COMPREHENSIVE DROUGHT ANALYSIS USING PDSI, AND REMOTE SENSING DATA

Roll Number: 2023121006

INTRODUCTION

- Drought affects ecosystems, agriculture, and water resources, leading to food insecurity, economic losses, and environmental degradation.
- Early Detection is crucial for managing water resources and agriculture practises

Why PDSI is Preferred

- Key advantages of PDSI:
  a. The Palmer Drought Severity Index (PDSI) considers multiple factors—precipitation, temperature, and soil moisture—making it a more comprehensive measure of drought.

  a. In contrast, Standardized Precipitation Index (SPI) focuses solely on precipitation, missing critical soil moisture and temperature effects.

DATASET AND DATA COLLECTION

- Monthly data (1895–2017).
- Sources: National Drought Mitigation Center, drought.gov.
- Key parameters: Precipitation, potential evapotranspiration, available water capacity(soil).

PDSI CALCULATION OVERVIEW

- Data preparation: datetime conversion, segmentation, removing nan, saving in csv from xarray format
- Variables: Precipitation, PET, AWC.

```
Year,Month,Latitude,Longitude,Precipitation
1895,1,25.229166,-80.6875,37.30957
1895,1,25.895834,-81.354164,38.259766
1895,1,25.895834,-80.6875,37.299805
1895,1,26.5625,-98.6875,19.160156
```

METHODOLOGY

1. AVAILABLE WATER COMPONENTS

- **Surface Layer (SS):** $\mathrm{SS} = \min(1.0, \mathrm{AWC})$
  Represents water available in the topsoil layer, capped at 1.0 inch.
- **Under Layer (SU):** $\mathrm{SU} = \max(\mathrm{AWC} - 1.0, 0)$
  Represents deeper soil moisture beyond the surface layer.

TOTAL SOIL MOISTURE (MT_0) IS THE SUM OF WATER IN THESE LAYERS AT EACH TIME STEP

METHODOLOGY

2. WATER BALANCE CALCULATION

2. Water Balance Calculation:

1. **When $P \geq PET$:**
   - Evapotranspiration (ET) = PET.
   - Recharge (R) = $\min(P - PET, AWC - M_t)$.
   - Runoff (RO) = $P - PET - R$.
   - Updated Soil Moisture: $M_{t+1} = M_t + R$.

MT_0

NEW SOIL MOISTURE MT_1= MT_0 + RO

2. **When $P < PET$:**
   - Loss (L) = $\min(M_t, PET - P)$.
   - Evapotranspiration (ET) = $P + L$.
   - Recharge (R) = 0.
   - Runoff (RO) = 0.
   - Updated Soil Moisture: $M_{t+1} = M_t - L$.

NEW SOIL MOISTURE MT_1 = MT_0 - L

METHODOLOGY

3. MOISTURE ANOMALY (Z)

The moisture anomaly (Z) measures deviations from normal conditions:

$$Z = K \cdot (P - \hat{P}),$$

where $\hat{P}$ is the **CAFEC precipitation**, calculated as:

$$\hat{P} = \alpha \mathrm{PET} + \beta \mathrm{R} + \gamma \mathrm{RO} - \delta \mathrm{L}.$$

- $\alpha, \beta, \gamma, \delta$: Calibration coefficients for PET, recharge, runoff, and loss contributions.

METHODOLOGY

4. RECURSIVE PDSI CALCULATION

- Assume $w_1 = 0.9$ and $w_2 = 0.1$.
- Starting with $PDSI_0 = 0$, and using calculated Z_t values:

Month	Z_t	$PDSI_t$ (calculated as $0.9 \cdot PDSI_{t-1} + 0.1 \cdot Z_t$)
1	1.5	$0.9 \cdot 0 + 0.1 \cdot 1.5 = 0.15$
2	-0.5	$0.9 \cdot 0.15 + 0.1 \cdot -0.5 = 0.09$
3	2.0	$0.9 \cdot 0.09 + 0.1 \cdot 2.0 = 0.27$

