

Supplementary Information

1 Study region and datasets

Fig. S1 summarizes the regional topographic and land-cover setting of the Pantanal, highlighting the low-relief floodplain structure and heterogeneous vegetation patterns that shape regional fire susceptibility and hydrological connectivity. Fig. S2 and Fig. S3 further summarize the seasonal timing and spatial expression of burned-area and inundation peaks examined in this study, while Fig. S4 provides long-term hydroclimatic variability and trend decomposition across precipitation, land surface temperature, and inundation extent. Table S1 summarizes all datasets used in the analysis. Noted that in this study, a “megafire” is defined as a burned area exceeding 6% of the study region, which spans 14°S to 22°S in latitude and 61.5°W to 54°W in longitude. Fire-event reconstruction was performed across this analysis domain, acknowledging that fire progression can extend beyond the ecosystem’s boundaries. Meanwhile, hydroclimatic analyses and land-cover assessments presented in the main text were calculated within the defined Pantanal ecoregion boundary shown throughout the study figures.

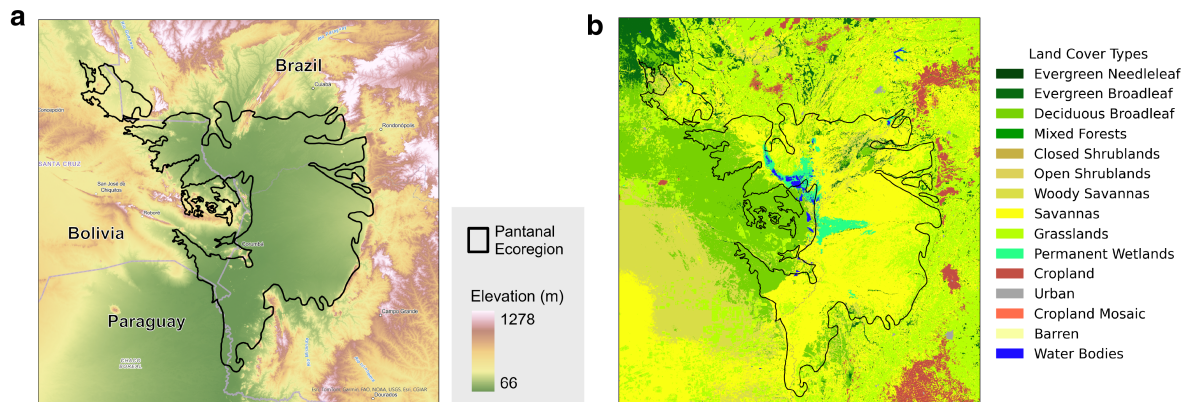


Figure S1: Topography, and land-cover patterns across the Pantanal wetland. (a) Digital Elevation Model (DEM)-derived regional topography highlighting the low-relief landscape that sustains seasonal flooding. (b) Land-cover distribution (2024) providing ecological context for fire-inundation dynamics.

Table 1: Summary of datasets used in this study.

Dataset	Variable	Spatial resolution	Temporal resolution	Study period	Source
MCD64A1 V6	Burned area	500 m	Monthly	2001–2024	NASA LP DAAC
MCD12Q1 V6.1	Land cover type	500 m	Annual	2001–2024	NASA LP DAAC
MOD11A2	Land surface temperature	1 km	8-day (monthly aggregated)	2001–2024	NASA LP DAAC
CHIRPS V2.0	Precipitation	0.05° (~5.5 km)	Monthly	2001–2024	UCSB Climate Hazards Group
Berkeley-RWAWC (Monthly)	Inundation extent	0.01° (~1 km)	Monthly	2018–2024	NASA PO.DAAC
Berkeley-RWAWC (Daily)	Inundation extent	0.01° (~1 km)	Daily (31-day rolling)	2018–2024	NASA PO.DAAC

Abbreviations: MODIS, Moderate Resolution Imaging Spectroradiometer; LP DAAC, Land Processes Distributed Active Archive Center; CHIRPS, Climate Hazards Group InfraRed Precipitation with Station data; UCSB, University of California, Santa Barbara; GNSS-R, Global Navigation Satellite System Reflectometry; CYGNSS, Cyclone Global Navigation Satellite System; PO.DAAC, Physical Oceanography Distributed Active Archive Center. The source column indicates the data archive or provider used to access each dataset.

