CROSSDRO

ANNUAL NEWSLETTER

Research partners:

Supported by:

No. 2 - December 2021

What is CROSSDRO?

CROSSDRO (*CROSS-sectoral impact assessment of DROughts in complex European basins*) is a EU JPI Climate project that runs from September 2019 to March 2023.

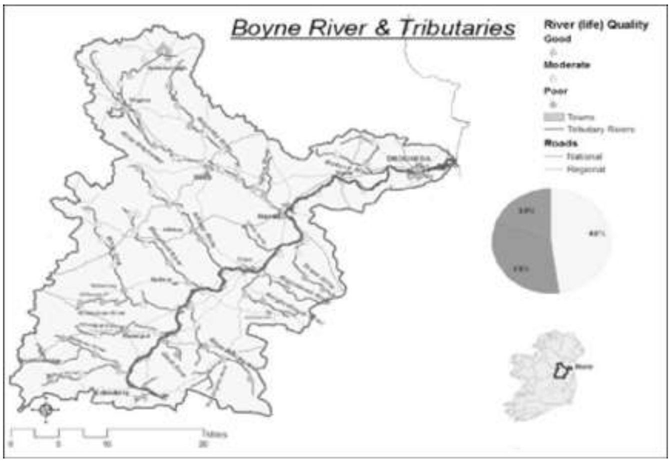
Where is the research taking place?

CROSSDRO is analysing drought in four European basins with very different socio-ecological contexts. Case study sites include:

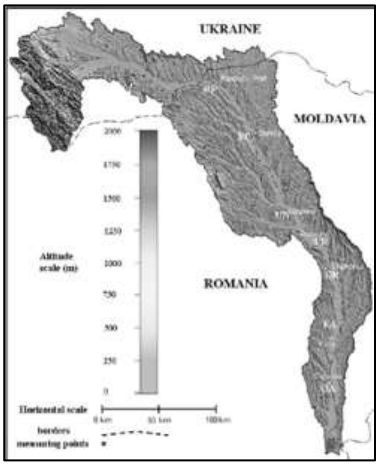
i) the upper Aragon basin in Northeast Spain,

ii) the German part of the Elbe basin,

iii) the Boyne basin in Ireland.



iv) the Moldovan part of Prut basin.



What are the project objectives?

The CROSSDRO objectives are to:

- Better understand the multi- and cross-sectoral impact of droughts including the connection between physical and socioeconomic impacts and pathways.
- Better understand stakeholder needs and perceptions of drought.
- Examine drought impact across scales – catchment to European scale, and both historically and into the future.

Who is involved?

CROSSDRO brings together scientists from five research institutions. The leading institution is the Spanish National Research Council, and the project coordinator is Sergio Vicente-Serrano. Partner institutions are University of Maynooth in Ireland (group leader C. Murphy), Lund University in Sweden (group leader L. Eklundh), Research Institute of Field Crops "Selectia" in Moldova (group leader B. Boincean) and Potsdam Institute for Climate Impact Research in Germany (group leader T. Conradt).

Progress so far...

We are now two years into the project and would like to provide an update on the latest developments, project milestones and lessons learned over the last 12 months (see Newsletter No 1 for 2020 update).

Stakeholder events

The CROSSDRO project aims to develop practical guidance for future planning through the strong engagement of drought-sensitive stakeholders in each basin. While the Covid-19 pandemic has disrupted stakeholder engagement to some extent, there has been engagement events, surveys and in-depth interviews conducted across the four basins.

Aragon basin, Spain

There have not been opportunities for engagement or capacity building events this year in the basin as stakeholders and authorities are occupied in developing a new drought plan.

Elbe basin, Germany

Stakeholder activities were still largely hampered by the pandemic situation. On 21 October 2021 Tobias Conradt represented CROSSDRO in an expert hearing about high end climate change (i.e. end-of-century conditions under the pessimistic RCP 8.5 emission scenario) consequences for Germany. This was a four-hours virtual meeting with about 20 participants from German research institutions and ministries, organized by the Berlin-based Adelphi company and another of PIK's departments, with a break-out group focusing on drought effects in agriculture and forestry. For 30 November, Tobias Conradt was invited by a Bavarian producer of agricultural soil cultivation machinery (Horsch Maschinen GmbH, Schwandorf) to a panel discussion about future yield expectations and climate-change related pressures on agricultural production. The German-language talk was video-streamed live on the Internet.

Boyne basin, Ireland

Stakeholder engagement and outreach in the Boyne basin has been ongoing. Lessons and insights from the project were disseminated nationally in Ireland via an invited presentation to a technical workshop on droughts organised by the Irish group of the International Association of Hydrogeologists (IAH). At the event Prof. Murphy outlined findings from the European and national scale from CROSSDRO to inform current and future thinking about drought on the island. Engagement with other national drought projects also took place to ensure sharing of insight and knowledge to be benefit of all parties. Of note are ongoing interactions with the Irish Research Council funded project 'Forgotten droughts: Cultural memories of a neglected hazard in Ireland'. This project offers insight into the cultural and historical impacts of drought in Ireland with sharing of information around the Boyne basin and the impacts of historical drought ongoing. Prof. Murphy has also had the opportunity to discuss drought and management plans with Irish Water, the national water management agency to ensure that results from the project clearly communicated to this important stakeholder and that their needs for more effective drought management are taken onboard by the project.

Prut basin, Republic of Moldova

Selectia Research Institute of Field Crops (Moldova) has organized many events in 2021 dedicated to sustainable and resilient soil and crop management in the conditions of extreme weather conditions. This included 24 seminars with agricultural producers in different districts of Moldova and 6 scientific-practical conferences with the national and international participation. Simultaneously the work of the institute was reflected in 22 reports on the national radio and 23 reports on national TV.

Field trials with different varieties of winter wheat, winter barley, peas, soybeans have been visited by farmers of Moldova. Long-term field experiments with different crop rotations, systems of soil tillage and soil fertilization have been visited by both local producers as well as official representatives from the Government of Moldova.

The director of Selectia Research Institute of Field Crops has participated with two public lectures at the Academy of Sciences of Moldova on topics related to sustainable management of Chernozem soils in the conditions of global warming and the restoration of seed production in Moldova. These topics are very important especially in the pandemic situation for providing food security of the country.

