Supplementary Information: Rationale for Selecting Explanatory Variables

1. Climatic Variables (Temperature, Precipitation, Radiation)

Climatic factors were included because temperature and precipitation are widely recognized as the dominant controls of vegetation stability. Huang and Xia (2019) demonstrated that these factors exert stronger effects on resistance and resilience than biodiversity-related attributes. Moreover, antecedent and post-event climatic conditions influence both pre-conditioning processes and recovery dynamics. Therefore, temperature, precipitation, and radiation were incorporated for the event year, the preceding year, and the recovery year.

2. Elevation

Elevation was selected because vegetation in high-altitude regions has been shown to be more sensitive to climatic variability. Li et al. (2018) reported that resistance can vary substantially with elevation in regions such as Tibet, northeastern China, and montane ecosystems. Although empirical evidence linking elevation to resilience is limited, elevation was included to capture potential topographic modulation of stability.

3. Biodiversity-Related Factors (ASR, ASI, ASL)

Biodiversity metrics were included because numerous field studies have revealed strong relationships between species diversity and ecosystem stability. Changes in community composition—especially anthropogenic species loss and gain—can alter the capacity of vegetation to withstand and recover from climatic extremes. Hautier et al. (2015) showed that anthropogenic biodiversity changes significantly modify vegetation responses to environmental stress. Therefore, anthropogenic species richness (ASR), species increase (ASI), and species loss (ASL) were included.

4. Soil Properties (Bulk Density, Carbon, Nitrogen, Moisture)

Soil properties were considered because soil water-holding capacity influences vegetation responses to extreme climatic conditions. Although Berdugo et al. (2022) noted that the role of soil characteristics in ecosystem stability remains insufficiently understood, several mechanistic relationships justify their inclusion in studies. Water retention varies by soil type and is inversely related to the bulk density (FAO/ISRIC/ISSS, 1998). Blanco-Canqui et al. (2006) demonstrated that soil carbon content is positively associated with water retention and negatively correlated with the maximum bulk density. Nitrogen content is a key determinant of vegetation function. Based on these relationships, multiple soil attributes were included in the study.

5. Land-Use History (Cropland and Pastureland Duration)

Land-use history was incorporated because ecological legacies influence vegetation responses to extreme events such as droughts. Holmgren et al. (2006) proposed that disturbances associated with ENSO-driven droughts and heavy rainfall can cause long-term shifts in species composition. Yanagawa et al. (2016) showed that lands with a longer cultivation history exhibit higher resilience following droughts, likely due to repeated exposure to past extremes. Therefore, the duration of cropland and pastureland use was also included in the study.

6. Irrigation Extent

Irrigation was included because anthropogenic water inputs directly modify the moisture environment and buffer vegetation against water stress. Differences in irrigation extent can influence spatial variation in resistance and resilience. Thus, the irrigation adoption rate (Siebert et al., 2013) was selected as a key management-related variable.

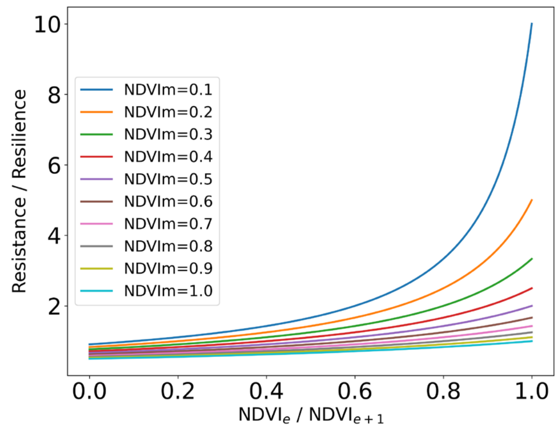


Figure S1. A conceptual diagram of resistance and resilience, illustrating the possible values of $NDVI_e$ and $NDVI_e$+1 when $NDVI_m$ is varied from 0.1 to 1.0 in increments of 0.1.Illustrates the resistance and resilience when NDVIm = 0.5.