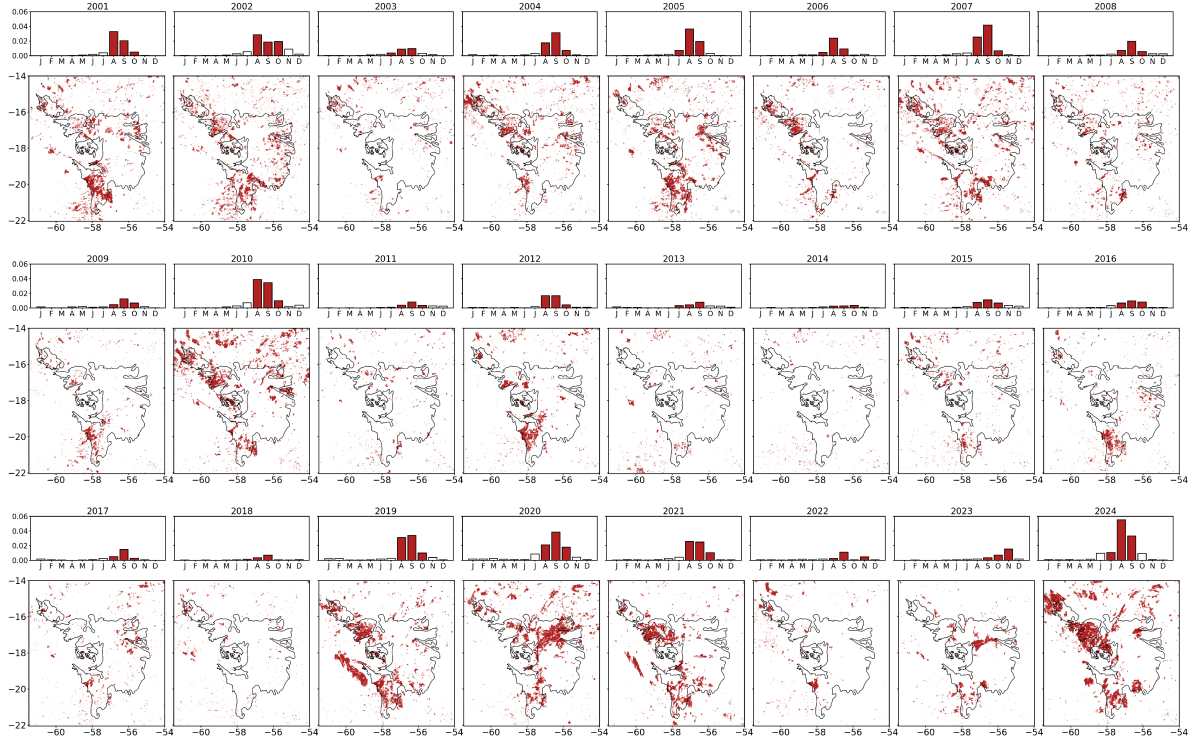


Figure S2: Seasonal timing and spatial distribution of peak burned area in the Pantanal from 2001–2024. For each year, histograms show monthly burned area, with the three peak months highlighted. Corresponding maps show the spatial distribution of burned area during those peak months. The Pantanal ecoregion boundary is outlined in black.

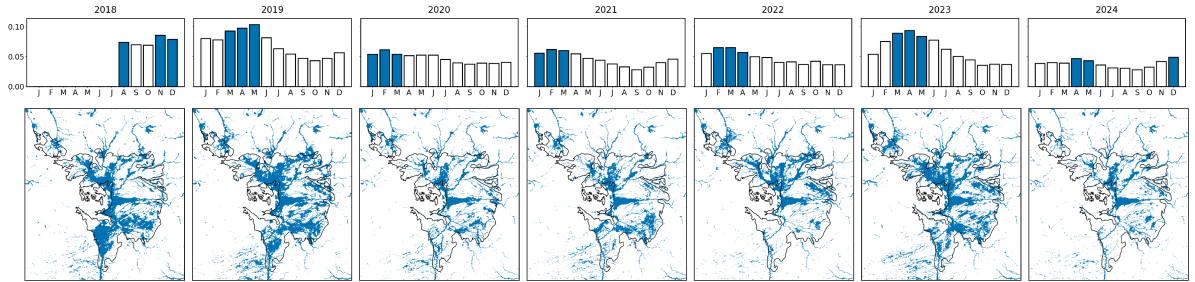


Figure S3: Seasonal timing and spatial distribution of peak inundation in the Pantanal from August 2018–2024. For each year, histograms show monthly inundation extent, with the three peak months highlighted. Corresponding maps show the spatial distribution of inundation during those peak months. The Pantanal ecoregion boundary is outlined in black. Blue indicates water and white indicates non-water land, based on the Berkeley-RWAWC monthly binary inundation product.