Scientific outputs

Boyne Basin, Ireland

We have conducted stakeholder interviews with Boyne and national-level stakeholders to better understand sectoral sensitivities and understandings of drought, past drought experiences and challenges, and concerns about future drought events. We approached target interviewees in January 2021 and conducted interviews between February and July 2021. We interviewed 40 individuals who can be broadly divided into three groups: individuals with a direct interest in drought from a livelihood perspective; individuals with a direct interest in drought from a recreational or general perspective; and those with an indirect professional interest. Interview findings indicate that drought impacts in the Boyne (and Ireland more broadly) are understood and experienced from diverse perspectives (e.g. water supplies, freshwater systems, agriculture, forestry, ecology, fire risk, landslides).

Streamflow database generated for Europe and hydrological droughts analysed

The **Instituto Pirenaico de Ecología (IPE-CSIC)** in the frame of the project CROSSDRO has developed a dataset of streamflow series covering the entire European continent. The dataset contains more than 3200 series, which cover the period 1962-2017. The series have been quality controlled and reconstructed to avoid the existence of data gaps. This information is available at https://msed.csic.es/

Figure 1. *Web server of the European hydrological database.*

This hydrological information is being used to analyse the evolution of hydrological droughts in the region and to determine the strong complexity and spatially diverse patterns across Europe. The results show a positive trend towards more frequent and severe droughts in Southern and Eastern Europe and conversely a negative trend over Northern Europe. This emphasizes that hydrological droughts have shown complex spatial patterns across Europe over the past six decades, implying that hydrological drought behaviour in Europe has a regional character.

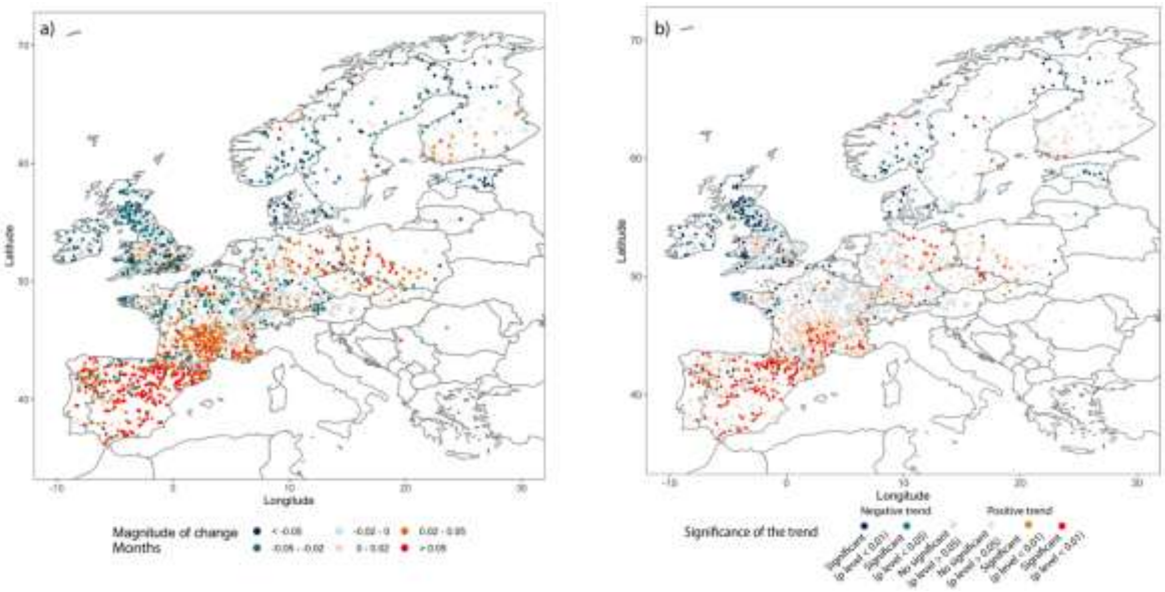


Figure 2. Trends in the duration of drought events from 1962 to 2017. (a) Spatial distribution of the magnitude of change in SSI and (b) the corresponding significance of trends (at p < 0.05, p < 0.01) over the same period. Each circle represents one gauging station.

The response of hydrological droughts to vegetation changes in the Aragon basin in the central Spanish Pyrenees

The CROSSDRO project has published an article in Geophysical Research Letters demonstrating that increased vegetation in mountainous headwaters amplifies water stress during dry periods. The dynamics of blue and green water partitioning under vegetation and climate change, as well as their different interactions during wet and dry periods, are poorly understood in the literature. For this reason, we analysed the impact of vegetation changes on blue water generation in a central Spanish Pyrenees basin undergoing intense afforestation. We found that vegetation change is a key driver of large decreases in blue water availability. The effect of vegetation increase is amplified during dry years, and mainly during the dry season, with streamflow reductions of more than 50%. This pattern can be attributed primarily to increased plant water consumption. Our findings highlight the importance of vegetation changes in reinforcing the decrease in water resource availability. With aridity expected to rise in southern Europe over the next few decades, interactions between climate and land management practices appear to be amplifying future hydrological drought risk in the region. The key points of the study are: i) Forest secondary succession is the main driver of streamflow trends in mountain Mediterranean areas, ii) The effects of vegetation changes on water availability strongly differ between dry and humid periods, iii) Trends in streamflow in response to vegetation changes are mostly recorded during the dry and warm season. The article is available at: https://doi.org/10.1029/2021GL094672

