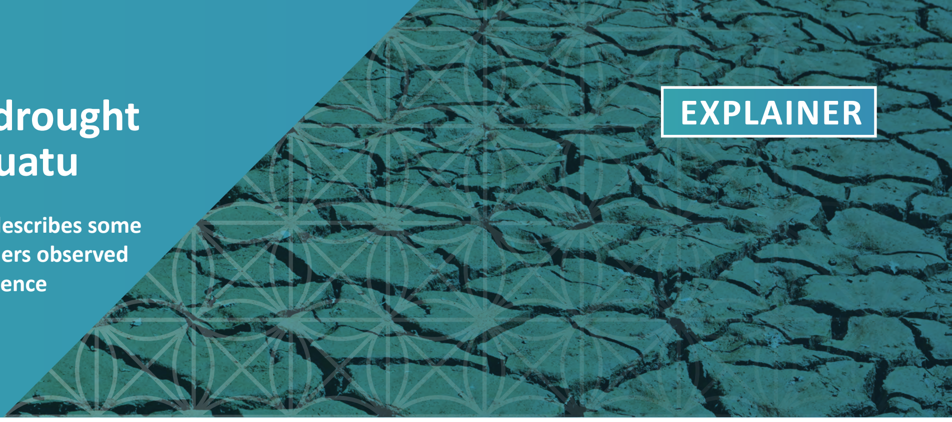


Current and future drought climatology for Vanuatu

EXPLAINER

This Explainer defines droughts and describes some common drought indicators. It considers observed and projected droughts, and the influence of the El Nino Southern Oscillation.

Drought definitions

In general, drought refers to an acute lack of water compared to normal conditions. The primary cause of any drought is a lack of rainfall over an extended period, usually more than a few months, resulting in a water shortage for some activities, groups, sectors, and related natural resources (including marine and terrestrial biodiversity) [1]. There are different drought indicators that are appropriate to different purposes [2]:

- Meteorological drought (below normal rainfall)
- Agricultural drought (below normal water storage in the soil)
- Hydrological drought (below normal water availability in streams, lakes, and groundwater)

Indicators commonly employed for declaring drought include the Standardised Precipitation Index (SPI) [3] or rainfall percentiles [1], though there are other methods accounting for relevant factors such as evapotranspiration [4], soil moisture [5], or crop productivity [2].

Drought indicators

Standardised Precipitation Index (SPI)

Rainfall anomalies, preferably normalised by standard deviation, are often used to represent drought [2]. The SPI is a widely used indicator for drought, including by the Vanuatu Meteorology and Geo-hazards Department (VMGD), and is endorsed as the world standard for determining meteorological drought by the World Meteorological Organization [6].

The SPI is calculated by fitting a probability density function to the frequency distribution of monthly rainfall totals (ideally for a continuous period of at least 30 years). This is illustrated in Figure 2. The rainfall values are calculated as a monthly moving average [5]. For example, the moving average of the 12 previous months rainfall is often used for agriculture. Subsequently, the probability distribution is 'normalised,' with the SPI having a mean of zero and standard deviation of one. The result gives negative values for dry conditions and positive values for wet conditions. The fitting is conducted for each month separately, e.g. all January rainfall values.

The concept which underpins the SPI is that it allows quite different rainfall regimes to be expressed in relative terms, i.e. relative to the time of year and the location [7]. For example, 100 mm of precipitation in Madrid for June–August is unusually wet (SPI of +2), whereas for London, 100 mm is relatively dry (SPI of-1.3) (Figure 1).

A drought event is declared any time the SPI is continuously (over at least 3 months) negative and reaches an intensity of -1.0 or less at some time during each event (see Figure 2). The drought begins when the SPI first falls below zero and ends with the first positive value of SPI following a value of -1.0 or less [3]. The drought intensity is the average of cumulative SPI from all events for the drought period. The SPI has been used to assess droughts in the Pacific [4].

