**Supplementary material: Drought hazard assessment across Sweden's diverse hydro-climatic regimes**

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**SM1. Calculation of standardized drought indicators: SPI, SPEI, SSMI, SSI**

600  The standardized drought indicators were defined using the daily simulated precipitation, evapotranspiration, soil moisture, and streamflow from S-HYPE model. The monthly data was defined by the sum of the precipitation and the average evapotranspiration, soil moisture, and streamflow for each month. For the calculation of SPI and SPEI, we used monthly data of precipitation and evapotranspiration applying the SPEI R package: SPEI (Beguería and Vicente Serrano, 2009; Vicente-Serrano et al., 2010). The statistical tests showed that Gamma probability distribution models best the observed precipitation

605  values, aligning with the standard recommendations for calculating SPI in Europe (McKee et al., 1993). The SPEI was defined by computing the monthly difference between precipitation and potential evapotranspiration. And the statistical, distribution used for obtaining the SPEI was the log-logistic distribution, which was considered a suitable distribution based on the findings of Vicente-Serrano et al. (2010). To calculate the Standardized Soil moisture Indicator (SSMI), the SPEI R package and the SPEI function was used, applying the log-logistic distribution (Tian et al., 2021). And for the calculation of Standardized

610  Streamflow Indicator (SSI), applying the SPEI R package and the SPEI function, the log-logistic distribution was used (Teutschbein et al., 2022; Tian et al., 2021).

## SM2. Spatial-temporal analysis of drought indicators

Figure S1 shows the distribution of the mean SMA values per cluster. Wider sections indicated a higher probability of SMA values falling within a particular drought severity level. For instance, the largest data density ranges from -1 to 1, indicating non-drought conditions on most occasions. However, Clusters C, D, and E showed ***extreme*** (SMA < -2) and ***severe*** (SMA from -2 to -1.5) drought events more frequent. ***Moderate*** drought occurrence (SMA from -1.5 to -1) is quite common in all clusters, except cluster A.
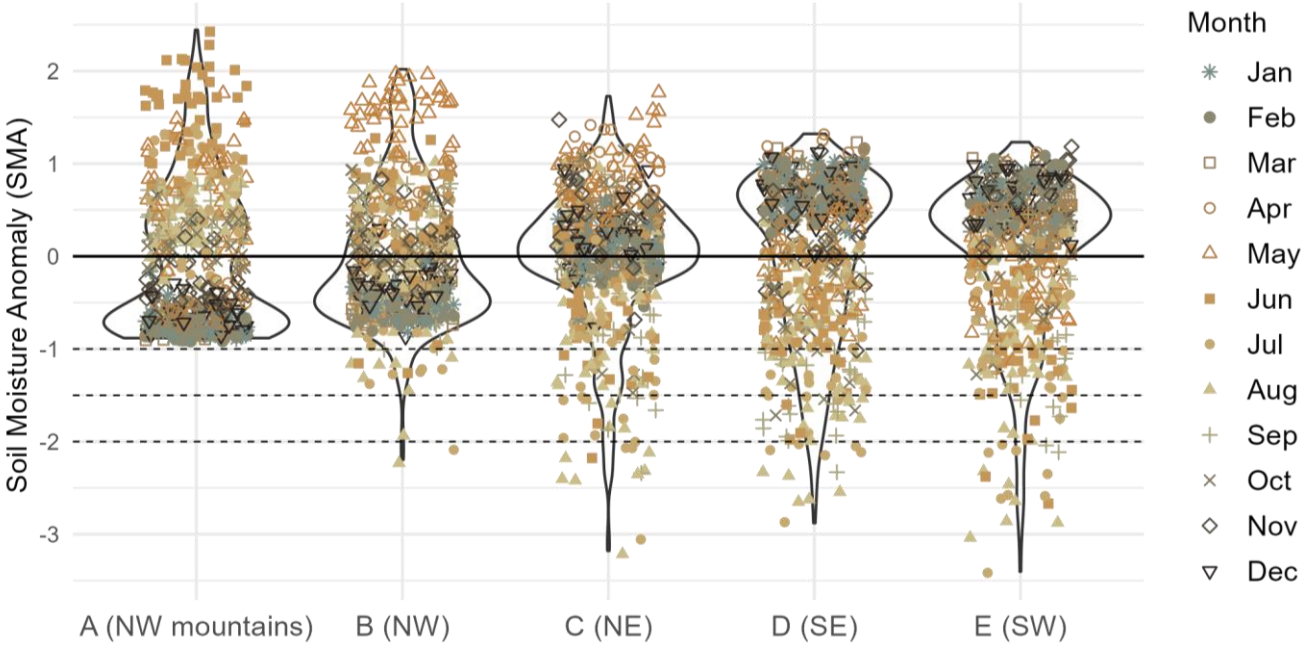