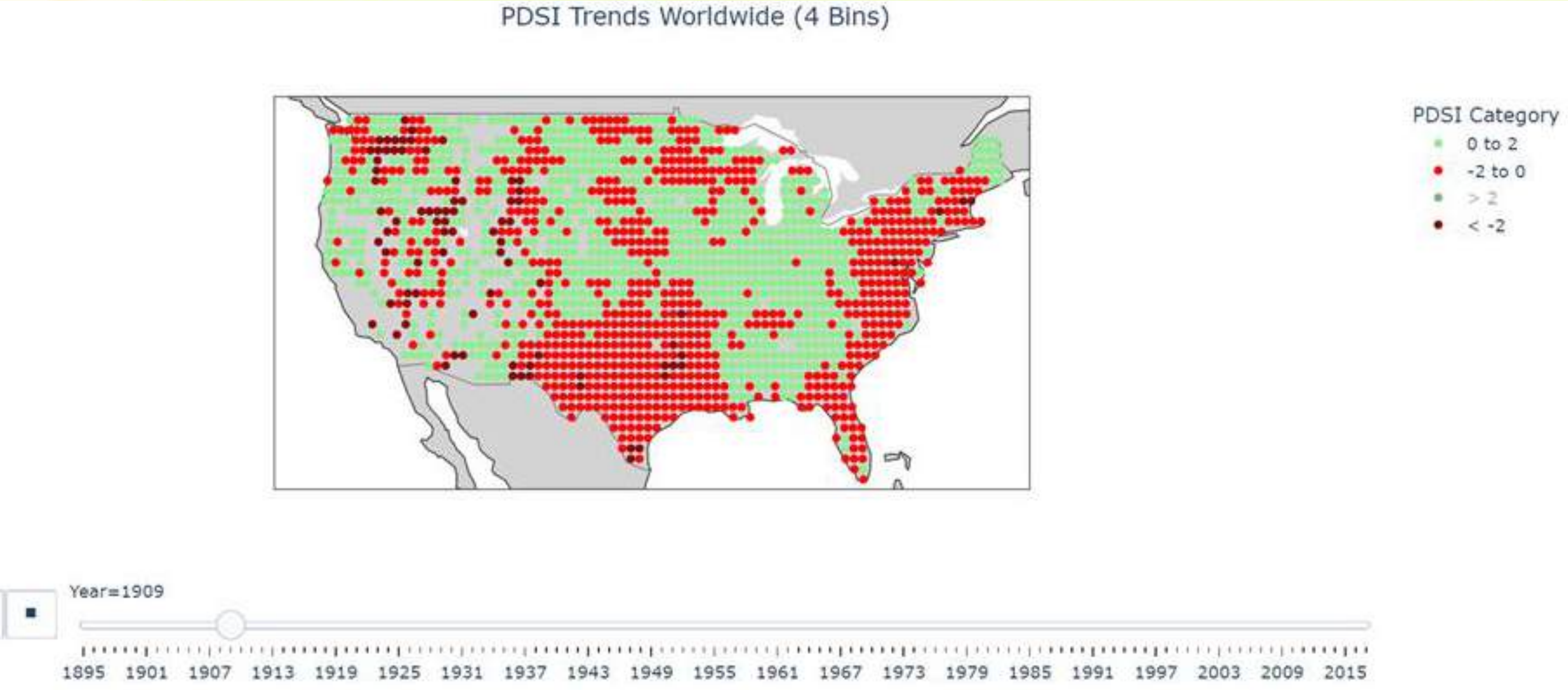
This recursive process ensures that both historical trends and current anomalies are accounted for in the evolving PDSI.

INTERPRETATION

- PDSI > 0: Wet conditions or above-average moisture.
- PDSI = 0: Normal moisture conditions (neither drought nor excess).
- PDSI < 0: Drought conditions, with the magnitude indicating the severity:
  - -0.5 to -1.0: Mild drought
  - -1.0 to -2.0: Moderate drought
  - -2.0 to -3.0: Severe drought
  - <-3.0: Exceptional drought

VISUALIZATION

- Trends in drought occurrence.
- Heatmap or color-coded map of PDSI data.



HISTORICAL DROUGHT CASE:STUDY 1

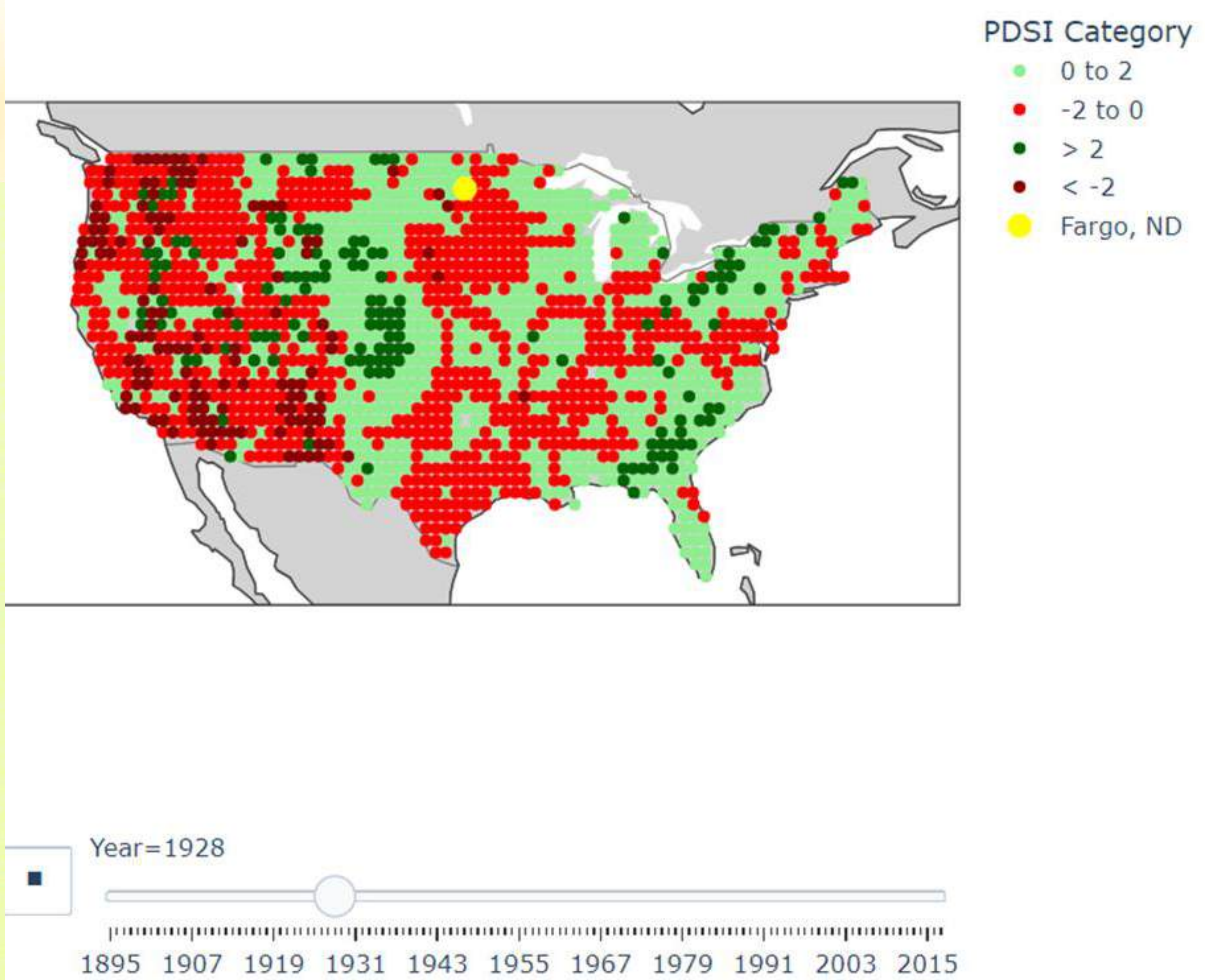
- https://labs.waterdata.usgs.gov/visualizations/drought-timeline/index.html#/

