Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



Table of Contents

Executive summary	. 1
Risk of Drought Impact for Agriculture (RDrI-Agri)	. 2
Precipitation	. 4
Standardized Precipitation Index (SPI)	. 8
Soil moisture anomaly	11
fAPAR anomaly	12
References	14

Executive summary

- The 10-year period from 2011 to 2020 in South America has been characterised by severe and persistent drought events, involving in particular Brazil, Argentina, Uruguay, Paraguay, Bolivia, Chile, Colombia, and Venezuela. A remarkable event originated in 2019 in the La Plata Basin is still ongoing. The cumulative values of the Risk of Drought Impact for Agriculture indicator provide an overview of the spatial distribution of the most critical conditions during the analysed period.
- The regions most affected by drought are characterised by a reduction in the total precipitation amount compared to the baseline long-term data. Seasonal analysis points to a larger reduction from June to August, mainly in central Brazil, Argentina and Chile.
- Yearly based SPI-analysis identifies critical precipitation deficit in 2014-2015 in Brazil, and in 2019-2020 in the La Plata Basin.
- Soil moisture and vegetation conditions consistently reflect the spatial precipitation anomaly patterns.
- Impacts were observed on multiple sectors, such as agriculture, energy, transportation, and water supply. Some of them are detailed in dedicated analytical reports available on the Global Drought Observatory website (GDO, https://edo.jrc.ec.europa.eu/reports) and in the cited literature.

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



Risk of Drought Impact for Agriculture (RDrI-Agri)

The GDO indicator RDrI-Agri estimates the risk of having impacts from drought by considering exposure and socio-economic vulnerability of the area under analysis, with particular focus on agricultural impacts.

By aggregating the temporal evolution of RDrI-Agri during the 10-year period from 2011 to 2020, it is possible to highlight the regions most affected by agricultural drought (Figure 1).

The regions ranging from medium to very high values in the heatmap are central Argentina and Uruguay (April 2018¹); the coastal regions of Colombia and Venezuela (March 2019²); Great Chaco and Paraguay basin (April 2020³), central Brazil (June 2021⁴) and La Plata Basin (September 2021⁵). In addition, the north-eastern regions of Brazil were affected by frequent dry conditions during the whole period.

The spot in Rondonia-Amazonas rainforest would require more detailed analysis. RDrI-Agri here is based almost entirely on the Standardized Precipitation Index (SPI) because of the lack of soil moisture and vegetation condition anomalies data. In this region soil moisture data availability could be reduced by cloud and vegetation cover and disagreement between the underlying datasets (Figure 6). Vegetation conditions based on fraction of Absorbed Photosynthetically Active Radiation (fAPAR) are quite stable and for this reason anomalies are not relevant and filtered out in the data (Figure 7).

The drought in the La Plata Basin started in 2019 and is still ongoing. It has been one of the most severe and long-lasting events in the recent past and it still affects the region with ongoing dry conditions and severe impacts on agriculture, water supply, river flow, reservoir storage, hydropower production and inland navigation and transportation.

In the recent past, severe drought impacts have also occurred in some nearby watersheds (e.g. Paraguay, Great Chaco, etc.). Countries affected are mainly Brazil, Argentina, Uruguay, Paraguay, Bolivia, Chile, Colombia and Venezuela. The extent has been wide, even if not all the regions were interested by drought conditions simultaneously.

- ² https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews201903_Central_America_and_Caribbean.pdf
- ³https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202004_Great_Chaco_and_Paraguay_basin.pdf

¹ https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews201804_Argentina_Uruguay.pdf

⁴ https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202106_Brazil.pdf

⁵ https://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews202109_La_Plata_Basin.pdf

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



Combining drought hazard (probability of drought) with exposure (population and assets possibly affected) and vulnerability (coping capacity) results in high risk in the south-east of South America and the east of Brazil (Fraser, 2013; Carrão and Barbosa, 2015). In these areas, crop productivity shows clear correlation with El Niño–Southern Oscillation (ENSO) patterns (Heino et al., 2018) and drought has a wide range of impacts (Naumann et al., 2021) on e.g. agriculture (Diaz et al., 2016; Vogt et al., 2018), energy (van Vliet et al., 2016), ecology (Mol et al., 2000), water resources (Nobre et al., 2016), and health (Gagnon et al., 2002).

