. In 2002, total inflow to the Nordic countries was 21.9% of the average for the past 25 years.

**References**

2000 Drought Event

Drought of 2000
East and southeastern Europe

Drought Event Summary
From spring to summer in 2000, drought conditions persisted particularly in the eastern and southeastern European countries, which severely affected agriculture, and in particularly early crops (Balogh Janos et al., 2001).

Climatological Drought
Pronounced droughts during the drought of 2000 occurred almost exclusively in southeastern Europe. Drought peaks were in particular in Romania, Greece, Turkey and the Balkan countries. Additionally, a winter drought occurred along the western coast of Scandinavia, though this did not produce a significant hydrological drought.

Drought Impacts
From spring to summer in 2000, drought conditions persisted particularly in the eastern and southeastern European countries, which severely affected agriculture, and in particularly early crops (Balogh Janos et al., 2001). The year 2000 was also identified among the major drought years of the period 1968-2000 in the South Russian-European region by Hámor (2002).
### Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Event</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Impact Category</th>
<th>Impact Description</th>
<th>NIFS 1</th>
<th>NIFS 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 drought, Germany</td>
<td>Germany</td>
<td>2000-01-01</td>
<td>2000-02-29</td>
<td>Reduced productivity of annual crop</td>
<td>An extreme drought in 2000 led to a reduction in crop yields.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### References

3. IPCC, the IPCC-CORE International Disaster Database, UNESCO, Institut de l'environnement, Brussels, Belgium. www.icecat.be

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2003 Drought Event

Drought of 2003

Drought Event Summary

The 2003 drought event is considered exceptional for Europe, combining significant precipitation deficits with record-breaking heat extremes, which increased evapotranspiration. In its peak, nearly all of Europe was in drought, except for the Iberian Peninsula and the far western Mediterranean region. It is a consequence of large losses in crop yield and extremely low discharge levels of rivers were reported in large parts of Europe.

Climatological Drought

The 2003 drought event began with a precipitation deficit in Scandinavia in early spring. This precipitation deficit expanded and in June 2003 the zone was expanded to central Europe. Climatological drought remained severe throughout June and July, when the eastern and central part of the precipitation deficit rapidly expanded to cover most of Europe. This rapid expansion of drought was caused by a persistent high-pressure system that formed over western Europe.

The most severe precipitation deficits, which occurred in July and August of 2003, were accompanied by the warmest temperatures ever recorded in Europe at this time. This greatly increased evapotranspiration, reducing available water.

The meteorological drought began to quickly resolve in late September and October, with drought conditions only remaining in northern Italy and southern France.

Drought Impacts

In terms of impact, the European drought of 2003 affected an area spreading from the Iberian Peninsula and the Balkans to the Nordic regions. In 2003, it was characterized by extreme and far-reaching effects resulting from an exceptional water deficit combined with extended heat wave conditions (Europe, 2004).

Agriculture was particularly affected in Southern and Central Europe, French, Italian, German, Hungarian, Swiss, Slovakian, Spanish and Portuguese
Drought Impacts

In terms of impacts, the European drought of 2003 affected an area spanning from Portugal, Romania, and Bulgaria (East) to the Netherlands, Germany, Austria, Switzerland, Spain, and Portugal. The drought had severe consequences in both agricultural and socio-economic conditions (European Commission, 2004).

Agriculture was particularly affected in Southern and Central Europe, France, Germany, Austria, Switzerland, Spain, and Portugal, affecting agriculture but also eastern countries that have been among the most affected by the drought and the same year in 2005 (ECHA, 2006). The European Environment Agency (EEA) estimated the direct economic cost of the drought in 2003 as being €9.4 billion. The economic impact in specific sectors was €1.2 billion, which was attributed to several factors, including reduced crop yields and lower prices for agricultural products. The European Union (EU) and the European Commission (EC) provided financial assistance to affected countries (EEA, 2006).

The drought's impact on the environment was substantial, with many species and habitats affected. The drought also had significant impacts on water quality, with many rivers and lakes experiencing reduced water levels and increased salinity. The impact on water bodies was particularly severe in Southern and Eastern Europe, where the drought lasted longer and the water supply was more limited (EEA, 2006).

In addition to agricultural and environmental impacts, the drought had significant socio-economic impacts, including reduced tourism revenues and increased energy costs. The drought also led to increased social unrest and political instability in some affected countries (EEA, 2006).

Impact Detail Table

<table>
<thead>
<tr>
<th>Event</th>
<th>Country</th>
<th>Start Date</th>
<th>End Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003 summer drought</td>
<td>Europe</td>
<td>7/2003</td>
<td>2003</td>
<td>Critical drought conditions (abnormally low rainfall) occurred in the cereal crop-growing season, which is generally the time when the crop is at its most vulnerable stage of development. This led to a significant reduction in crop yields, which in turn led to increased food prices and reduced crop availability.</td>
</tr>
<tr>
<td>2003 summer drought</td>
<td>France</td>
<td>8/2003</td>
<td>2003</td>
<td>Special drought conditions (abnormally low rainfall) occurred in the cereal crop-growing season, which is generally the time when the crop is at its most vulnerable stage of development. This led to a significant reduction in crop yields, which in turn led to increased food prices and reduced crop availability.</td>
</tr>
</tbody>
</table>

Notes: 

- **Impact Category**
  - **Critical drought conditions** (abnormally low rainfall)
  - **Special drought conditions** (abnormally low rainfall)

- **Country**
  - **European Union** | **EU**
  - **France** | **Fr**

- **Start Date**
  - **July 2003** | **2003**
  - **August 2003** | **2003**

- **End Date**
  - **2003** | **2003**

- **Description**
  - **Critical drought conditions** (abnormally low rainfall)
  - **Special drought conditions** (abnormally low rainfall)
2004-2007 Drought Event

Drought of 2004-2007

Drought Event Summary

2004 and 2005 were characterized by dry conditions affecting most of western Europe, but particularly the Iberian Peninsula. This period is considered the most severe drought in the 2004-2007 period, with serious consequences for the Iberian Peninsula.