DUST BOWL (1930 - 1941)

- The drought was particularly severe in the Fargo, North Dakota area.
- Latitude and Longitude:
- The latitude and longitude used, lat=[46.8772], lon=[-96.7898], is accurate for the Fargo, North Dakota area represented by yellow dot in visualization.

HISTORICAL DROUGHT CASE:STUDY 1

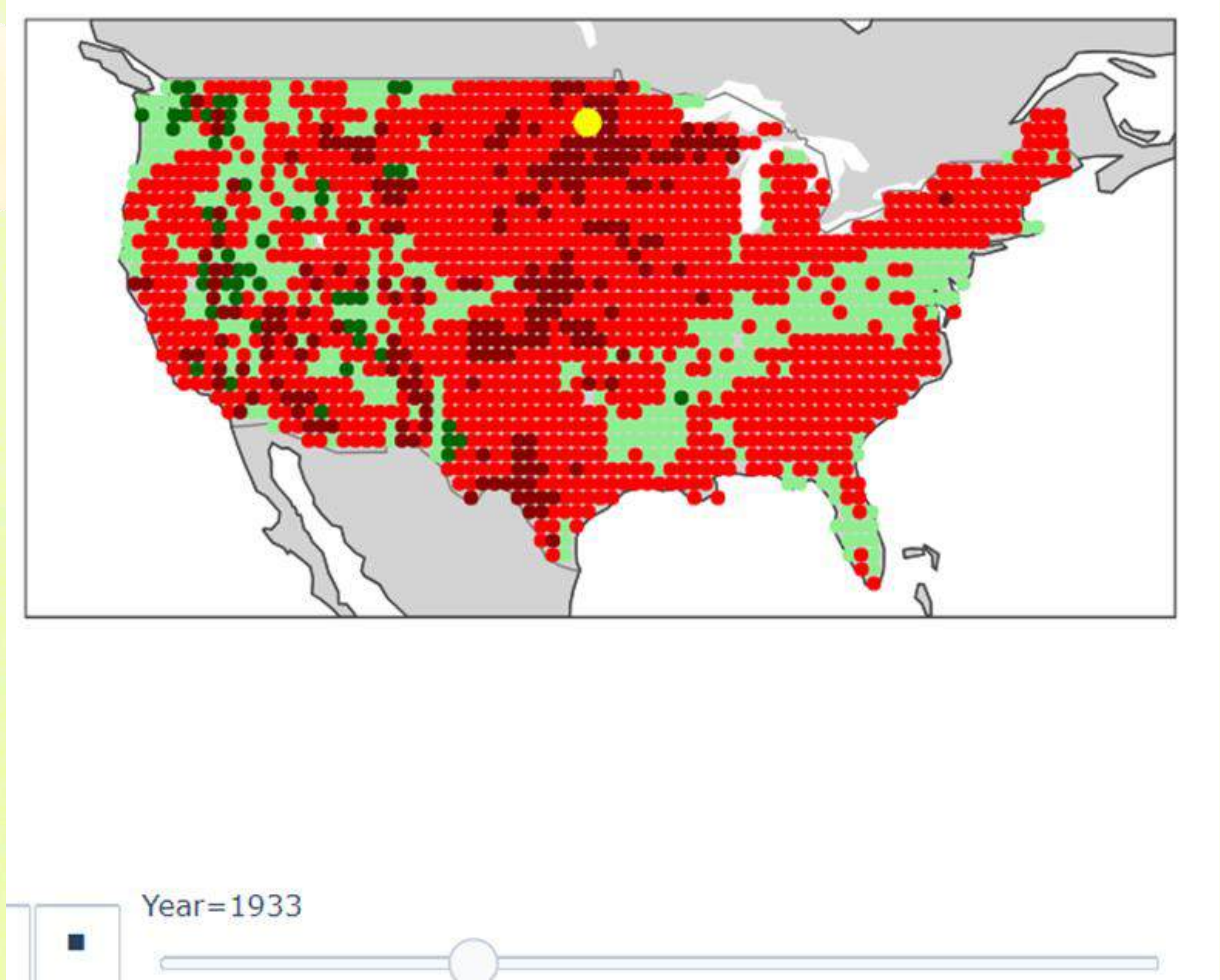
DUST BOWL (1930 - 1941)