A comprehensive overview of where and when a particular impact occurred over the whole of South America and the whole period from 2011 to 2020 is not available, however. Attributing impacts to drought is not always straightforward and impact data are currently not collected structurally. Hence, the impacts mentioned in this report should be considered merely as examples, not as an exhaustive list.

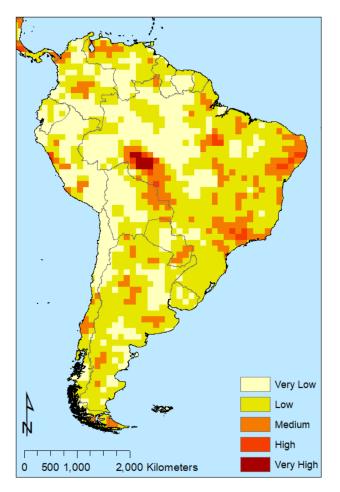


Figure 1: Heatmap of Risk of Drought Impact for Agriculture (RDrI-Agri) – sum of values of all the ten-day periods from 2011 to 2020. The map has been obtained by giving different weights to the

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



individual drought occurrences according to each class of the indicator: high class of risk counted as 3 each time, medium as 2 and low as 1, and accumulating the scores.

Precipitation

Precipitation is measured by total monthly accumulated values and it is the main component to understand and characterize drought events. The extent and general north-south orientation of South America, spanning latitudes from 12 °N to 55 °S, gives rise to the presence of a whole range of climate types ranging from a tropical climate on the Brazilian plateau to a polar climate in the southernmost part, encompassing some of the driest and wettest places on earth (Atacama Desert and Colombian rainforest respectively). At the continental scale, the South American climate and rainfall are furthermore determined by the presence of the Andes and its rain shadow, the prevailing south-easterly trade winds over the northern part of South America and westerly trade winds over the southern part of South America, the warm Brazil sea current on the east coast, and cold Peru (or Humboldt) sea current on the west coast of South America.

On a year-to-year basis, droughts in South America are related to the El Niño–Southern Oscillation (ENSO) (Williams et al., 2005; Penalba and Rivera, 2016; Steiger, 2021), while on the longer decadal scale also other climatic drivers such as the Pacific Decadal Oscillation (PDO) play a role (Diaz et al., 2016). The period between 2011 and 2020 was characterized by a large La Niña event from early 2010 to early 2012, an extreme El Niño event from late 2014 to early 2016, smaller La Niña and El Niño events between 2016 and 2020 and again a somewhat bigger La Niña event from early 2020 onward (Figure 2). The effect of ENSO is regionally diverse with El Niño phases associated with droughts in the Amazon and north-eastern South America and flooding in the tropical west coast and south-eastern South America (Lyon et al., 2004; Lyon et al. 2005; Cai et al., 2020). La Niña phases have in the recent past resulted in droughts in north-east Brazil and floods in Amazonia (Marengo et al, 2013).

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



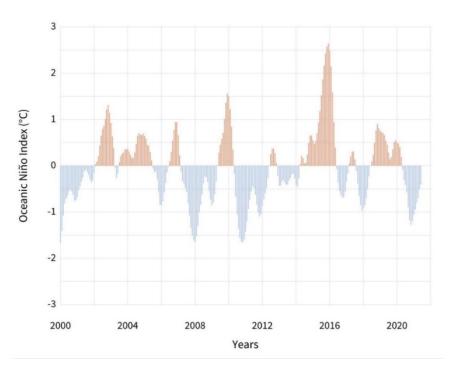


Figure 2: Oceanic Niño Index: seasonal (3-month) sea surface temperatures in the central tropical Pacific Ocean compared to the 1981-2010 average, with warmer than average phases in red and colder than average phases in blue. An El Niño phase is considered to occur when a warm anomaly of > +0.5 °C occurs, while a La Niña phase occurs for a cold anomaly of < -0.5 °C. Source: NOAA (National Oceanic and Atmospheric Administration of the United States of America)

The large climatic variation in South America and regionally diverse effects of drought drivers also means that droughts manifest in very different ways across the continent. In arid areas and notably the Atacama Desert, drought has little meaning. Other regions such as the polar regions and north-west South America have a generally small probability of drought occurrence (Carrão et al., 2014). Drought hotspots with a high frequency, duration, and severity are found in parts of western Brazil, north-east South America and central Argentina (Carrão et al., 2014; Spinoni et al., 2014). In the period 1951-2010, droughts have tended to increase in frequency, duration, and severity in hotspots in the northern part of the continent, while a decrease was observed in the eastern central part (Spinoni et al., 2014; Spinoni et al., 2019). Over this period, new arid areas have arisen in north-eastern Brazil, and while central Argentina is getting wetter, south-western Argentina is drying (Spinoni et al., 2015).