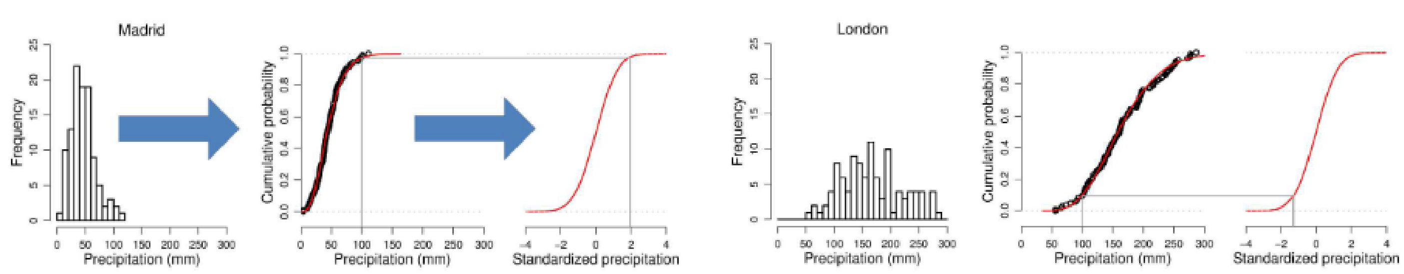
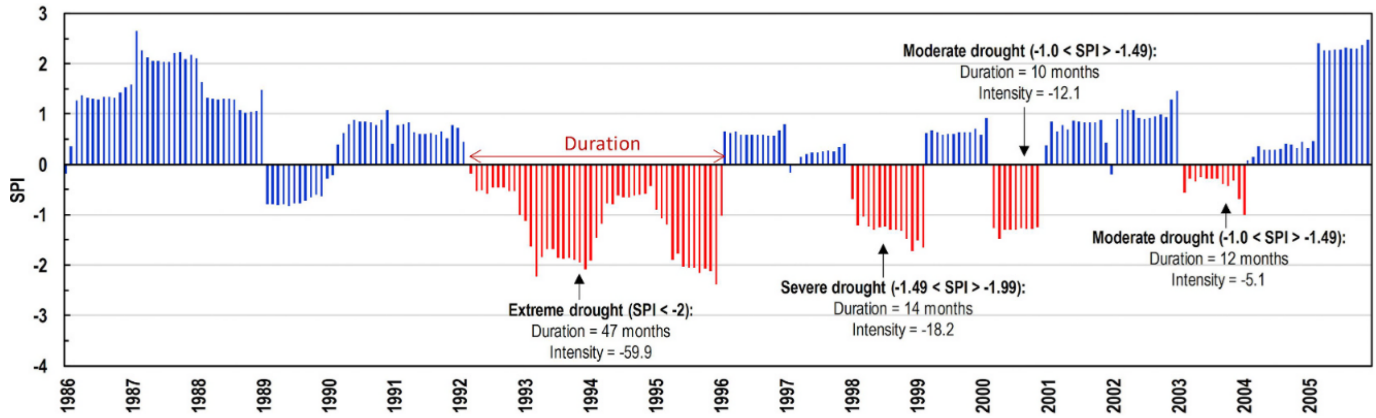


Figure 1 Standardised Precipitation Index applied to summer three-month accumulations (June–August) for Madrid and London, 1901–2005. Source: [7].



Drought category	SPI value
Near normal	-0.99 to 0
Drought	Less than or equal to -1.0
Moderate drought	-1.0 to-1.5
Severe drought	-1.5 to -2.0
Extreme drought	Less than -2.0

Figure 2 Example illustration of a Standardised Precipitation Index (SPI) time series and the associated drought events for the period 1986–2005 [5]. In this 20-year period, the site experiences four droughts (with a mean duration of 28.3 months, frequency of 4, and intensity per event of -31.8). There are two moderate droughts (with a mean duration of 11 months, frequency of 2, and intensity per event of -8.6), one severe drought, and one extreme drought. The site experiences 45.4 % and 19.5 % of time in drought and in extreme drought, respectively. Drought categories based on SPI are also indicated [3] noting the ranges in the table differ slightly from the example graph.

Rainfall percentiles used to describe observed drought

The Bureau of Meteorology (BoM) in Australia describes meteorological drought using the concept of rainfall deficiencies [8]. The terms serious and severe are defined by:

- Serious rainfall deficiency: rainfall lies above the lowest five per cent of recorded rainfall but below the lowest ten per cent (decile range 1) for the period in question
- Severe rainfall deficiency: rainfall is among the lowest five per cent for the period in question
- Areas where the rainfall is lowest on record for the given period.

Iese et al. [1] also use percentiles to describe meteorological drought in the Pacific, with drought being declared if the rainfall total in the previous 3- or 6-month period is in the bottom 25 % of historical rainfall totals for that corresponding 3- or 6-month period, which is slightly different to the BoM definition described above.