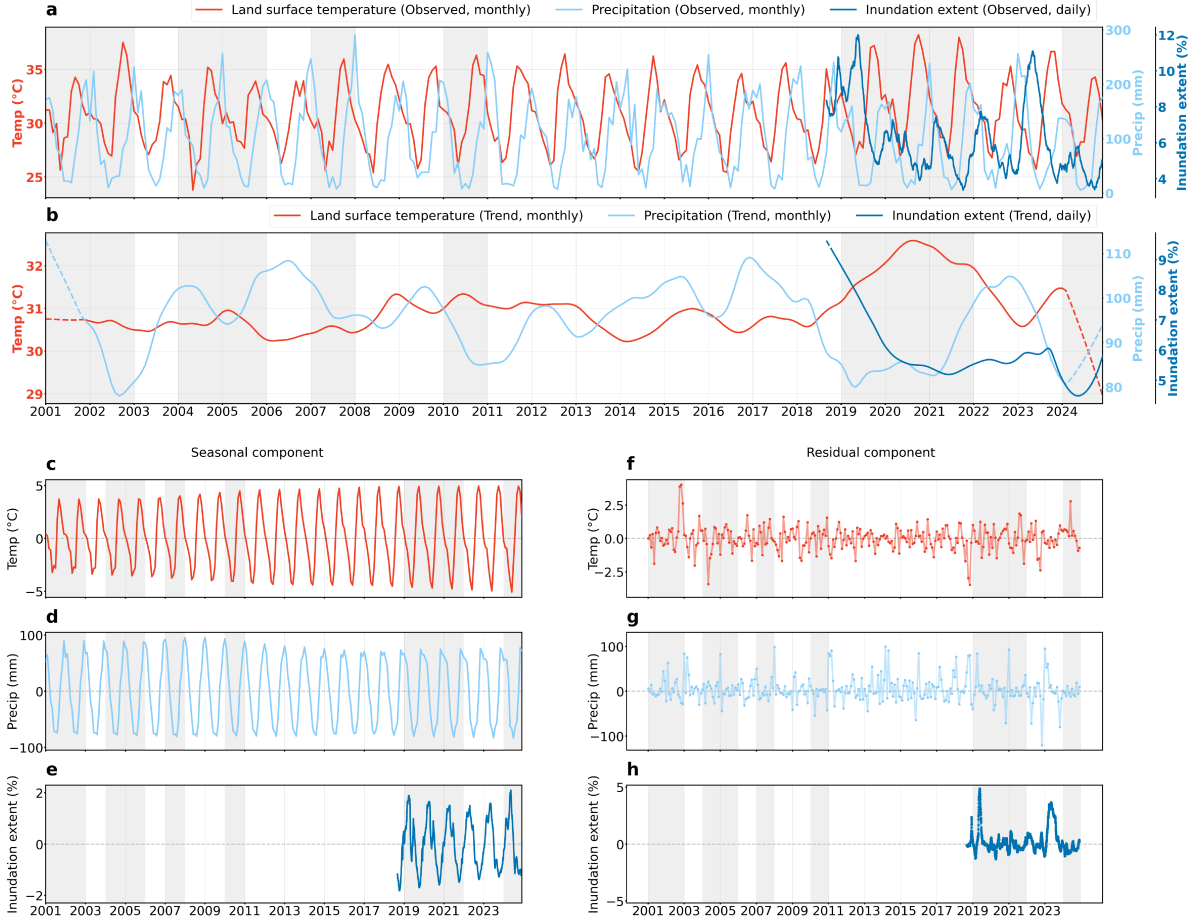


Figure S4: Time series of precipitation, land surface temperature, and inundation extent with megafire years highlighted. (a) MODIS land surface temperature (red) and CHIRPS precipitation (light blue), averaged over the Pantanal (2001–2024), together with Berkeley-RWAWC daily inundation extent (dark blue; available from September 2018). (b–h) Signal decomposition showing (b) long-term trend, (c–e) seasonal component, and (f–h) residuals. Grey shading denotes megafire years. Because STL estimates are less reliable near the beginning and end of the series, dashed lines in (b) indicate edge-affected periods.

2 Fire-event reconstruction framework

Fig. S5 shows that earlier years were characterized by a relatively stable late-summer ignition peak, whereas recent seasons exhibit greater variability in fire onset, including both anomalously early ignitions and activity extending into autumn. This broadened ignition window suggests a weakening of the historically dominant seasonal signal, consistent with more permissive climatic or fuel conditions under drought stress and shortened wet seasons.

The spatiotemporally resolved burned-area archive enables event-scale fire dynamics to be examined as coherent evolving processes rather than isolated burned pixels. We illustrate this capability using 2024, an extreme fire year in which more than 12% of the Pantanal burned (Fig. S6). Event reconstruction shows that the ten largest fires differed markedly in ignition structure and spread behavior. Events 1 and 2 exhibit broadly distributed ignition points, consistent with multiple localized ignitions or rapid merging of nearby fires. Events 3 and 4 show ignition points aligned along a central corridor, suggesting corridor-structured fire growth and subsequent outward spread. Event 5 illustrates landscape memory: an unburned core within the fire perimeter corresponds to an area burned earlier in the season, suggesting that fuel depletion constrained re-burning and shaped the final event geometry. These examples show that large burned extents can arise through distinct pathways, including ignition clustering, fire merging, corridor-guided spread, and feedbacks from prior burning. Comparable event structures across other megafire years are shown in Fig. S7.