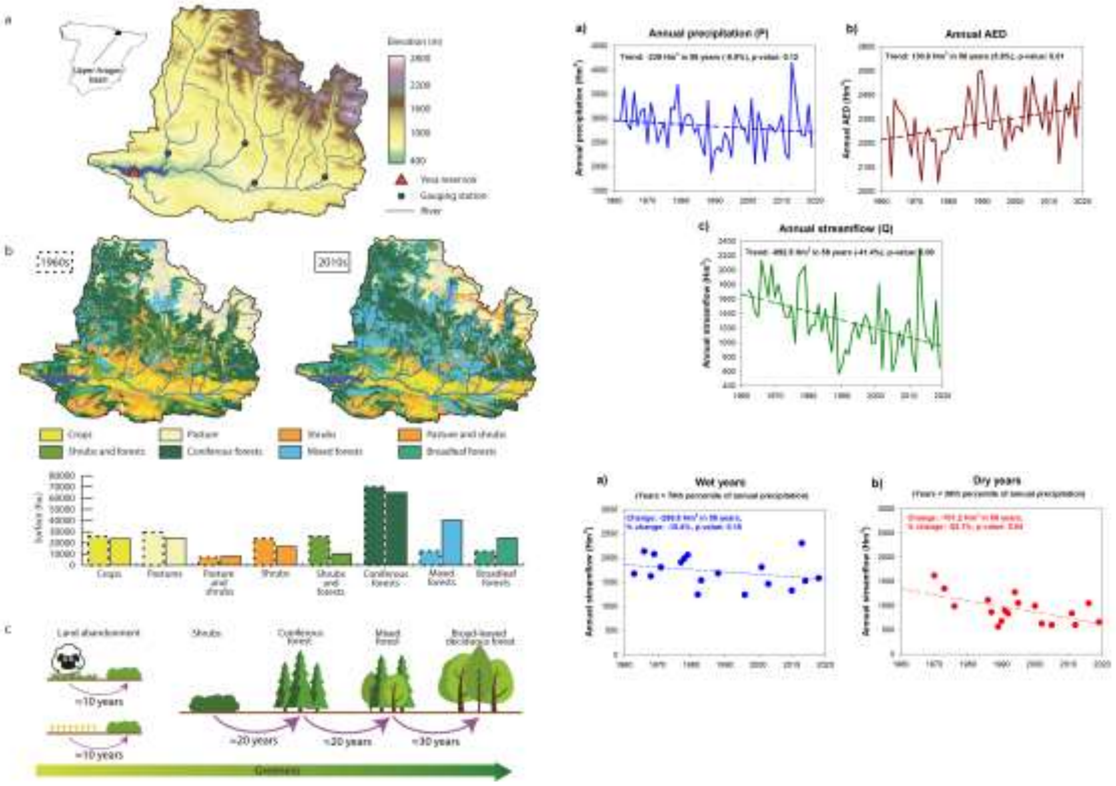


Figure 3. *Land cover changes in the Aragon catchment (left), evolution of precipitation, streamflow and the atmospheric evaporative demand (top right), and the response of streamflow to dry and humid years (bottom right).*

Prut Basin, Moldova

Sensitivity of crop yields in Moldova increases in response to global warming

80% of the Republic of Moldova is covered by non-irrigated crops, with the agriculture sector employing more than 30% of country's population. This region has been frequently affected by droughts, with large negative consequences on crop yields. The year 2020 was particularly serious since crop yields reduced by 30% on average, reducing employed people in the sector to 20%, which contributed to an 8% decline in Gross Domestic Product (GDP). For these reasons, CROSSDRO project has analysed in depth the relationship between crop yields and drought severity under a scenario of global warming in the Republic of Moldova. We have showed that the vulnerability of crop yields to precipitation variability has noticeably increased during the last twenty years related to the strong temperature increase recorded in the region. Climate change projections suggest a reinforcement of limiting climate conditions for adequate crop yield. For this reason, it is necessary to promote more conservative land management practices, characterized by perennial spring crops and winter cereals, to increase the stock of soil moisture and vineyards that may adapt to more arid and warmer climate conditions, maintaining productivity and grape quality. Crop adaptive measures are then essential to guarantee an adequate yield in crops in a region in which agriculture has a very important role in the country's economy.

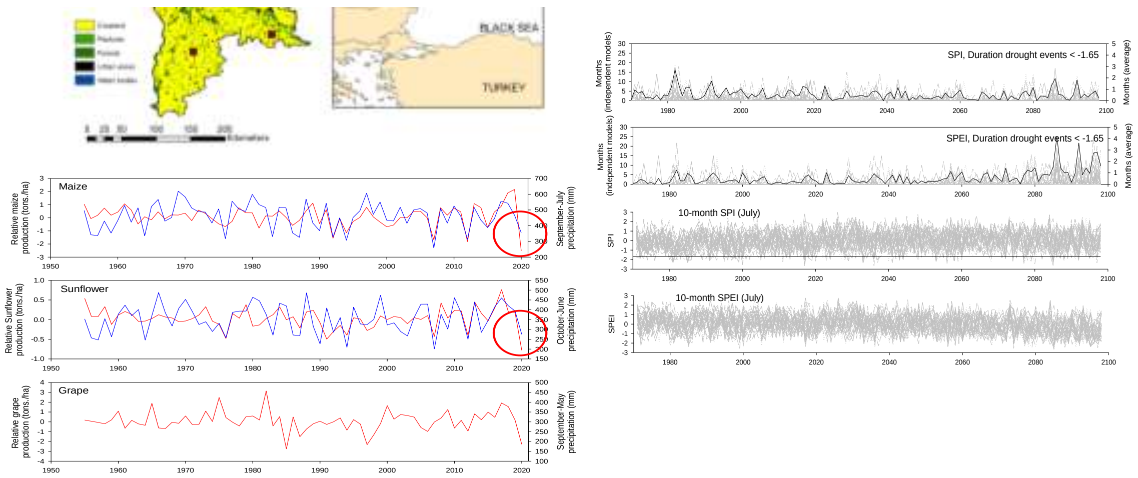


Figure 4. Land cover map of Moldova (top left), Evolution of the temporal variability of precipitation during the period of higher correlation with the anomalies in crop yield (top right) and the annual yields of the three crops and evolution of the drought duration from 43 climate change models in Moldova using the SPI and the SPEI (bottom left). Gray lines show the evolution for each model and black lines represent the average. Two bottom plots show the evolution of the SPI and SPEI at the time scale of 10 months in July. Horizontal black lines represent SPI and SPEI values equal to -1.65.

Elbe Basin, Germany

The impacts of the 2018–2019 drought over Central Europe

The Potsdam Institute for Climate Impact Research (PIK) assessed drought impacts for the German Elbe River basin (97 175 km², including the cities of Hamburg, Berlin, and Dresden). According to the meteorological drought indices for the region, this event was the most extreme drought in the last six decades, with some literature suggesting you would have to go back to the year 1540 to find a comparable event in Germany.

