ISSN 1831-9424

European Commission

JRC Technical Report

Drought in South America
April 2023

GDO Analytical Report

Copernicus Europe's eyes on Earth

Emergency Management Service

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2023

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JRC133788

EUR 31522 EN

PDF ISBN 978-92-68-03936-6 ISSN 1831-9424 doi:10.2760/873366 KJ-NA-31-522-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Toreti, A., Bavera, D., Acosta Navarro, J., Arias Muñoz, C., Barbosa, P., de Jager, A., Di Ciollo, C., Fioravanti, G., Grimaldi, S., Hrast Essenfelder, A., Maetens, W., Magni, D., Masante, D., Mazzeschi, M., McCormick, N., Salamon, P., Spinoni, J., *Drought in South America April 2023*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/873366, JRC133788.

Drought in South America - April 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - GDO data up to 28/04/2023

Drought in South America - April 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - GDO data up to 28/04/2023

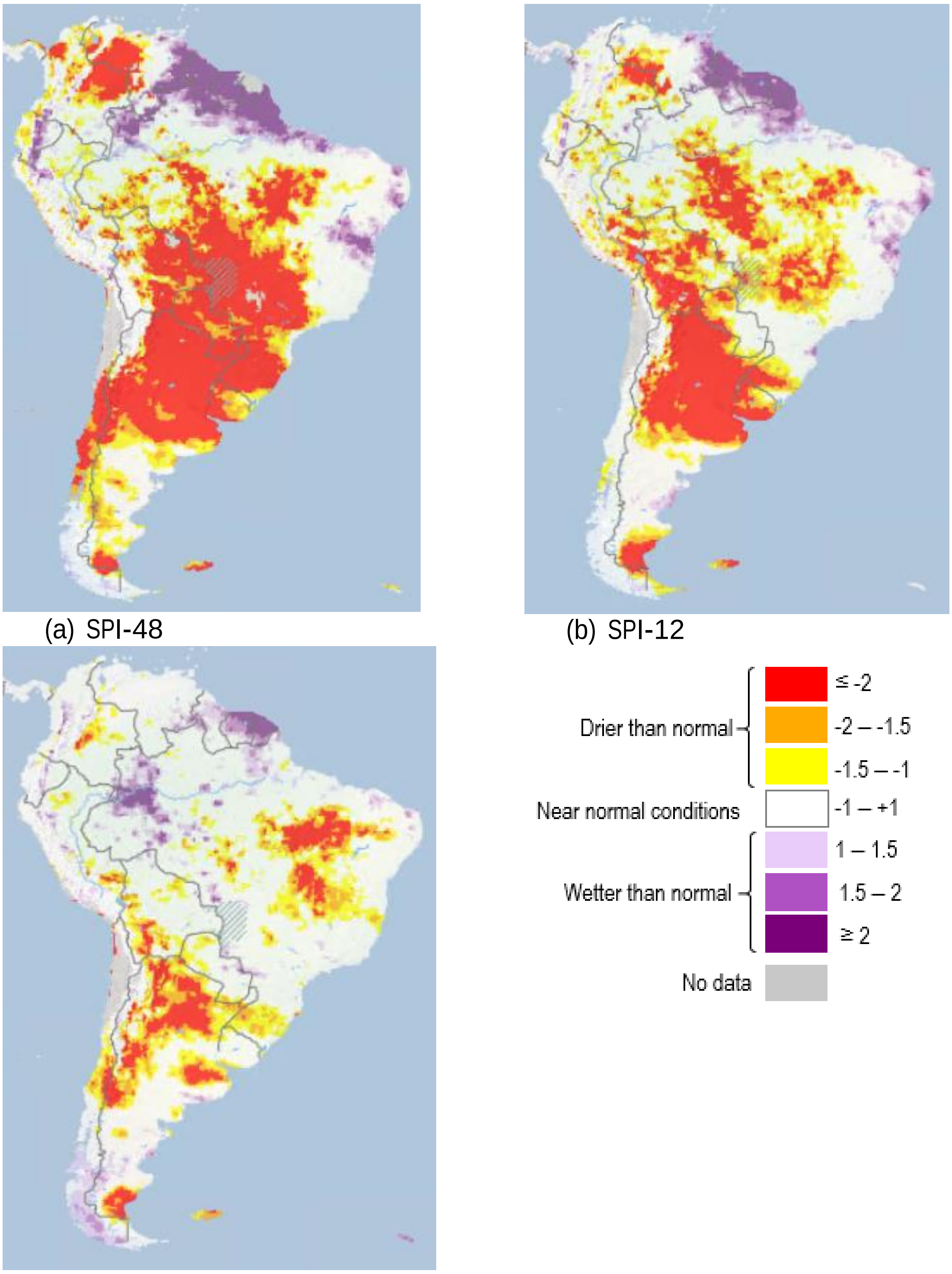
Executive summary

- Multi-annual precipitation deficits combined with above-average temperatures and a sequence of heatwaves are the cause of the long-running and extensive drought in central-southern South America.
- From August 2022 to March 2023 the drought has diminished in Brazil and moved southwards, now affecting mainly northern Argentina and Uruguay.
- Hydrology and vegetation are severely affected by the drought, with impacts on crops, rivers flow and energy production. Widespread impacts due to the drought can be linked to the estimated 3% GDP reduction in 2023 in Argentina.
- After three years of La Niña conditions, the tropical Pacific Ocean has entered neutral ENSO conditions and a transition to an El Niño phase is forecasted for the coming months.
- Seasonal forecasts point to warmer temperatures, close to average precipitation and lower than average river flows.

Standardized Precipitation Index (SPI)

Multi-annual negative anomalies of precipitation are currently affecting many parts of South America. The SPI-48 (i.e. SPI computed for an accumulation period of 48 months) shows extremely dry conditions in central Chile, Northern Argentina, Uruguay, Paraguay, eastern Bolivia, central-southern Brazil, and even northern Colombia (Fig. 1a). The SPI-12 (accumulation period of 12 months) shows that the past year has been exceptionally dry in northern Argentina, Uruguay, southern Bolivia and central Brazil (Fig. 1b). The SPI-3 (accumulation period of 3 months) shows that precipitation has been absent in northern Argentina and Uruguay, while the lack of precipitation has also affected north-eastern Brazil, central Colombia, northern Peru, and southern Bolivia in the last three months (Fig. 1c).[1]

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



(c) SPI-3

Figure 1: Standardized Precipitation Index SPI-48 (a), SPI-12 (b), and SPI-3 (c), respectively for the 48-, 12-, and 3-month accumulation periods ending in March 2023.[1]

The lack of precipitation is visible in the annual sequence of the June SPI-12 indicator from 2014 to 2022 (Fig. 2). The multi-annual drought began in late 2019 in central-southern Brazil, Paraguay and northern Argentina[2]. By June 2021, it had extended northwards, to include the whole of central Brazil, and, with a lower intensity, southwards, in more parts of northern Argentina and Uruguay. By June 2022, much needed rainfall reduced or counterbalanced the negative precipitation anomaly in central Brazil, while drought conditions persisted in central-northern Argentina and Paraguay. The years 2020, 2021 and 2022 show a very strong negative SPI-12 anomaly, pointing to a wide and persistent drought event over most of central / central-southern South America. Extremely dry conditions have also been observed in Bolivia and Venezuela, but with smaller extent and lower persistence, with a full recovery in 2021.

The 2019-2023 drought event is likely to be one of the most significant in South America in recent decades, both in terms of extent and duration. Another wide and extremely dry event occurred in 2015-2016 in central-northern Brazil (June 2016 map in Fig. 2), but distinct from the ongoing multi-annual drought, since more variable and close to normal precipitation conditions were observed from 2017 to 2019 (Fig. 2).