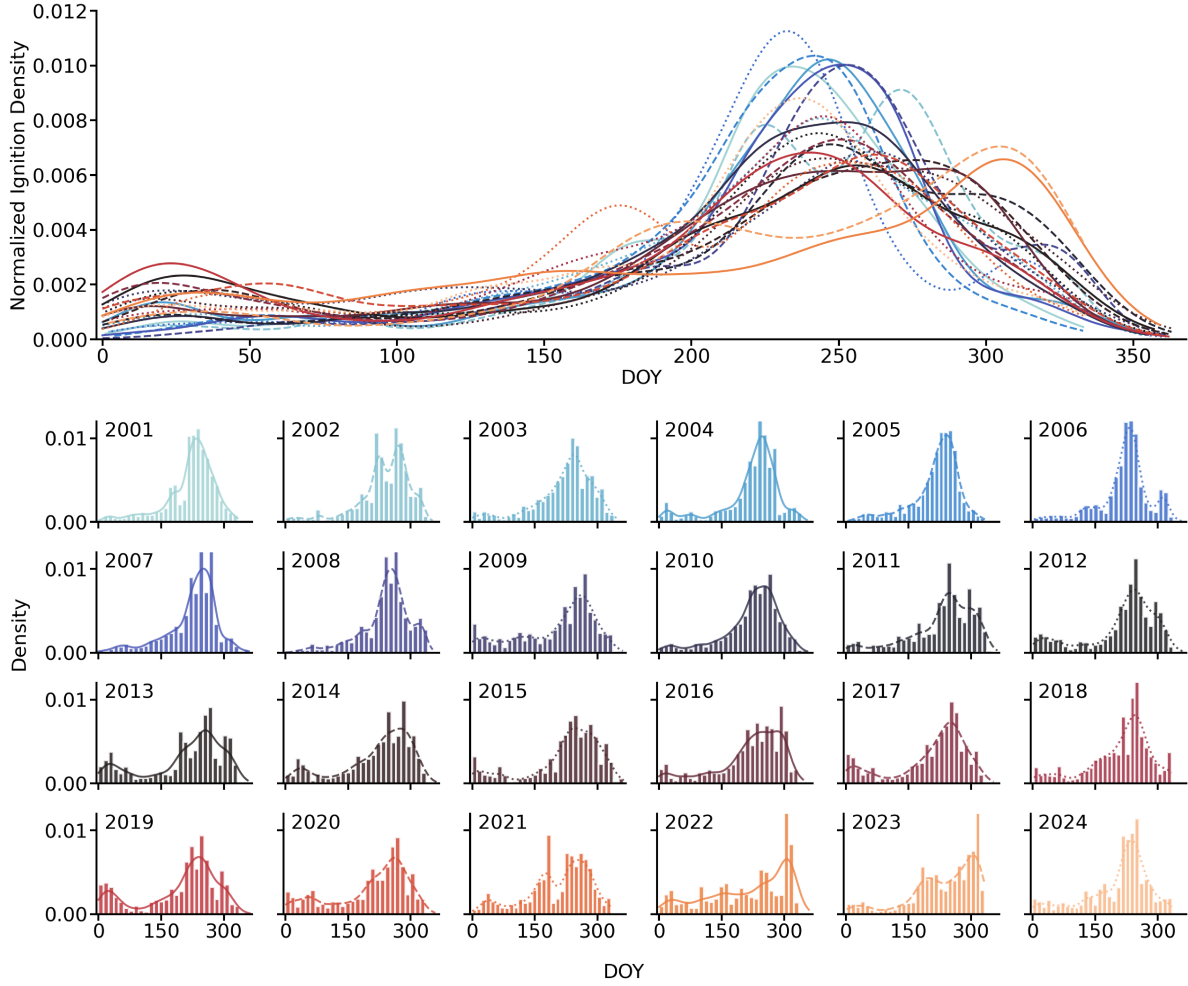


Figure S5: Interannual variability in ignition timing across the Pantanal from 2001 to 2024. Top: Kernel density estimates of ignition timing for each year, with colors and line styles indicating year. Bottom: Year-specific histograms and kernel density estimates of ignition timing, with each panel labeled by year to identify the corresponding color and line style used in the combined upper panel. All panels use the same x-axis (day of year) and y-axis ranges to facilitate comparison across years.