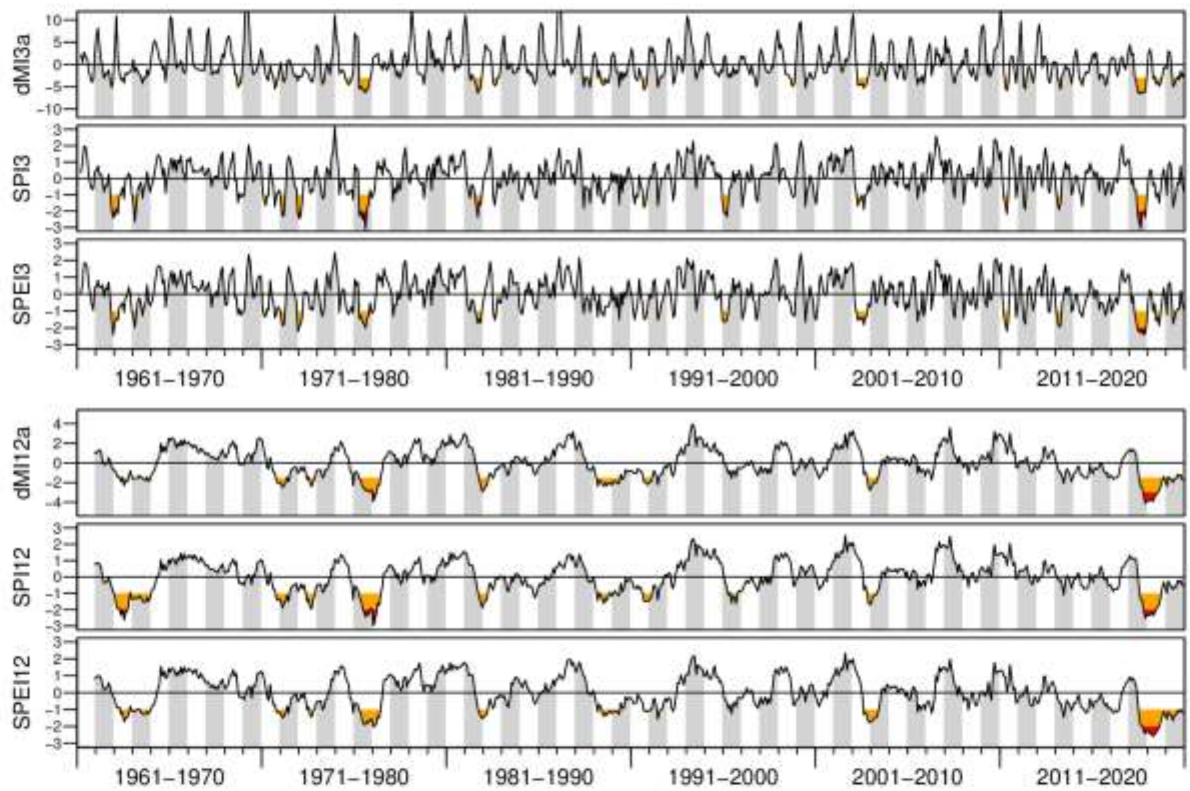


Figure 5. *Drought indices calculated from meteorological averages over the German part of the Elbe River basin (weather data provided by DWD, the German Weather Service). Red colour indicates extreme drought. The acronyms refer to de Martonne's index (dMI), describing compound anomalies of precipitation and temperature, the WMO-recommended Standardized Precipitation Index (SPI) based on seasonal precipitation frequency distributions, and the Standardized Precipitation Evaporation Index (SPEI) which also takes evaporation into account. The numbers refer to the two different time windows applied (3 and 12 months).*

The most prominent effect was a breakdown of agricultural yield levels in the region. Average yields of the six pre-drought years (2012–2017) dropped by 20–40 % in 2018, with maize, potatoes, sugar beets and fodder plants most affected. In the most affected districts, much higher losses were reported, and some farmers had to face total harvest failures. Animal production remained however quite stable, but additional fodder had to be imported or bought from less drought-affected parts of the country. This is reflected in the animal producer prices which rose in 2019, the second drought year, up to 17.8 % over the 2018 level and went back to that level not before November 2020. Forestry was also affected by drought-related damages: Wood harvests were driven up by windstorms and bark beetle attacs (which especially hit already drought-affected spruce stands).

Nevertheless, immediate economic drought consequences seem limited to Agriculture and Forestry which make up only one percent of the regional economy, calculated by gross value added (GVA). In contrast to the financial crisis of 2008–2009 and the pandemic kicking in in 2020, no drought- or heat-related dents are visible in the regional economic time series.

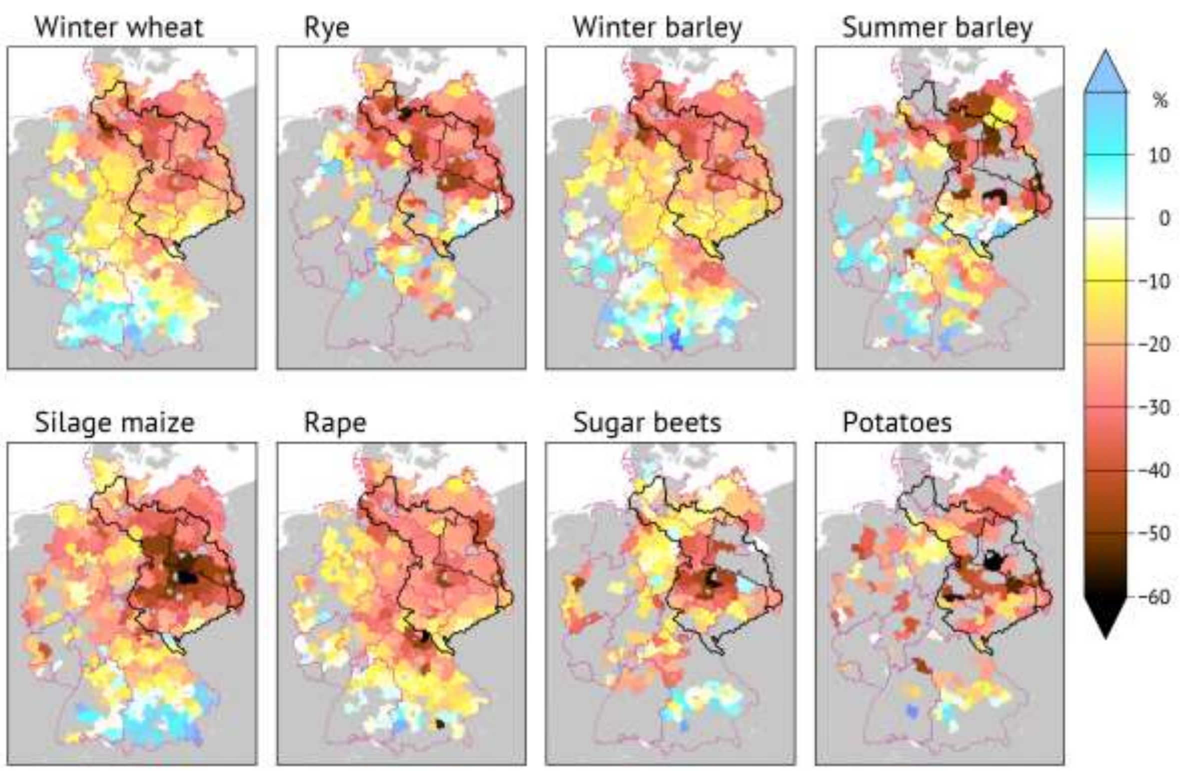


Figure 6. *Crop yields of 2018 relative to the 2012–2017 averages in German district-level administrative units; grey areas indicate missing data. The areas of the German Elbe River basin (and the Havel River tributary) are outlined in black. Data source: Statistische Ämter des Bundes und der Länder [statistical offices of the federation and the federal states], Map geometries © 2018 GeoBasis-DE/BKG (VG1000, 2018).*