[2] For detailed analysis read also the following GDO analytical reports:
Extreme and long-term drought in the La Plata Basin: event evolution and impact assessment until September 2022
https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202301_La_Plata_Basin.pdf;
Droughts in South America - 10 years overview, December 2021
https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202112_South_America_10-year_overview.pdf;
The 2019-2021 extreme drought episode in La Plata Basin
https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202109_La_Plata_Basin.pdf;
Drought in centre-south Brazil – June 2021 https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202106_Brazil.pdf;
Drought in Great Chaco and Paraguay basin – April 2020
https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202004_Great_Chaco_and_Paraguay_basin.pdf;
Drought in Argentina / Uruguay – April 2018
https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews201804_Argentina_Uruguay.pdf;

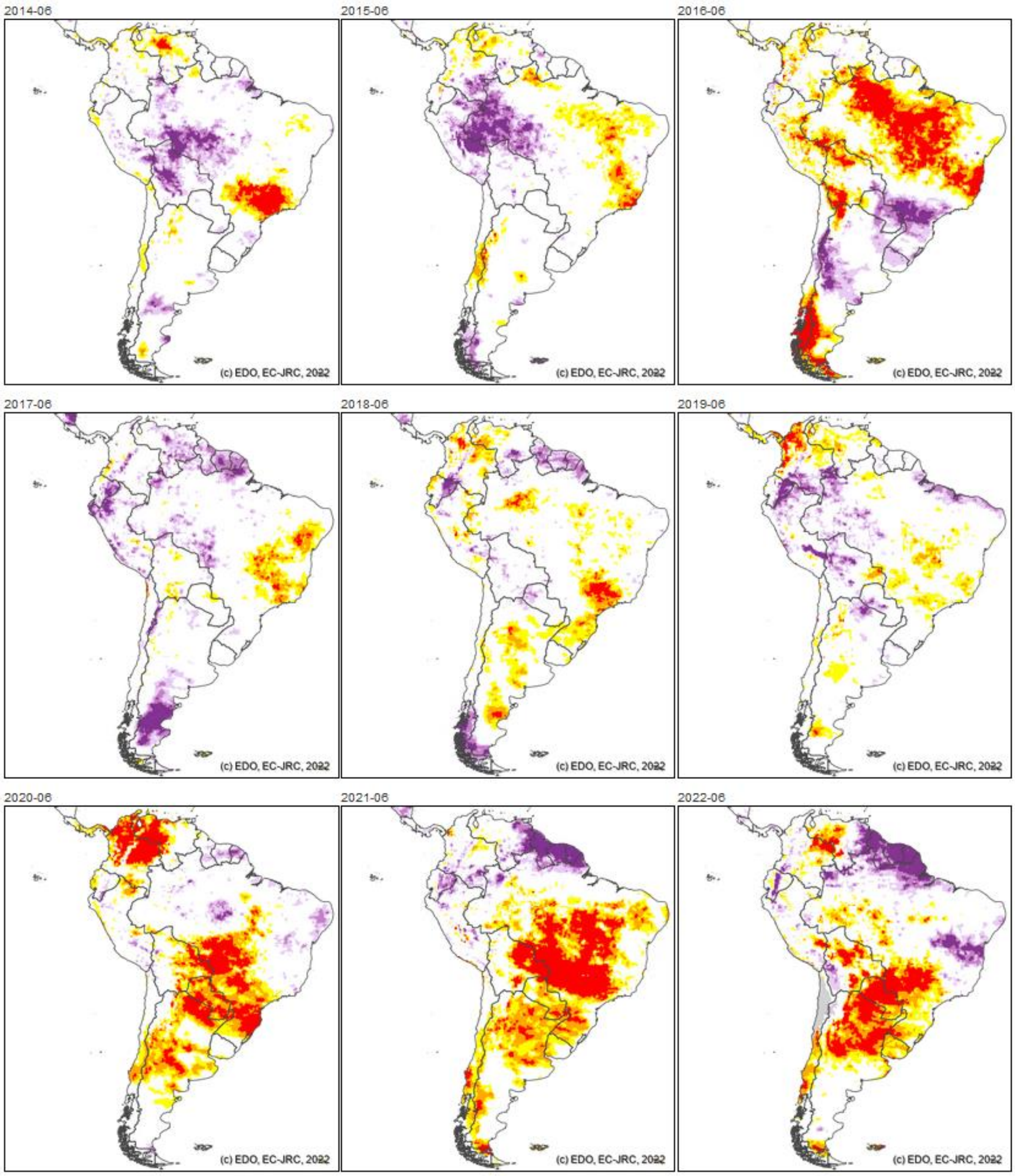


Figure 2: Standardized Precipitation Index SPI-12, for the 12-month accumulation periods ending on June from 2014 to 2022.[1]

As is shown in Fig. 3, the period from July 2022 to March 2023 has seen a severe and persistent lack of precipitation. Wide and persistent extremely dry anomalies are visible from October-November 2022 to January 2023 in Peru, Bolivia, northern Argentina, and Uruguay. As can be seen, from February to March 2023 the driest regions are concentrated in Northern Argentina. Paraguay and Brazil show more variable conditions, with extremely dry peaks alternated with close to normal conditions. In Brazil, a clear improvement is visible in Minas Geiras (western Brazil) since September 2022, as well as in Amazonas since December 2022. Fluctuating conditions between normal and dry anomalies are observed in central Brazil, but no deficit recovery, and a possible new dry wave is appearing in the north-eastern region. Improving precipitation conditions are detected in the far south, bordering with Paraguay.

A more detailed spatial and temporal analysis shows how the multi-annual drought event might be seen as the result or summation of many smaller sub-events, affecting different regions of the continent. However, the persistent lack of precipitation and the presence of climatic dry regions in the same watershed (the La Plata Basin) make it more reasonable to consider all sub-events as a single drought event, also in terms of their impacts.