YEAR 1928

HISTORICAL DROUGHT CASE:STUDY 1

DUST BOWL (1930 - 1941)

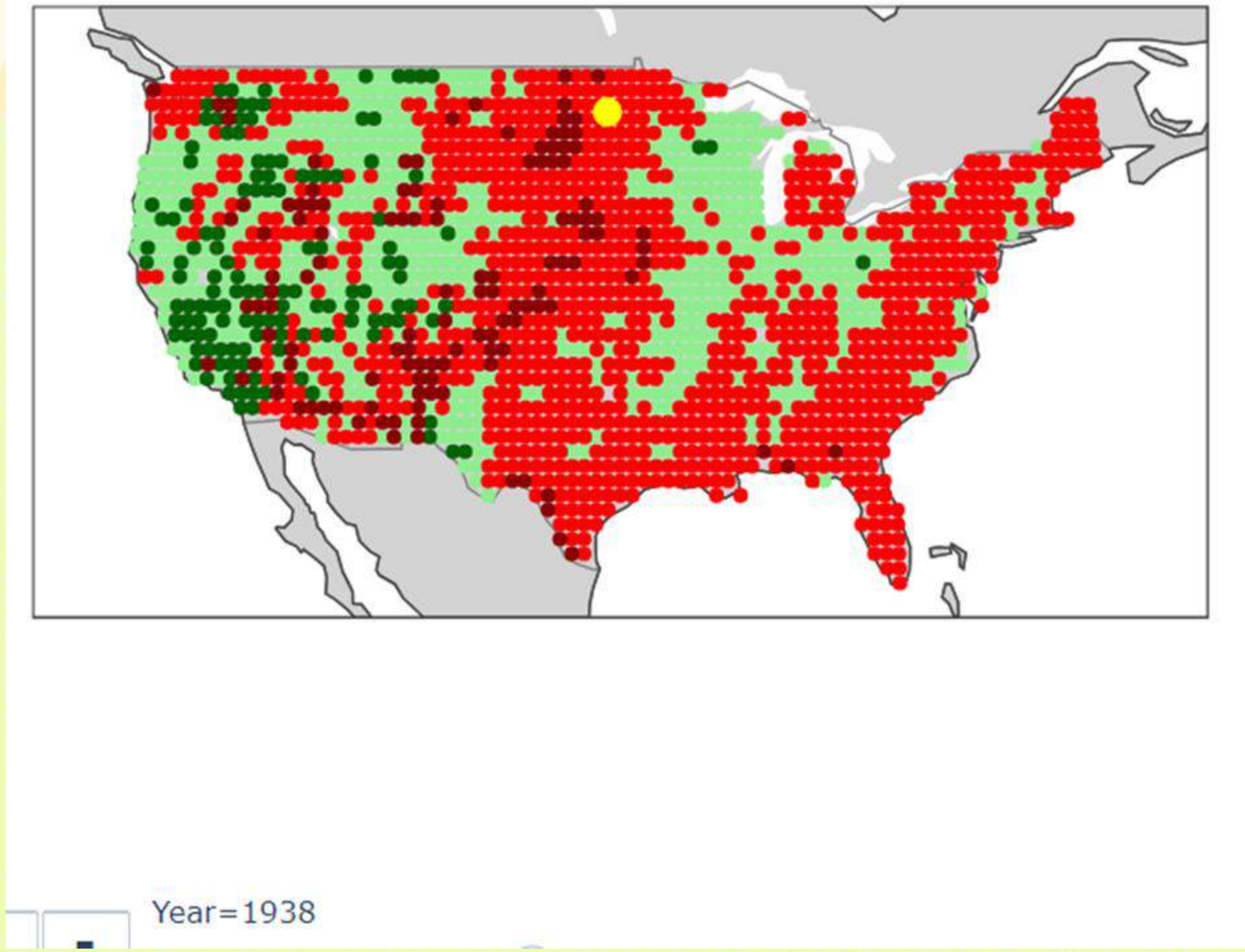


HIGH SIMILARITY WAS FOUND IN (CENTRAL ,SOUTHWEST, WEST COAST PART OF US)

HISTORICAL DROUGHT CASE:STUDY 1

DUST BOWL (1930 - 1941)