In the period 2011-2020 compared to the baseline period 1981-2010 (Figure 3) the annual average precipitation declined to totals between 30 % to 90 % of the baseline value in central and eastern Brazil, on the coastal regions of Venezuela, Ecuador and Peru, and in southern Chile

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



and Argentina. Only very few spots feature an increase of annual precipitation. This spatial distribution reflects quite well the assessed RDrI-Agri patterns.

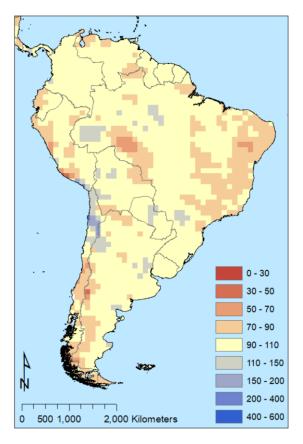


Figure 3: Percentage of average annual precipitation from 2011 to 2020 compared to the baseline from 1981 to 2010

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Constructions Emergency Management Service (CEMS) = 14/12/2021



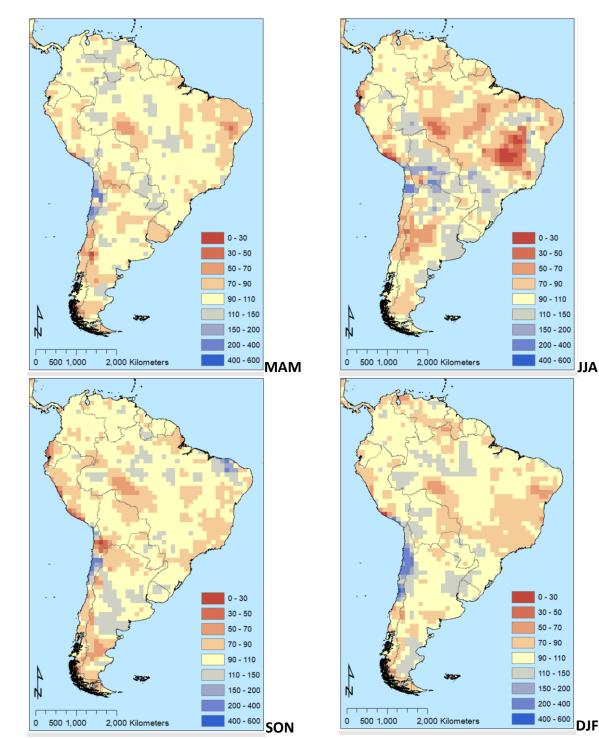


Figure 4: Percentage of average seasonal precipitation from 2011 to 2020 compared to the baseline from 1981 to 2010: March-April-May (top-left), June-July-August (top-right), September-October-November (bottom-left), and December-January-February (bottom-right)

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



Seasonal distribution of precipitation (Figure 4) shows that the most relevant reduction in central-eastern Brazil and central Argentina and Chile is concentrated in June, July, and August. In the other seasons, the pattern is similar but with a lower magnitude. The period from March to May is the lesser affected by precipitation changes, if compared to the baseline. The western coast of the continent is mainly affected by relevant precipitation reduction from July to November.

Standardized Precipitation Index (SPI)

The indicator SPI⁶, as one of the driving components of the RDrI-Agri, provides information concerning the intensity and duration of the precipitation deficit (or surplus).

The time series of SPI-12 (covering from January to December of each year) highlights the interannual variability of the analysed regions in terms of severity of precipitation anomalies, spatial extent and location (Figure 4).

2012 features extremely dry conditions in north-eastern Brazil and 2014 in the northern countries of the continent and in south-eastern Brazil. 2015 is characterized by a wide and severe precipitation deficit over most of Brazil and northern countries, then, after a few years with smaller events, in 2019 the La Plata Basin drought started, with outstanding dry conditions in 2020 in terms of severity and extent. This event is still ongoing as described in a dedicated report (Naumann et. al 2021).

⁶ 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 months period is often used to evaluate agricultural drought and the 12 month accumulation period can be used for hydrological drought, when rivers fall dry and groundwater tables lower.