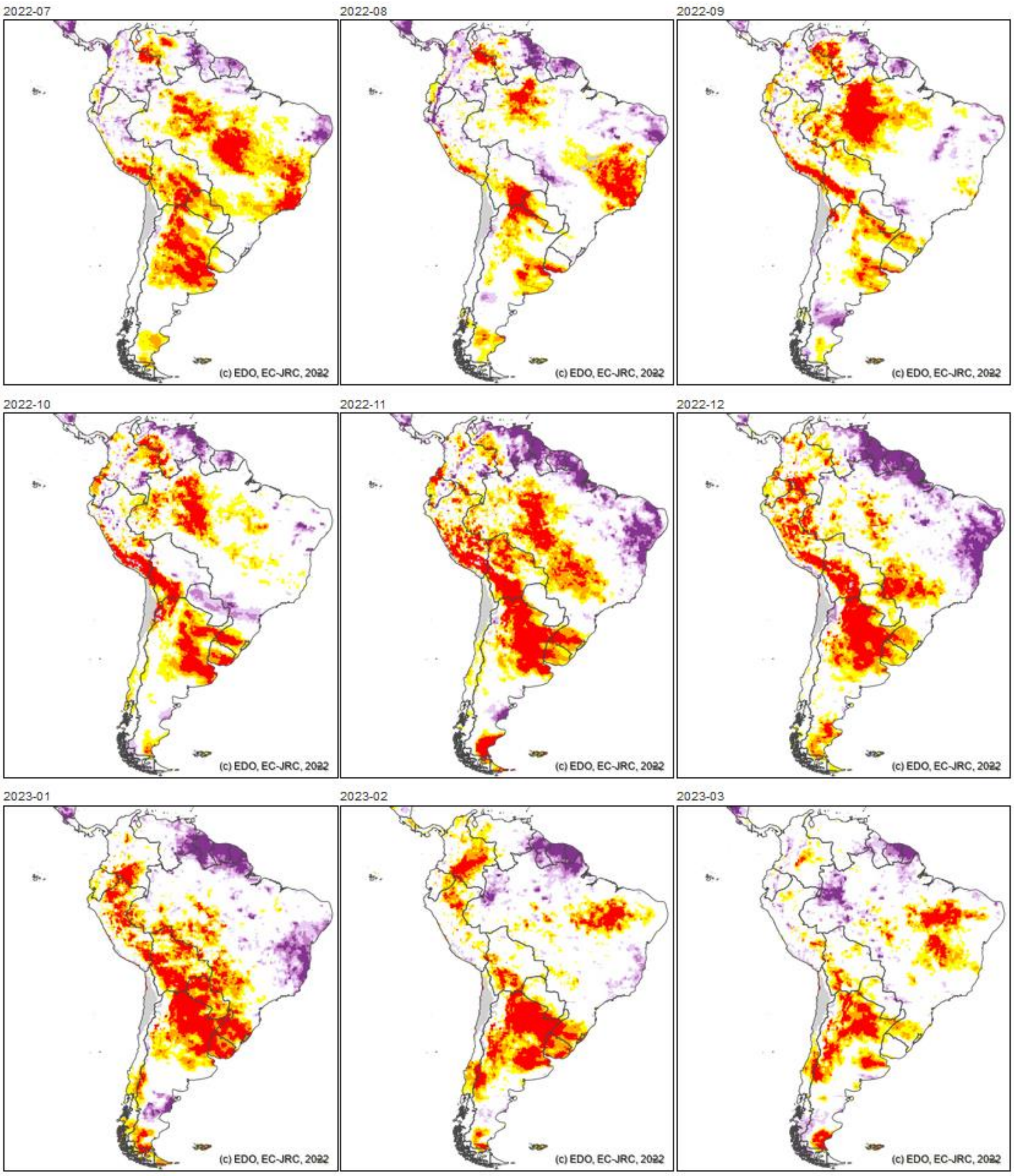


Figure 3: Standardized Precipitation Index SPI-3, for the 3-month accumulation periods ending on each month from July 2022 to March 2023.[1]

The La Plata basin multi-annual drought event has covered areas including southern and central-eastern Brazil, northern and central Argentina, Paraguay, and Bolivia. An estimate of the spatial and temporal dynamics of the drought can be achieved using a recently developed method for drought events tracking based on a generalized three-dimensional density-based clustering algorithm (DBSCAN)[3]. The application of this algorithm allows to identifying areas which were under drought conditions at least once since 2019 (Fig. 4).

Figure 4: Total extent of the multi-annual La Plata drought event, identified using a recently developed method for spatio-temporal tracking of drought events based on the DBSCAN density-based spatial clustering algorithm.[3] Data source: SPI data derived from the ERA5 precipitation reanalysis.

Temperature

Most of central-southern South America experienced prolonged above-average temperatures from November 2022 to March 2023. On 20th December 2022, the 30-day average temperature anomaly (baseline 1989-2021) ranged from 3 °C to 6 °C above normal for central-northern Argentina, while anomalies generally ranged between 1 °C and 3 °C elsewhere in Argentina and Uruguay (Fig. 5 - left).

A subsequent more severe heatwave affected the same regions with similar spatial patterns, as shown by the 30-day average temperature anomaly on 20th March 2023 (Fig. 5 - right).

These long-lasting and intense heatwaves worsened the effect on soil moisture content of the precipitation deficit.

[3] Cammalleri, C., and A. Toreti, 2023: A Generalized Density-Based Algorithm for the Spatiotemporal Tracking of Drought Events. J. Hydrometeor., 24, 537–548, https://doi.org/10.1175/JHM-D-22-0115.1.

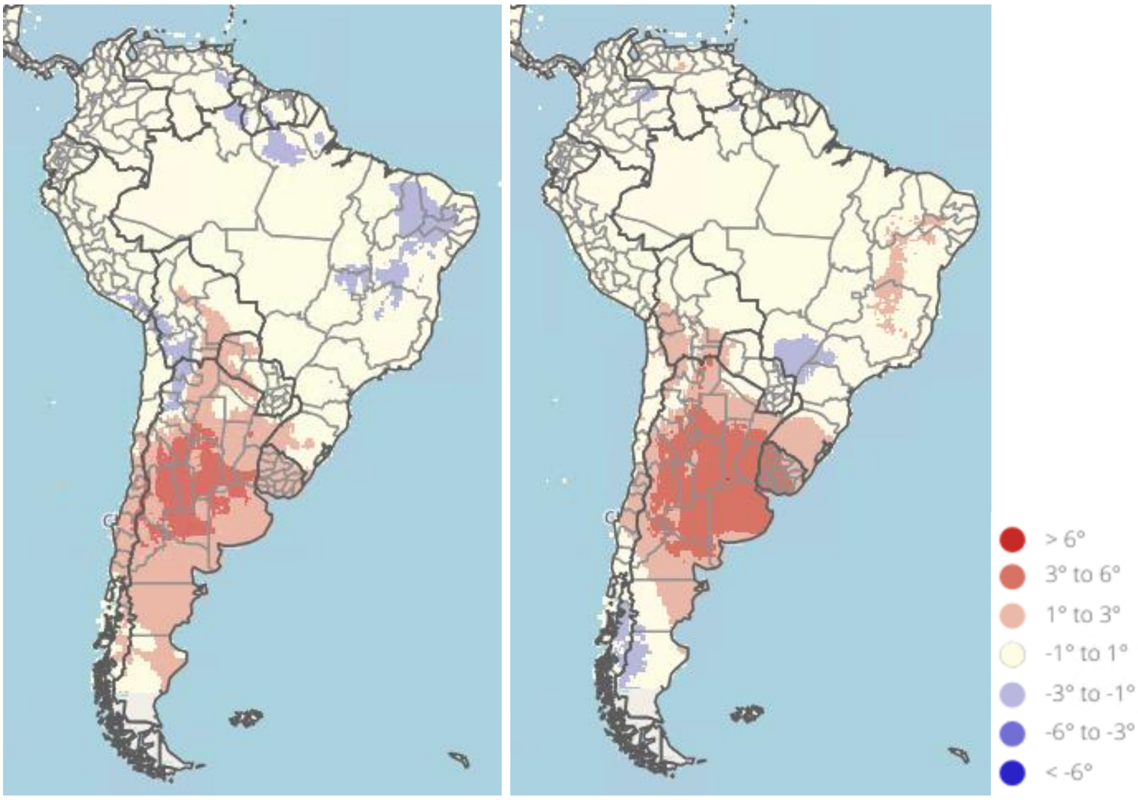


Figure 5: *30-day moving average temperature anomaly (ERA5) for 20th December 2022 (left) and 20th March 2023 (right). Source: The JRC's ASAP (Anomaly Hotspots of Agricultural Production) global early warning system.*[4]

Soil moisture

At the end of March 2023, the Soil Moisture Anomaly was remarkably negative in central-northern Argentina, Uruguay, central Brazil, southern Bolivia, southern Peru, and southern Argentina (Fig. 6). This is the result of a combination of low precipitation and high temperatures in the previous months. The drier than normal soil moisture pattern is consistent with the precipitation deficit of the previous months (i.e. SPI-3, see Fig. 1c and Fig. 3 - last panel). Therefore, the regions with the strongest precipitation anomalies were also affected by high temperatures, which contributed to accelerate the water loss from the soil. Large areas show a Soil Moisture Anomaly below -2 (corresponding to the driest class of the GDO indicator, Fig. 6).[5]

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[4] The JRC's Anomaly Hotspots of Agricultural Production (ASAP) online decision support system for early warning about hotspots of agricultural production anomaly (crop and rangeland): https://mars.jrc.ec.europa.eu/asap/