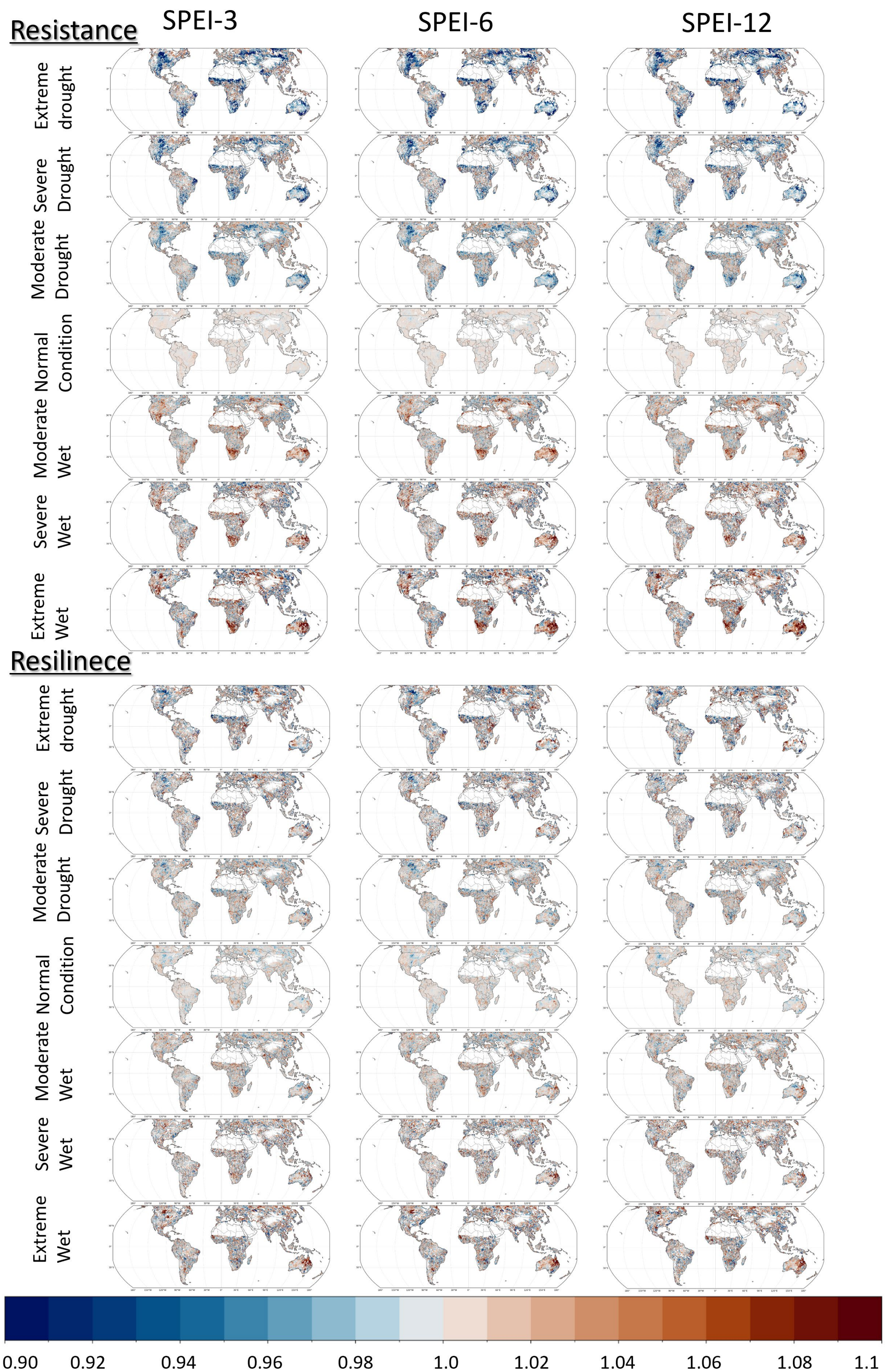

Resistance
SPEI-3
SPEI-6
SPEI-12
Extreme drought
Severe Drought
Moderate Drought
Normal Condition
Moderate Wet
Severe Wet
Extreme Wet
Resilinece
Extreme drought
Severe Drought
Moderate Drought
Normal Condition
Moderate Wet
Severe Wet
Extreme Wet
0.90
0.92
0.94
0.96
0.98
1.0
1.02
1.04
1.06
1.08
1.1

Figure S2. Reisitance and resilience maps under seven climate valiables at SPEI-3, -6, and 12 month.