**Figure S1.** Violin plot of the monthly mean SMA across the 39,635 studied sub-catchments, grouped into the five clusters. Points represent the monthly mean SMA of a sub-catchment. SMA lower than -2 represents extreme drought, SMA values from -2 to -1.5 is severe drought, and SMA from -1.5 to -1 is moderate drought.

**SM3. Characterization of drought events in Sweden – Additional material**

625 Figure S2 shows the drought frequency, which represents the total number of drought events recorded during the study period from 1975 to 2021. In general, short-term meteorological drought events (including SPI-1, SPI-3, SPEI-1, and SPEI-3) were more frequent and have a lower standard deviation, while short-term agricultural and hydrological drought events (including SSMI-1, SSMI-3, SSI-1, and SSI-3) were less frequent and showed larger regional variation. The SPEI analysis revealed a high frequency of drought events during the study period. Specifically, SPEI-1 recorded approximately 70 to 90 drought events,

630 while SPEI-3 observed around 40 to 50 drought events (see Fig. S2 left). Long-term droughts (including SPI-12, SPI-24, SPEI-12, SPEI-24, SSMI-12, SSMI-24, SSI-12, and SSI-24) were less frequent but more uniform across regions. Fewer than 30 drought events were generally observed across the four standardized indicators for the 12- and 24-month timescales. This corresponds with the progression of drought, as only prolonged precipitation and evapotranspiration deficits result in reduced soil moisture and lower streamflow levels.

635 The percentage of time in drought due to precipitation deficit (as measured by SPI-1 to SPI-24) ranged from 12 to 18% during the study period (see Fig. S2 right). Drought based on short-term precipitation deficits, often show rapid recovery following precipitation events, which may explain the observed lower percentage of time in drought as measured by SPI-1 and SPI-3. Short-term droughts (SPEI-1 and SPEI-3) and mid-term droughts (SPEI-6), as measured by precipitation and evapotranspiration, demonstrate a percentage of time in drought ranging generally from 16% to 20%. The larger percentage

640 of time in drought observed with SPEI compared to SPI highlights the influence of temperature and evapotranspiration, which contribute the persistence of drought conditions. The percentage of time in agricultural and hydrological droughts (based on soil moisture and streamflow) generally ranged from 14% to 18%. However, parts of southern and northern Sweden experienced from 18% to 30% percentage of time in droughts (including SSMI-1 to SSMI-24 and SSI-1 to SSI-24) during the study period. SSMI and SSI reflect the cumulative effects of drought over time and respond to meteorological changes. This