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

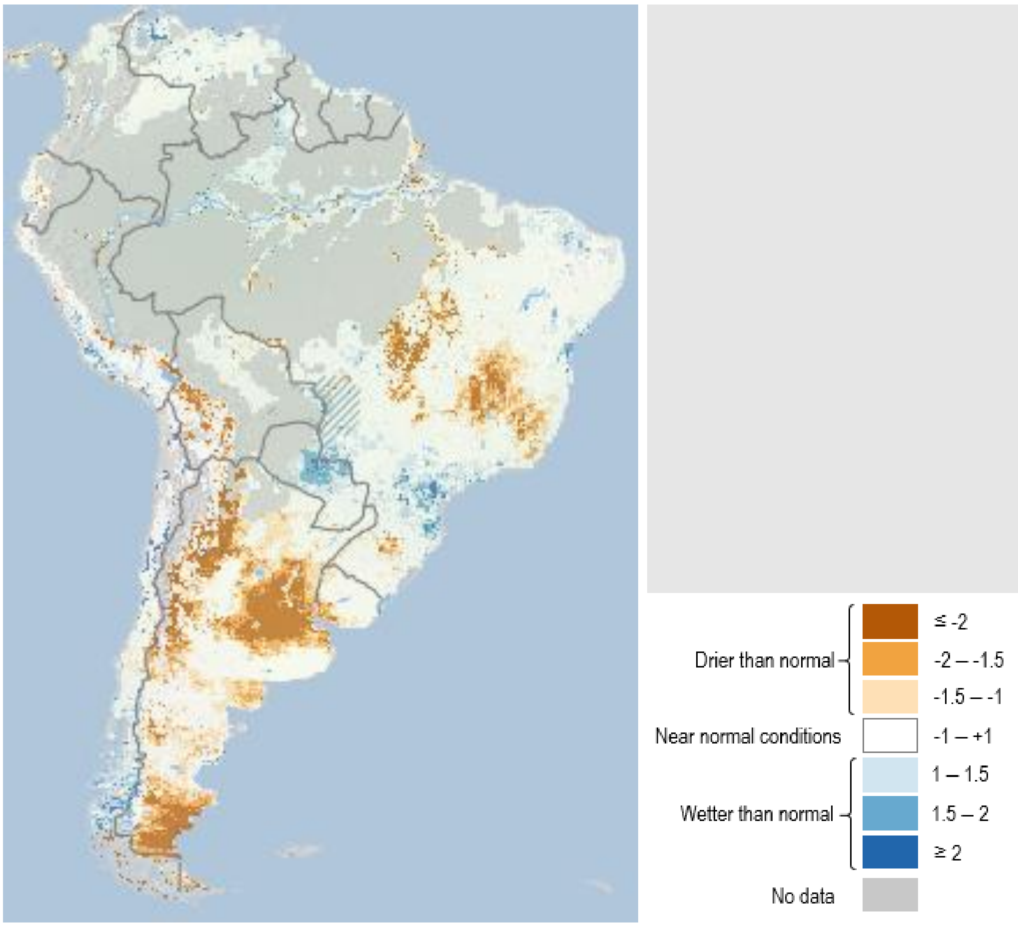

Figure 6: *Soil Moisture Anomaly, end of March 2023.* [5]

The evolution of the Soil Moisture Anomaly, as shown in Fig. 7, starts with a phase affecting central regions (March to May 2022), then the most affected regions moved towards central northern Brazil (May to July 2022), and then, after a short improvement (August 2022), moved further south to Peru, Bolivia, and finally to northern and central Argentina and Uruguay (from September 2022 to February 2023). In the last months a strong persistence and severity of the Soil Moisture Anomaly over northern Argentina and Uruguay can be seen.

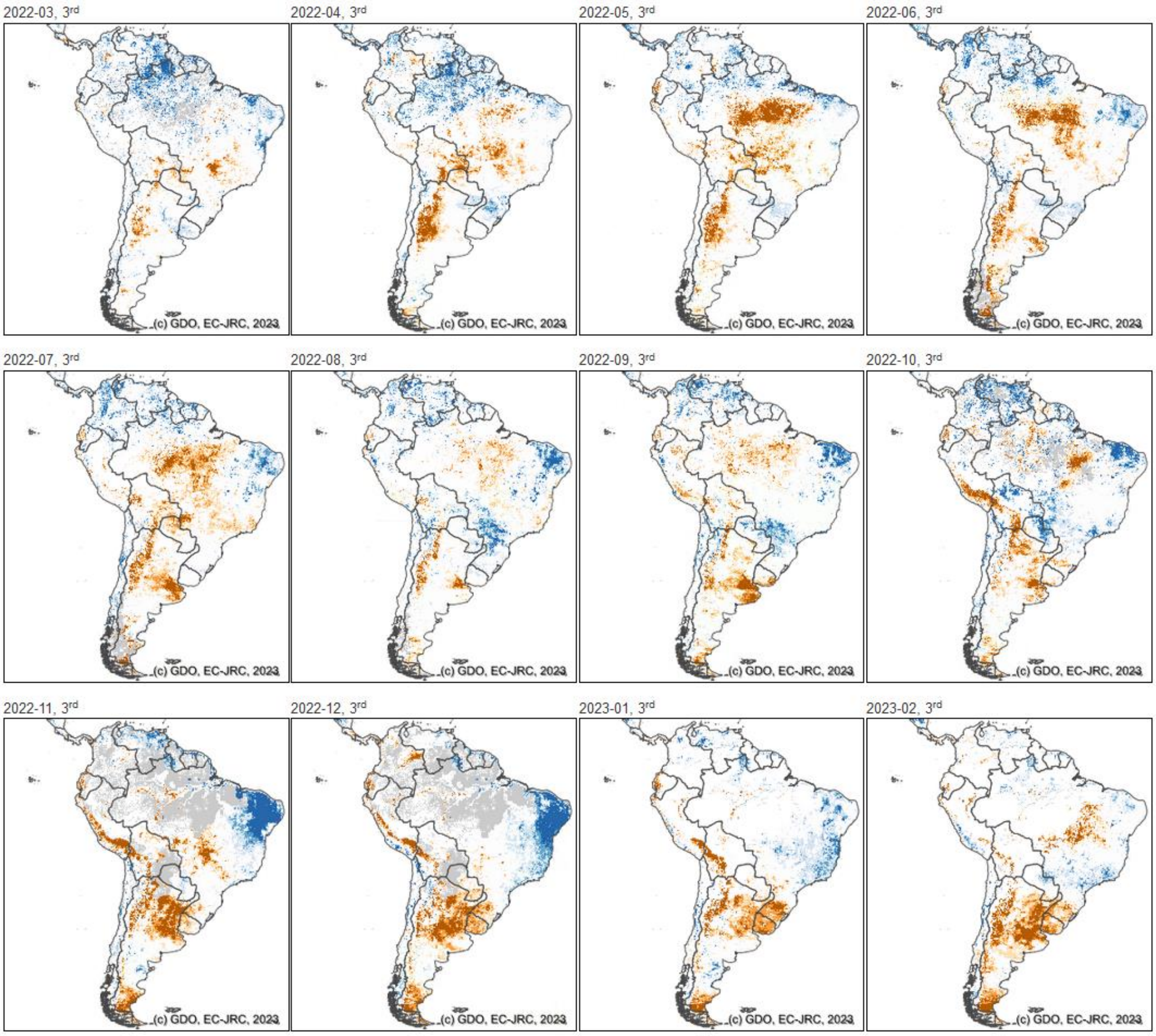

Figure 7: *Soil Moisture Anomaly, from March 2022 to February 2023.*[5]

The Total Water Storage (TWS) Anomaly indicator is used for determining the occurrence of long-term hydrological drought conditions and is often used as a proxy of substantial lowering of the groundwater level. This indicator is computed as anomalies of TWS data derived from the GRACE (Gravity Recovery and Climate Experiment) twin satellites.[6]

The TWS anomaly has a good correlation with long-term SPI (12, 24, 48 months).[7] In December 2022, large areas of South America were suffering from severe negative anomalies (Fig. 8).[8]

[6] Landerer, F.W.; Swenson, S.C. Accuracy of scaled GRACE terrestrial water storage estimates. Water Resour.Res. 2012, 48, W04531

[7] Cammalleri, C., Barbosa, P., Vogt, J.V. 2019. Analysing the Relationship between Multiple-Timescale SPI and GRACE Terrestrial Water Storage in the Framework of Drought Monitoring. Water 11(8), 1672. https://doi.org/10.3390/w11081672.