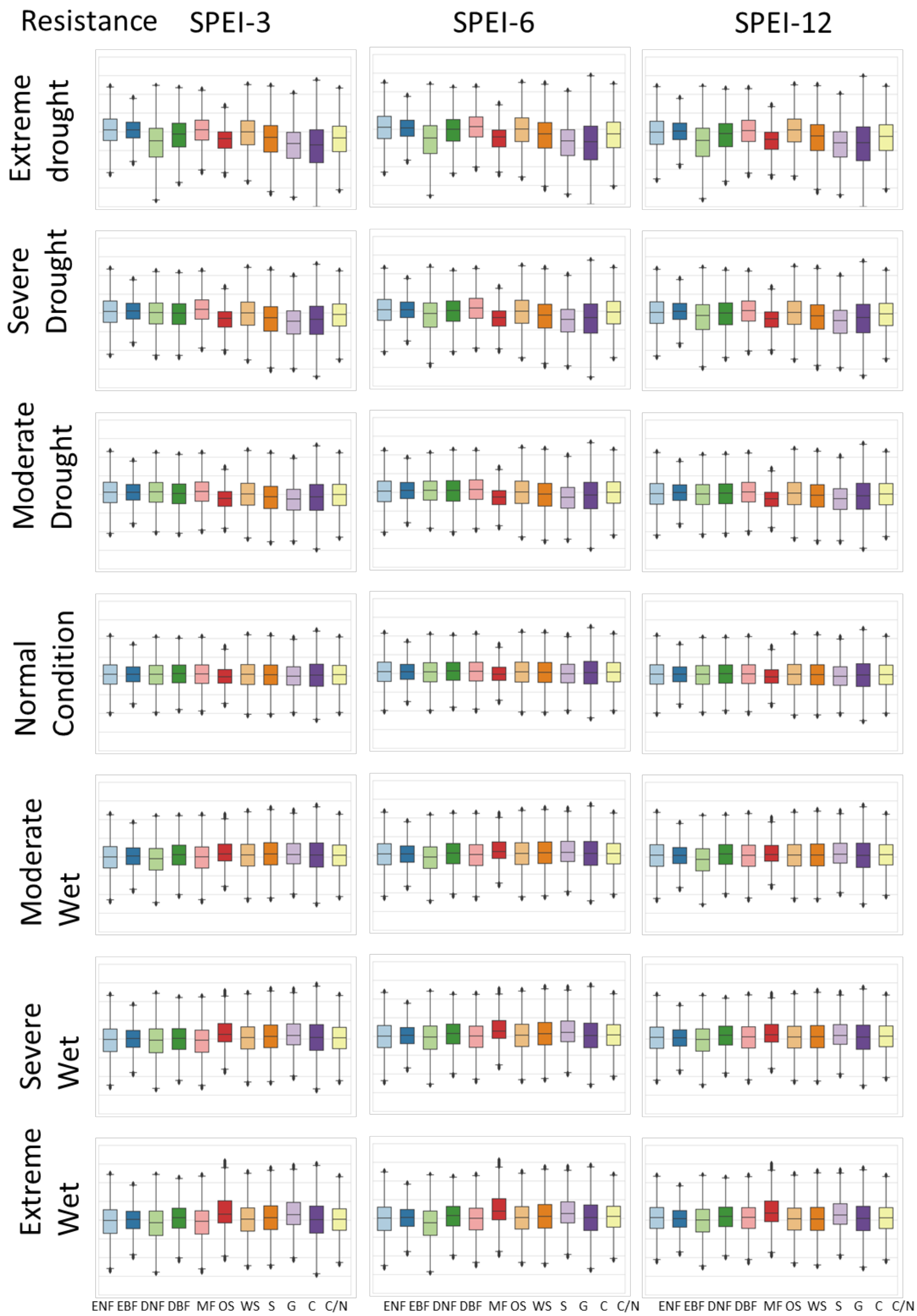


Figure S3. Boxplots of resistance for each land-cover type under different SPEI conditions. Resilience values were filtered by removing IQR-based outliers and restricting the display to the range 0.8–1.2. Each land cover type is shown using colors selected from the paired palette. Boxes denote the interquartile range (25th–75th percentiles), and whiskers indicate the maximum and minimum non-outlier values of the data.