Standardised Precipitation Evapotranspiration Index (SPEI)

The SPEI is an extension of the SPI, taking account of evapotranspiration, which is influenced by temperature, wind speed and solar radiation. Although rainfall is often the dominant factor determining the aridity of a region, local droughts and wet spells are determined by the cumulative effect of the imbalance between atmospheric water supply (i.e. rainfall) and demand (i.e. potential evapotranspiration) [2]. The SPEI has been used in the Pacific, including for Vanuatu [4].

Observed droughts

At Aneityum the observed number of wet days each year has decreased (2.9 days/decade) [4]. There is no significant trend (1951–2020) in the annual longest run of consecutive dry days at either Port Vila or Aneityum (Figure 4) [4]. There has been no significant trend in annual or seasonal rainfall at either Port Vila or Aneityum since 1951 [4].

The trends in drought based on the SPI between 1981–2010 and 1951–1980 [9], and consecutive dry days (1951–2020) [10], are statistically non-significant and mixed spatially, with Bauerfield and Efate showing positive trends while Sola and Aneityum indicate negative trends. McGree et al. reported no statistically significant trends in the SPEI in either the wet season or the dry season, based on station data from Aneityum and Port Vila [11], though longer dry spells were typically experienced during El Niño years compared to La Niña years [4].

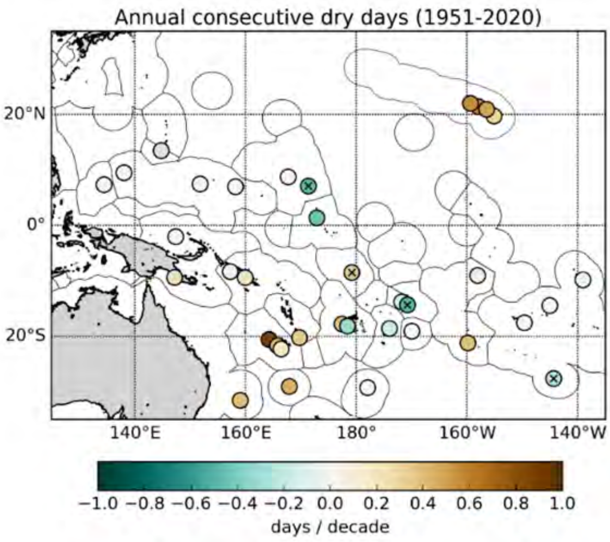


Figure 4 Trend in annual consecutive dry days over 1951–2020. Circles with 'x' represent trends statistically significant at the 95 % level. Source: McGree et al. (2022) [10].

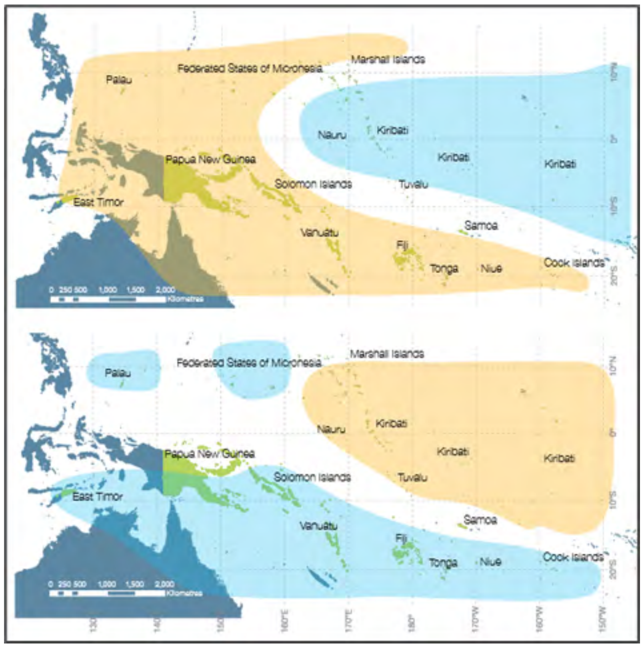


Figure 5 Typical changes to rainfall patterns during El Niño (top) and La Niña (bottom) events in the western tropical Pacific (blue shading, wetter than average; yellow shading, drier than average) [14].