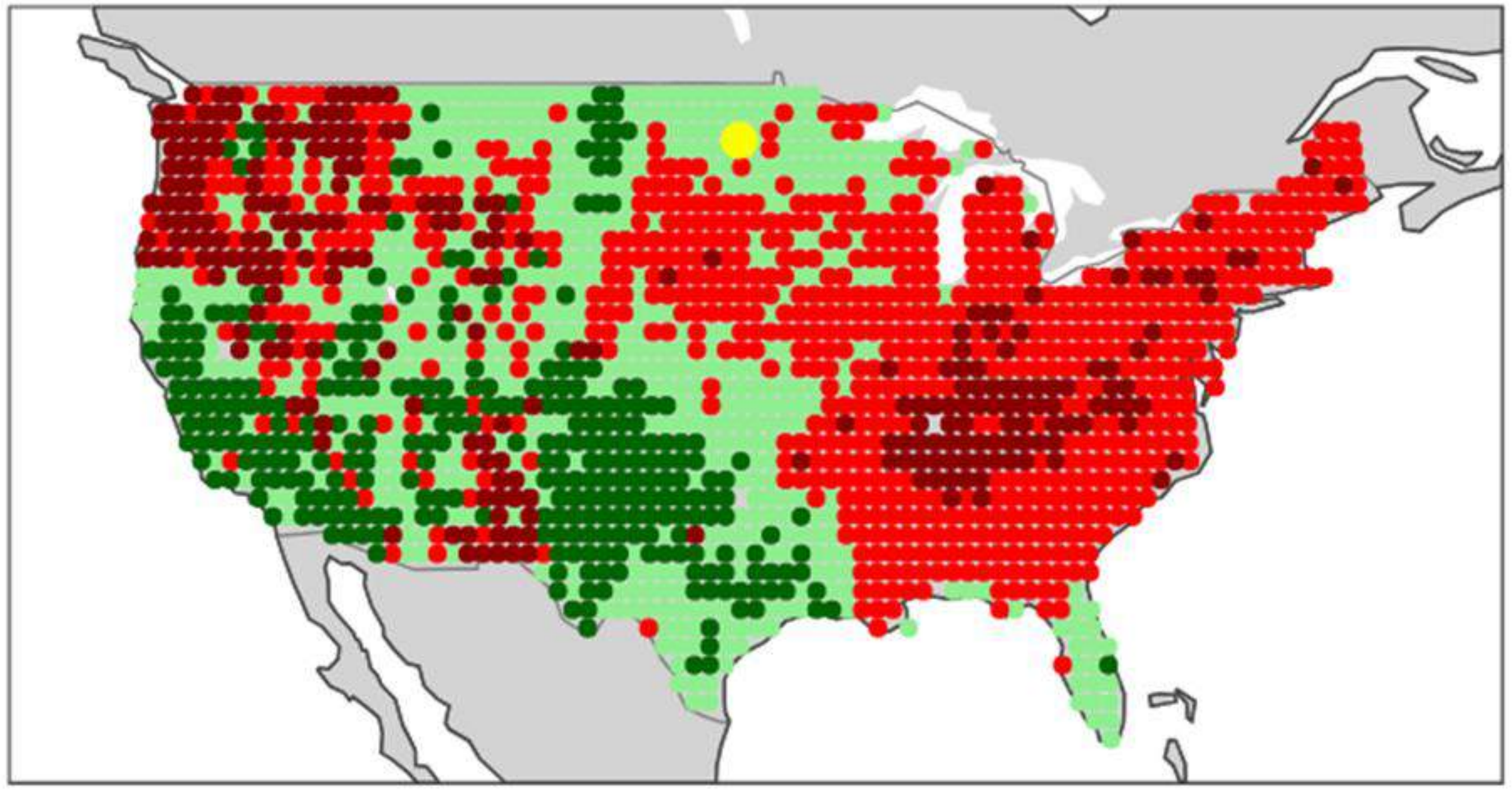
FROM YEAR 1938 (DROUGHT STARTED TO DECREASE)



HISTORICAL DROUGHT CASE:STUDY 1

DUST BOWL (1930 - 1941)

DROUGHT IS OBSERVED CONSTANTLY AROUND FARGO AREA TILL 1940



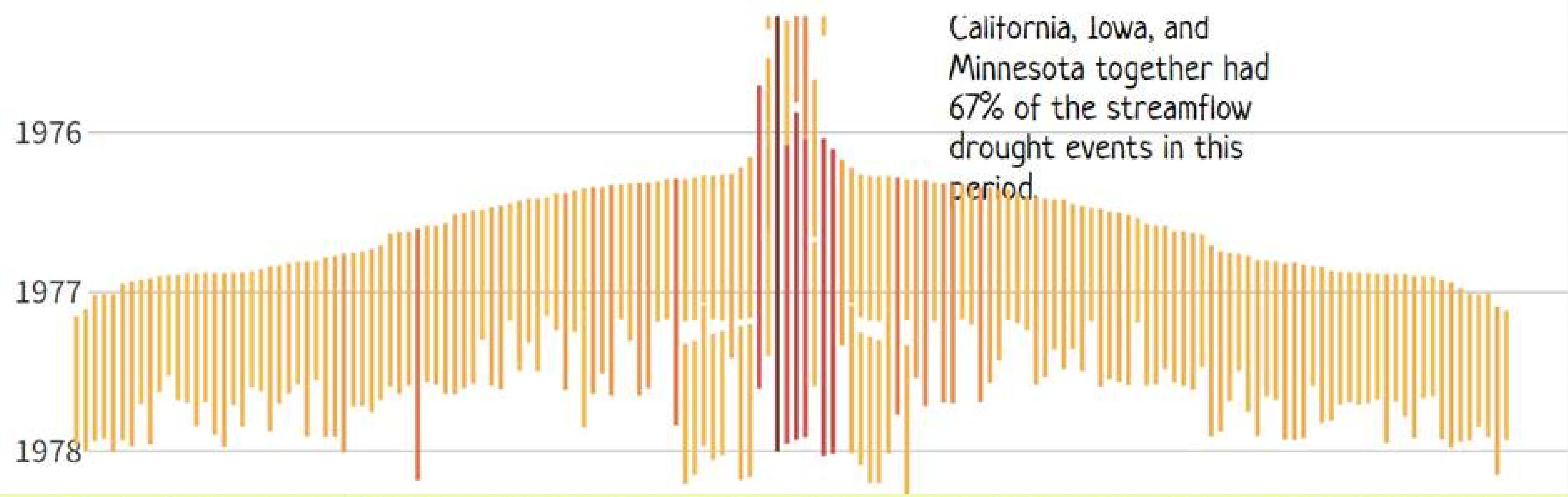
YEAR 1941 (DROUGHT SEVERITY REDUCED AROUND YELLOW AREA

Year=1941

HISTORICAL DROUGHT CASE:STUDY 2

1970S DROUGHT (1976 - 1978)