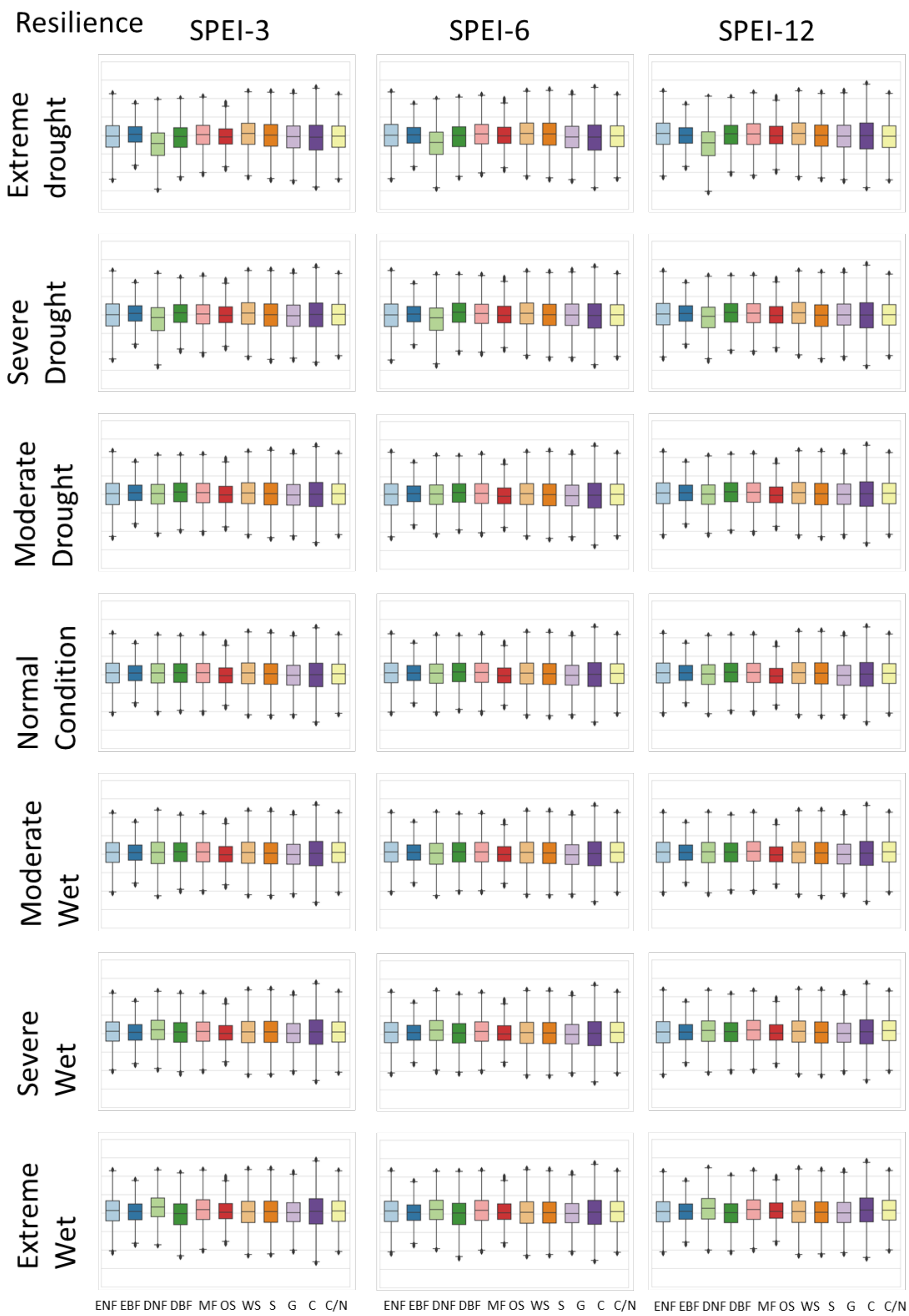