The occurrence, duration and intensity of meteorological droughts can occur at different times within Vanuatu, based on sub-national climatological classification of north, central and south Vanuatu (Figure 1) [1, 12]. For instance, the 1982 drought[1] in Vanuatu commenced in Pekoa (North Vanuatu) a year earlier than Port Vila (Central Vanuatu) and 16 months before White Grass (Southern Vanuatu) [1]. Droughts are often broken with heavy rainfall associated with a tropical cyclone. Descriptions of Vanuatu's droughts in 1982–1983, 1997–1998, and 2015–2016 have been documented [1, 12].

El Niño Southern Oscillation and drought

The El Nino Southern Oscillation (ENSO) is a natural, large-scale ocean-atmosphere interaction in the tropical Pacific region (see Climate variability explainer). Variations in ocean temperatures drive changes in atmospheric circulation patterns leading to widespread and persistent changes in air temperatures, rainfall, cyclones, and sea level. ENSO is one of the key factors influencing drought occurrence in the Pacific region, including Vanuatu [9, 13]. During an El Niño event drier conditions are usually experienced in Vanuatu, while La Niña events tend to bring wetter conditions (Figure 6) [14]. In Vanuatu, droughts (and their duration) associated with El Niño events occurred in 1982–1983 (5 to 27 months), 1997–1998 (5 to 13 months) and 2015–2016 (2 to 23 months) [1].

Projected drought

Ongoing increases in greenhouse gas emissions are projected to cause further climate change [15]. Climate model simulations of future SPI drought are similar across Vanuatu's sub-national regions [12] (Figures 6 and 7). The characteristics of drought are represented here by three measures [8]:

- Drought duration: the average length (in months) of an event in a selected 20-year period.
- Drought frequency: the number of droughts in a selected 20-year period.
- Drought intensity per event: the average of the cumulative SPI from all events in a selected 20-year period. The more negative the value the more intense the event.

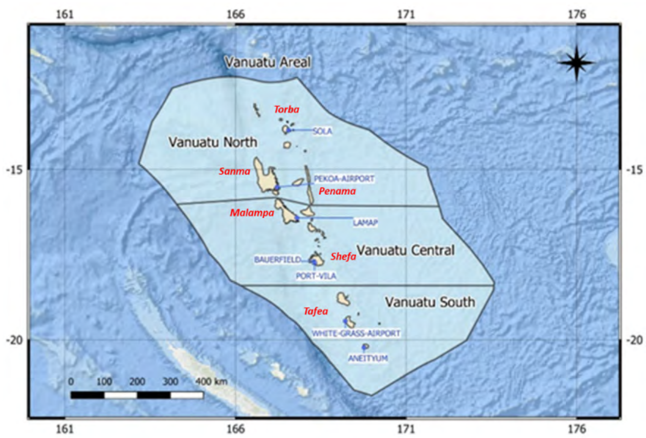


Figure 6 Map of Vanuatu and the three sub-national regions: North, Central and South. Provinces (red labels) and locations of key weather stations (blue labels) used for the study are also shown. The pale blue shaded region delineates the Exclusive Economic Zone (EEZ) of Vanuatu. Latitudes and longitudes are shown around the perimeter of the map.

[1] Bottom 25 % of historical rainfall totals. See [1].

Iese, V., et al., Historical and future drought impacts in the Pacific islands and atolls. *Climatic Change*, 2021. 166(1): p. 1-24.