645 could explain the generally lower frequency but longer percentage of time in drought detected by SSMI and SSI.
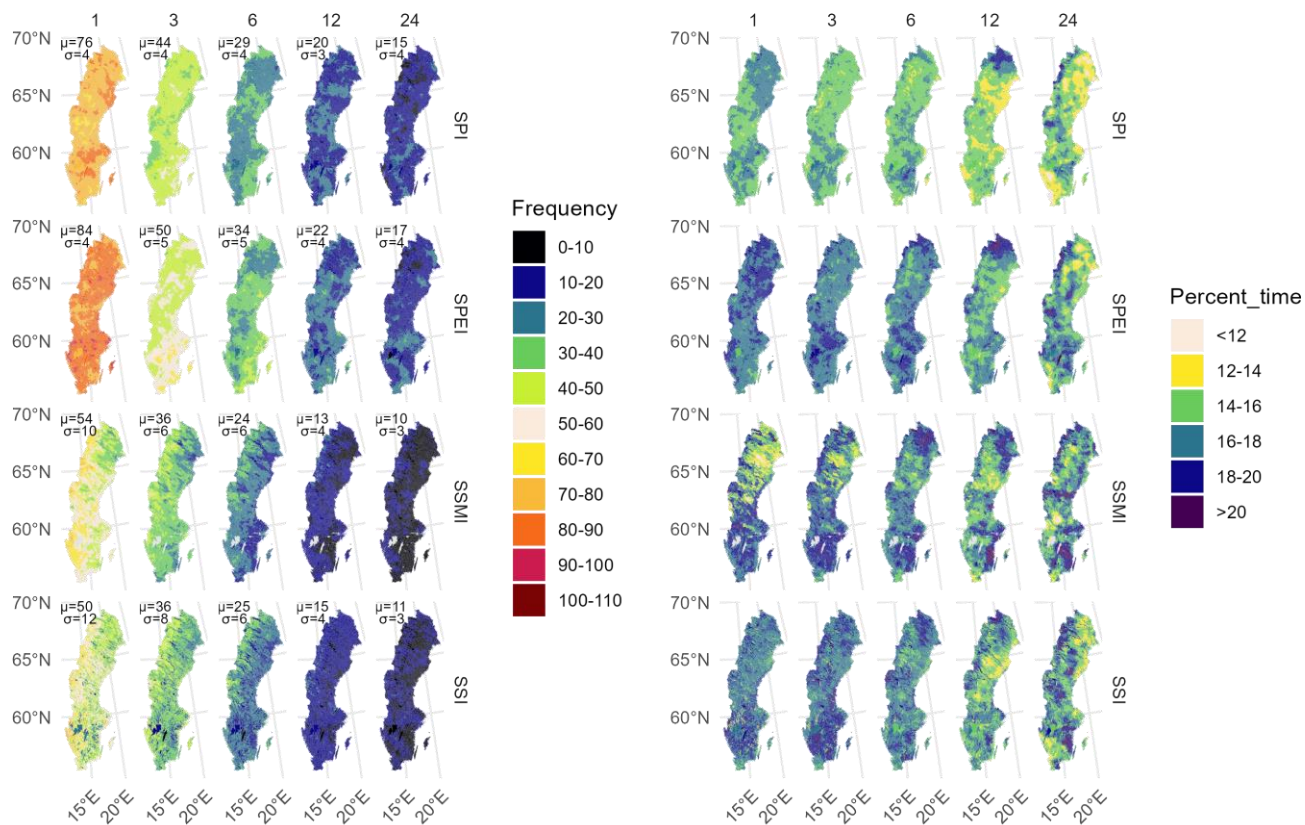
**Figure S2 The drought frequency (left) and the percentage of time in drought (right) during the study period 1975 – 2021 for the standardized drought indicators –SPI, SPEI, SSMI, and SSI– for the timescales of 1, 3, 6, 12, and 24 months.**