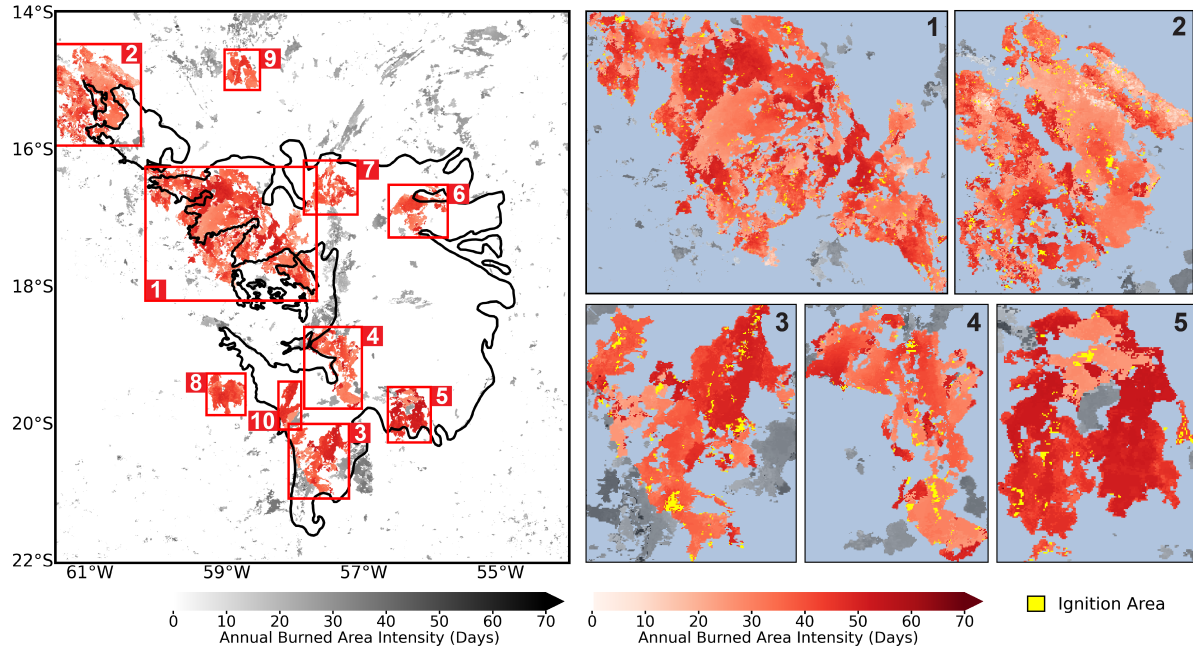


Figure S6: Event-scale burned area extent and ignition locations for major wildfire events in 2024. Left: The ten largest reconstructed wildfire events in 2024, ranked by total burned area, are delineated by red bounding boxes and labeled by rank. Burned-area intensity within these events is shown using red shading, while grayscale shading represents annual burned-area intensity across the remainder of the Pantanal. Right: Zoomed-in views (not to scale) of the five largest wildfire events, with ignition locations highlighted in yellow, illustrating event-specific differences in fire initiation, growth, and spatial propagation. A muted blue background is used to reduce visual clutter and improve visual contrast.