[8] For more details on the GRACE-derived Total Water Storage (TWS) Anomaly indicator, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

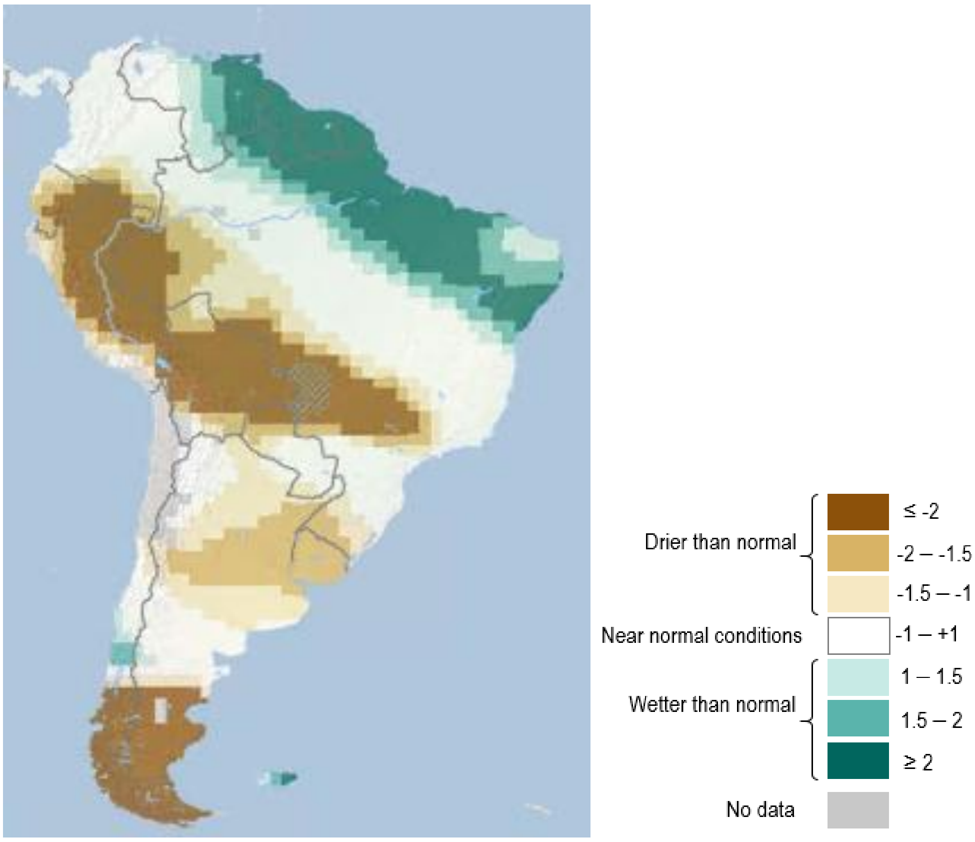

Figure 8: *GRACE-derived Total Water Storage (TWS) Anomaly, for December 2022.*[8]

As is shown Fig. 9, the evolution of TWS anomaly during 2022 resembles that observed for Soil Moisture Anomaly. In January and February 2022, previous dry conditions were reducing and improving. From March to December 2022, a dry spot centred at the border between Brazil, Paraguay, and Bolivia started and has been always increasing in size and severity, reaching the maximum at the end of 2022, covering Peru, Bolivia, northern Paraguay, southern Brazil, Uruguay and northern Argentina. As can be seen, the northern regions of the continent have been almost constantly wetter than normal. Conversely, Patagonia has constantly been drier than normal.

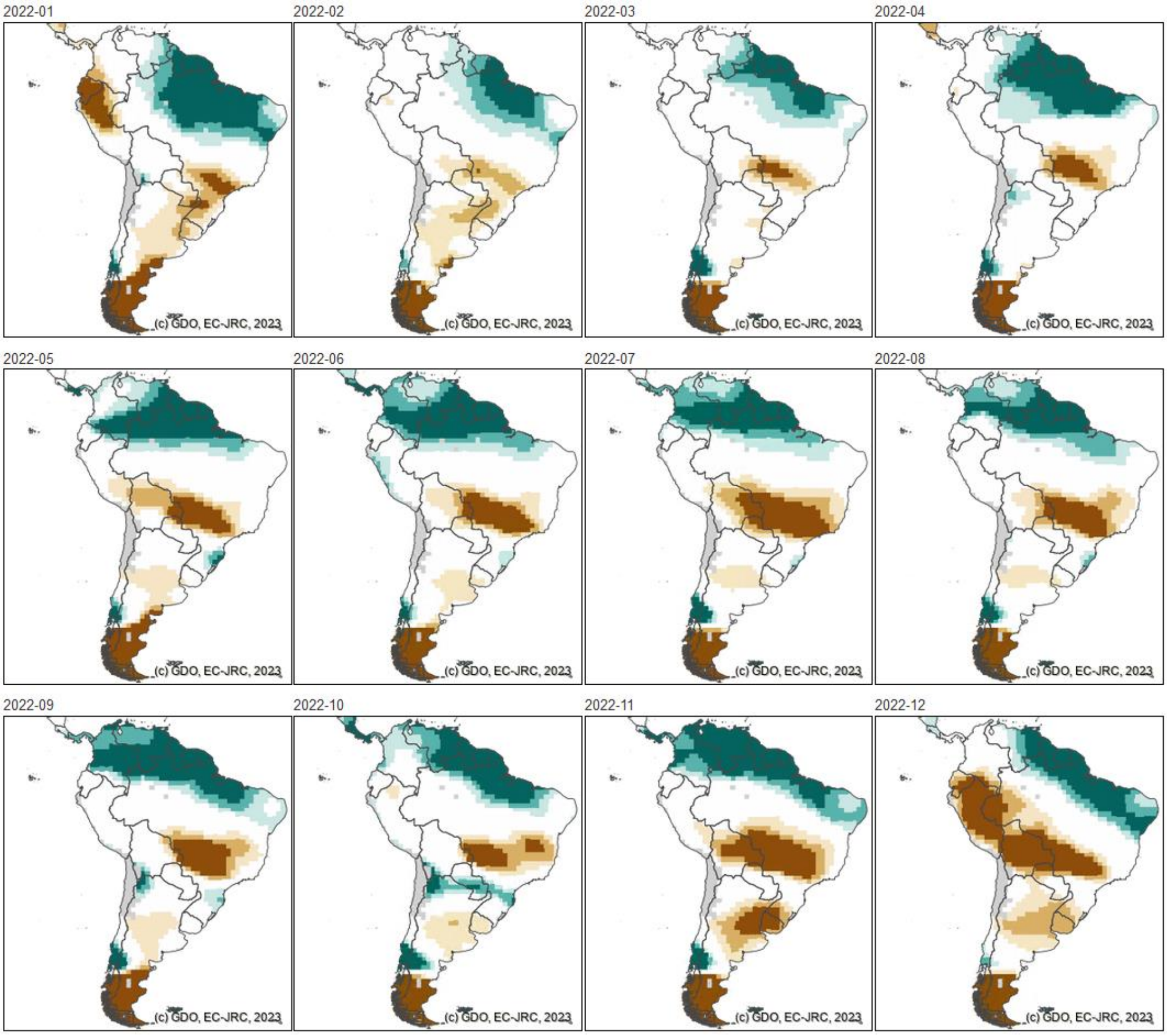

Figure 9: *GRACE-derived Total Water Storage (TWS) Anomaly, from January to December 2022.*[8]

Vegetation biomass

At the end of March 2023, the satellite-derived fAPAR anomaly indicator shows severe vegetation stress over Uruguay, northern Argentina, and southern Patagonia, as shown in Fig. 10. As can be seen, more sparse and less severe conditions affect central Brazil, central Chile, and at the border between Peru and Bolivia. These critical and widespread conditions are due to the combined severe lack of precipitation and higher than normal temperatures.