Figure S3 shows the drought intensity for 1976, 1996, and 2018. Largest drought intensity was shown for SPI in 1976 and 650    1996. Moreover, in 2018, high drought intensity was shown for SPI-1, SPEI-1 and SSMI (1 to 12 months).
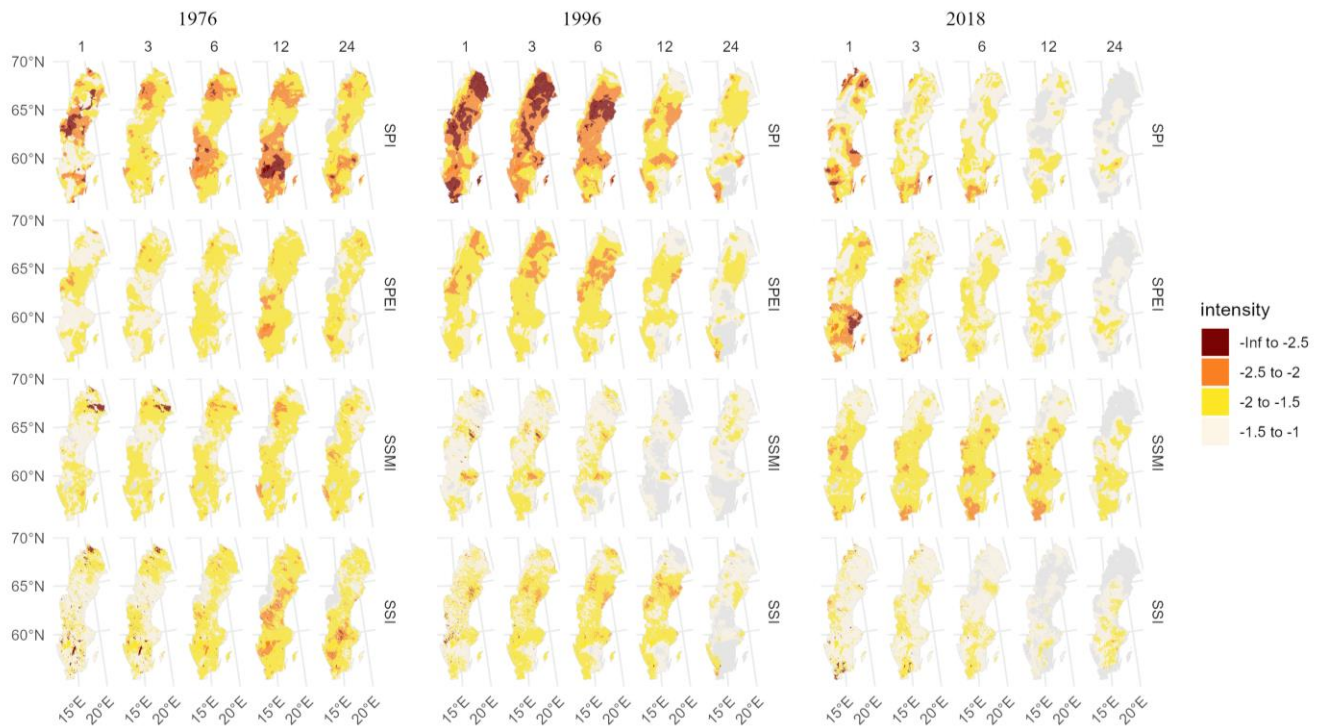
**Figure S3 Intensity of the standardized drought indicators –SPI, SPEI, SSMI, and SSI– for the timescales of 1, 3, 6, 12, and 24 months for the years 1976 (left), 1996 (mid), and 2018 (right).**

655 SSMI-1 for cluster A exhibited extreme in over 50% of the catchments during August 2006 and severe drought conditions October 1976, May 1977, July 1980, November 1992, October–November 2002, July 2003, September 2014, and July 2018 (Fig. S4). SSMI-1 for cluster B showed severe droughts in over 50% of the catchments during April 1985, May 1990, June and November 1992, August 1994, May–June 2002, September-December 2002, July 2003, August 2006, September 2014, and July 2018. SSMI-1 for cluster C showed extreme droughts in over 50% of the catchments during May 1990, December