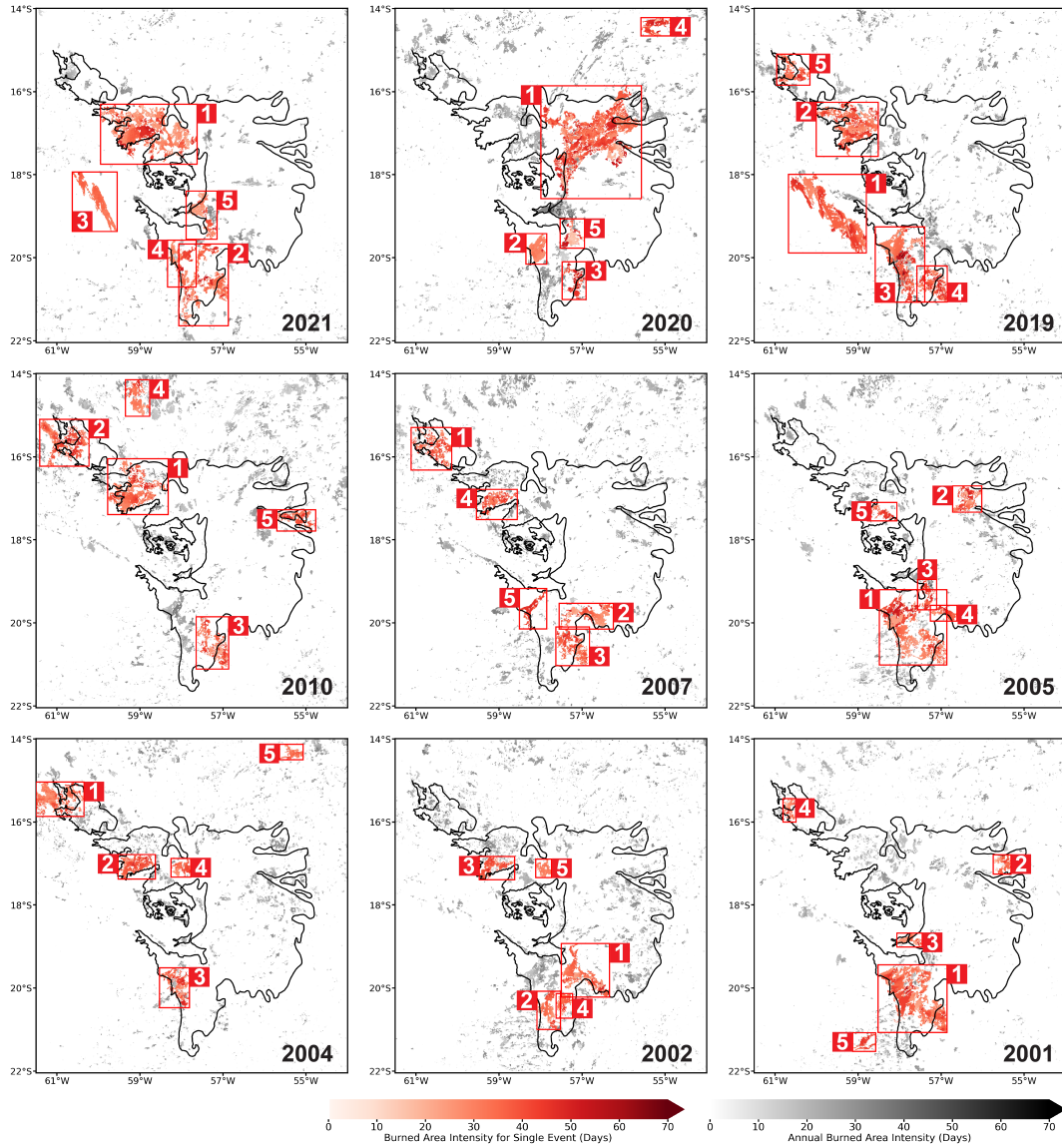


Figure S7: Spatial characteristics of the five largest fire events during extreme burned-area years (total burned area >6% of expanded study domain). For each megafire year, panels show the spatial extent of the five largest reconstructed fire events. Annual burned-area intensity is shown in gray in the background, while major fire events are outlined, boxed, and labeled according to their rank (1–5) based on total burned extent. Ecoregion boundaries are overlaid for geographic reference.

3 Land-cover transitions

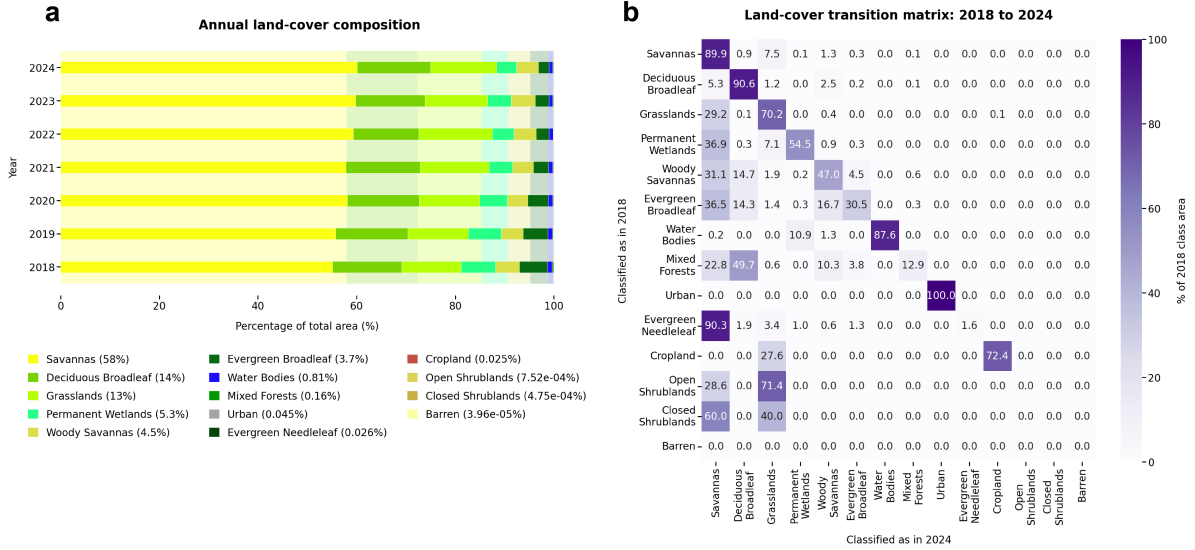


Figure S8: Land-cover composition and transitions across the Pantanal from 2018–2024. (a) Annual land-cover composition relative to the 2018–2024 mean. Foreground bars show yearly class fractions, while semi-transparent background blocks show the multi-year mean composition. Classes are ordered by mean fractional area; legend values indicate mean class contributions. (b) Land-cover transition matrix comparing 2018 and 2024 classifications. Rows indicate 2018 classes and columns indicate 2024 classes; diagonal values show class persistence, and off-diagonal values show transitions. Elevated transitions from Grassland and Permanent Wetlands to Savanna indicate redistribution toward more savanna-dominated landscapes.