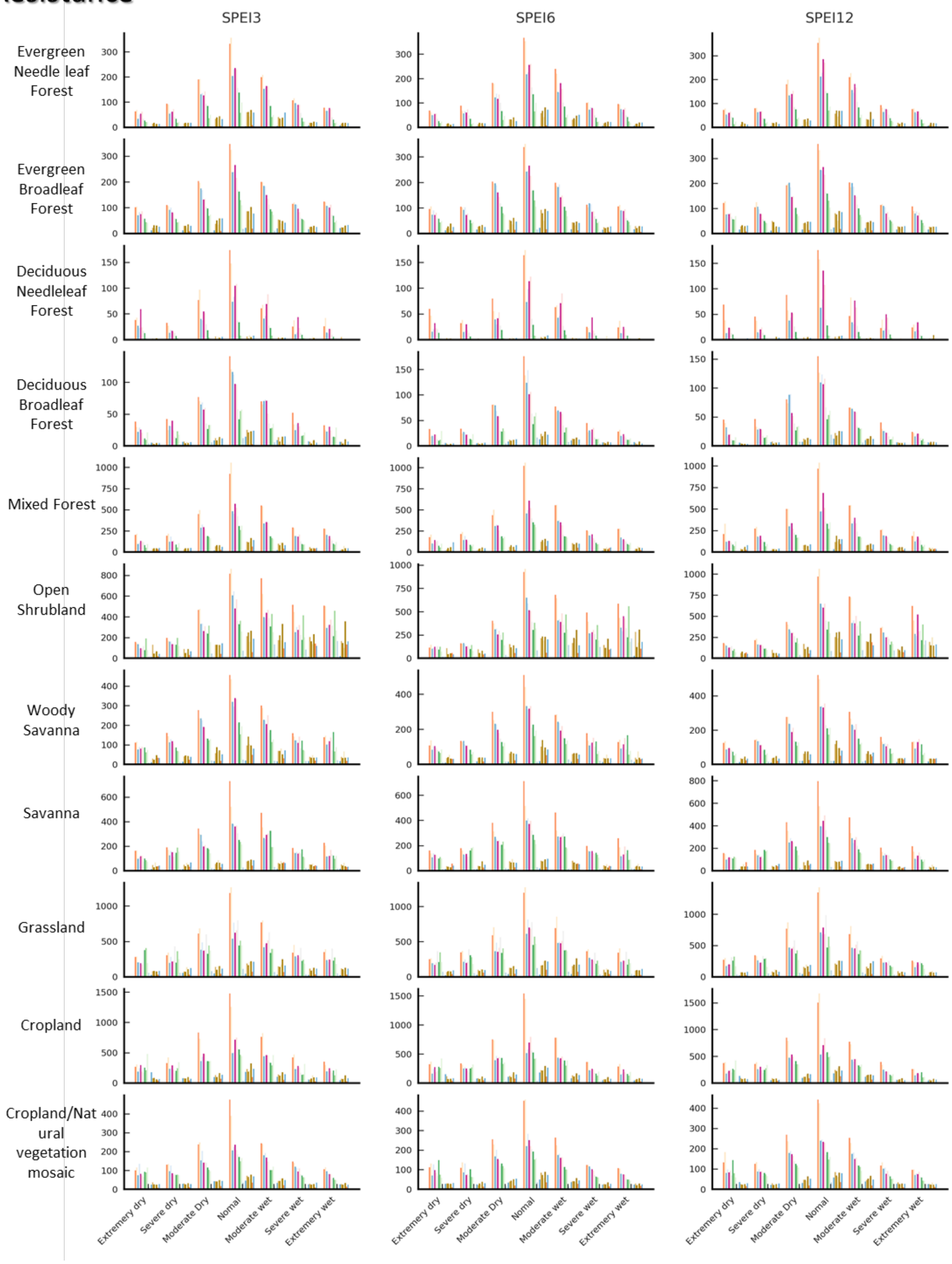