660 2002, January 2003, and July 2018; and severe droughts in April 1985, October 1989, June 1992, August 1994, May–June 2002, September 2002 – January 2003, August 2006, and June and October 2018. SSMI-1 for cluster D indicated extreme droughts in June–July 2018; and severe droughts in August, November–December 1975, February 1977, August 1983, May 1990, June 1992, May 1993, September 2002, June 2008, October 2016, August–December 2018, April 2019 and April 2020 affecting over 50% of the catchments. SSMI-1 for cluster E showed extreme drought in June 1992 and April 2019; and severe

665 droughts in August 1975, July–September 1976, December 1978 – February 1979, January 1982, August 1983, January 1987, May 1990, May 1993, May and July 1994, April 2002, September–October 2002, June 2008, January–February and December 2010, October 2016, June–August 2018, April 2019, and April 2020 affecting over 50% of the catchments.
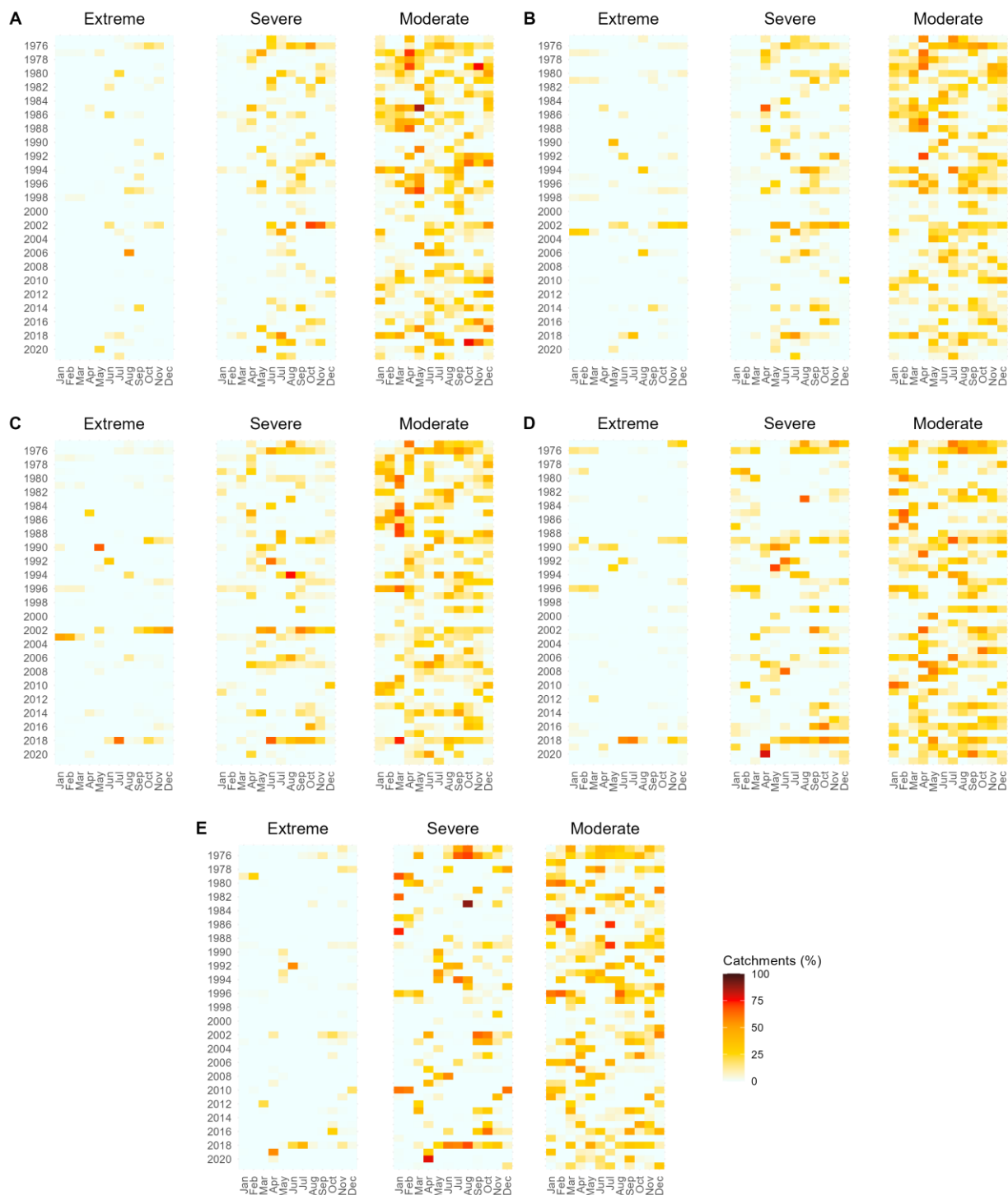
**Figure S4. Heatmap of the percentage of catchments in drought for SSMI-1 for cluster A – cluster E by severity level: moderate (-1.5 to -1), severe (-2 to -1.5), extreme (< -2), and the total percentage of catchments in drought (<-1).**