The evolution of the fAPAR anomaly from April 2022 to March 2023, shown in Fig. 11, indicates a slow but progressive worsening of the vegetation stress, starting from northern Brazil (April 2022) and expanding to wider regions, including central Brazil and Paraguay by July 2022. The widest extent of negative anomalies was reached in August 2022, when almost the entire continent was affected by poor vegetation development. Afterwards, the situation slowly improved, but from November 2022 to March 2023 again a persistent and wide spot of vegetation stress covered northern Argentina southern Bolivia, Uruguay, and Paraguay. In March 2023 also central Brazil entered negative fAPAR anomaly domain.[9]

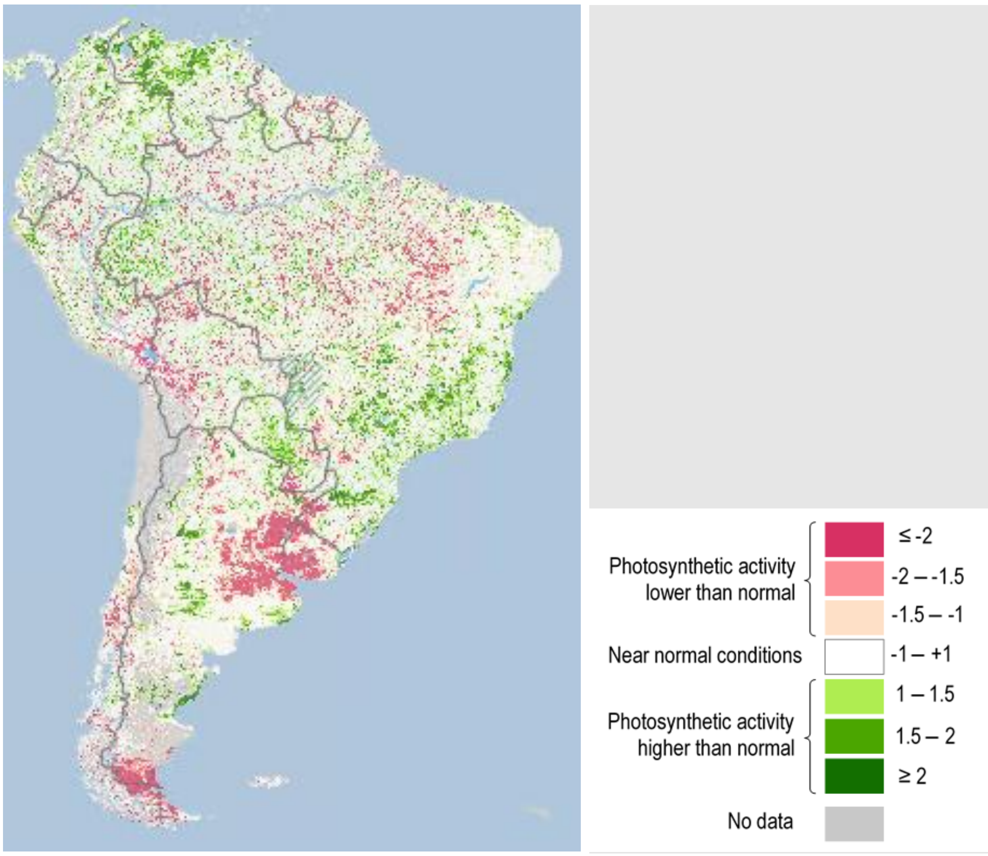

Figure 10: *Satellite-derived fAPAR anomaly indicator, measuring photosynthetic activity of vegetation, at the end of March 2023.*[9]

[9] For more details on the satellite-derived fAPAR anomaly indicator, and the other GDO and EDO indicators of drought-related information used in the report, see the Appendix at the end of the document.

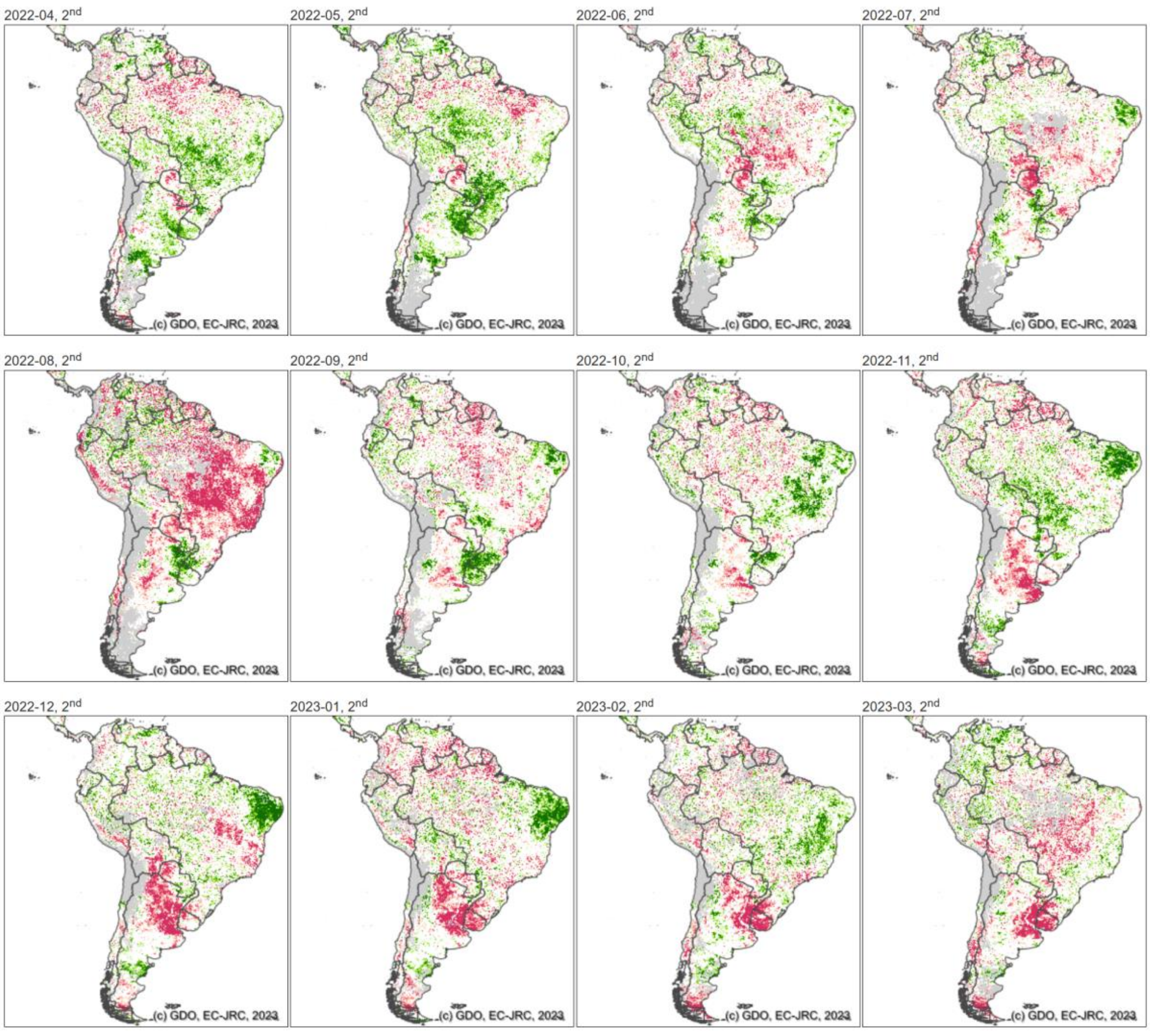

Figure 11: *Satellite-derived fAPAR anomaly indicator, measuring photosynthetic activity of vegetation, at the end of each month from April 2022 to March 2023.*[9]

Large-scale atmospheric conditions

The El Niño Southern Oscillation (ENSO) and the Antarctic Oscillation are major large-scale drivers of precipitation variability on seasonal timescales in south-eastern South America. Since early 2020, ENSO has been in a negative phase (La Niña), while the Antarctic oscillation has been in a positive phase (Fig. 12), both of which drive below average precipitation in the region. Based on the results from a composite analysis, La Niña's impact is most pronounced during the austral spring (September-November), while the Antarctic Oscillation has the strongest effect during the austral (or southern hemisphere) spring and summer, still with small influence in the austral autumn (Naumann et al., 2023[10]). Furthermore, the non-linear interaction of La Niña with a positive Antarctic Oscillation during the austral spring appears to be crucial in reducing rainfall in

[10] European Commission, Joint Research Centre, Naumann, G., Podestá, G., Marengo, J., et al., *Extreme and long-term drought in the La Plata Basin : event evolution and impact assessment until September 2022 : a joint report from EC-JRC, CEMADEN, SISSA and WMO*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2760/62557

south-eastern South America (Hu et al., 2022[11]). It is also worth noting that despite a decaying of La Niña into a neutral phase during 2023, and possibly transitioning into El Niño in the coming months (based on Copernicus C3S seasonal Forecasts), the Antarctic Oscillation reached extremely high values in the end of 2022 and beginning of 2023. These values have only been observed three times in the past four decades (Fig 12). The intensification of the drought in the past months also coincides with this intensification of the Antarctic oscillation.