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



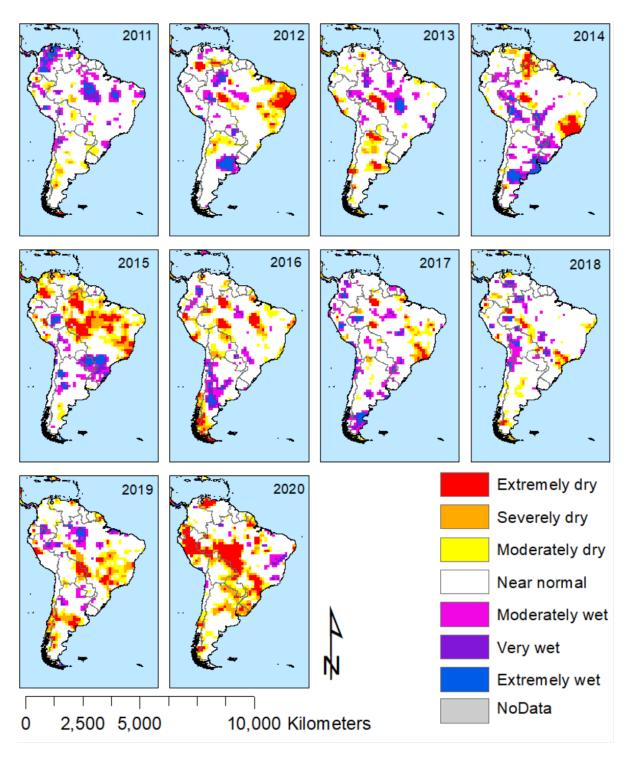


Figure 4: Standardized Precipitation Index (SPI-12 of December) from 2011 to 2020.

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



In order to provide an overall evaluation of drought severity during the ten-year period from 2011 to 2020, the number of months with SPI-12 lower than -1 (corresponding to one standard deviation of the mean in the associated standard normal distribution, considered as the triggering value for a drought event) has been considered and divided by the total number of months in the target period, to obtain the time percentage when a grid cell was under drought conditions. The resulting map (Figure 5) highlights the areas most affected by drought and for longer periods. Data availability has been verified to be more than 90% for each grid cell granting a sufficient reliability of the analysis.

All the severe annual dry conditions are well delineated in the figure (north-eastern and Central Brazil, La Plata Basin, Southern Chile and Argentina, northern coast of the continent), but also more frequent events, even if shorter and smaller in extent, come up, for example in Peru, in Bolivia, or in the eastern coast of Brazil.

Regions where a persistence of SPI-12 below -1 is for 50% of the time or more correspond very well to the "Medium" to "Very High" values of the RDrI-Agri heatmap of Figure 1, confirming precipitation as the main driver. On the other side, even considering all the regions where at least 20% of the time SPI-12 was below -1, these not fully cover completely the areas affected by severe drought impacts. This may depend on different complex interactions among other drivers and also on the wide extent of some watersheds, where severe impacts are reported also downstream even if the precipitation deficit is highlighted only in the upper part of the watershed, as happened for example in the La Plata Basin.

A side consideration regards the long-lasting persistence of SPI-12 low values in the spot of the Rondonia-Amazonas rainforest that should need a further investigation. Long-term trend effects should be considered as one of the reasons of such a persistent deficit, given the remarkable average difference between the analysed period and the baseline in this area. In any case, this spot affects directly also RDrI-Agri values and should be considered accordingly.

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



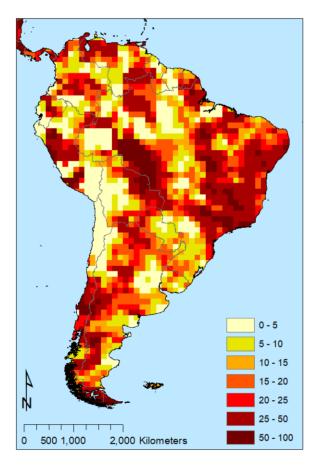


Figure 5: Percentage of Standardized Precipitation Index (SPI-12) values below -1 from 2011 to 2020.

Soil moisture anomaly

The main effect of the prolonged lack of precipitation is the reduction of the soil water content. The aim of the Soil Moisture Anomaly indicator is to provide an assessment of the topsoil water content, which is a direct measure of drought conditions, specifically regarding the difficulty for plants to extract water from the soil.