Figure S4. Boxplots of resilience for each land cover type under different SPEI conditions. Resiliene values were filtered by removing IQR-based outliers and restricting the display to the range 0.8–1.2. Each land-cover type is shown using colors selected from the Paired palette. Boxes denote the interquartile range (25th–75th percentiles), and whiskers indicate the maximum and minimum non-outlier values.

Resistance


SPEI3
SPEI6
SPEI12
Evergreen Needle leaf Forest
Evergreen Broadleaf Forest
Deciduous Needleleaf Forest
Deciduous Broadleaf Forest
Mixed Forest
Open Shrubland
Woody Savanna
Savanna
Grassland
Cropland
Cropland/Natural vegetation mosaic
Extremery dry
Severe dry
Moderate Dry
Nomal
Moderate wet
Severe wet
Extremery wet

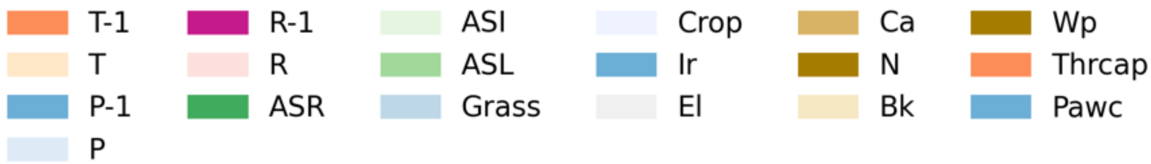
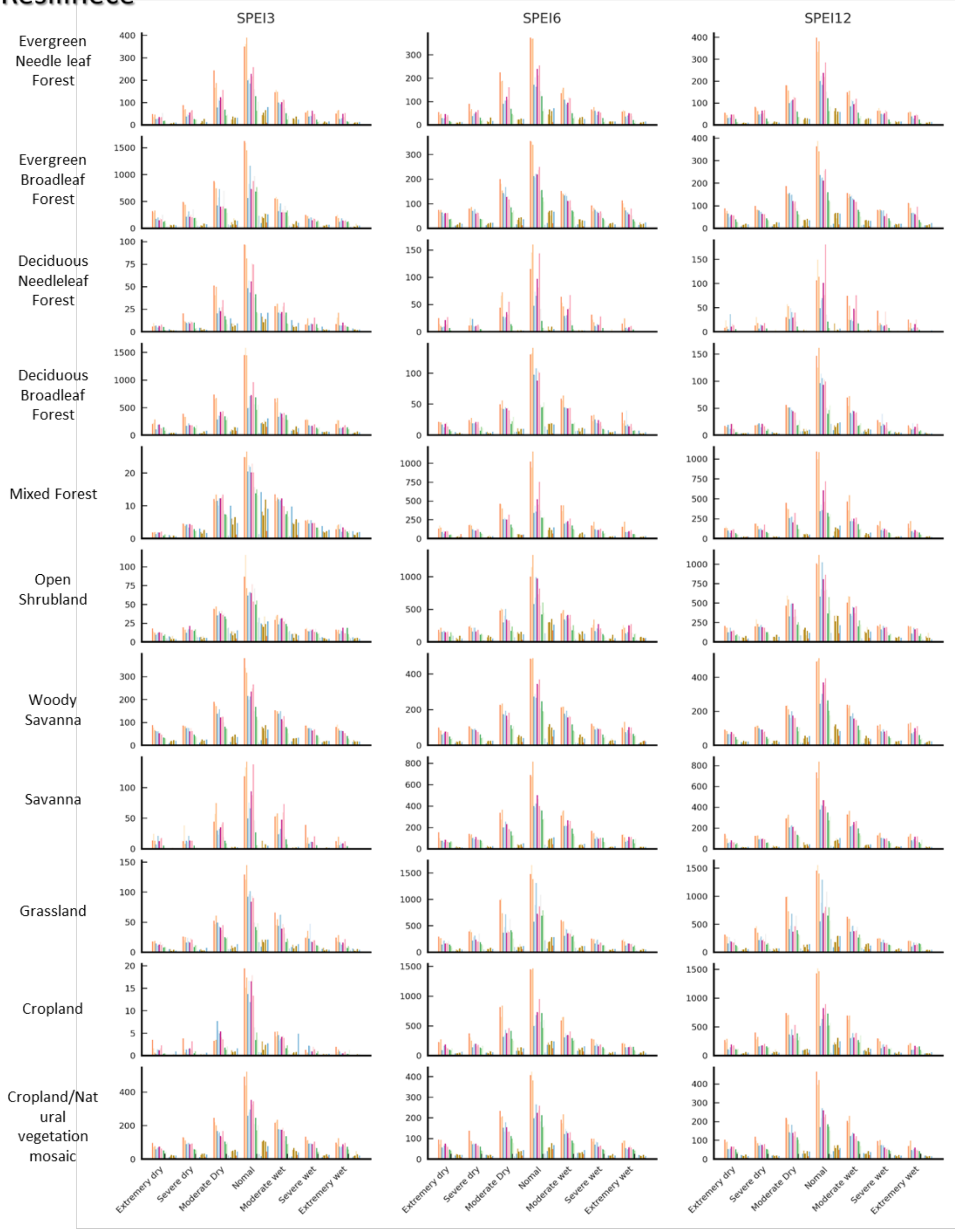