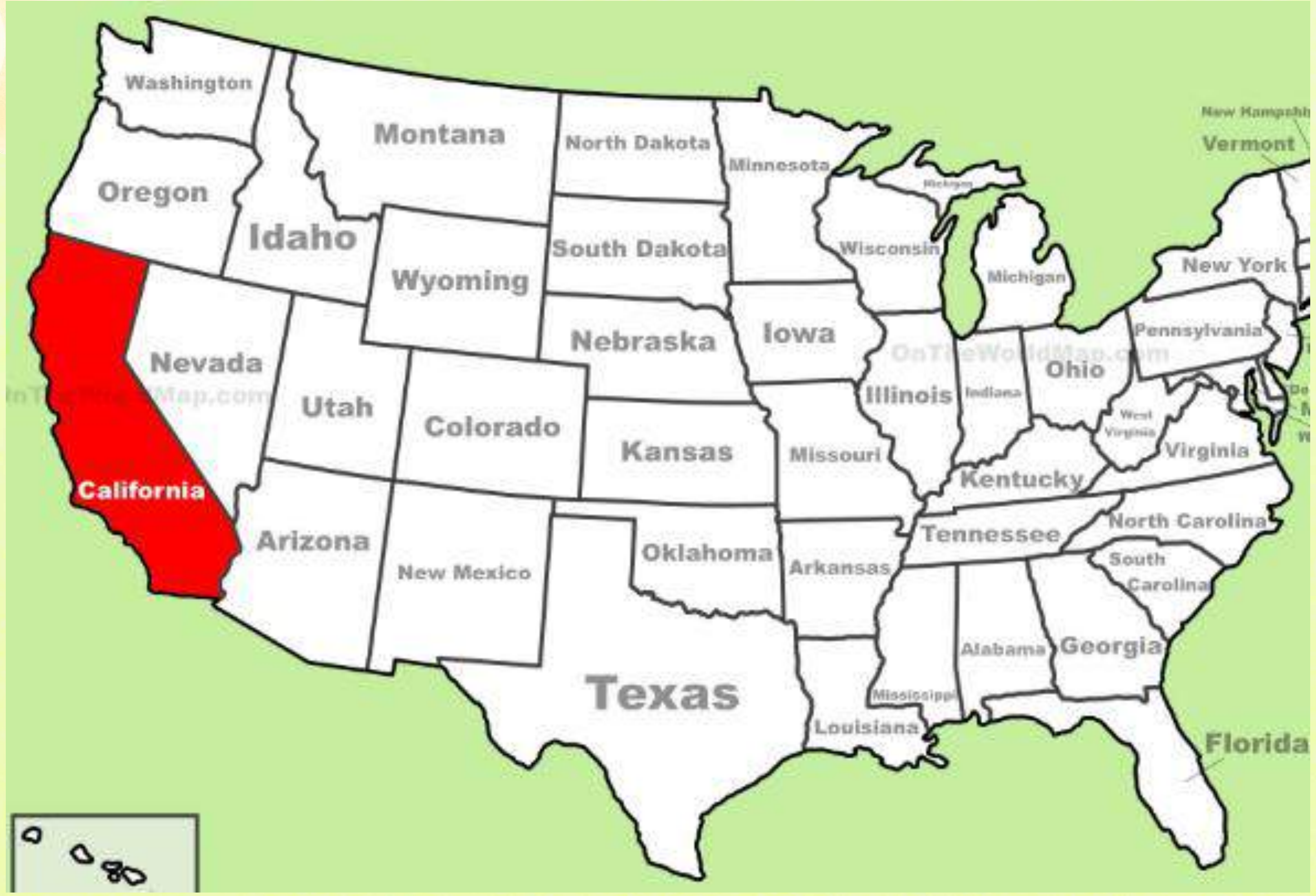
- The 1976-1977 drought was short
- But this two-year drought caused agricultural losses and hydropower shortages across much of the western U.S