Climatological Drought

Drought conditions began during the summer of 2004, with a severe meteorological drought scenario in Portugal. Drought conditions remained closer to normal in the Iberian Peninsula during the fall of 2004. Drought persistence was significant over the whole period considered.

By February 2005, climatological drought conditions returned to the Iberian Peninsula. The area affected increased to an extreme in July 2005 and again in October. Drought conditions were almost exclusively centered in Spain and Portugal, with the rest of Europe experiencing normal conditions.

Prognosis of climatological Drought

Climatological drought is defined by the SPI-6, which sums precipitation over the previous 6 months and compares this value to the expected normal distribution. Negative SPI values indicate below-normal conditions, measured in standard deviations from normal conditions. Percent area in drought is calculated by summing all cells less than the 20th percentile (SPI < -0.4).
Due to the exceptional conditions in the hydrological year 2004-2005 agriculture suffered from severe water restrictions and was completely devoid of virtually all kinds of crops. As a result, demand for farm inputs (e.g., fertilizers) increased steeply and farmers reported significant costs. To counteract these challenges, the government introduced emergency measures to support agriculture, which included the provision of water from public water supplies and the removal of certain restrictions on water usage. Despite these efforts, the drought persisted until the end of the year, leading to significant agricultural losses and food shortages.

The impact of the drought on the broader economy was also severe. The agriculture sector, which is a major contributor to the national economy, suffered a significant decrease in production. Additionally, the tourism industry, which relies heavily on the agricultural sector, experienced a decline in visitor numbers, leading to a decrease in revenue for hotels, restaurants, and other related businesses. The overall economic impact was estimated to be several billion Euros, with the hospitality sector alone losing hundreds of millions in sales. Public health services were also strained due to the increase in waterborne diseases, leading to an increase in medical costs.

Due to the severe nature of the drought, water management strategies were put in place to ensure sustainable water use in the future. These included the construction of new water storage facilities, improvements in irrigation systems, and the implementation of water conservation measures. The government also launched public awareness campaigns to encourage citizens to use water more efficiently. These efforts were aimed at reducing the vulnerability of the country to future droughts and ensuring a more resilient water supply system.
2007 Drought Event

Drought Event Summary

Beginning in the summer of 2007, a drought developed in southeastern Europe, continuing into the summer. The primary areas affected are those countries that surround the Black Sea and central Asia.

The 2007 event was not particularly severe, with several areas affected, but was quite severe in three Southeastern regions.

Climatological Drought

A precipitation deficit developed during the summer of 2007 across areas of southeastern Europe. By late spring and early summer this deficit was confirmed in southeastern Europe, Romania, Ukraine, Bulgaria, and Turkey.

A more localized drought developed in several and continued until reaching a maximum in late June.

Progression of climatological SPI-6 drought. Climatological drought is defined by the SPI, which sums precipitation over the previous 6 months and transforms this value to the standard normal distribution. Negative SPI values (shown in red) represent dry conditions, measured in standard deviations from normal conditions. Percentage area in drought is calculated by summing all cells below the ZST percentile (SPI = -0.5).

Drought Impacts

In the year 2007 drought impacts were reported in several parts of Europe, including Italy, Greece, and the Balkans. Some regions had already experienced drought conditions during 2006, which Improved from the previous year. In the summer, drought conditions worsened in the Balkans, where the rainfall was below average. In April 2007, floods occurred due to severe rainfall in the central areas.

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Drought Impacts

In the year 2007 drought impacts were reported in several parts of Europe, including Italy, in Norway, and on the northeastern coast of the Netherlands. As some regions had already experienced drought conditions during 2006, what amplified the impact in 2007 was the relatively dry conditions in the spring and summer of 2007, which, in combination with high temperatures and poor precipitation, led the European Commission to declare a state of emergency. The drought also affected the national rice-growing areas in India, where rice yield losses occurred. The European Union (EU) in 2007 provided €200,000 for emergency relief measures. A total of €400,000 was allocated to the EU's emergency relief budget.

Impact Detail Table

<table>
<thead>
<tr>
<th>Drought Event</th>
<th>Country</th>
<th>Year</th>
<th>Impact Category</th>
<th>Impact Description</th>
<th>Mouse</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 summer drought, northern Europe</td>
<td>Germany</td>
<td>2006</td>
<td>Reduced production of annual crop</td>
<td>Damage to crop quality, crop failure due to drought, mortality of plants, pasture, or livestock disease</td>
<td>None</td>
<td>Need for immediate intervention</td>
</tr>
<tr>
<td>2007 drought, Europe</td>
<td>Germany</td>
<td>2007</td>
<td>Reduced production of annual crop</td>
<td>Damage to crop quality, crop failure due to drought, mortality of plants, pasture, or livestock disease</td>
<td>None</td>
<td>Need for immediate intervention</td>
</tr>
<tr>
<td>2007 drought</td>
<td>Europe</td>
<td>2007</td>
<td>Reduced production of annual crop</td>
<td>Damage to crop quality, crop failure due to drought, mortality of plants, pasture, or livestock disease</td>
<td>None</td>
<td>Need for immediate intervention</td>
</tr>
</tbody>
</table>

References