Figure S5. The feature importance (gain) of each explanatory variable in the LightGBM analysis of resistance under different climatic gradients (SPEI-3, SPEI-6, and SPEI-12) varied by land cover type. Because feature importance is influenced by the number of samples used in the analysis, the bars for normal climate conditions, where events occur most frequently, tend to be larger overall. However, when examined separately for each climatic event category, the patterns of feature importance differ clearly among the climate conditions.

Resilinece


SPEI3
SPEI6
SPEI12
Evergreen Needle leaf Forest
Evergreen Broadleaf Forest
Deciduous Needleleaf Forest
Deciduous Broadleaf Forest
Mixed Forest
Open Shrubland
Woody Savanna
Savanna
Grassland
Cropland
Cropland/Natural vegetation mosaic
Extremery dry
Severe dry
Moderate Dry
Nomal
Moderate wet
Severe wet
Extremery wet

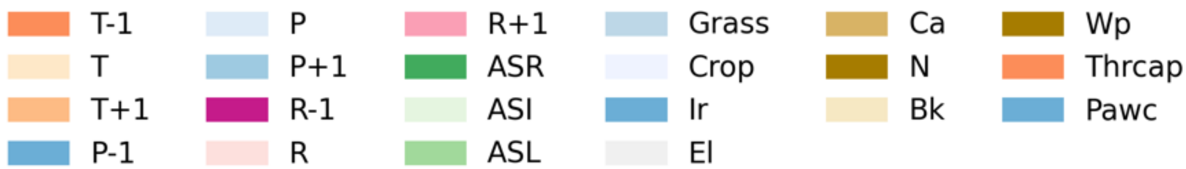


Figure S6. The feature importance (Gain) of each explanatory variable in the LightGBM analysis of resilience under different climatic gradients (SPEI-3, SPEI-6, and SPEI-12) varies by land-cover type. Because feature importance is influenced by the number of samples used in the analysis, the bars for the Normal climate condition—where events occur most frequently—tend to be larger overall. However, when examined separately for each climatic event category, the patterns of feature importance differ clearly among the climate conditions.