## SM4. Trends of drought events in Sweden

Figure S5 illustrates trends in the severity, intensity, duration and frequency of drought events across Sweden. Most of the locations show no-significant trends for severity, intensity, or duration. The few significant trends in severity and intensity are generally found in parts of northern Sweden, while negative trends in duration generally appear in the northern and western regions. Drought frequency exhibits generally significant positive trends in parts northern and western Sweden and negative trends in parts of central-eastern and south-eastern Sweden (see Fig. S6). These significant negative trends cover a wider area when assessed using SPEI.
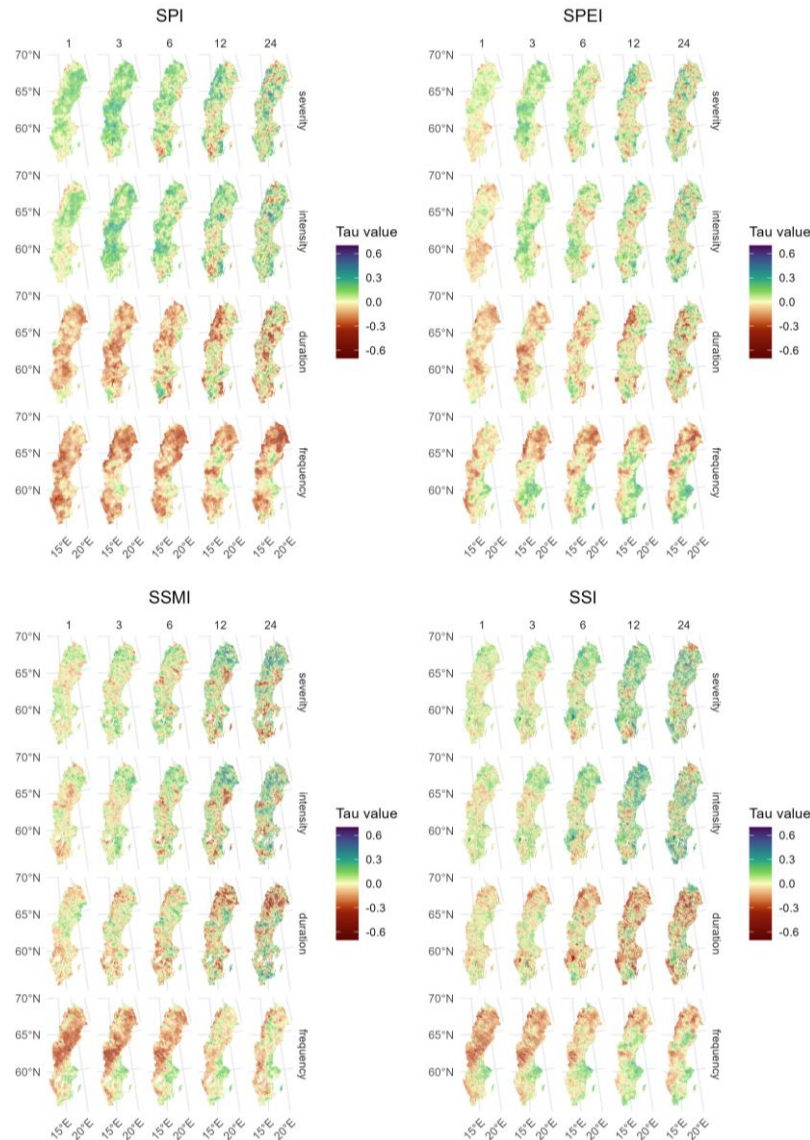