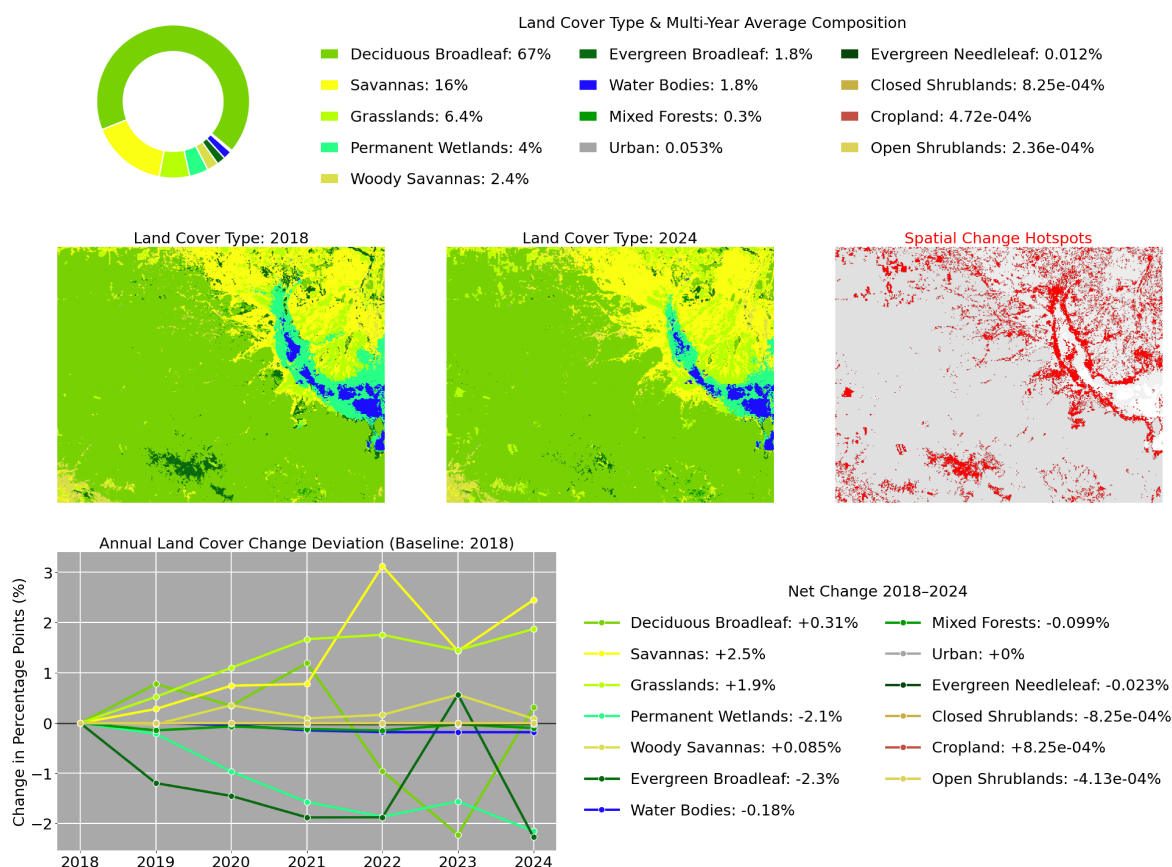


Figure S9: Land-cover dynamics in fire-prone Region A from 2018–2024. The top row shows mean land-cover composition across the study period. The middle row shows land-cover patterns in 2018 and 2024 and the spatial distribution of class changes. The bottom row shows annual land-cover change relative to 2018, with class-specific net changes summarized at right.