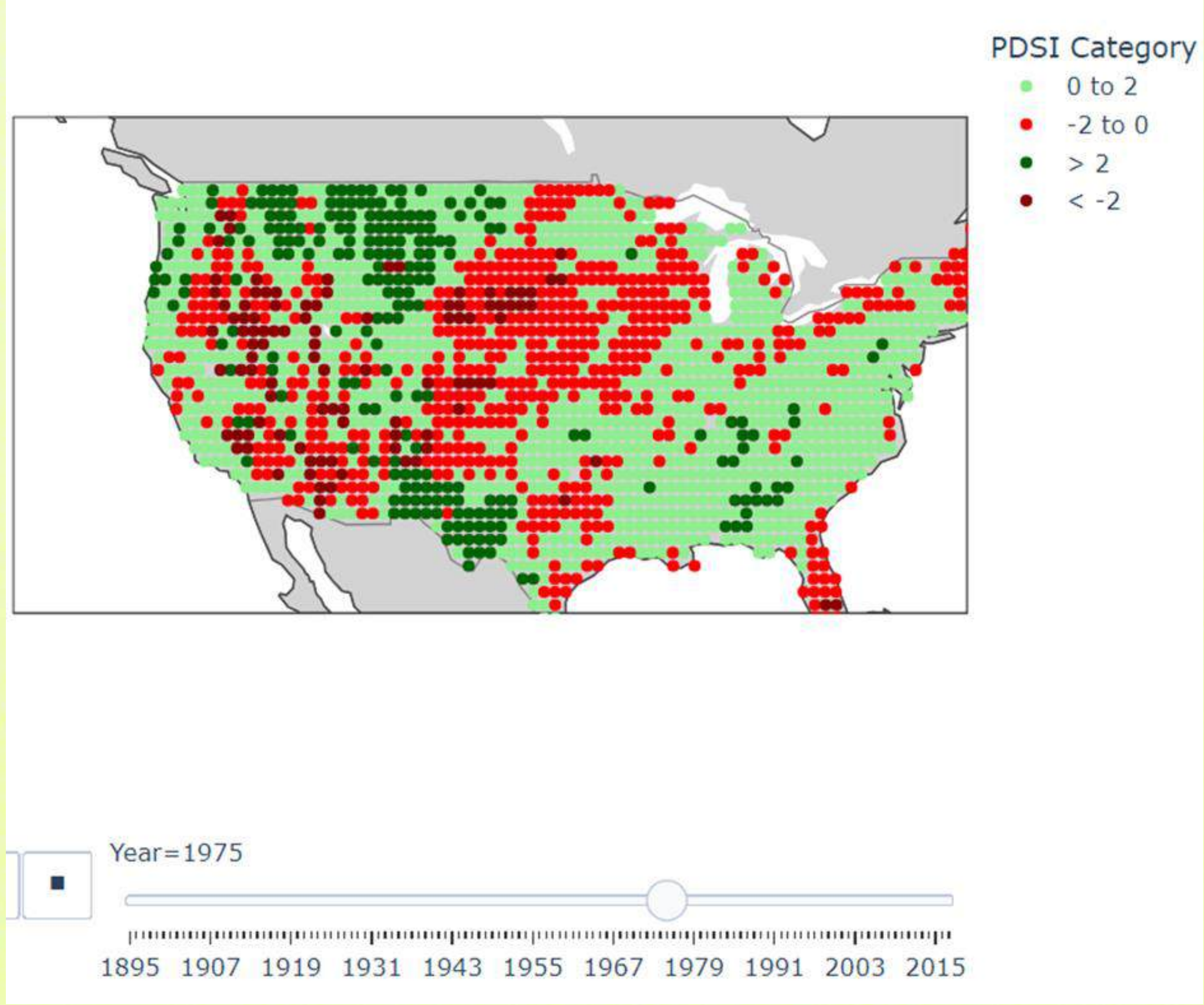


(FROM WEBSITE)

HISTORICAL DROUGHT CASE:STUDY 2

1970S DROUGHT (1976 - 1978)