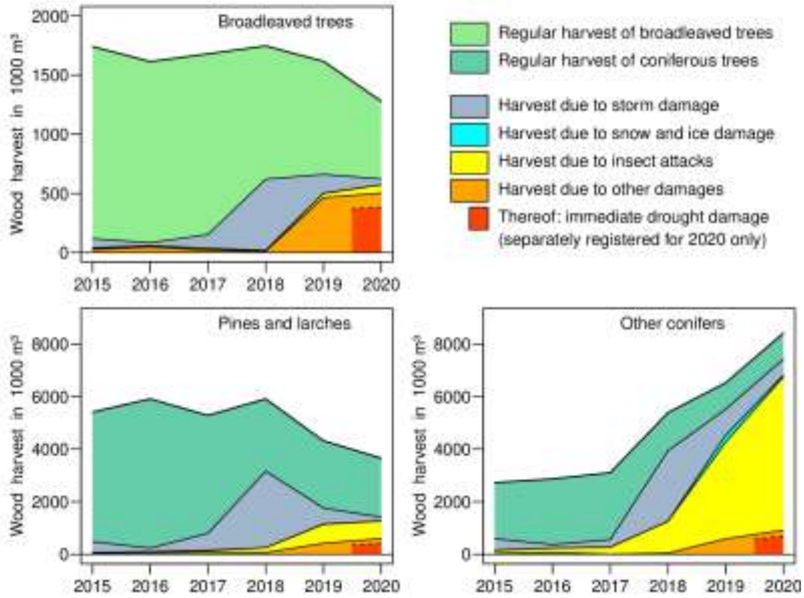


Figure 7. Wood harvests in forests of five federal states approximately covering the German Elbe River basin. Data source: Statistisches Bundesamt [federal statistical office], Wiesbaden.

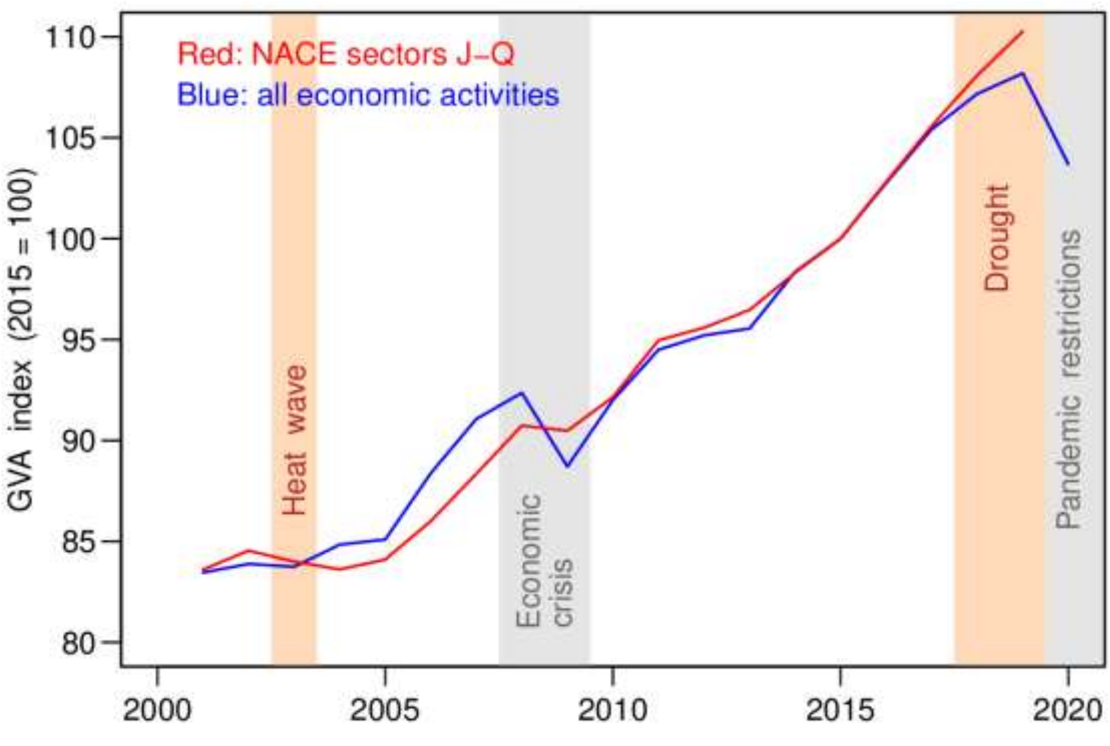


***Figure 8.** Two decades of economic activity in the five federal states representing the German Elbe River basin. Indexed gross value added (GVA) of the entire economy (blue) and the service sectors (red). Data Source: Statistische Ämter des Bundes und der Länder [statistical offices of the federation and the federal states].*

Along the River Rhine and other rivers in Western Germany, navigation was however hampered by the low water levels so that oil refineries, steel mills and chemical industries (e.g. BASF) had to be shut down, diesel and gasoline supplies were locally broken, and the accumulated losses are probably in the two-billion range. Several thermal power plants had to be throttled because of lacking cooling water, which points towards a potential tipping point under future droughts: As Germany's last nuclear plants and coal mines are currently being phased out from the energy mix, a drop in production from the remaining gas-driven thermal power plants could be critical for grid stability given the increasing shares of renewables (mainly wind and photovoltaics). A more detailed article about this research is currently in preparation for publication in a scientific journal.

Following a referee response to a manuscript about ABSOLUT (the statistical crop yield model used in CROSSDRO which was developed by Tobias Conradt (PIK) and originally submitted to Geoscientific Model Development in early 2021), the model code was cleaned from a systematic error, validation experiments re-computed, and a revision of the manuscript made and submitted for publication on 30 October. Fortunately, though the error principally caused considerable over-confidence in the model predictions, it hardly alters scenario calculations already made with the former version, e.g. for the Prut River basin.