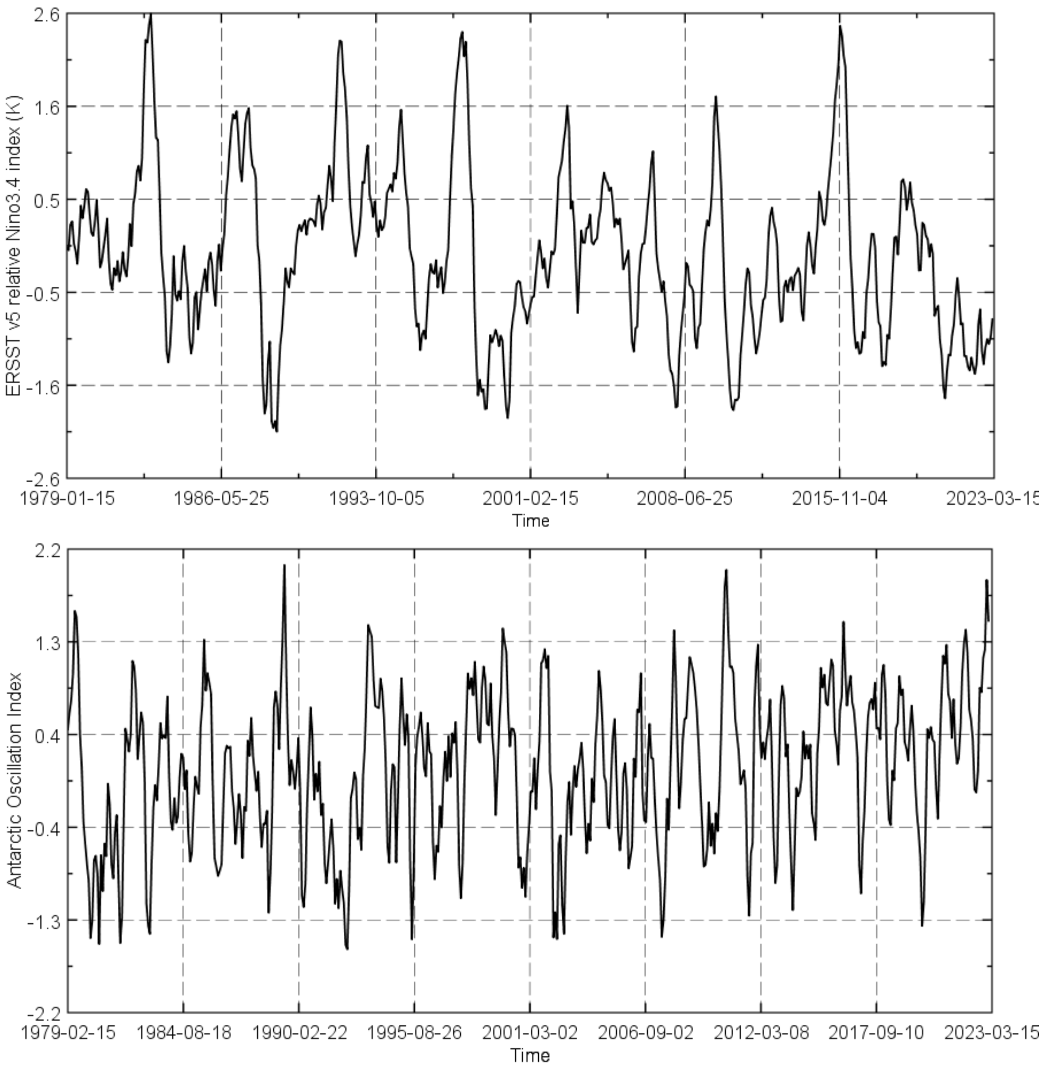

Figure 12*: Monthly mean NINO3.4 relative index (Top, ERSSTv5[12]) and 3-month running average of Antarctic Oscillation Index (Bottom, CPC/NOAA[13]):*

[11] https://link.springer.com/article/10.1007/s00382-022-06592-8

[12] https://iopscience.iop.org/article/10.1088/1748-9326/abe9ed

[13] https://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aao/month_aao_index.shtml

Seasonal forecast

From May to July 2023, drier than average conditions (baseline 1981-2016) are predicted in northern Argentina, Uruguay, and Peru, as shown in Fig. 13. Close to average or slightly wetter conditions are predicted for Brazil and Bolivia. Close to average conditions are predicted for northern and southern South America. According to Copernicus C3S seasonal forecasts[14], up to June 2023, warmer than usual conditions are likely in South America, with large positive anomalies. Precipitation forecasts are close to average conditions and predict drier conditions most likely for northern Brazil, but showing some variability between models. Close monitoring is required to better understand the impacts expected for the coming seasons.

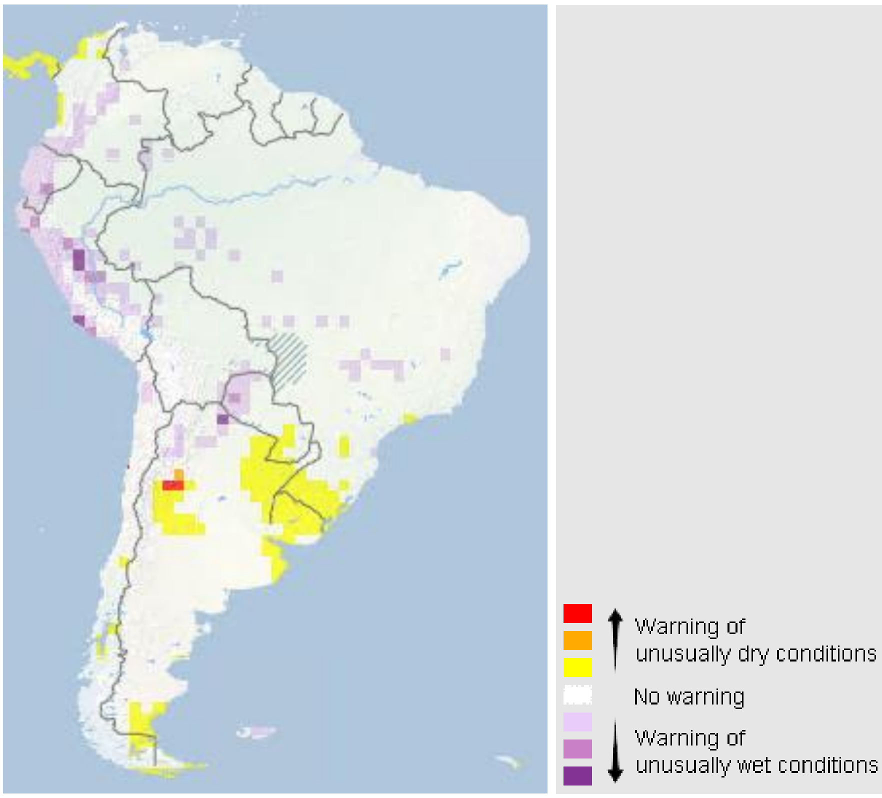

Figure 13: *Indicator for Forecasting Unusually Wet and Dry Conditions, May-July 2023 (based on ECMWF SEAS5).*[15]

The probability of occurrence of low flows for rivers from March to June 2023 is high, mainly in central South America, as shown in Fig. 14.[16]

The prolonged lack of precipitation, the severe heatwaves, and the warmer than average forecast are likely to cause a further reduction of river flows, with direct impacts on agriculture, ecosystems and energy production. Water resource management should be cautiously planned to limit impacts and identify adaptation strategies.

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

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

[16] The analysis is based on the LISFLOOD hydrological model outputs driven by 51 ensemble members of the ECMWF SEAS5 forecast. For more information on LISFLOOD: De Roo et al., 2000. Physically based river basin modelling within a GIS: the LISFLOOD model. Hydrological Processes, 14, 1981–1992.

