DROUGHT CHARACTERISTICS IN SUMATRA BASED ON HISTORICAL AND FUTURE PROJECTION

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Bogor, August 2025

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RINGKASAN

RAHMAT HIDAYAT. Karakteristik Kekeringan di Sumatra Berdasarkan Data Historis dan Proyeksi Masa Depan. Dibimbing oleh MUH. TAUFIK dan APIP.

Kekeringan merupakan tantangan serius bagi Sumatera, terutama dalam konteks perubahan iklim dan diperkuat oleh fenomena iklim skala besar seperti *El Niño-Southern Oscillation* (ENSO) dan *Indian Ocean Dipole* (IOD). Studi ini menginvestigasi karakteristik kekeringan menggunakan data curah hujan bulanan ERA5 (1981–2023) dan proyeksi CMIP6 yang dikoreksi bias (2015–2096). Analisis ini menerapkan *Standardized Precipitation Index* (SPI) pada skala 3, 6, dan 12 bulan, masing-masing mewakili kekeringan meteorologi, pertanian, dan hidrologi. Koreksi bias dilakukan menggunakan *quantile delta mapping* pada data historis dan masa depan, disertai dengan evaluasi tren curah hujan.

Hasil menunjukkan bahwa kekeringan di Sumatera berbeda, dengan daerah selatan dan dataran rendah, mengalami kekeringan meteorologi lebih sering dan berkepanjangan yang berlangsung hingga hingga lima bulan. Sinyal ENSO dan IOD memberikan pengaruh yang lebih kuat di belahan bumi selatan dan daerah dataran rendah. Ketika *El Niño* bertepatan dengan IOD positif, telekoneksi ini menunda onset monsoon, memperparah kondisi kekeringan dengan durasi hingga delapan bulan, serta mempercepat terjadinya propagasi kekeringan pertanian dan hidrologi. Tidak semua kekeringan meterologi membentuk kekeringan pertanian dan hidrologi. Kekeringan meteorologi harus berlangsung selama 3-4 bulan yang harus terpenuhi terlebih dahulu sebelum menyebar menjadi kekeringan pertanian dan hidrologi, dengan onset yang lebih cepat di bagian selatan dan dataran rendah Sumatra.

Proyeksi masa depan di bawah SSP5-8,5 menunjukkan peningkatan signifikan dalam risiko kekeringan, dengan daerah yang terkena dampak kekeringan meteorologi berkembang sekitar 40% (dari 45% menjadi 85%) dan frekuensi kekeringan meningkat hingga 90%, terutama di bagian selatan Sumatra. Selain itu, tren curah hujan menunjukkan pergeseran ke arah kondisi yang lebih kering, terutama selama musim kemarau (JJA dan SON). Mengingat kondisi kering yang berubah, telekoneksi iklim dapat semakin mengintensifkan risiko kekeringan dan meningkatkan kerentanan kebakaran di wilayah lahan gambut di dataran rendah yang kaya gambut. Studi ini menggarisbawahi kebutuhan mendesak akan strategi adaptasi khusus wilayah yang memperhitungkan kontras topografi, perbedaan hemisfer, dan pengaruh telekoneksi untuk mengurangi dampak kekeringan dan mengurangi bahaya kebakaran.

Kata kunci: CMIP6, propagasi kekeringan, ENSO, IOD, Sumatra, topografi

SUMMARY

RAHMAT HIDAYAT. Drought Characteristics In Sumatra Based On Historical and Future Projection. Supervised by MUH. TAUFIK and APIP.

Drought represents a serious challenge for Sumatra, particularly in the context of climate change and further amplified by large-scale climate phenomena such as the *El Niño–Southern Oscillation* (ENSO) and the *Indian Ocean Dipole* (IOD). This study investigates drought characteristics using monthly ERA5 rainfall data (1981–2023) and bias-corrected CMIP6 projections (2015–2096). The analysis applies the *Standardized Precipitation Index* (SPI) at 3-, 6-, and 12-month scales, representing meteorological, agricultural, and hydrological droughts, respectively. Bias correction was performed using the Quantile Delta Mapping method on both historical and future datasets, accompanied by rainfall trend evaluation.

The results reveal that droughts in Sumatra are spatially heterogeneous, with southern and lowland regions experiencing more frequent and prolonged meteorological droughts lasting up to five months. ENSO and IOD exhibits stronger influence in the southern hemisphere and lowland areas. When El Niño coincides with a positive IOD, this teleconnection delays monsoon onset, intensifies drought conditions for up to eight months, and accelerates the propagation of agricultural and hydrological droughts. However, not all meteorological droughts develop into agricultural or hydrological droughts; a persistence of 3–4 months is generally required before propagation occurs, with faster onset observed in southern and lowland regions.

Future projections under the SSP5-8.5 scenario indicate a substantial increase in drought risk, with meteorological drought-affected areas expanding by about 40% (from 45% to 85%) and drought frequency increasing by up to 90%, particularly in southern Sumatra. In addition, rainfall trends show a shift toward drier conditions, especially during the dry season (JJA and SON). Under these conditions, intensified climate teleconnections are likely to further exacerbate drought risks and increase fire susceptibility in peat-rich lowlands. This study underscores the urgent need for region-specific adaptation strategies that account for topographic contrasts, hemispheric differences, and climate teleconnection influences to mitigate drought impacts and reduce fire hazards.

Keywords: CMIP6, drought propagation, ENSO, IOD, Sumatra, topography

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PREFACE

All praise and gratitude be to Allah, for His blessings and guidance that enabled me to complete this thesis entitled *"Drought Characteristics In Sumatra Based on Historical and Future Projection"* as one of the requirements to obtain a Master's degree in Applied Climatology at IPB University.

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Above all, I express my deepest gratitude to my beloved parents, Rahma and Darwin, for their endless love, prayers, and sacrifices. I am also thankful to my two brothers, Ramadhan and Alpi, whose support and encouragement have always strengthened me throughout this journey.

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I hope this thesis contributes meaningfully to the understanding of drought characteristics in Sumatra and provides a foundation for future research and climate-related policy development. I am fully aware that this work is not without limitations and I sincerely welcome any constructive feedback for its improvement.

Bogor,August 2025

Rahmat Hidayat

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