The final months of 2021 were spent experimenting with the eco-hydrological model SWIM in the Havel River area to assess sensitivities of the plant–soil–groundwater systems and storages towards different drought levels. Furthermore, the set-up of a pan-European SWIM for continent-wide eco-hydrological modelling was commenced at PIK.

European-scale outputs

Vegetation responses to drought across European biomes

The Department of Physical Geography and Ecosystem Science of Lund University has investigated the association of vegetation productivity to meteorological drought across Europe using ERA5-Land derived SPEI and satellited-derived plant phenology index (PPI) for the period 2000 to 2020 on a bimonthly time step (Figure 1). The PPI is a vegetation index developed at Lund University. It keeps good properties of EVI (enhanced vegetation index) that have large dynamics for representing vegetation growth productivity and performs even better than EVI in seasonally snow-covered areas. PPI is thus advocated as an indicator for remote sensing vegetation productivity of European biomes by EEA (https://www.eea.europa.eu/data-and-maps/indicators/land-productivity-dynamics/assessment).

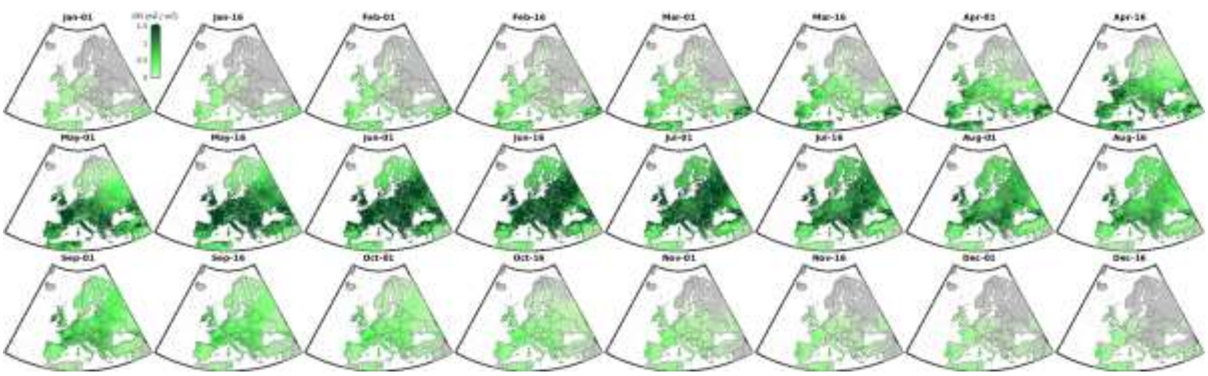


__Figure 9.__ Maximum bimonthly PPI from 2000 to 2020. The pixels with the maximum bimonthly PPI < 0.05 are regarded as having no active vegetation growth and were not considered in drought-vegetation association analysis.

The bimonthly PPI data are used to analyse how the drought has affected vegetation growth for the period 2000 to 2020. It is found that European **droughts have prohibited vegetation productivity** over more than 50% of middle and southern European land areas (35°N to 55°N, Figure 10 and 11), prominently during peak growing season from June through September (large significant positive correlation between SPEI and PPI). In northern Europe the drought-affected land area was below 40% during the peak growing season. It is also found that **drought promoted vegetation productivity** (negative correlation in Figures 10, and 11), prominently at the start of the vegetation growing season — from April through June in northern Europe and from January through April in middle Europe.

It was suggested that vegetation growth promoted in drought period was probably due to the elevated air temperature along with increasing water deficit that promotes photosynthesis. A partial correlation analysis found that the proportions of negative correlative reduced, and positive correlation increased. In southern Europe, more than half of the proportion of drought-promoting-growth areas (negative correlation) turned out as drought-prohibiting-growth areas (positive correlation), evident in Figure 11 top panel vs the second panel. In northern and middle Europe, there were also negative-to-positive correlation changes by controlling temperature, but not as markedly as in southern Europe. When using incoming net radiation as a control, partial correlation analysis shows that more than half of the negative correlation turned into a positive correlation in middle Europe, and a large proportion changes in northern Europe. When using both temperature and net radiation as controlling factors to do partial correlation analyses between PPI and SPEI, we did not find added effects more than using air temperature or net radiation as a single control.

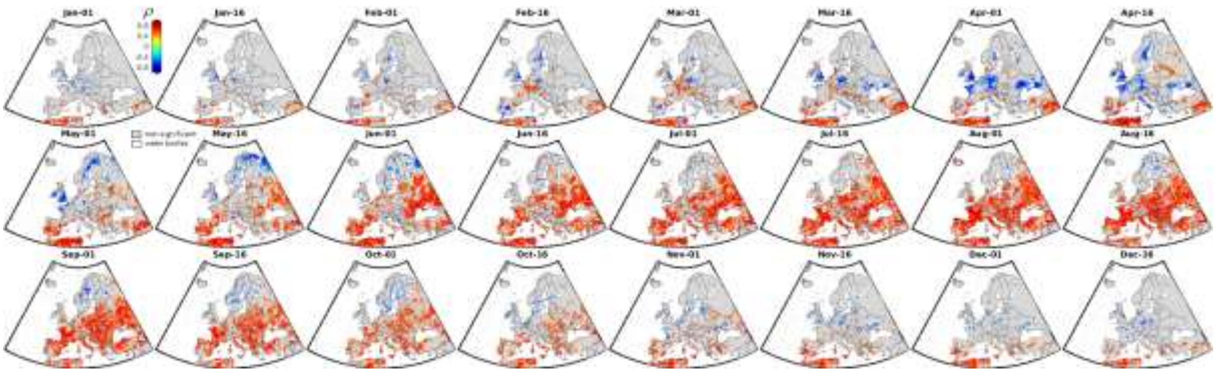


__Figure 10.__ Strongest partial correlation (significant at p⩽0.05, positive or negative) of PPI to SPEI on bimonthly time step among all time scales from 1 to 24, by controlling incoming net radiation of the same time scale.