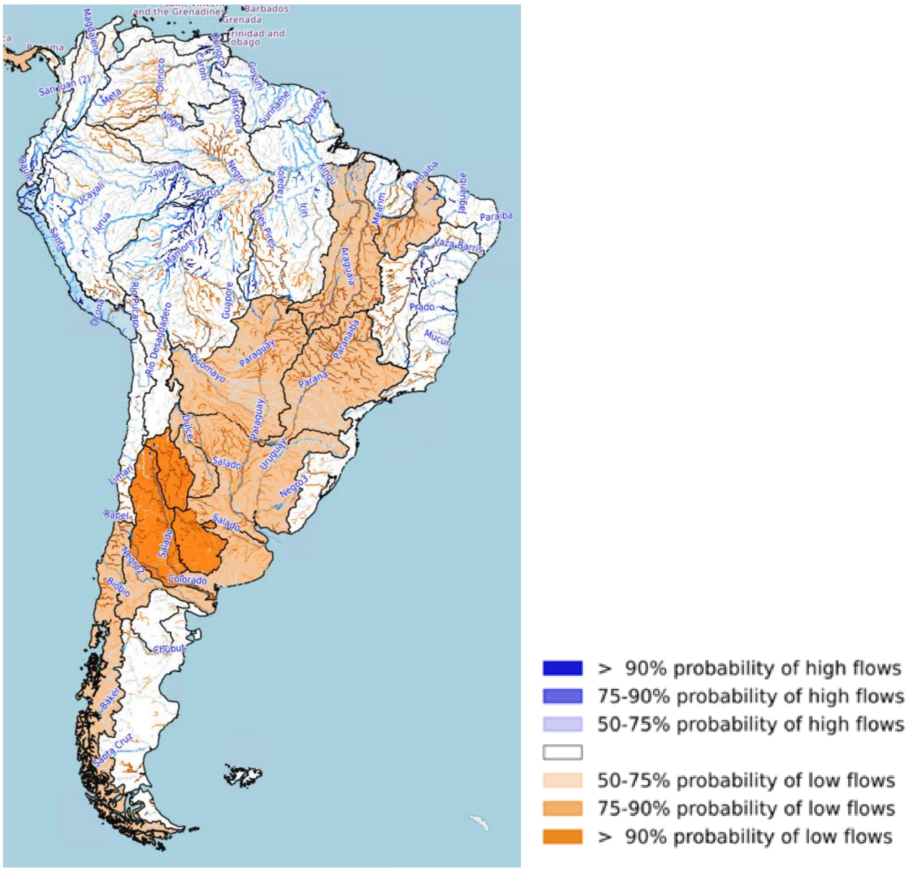

Figure 14: *Maximum probability [%] of high (> 80th percentile) or low (< 20th percentile) river flow during the 4-month forecast horizon for basins and river network, issued on 1st April 2023. Source: CEMS Global Flood Awareness System (GloFAS) https://www.globalfloods.eu.*

Reported impacts

The multi-annual drought – which started during 2019, due to the severe lack of precipitation, and exacerbated by sequences of heatwaves - is having severe impacts on the economy, agriculture, energy, transportation, fires, and ecosystem of South America. [17]

In the last four months of 2022, precipitation amounts in Uruguay have been less than half of the average, corresponding to the lowest rainfall in 35 years and leading the country to declare an agricultural emergency in October 2022. [18]

Argentina experienced eight consecutive heatwaves in the warm season according to Argentina's National Meteorological Service[19]. The lack of rain hit for the third consecutive year a large part of the Argentinian

[17] For a detailed analysis see also: https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202301_La_Plata_Basin.pdf

[18] https://public.wmo.int/en/media/news/heat-and-drought-bite-large-parts-of-south-america

[19] https://www.smn.gob.ar/

agricultural area. Damages to crops, livestock, regional economies and forestry activity were reported during 2022/2023.[20]

According to the Argentinian National Drought Monitoring Table, drought conditions are having a strong impact on the livestock sector, including depletion of forage, problems for watering the cattle and poor body condition.[21]

The Argentinian government is giving subsidies to meat producers to compensate the impacts of the drought. With this measure, the national government aims at ensuring the availability of meat for local consumption and contributing to the mitigation of increased food prices.[22]

In Argentina, the 2023 soybean production is expected to be 44% lower than the average of the preceding five years, while total wheat production is expected to be 31% lower with respect to the previous year.[23] Overall, 2022/23 production is expected to be the lowest in 20 years.[24]

Argentina soy harvest is forecasted to be the lowest since 2000, and the soy yield could be the worst since 1988/89. Drought is affecting the Argentinian economy by drastically reducing export income, increasing the risk of the country to fail achieving the targets previously agreed with the International Monetary Fund. [25]

According to the Rosario Stock Exchange (Bolsa de Comercio de Rosario) only considering soybean, wheat and corn (87% of grain production in Argentina and 43% of the country's total exports, as an average of the last 3 years) the losses for the producing sector exceed US$ 14,140 million dollars. The total losses for national economic activity amount to US$ 19,000 million. The drought has already reduced by 3 percentage points the estimated Argentine GDP for the year 2023.[26]

The multi-annual drought event and the sequence of warm and dry years in South America has contributed to the depletion of glaciers in the Andes. About 30-50 per cent of the ice cover in the Andes has been lost over the last 40 years, while some glaciers have disappeared completely. The reduction or disappearance of the tropical glaciers of the Andes is exacerbating water shortages caused by the current drought and hampering hydro-electric power generation across lowland communities, home to hundreds of millions of people.[27]

[20] https://www.clarin.com/rural/sequia-santa-fe-provincia-afectada-pais-perdidas-usd-4-290-millones_0_2UQ26m5zDd.html

[21] https://www.magyp.gob.ar/sitio/areas/d_eda/sequia/

[22] https://www.clarin.com/rural/14-976-millones-dolar-soja-gobierno-asistira-ganaderos-asegurar-oferta-carne_0_sSTVLtK1Nk.html

[23] https://apnews.com/article/argentina-drought-farms-6a4581685e448bef697e30370a42afd8

[24] https://www.clarin.com/rural/ventas-soja-campana-2022-23-bajas-20-anos_0_oItWa7NYLT.html

[25] https://www.reuters.com/business/environment/argentinas-unprecedented-drought-pummels-farmers-economy-2023-03-09/

[26] https://www.bcr.com.ar/es/mercados/mercado-de-granos/noticias/el-costo-de-la-sequia-202223-ya-asciende-mas-de-us-14140

[27] https://www.unep.org/news-and-stories/story/shrinking-glaciers-upend-lives-across-south-america

Appendix: GDO and EDO indicators of drought-related information

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

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

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

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

Check https://edo.jrc.ec.europa.eu/factsheets for more details on indicators.

Glossary of terms and acronyms

ASAP	Anomaly Hotspots of Agricultural Production
CEMS	Copernicus Emergency Management Service
EDO	European Drought Observatory
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA5	ECMWF Reanalysis v5
ERCC	European Emergency Response Coordination Centre
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GDO	Global Drought Observatory
GloFAS	Global Flood Awareness System
GRACE	Gravity Recovery and Climate Experiment
JRC	Joint Research Centre
LFI	Low-Flow Index
MARS	Monitoring Agricultural Resources
SMA	Soil Moisture Anomaly
SPI	Standardized Precipitation Index
TWS	Total Water Storage
VIIRS	Visible Infrared Imaging Radiometer Suite

GDO and EDO indicators versioning

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

Drought in South America - April 2023

JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) - GDO data up to 28/04/2023

GDO, EDO indicator	Version
▪ fAPAR (fraction of Absorbed Photosynthetically Active Radiation) Anomaly (VIIRS)	*v.1.0.0*
▪ Ensemble Soil Moisture Anomaly (SMA)	*v.3.0.1*
▪ Indicator for Forecasting Unusually Wet and Dry Conditions	*v .1.1.0*
▪ Standardized Precipitation Index (SPI)	*v.1.0.0*
▪ GRACE Total Water Storage (TWS) Anomaly	*v.1.1.1*

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

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