By looking at the percentage of Soil Moisture Anomaly values below the threshold value -1, we retrieved a proxy indicator of the severity of the drought in terms of its impact on soil dryness (Figure 6).

Frequent and/or prolonged periods of soil moisture drought are highlighted in Figure 6 for most of central Brazil and in the central part of Chile and Argentina. The main severe drought events in central Brazil, Great Chaco, Paraguay, central Chile and Argentina, and northern coastal zone of Colombia and Venezuela are represented. The aforementioned extreme event over La Plata

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



Basin is only partially included as it started in 2019 but it is still ongoing. Also, the frequent events in eastern Brazil show up with a wide red area in the region. Wide regions over Amazon rainforest, Northern Chile and Patagonia are masked out (white) due to low data availability and reliability.

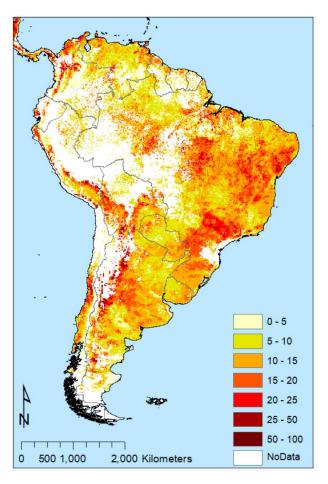


Figure 6: Percentage of Soil Moisture Anomaly values below -1 from 2011-2020. The value of each cell is the percentage of the number of Soil Moisture anomaly data below -1 respect to the whole number of available data. Data are filtered and computed only if data availability correspond to at least 90% of the analysed period.

fAPAR anomaly

The satellite based indicator fraction of Absorbed Photosynthetically Active Radiation (fAPAR) represents the fraction of the solar energy absorbed by leaves. fAPAR anomalies, specifically the negative deviations from the long-term average over the same period, are a good indicator of drought impact on vegetation.

Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



A frequency analysis of the percentage of time when the fAPAR anomaly was below -1 provides a view on the impact on vegetation conditions. Most affected regions appear to be in some areas of the La Plata Basin, most likely due to the extremely severe and persistent ongoing drought. A wide region in central-eastern Brazil is also highlighted, showing the relevance of short but frequent events in the region on vegetation conditions. The Great Chaco, Paraguay and central Argentina events are clearly represented, as well as the event in central-southern Chile. Severe impacts were reported over the coastal zone of Colombia and Venezuela. Similarly to Soil Moisture Anomaly, here even more wide regions over Amazon rainforest, Northern Chile and Patagonia are masked out (white) due to low data availability and reliability.

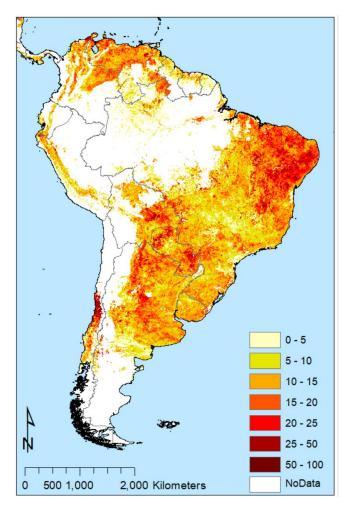


Figure 8: Percentage of fAPAR Anomaly values below -1 from 2011 to 2020. The value of each cell is the percentage of the number of fAPAR anomaly data below -1 respect to the whole number of available data. Data are filtered and computed only if data availability correspond to at least 90% of the analysed period.

Droughts in South America - 10 years overview

December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



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Droughts in South America - 10 years overview

December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



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Droughts in South America - 10 years overview

December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



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Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



GDO indicators versions:

The GDO indicators appear in this report with the following versions: Ensemble Soil Moisture Anomaly 2.3.0 fAPAR (fraction of Absorbed Photosynthetically Active Radiation) Anomaly 1.3.1 Precipitation (GPCC) 1.2.0 Risk of Drought Impact for Agriculture (RDrI-Agri) 2.3.2 Standardized Precipitation Index (SPI, GPCC) 1.2.0 Check https://edo.jrc.ec.europa.eu/download for more details on indicator versions.

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Droughts in South America - 10 years overview December 2021 JRC Global Drought Observatory (GDO) of the Copernicus Emergency Management Service (CEMS) – 14/12/2021



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