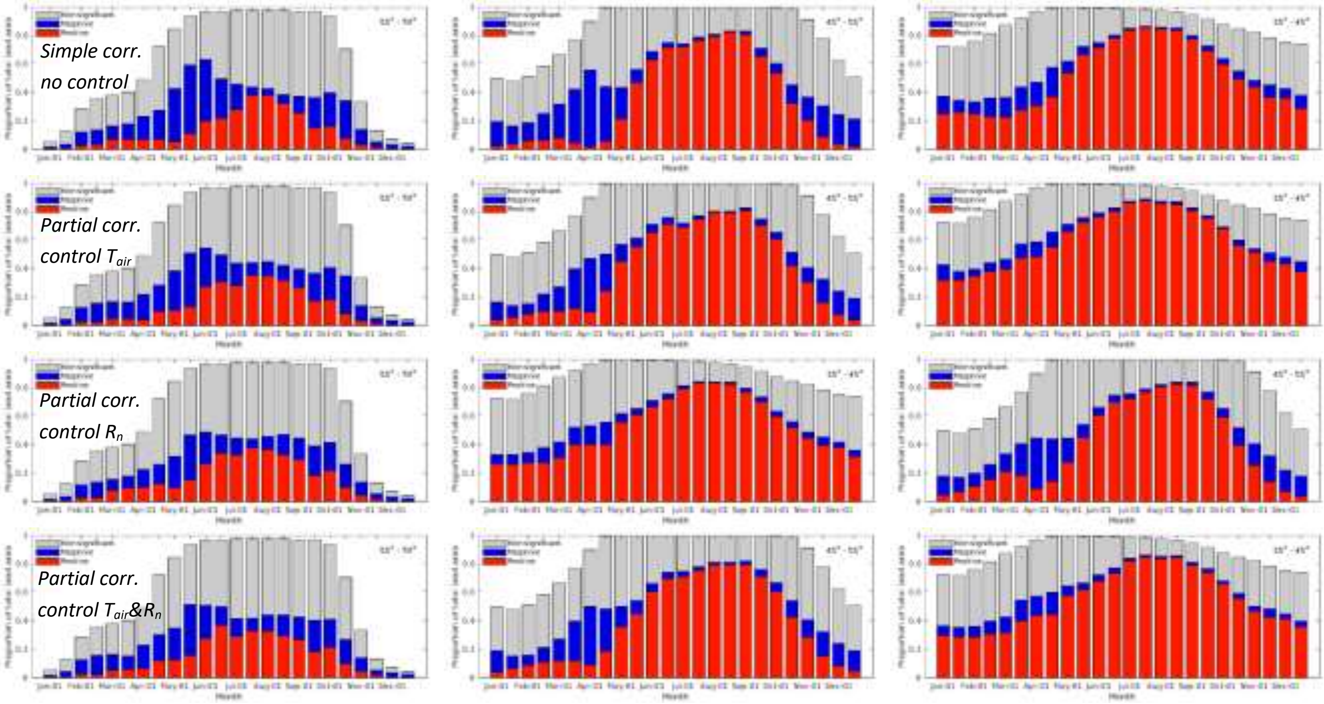


Figure 11. *The proportion of areas that has a strong correlation (significant at p⩽0.05, positive or negative) or no correlation (p>0.05) between PPI and SPEI on bimonthly step over three latitudinal zones of Europe biomes: north— 55°N to 70°N, middle— 45°N to 55°N, and south— 35°N to 45°N.*

This analysis shows that **meteorological drought hampered vegetation productivity during the peak growing season** but **promoted vegetation productivity at the start of the growing season**, when soil water availability (Figure 12) can still satisfy vegetation water demand (low water demand during the start of the season as evident by the low actual evapotranspiration). **The enhanced vegetation growth by meteorological drought is mainly due to either the elevated temperature** (in southern Europe) **or the increased radiation** (in middle Europe) along with reduced precipitation at the start of the growing season.

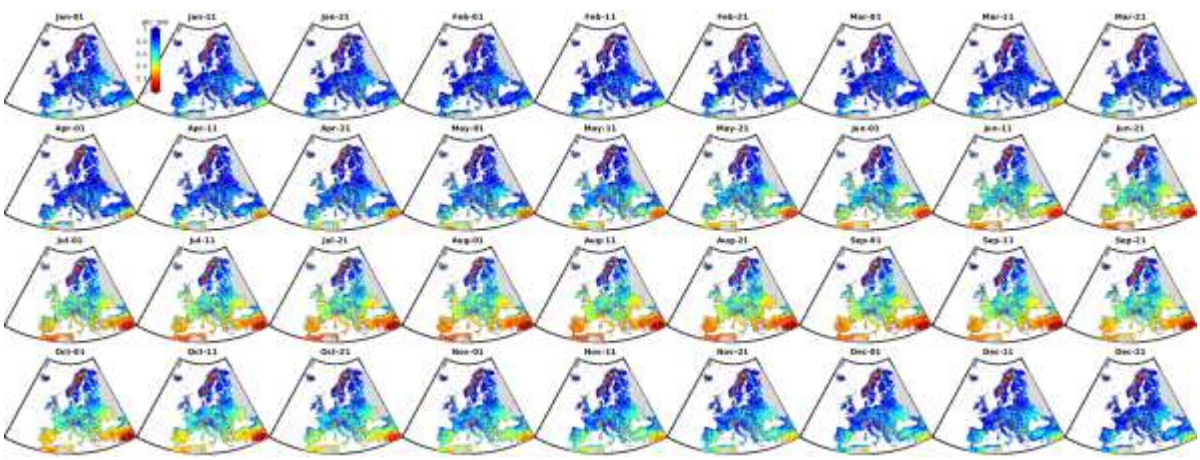


Figure 12. *Mean soil moisture index from 1995 to 2020 at dekad time step (from EDO Soil Moisture Index data)*

Our next step will be to summarize the PPI-SPEI association map and analyse how SPEI timescale (Figure 13) and time lag (Figure 14) were involved in drought -vegetation association.