**Figure. S5. Trends of the drought events' characteristics computed with the standardized drought indicators –SPI, SPEI, SSMI, and SSI– for the timescales of 1, 3, 6, 12, and 24 months.**
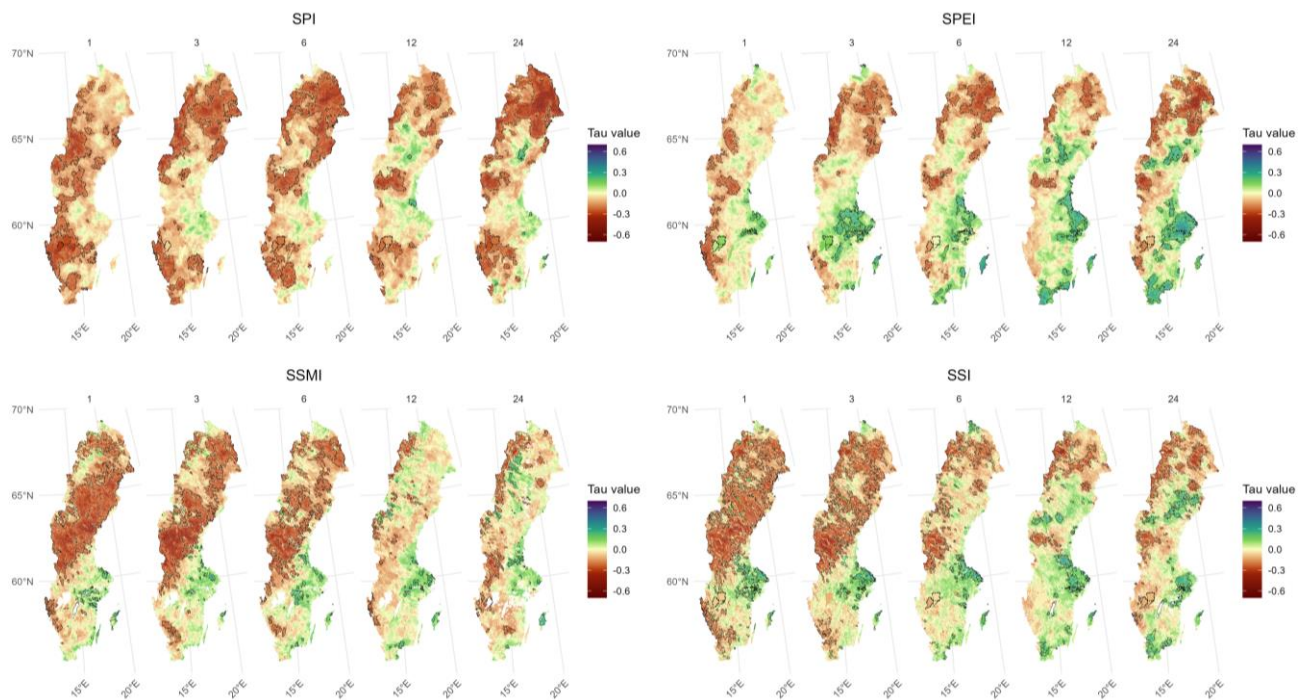
**Figure. S6.** Trends of the drought events' frequency computed with the standardized drought indicators –SPI, SPEI, SSMI, and SSI– for the timescales of 1, 3, 6, 12, and 24 months. Areas with a black boarder indicate significant tau values (p-value ≤ 0.05).