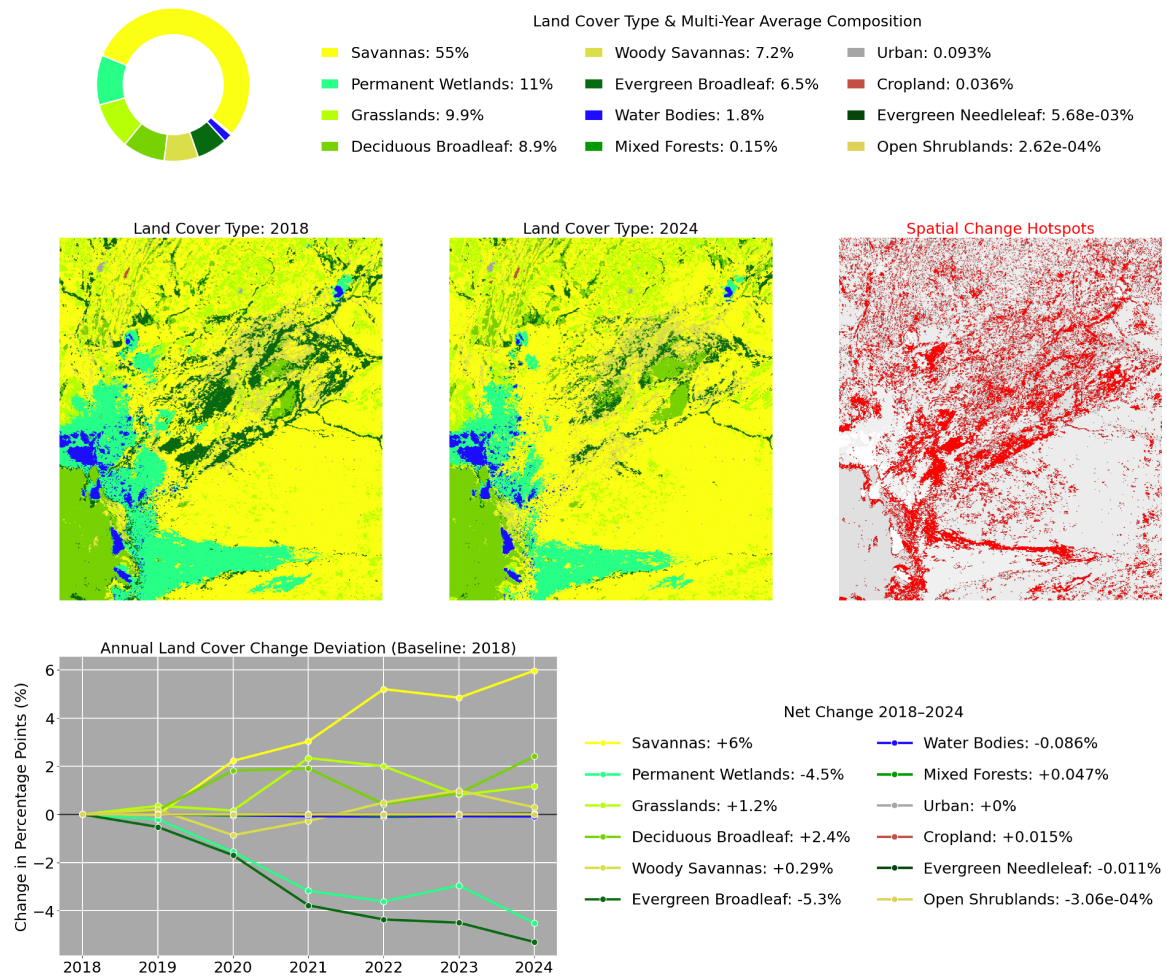


Figure S10: Land-cover dynamics in fire-prone Region B from 2018–2024. Same panel structure as Supplementary Fig. S8, showing mean land-cover composition, land-cover patterns in 2018 and 2024, spatial class changes, and annual land-cover change relative to 2018.

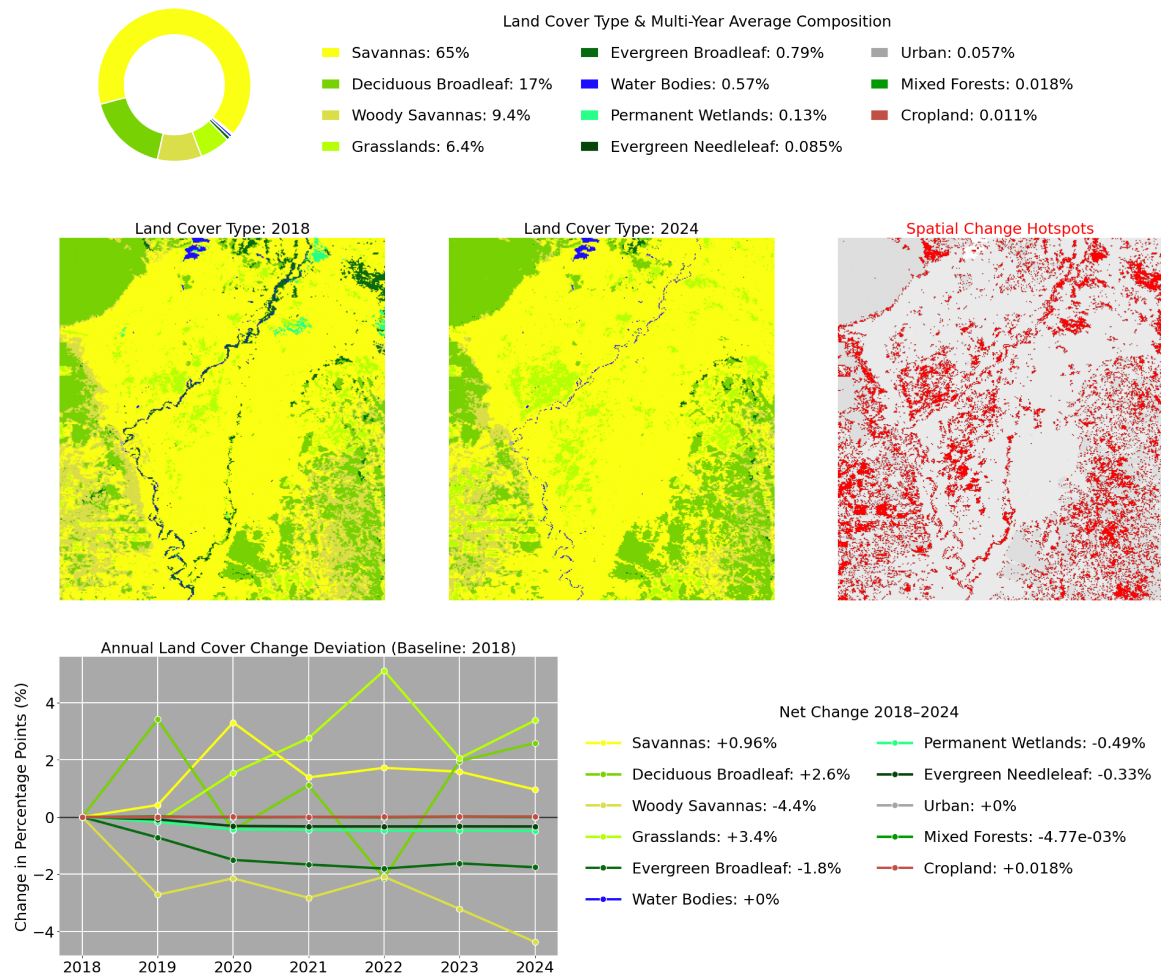


Figure S11: Land-cover dynamics in fire-prone Region C from 2018–2024. Same panel structure as Supplementary Fig. S8, showing mean land-cover composition, land-cover patterns in 2018 and 2024, spatial class changes, and annual land-cover change relative to 2018.