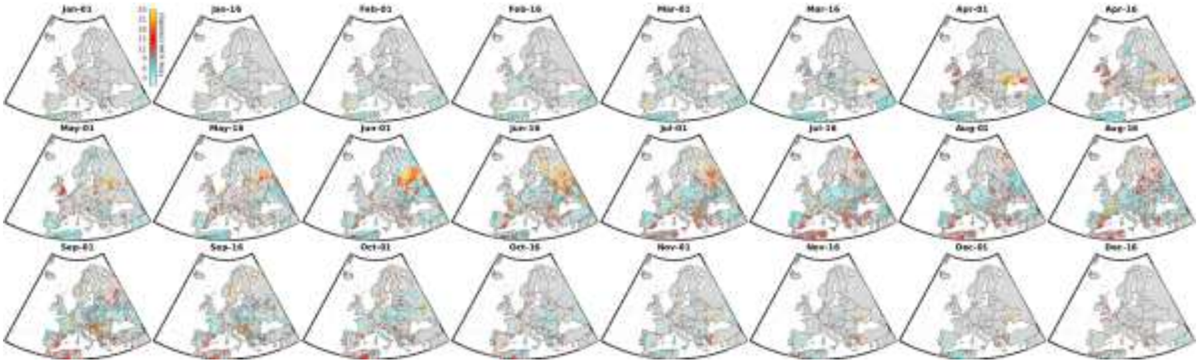


Figure 13. *The SPEI timescale with strongest partial correlation (significant at p⩽0.05, positive or negative) of PPI to SPEI on bimonthly time step, by controlling incoming net radiation of the same time scale.*

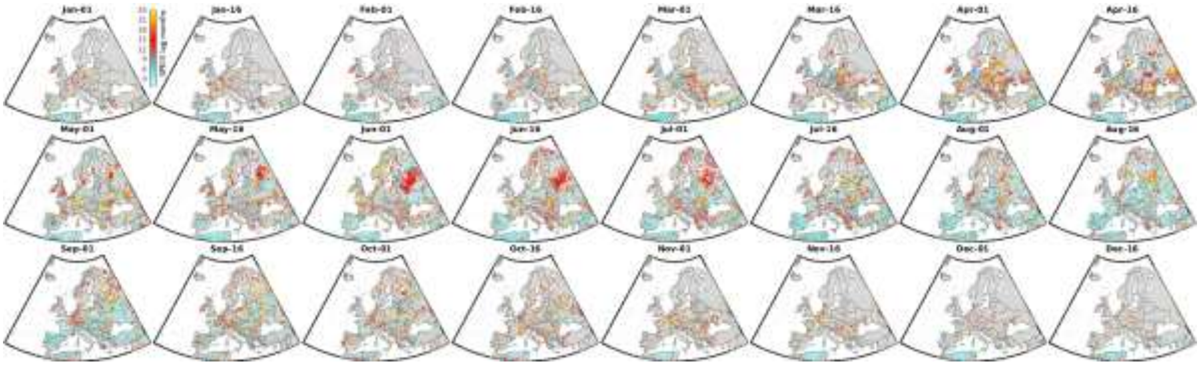


Figure 14. *The lag months of SPEI3 (3-month time scale of SPEI) that have the strongest partial correlation (significant at p⩽0.05, positive or negative) to PPI on bimonthly time step, by controlling incoming net radiation of the three months preceding PPI.*

Publications

Vicente-Serrano, S. M., Peña-Angulo, D., Murphy, C., López-Moreno, J. I., Tomas-Burguera, M., Domínguez-Castro, F., Tian, F., Eklundh, L., Cai, Z., Alvarez-Farizo, B., Noguera, I., Camarero, J. J., Sánchez-Salguero, R., Gazol, A., Grainger, S., Conradt, T., Boincean, B., & El Kenawy, A. (2021). The complex multi-sectoral impacts of drought: Evidence from a mountainous basin in the Central Spanish Pyrenees. Science of the Total Environment, 769, 144702.
https://doi.org/10.1016/j.scitotenv.2020.144702

Abstract: We analysed the impacts of drought severity on a variety of sectors in a topographically complex basin (the upper Aragón basin 2181 km2) in the Central Spanish Pyrenees. Using diverse data sources including meteorological and hydrological observations, remote sensing and tree rings, we analyse the possible hydrological implications of drought occurrence and severity on water availability in various sectors, including downstream impacts on irrigation water supply for crop production. Results suggest varying responses in forest activity, secondary growth, plant phenology, and crop yield to drought impacts. Specifically, meteorological droughts have distinct impacts downstream, mainly due to water partitioning between streamflow and irrigation channels that transport water to crop producing areas. This implies that drought severity can extend beyond the physical boundaries

of the basin, with impacts on crop productivity. This complex response to drought impacts makes it difficult to develop objective basin-scale operational definitions for monitoring drought severity. Moreover, given the high spatial variability in responses to drought across sectors, it is difficult to establish reliable drought thresholds from indices that are relevant across all socio-economic sectors. The anthropogenic impacts (e.g. water regulation projects, ecosystem services, land cover and land use changes) pose further challenges to assessing the response of different systems to drought severity. This study stresses the need to consider the seasonality of drought impacts and appropriate drought time scales to adequately assess and understand their complexity.

Grainger, S., Murphy, C., & Vicente-Serrano, S. M. (2021). Barriers and Opportunities for Actionable Knowledge Production in Drought Risk Management: Embracing the Frontiers of Co-production. Frontiers in Environmental Science, 9(April), 1–8. https://doi.org/10.3389/fenvs.2021.602128

Abstract: Drought risks pose serious threats to socio-ecological systems, built environments, livelihoods and human wellbeing. Managing these risks requires long-term collaboration between diverse groups with different values, interests and forms of knowledge. Funders, researchers and practitioners have increasingly advocated for collaborative models of knowledge production in which all participants recognise the multiple ways of understanding drought risk and strive to co-create knowledge for decision making. Such transdisciplinary research approaches aim to develop and sustain more equitable and meaningful interactions between scientific and societal actors, and have been shown to increase knowledge use and build resilience to climate variability. In practice, however, collaborations around drought remain largely science-driven and, as a result, can struggle to produce actionable knowledge necessary to better manage drought risk. This article draws from drought studies and related transdisciplinary fields to highlight common barriers inhibiting actionable knowledge production across a broad range of drought risk management contexts. We also propose opportunities for improved knowledge production that can guide researchers, practitioners and funders seeking to engage in transdisciplinary work. Diverse understandings of drought risk have hindered widespread advances in knowledge production and resilience building. We argue for multi-disciplinary researchers to come together with stakeholders and focus on creating inclusive and context-driven environments. While not appropriate or cost-effective in all situations, co-production between researchers, practitioners and other stakeholder groups offers opportunities for actionable management plans and policies that reflect the complex and contested problem framings and socio-ecological contexts in which droughts impact society.

Contact us

Project website: https://crossdro.csic.es/

Project coordinator: Sergio M. Vicente-Serrano, Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas

Avda Montañana 1005, 50059 Zaragoza, Spain Tel: +34 976369393 (ext. 880053)

E-mail: svicen@ipe.csic.es