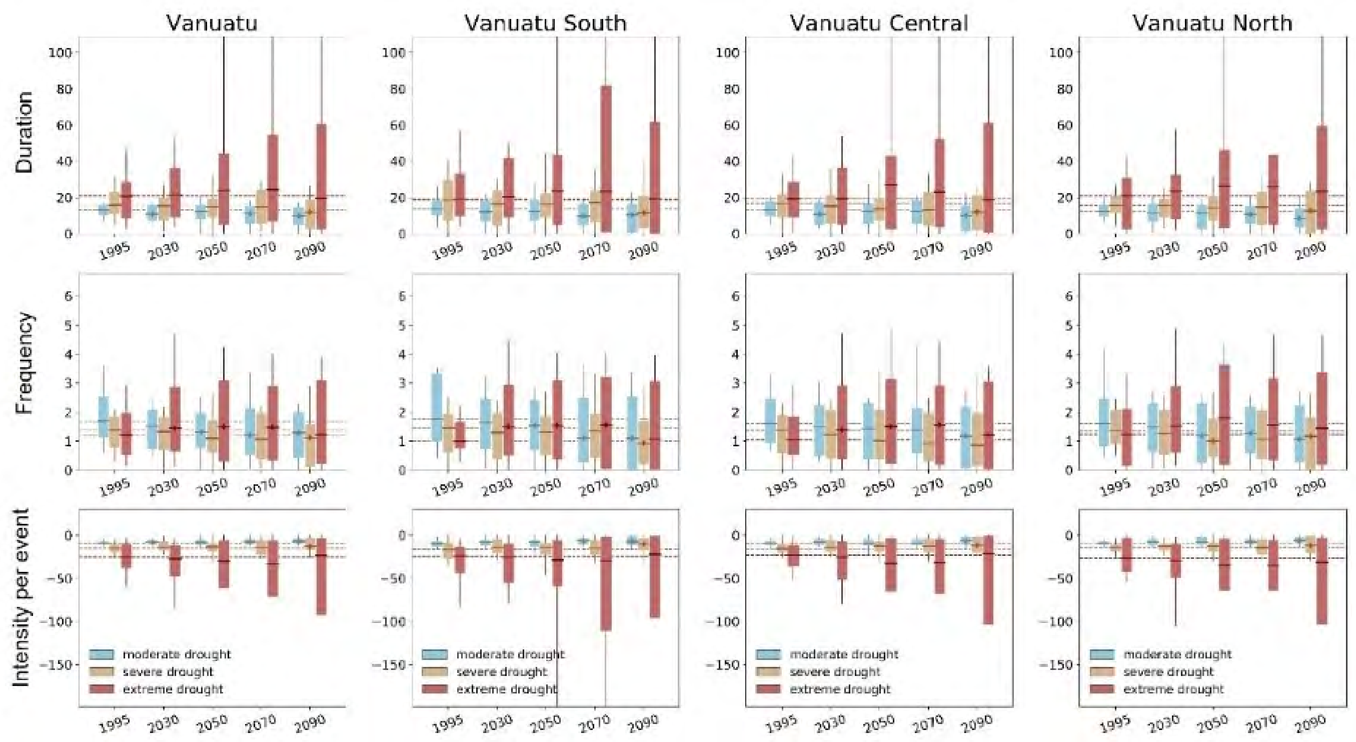


Figure 7 Whole country, South, Central and North Vanuatu (see Figure 6) average of drought duration (top), frequency (middle) and intensity (bottom) in the reference period (20 years centred on 1995) and future periods (20 years centred on 2030, 2050, 2070, 2090) for a high greenhouse gas emission pathway (RCP8.5). Different drought categories (moderate, severe, and extreme; Figure 2) are given. Drought duration is in months, frequency is in 'number of events per period' while intensity is unitless (NB: the more negative the value the more intense the event). Results from 34 climate model simulations are shown as the median (50th percentile), 10th and 90th percentile (bars) and minimum and maximum values (whiskers). The dashed lines show the multi-model median for the baseline period for each drought category [1, 8]. SPI is calculated monthly with the value for each month representing the rainfall anomaly over the past 12 months.

Drought duration is projected to change little by 2050, consistent with observed trends in drought duration [9, 11]. However later in the century the range of projections increases, with some climate models showing large increases in extreme drought duration while others show a slight decrease. There is a tendency for the models to show extreme droughts becoming longer, and moderate and severe droughts becoming shorter [12].

Moderate and severe drought frequency is projected to change little, consistent with the observed drought trends [11]. For extreme drought the multi-model median indicates little change, while the range of uncertainty, albeit large, is skewed towards an increase for most measures. This implies that future drought events for Vanuatu will tend to be classified in the extreme drought category rather than the moderate or severe drought category. This is consistent with the projected increase in the frequency of extreme El Niño events [16]. Projections of drought frequency are similar across sub-national regions [12].

There is not much projected change in the intensity of moderate or severe droughts. The intensity of extreme drought shows little projected change however the range is large with some models showing increases in extreme drought intensity [12].

The drought projections in Figure 7 are based on the SPI, which does not include the effect of projected increases in evapotranspiration. Therefore SPI-based drought projections may be conservative as increasing temperature, which affects evapotranspiration, is not taken into account.

When applying drought projections for impact assessments (e.g. see [Water security infobyte]) it is important to adopt a standardised approach to scenario analysis where possible, and to use the data in a manner consistent with the stated limitations (see [Climate projections informing hazard-based impact assessments explainer]).

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