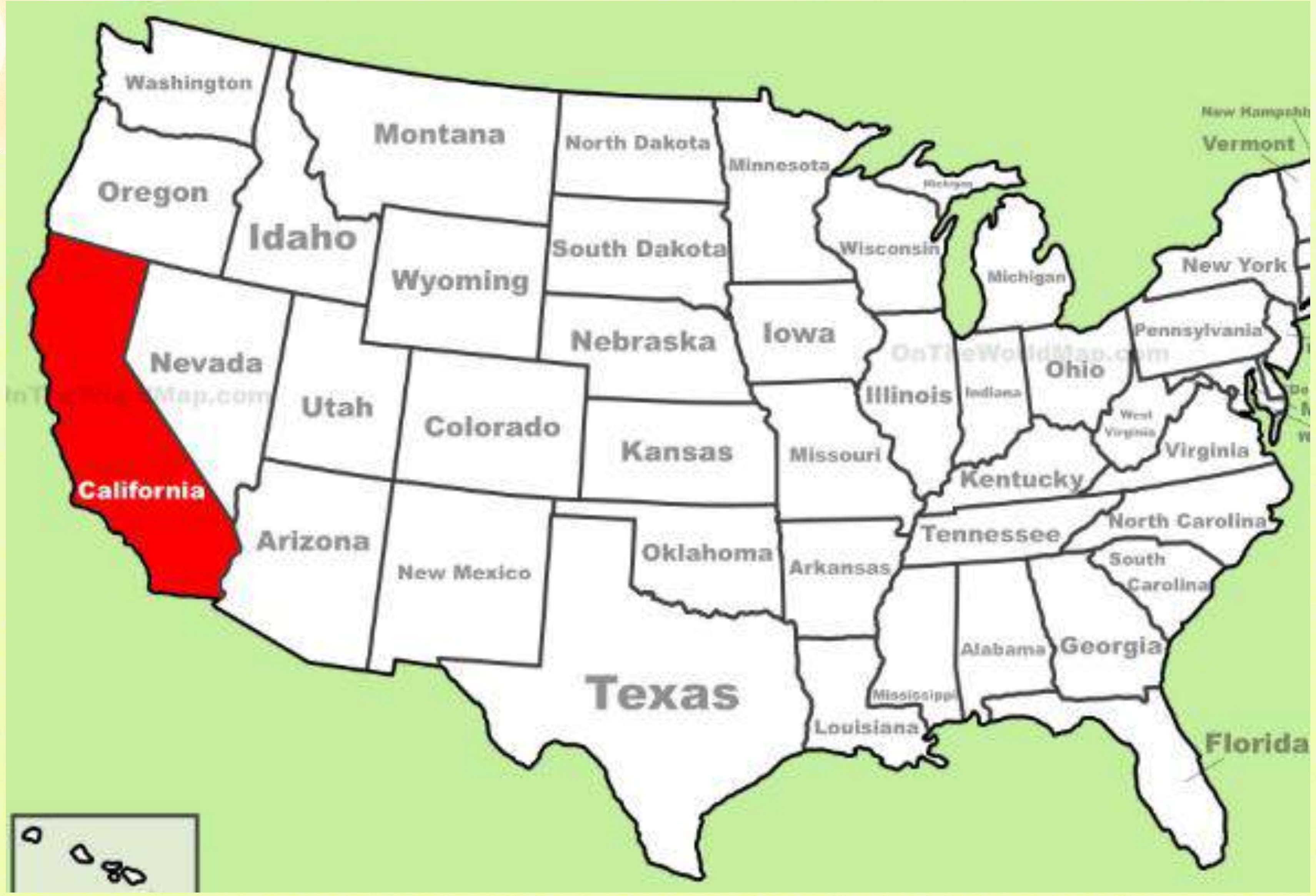


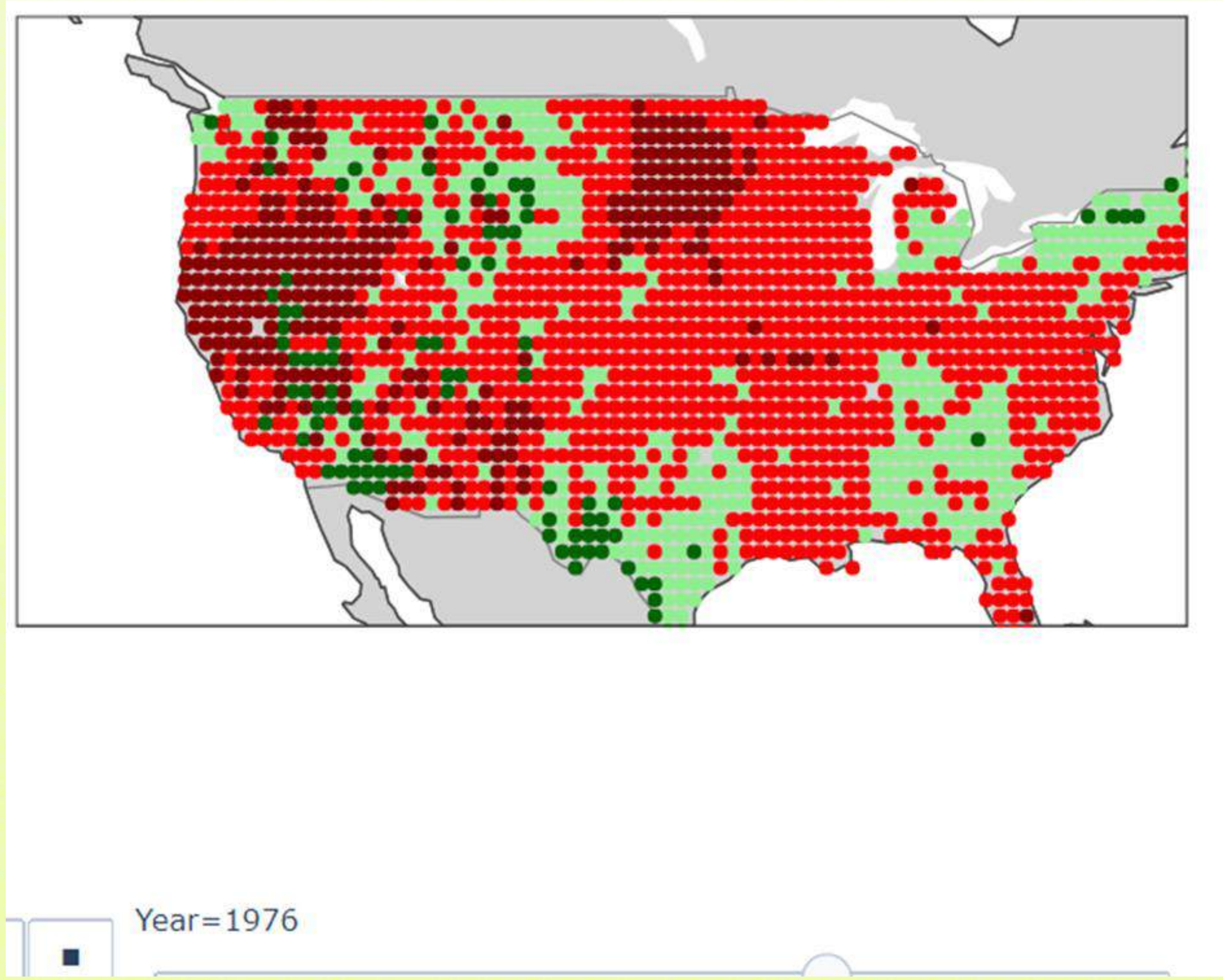


REGION OF INTEREST -CALIFORNIA

HISTORICAL DROUGHT CASE:STUDY 2

1970S DROUGHT (1976 - 1978)



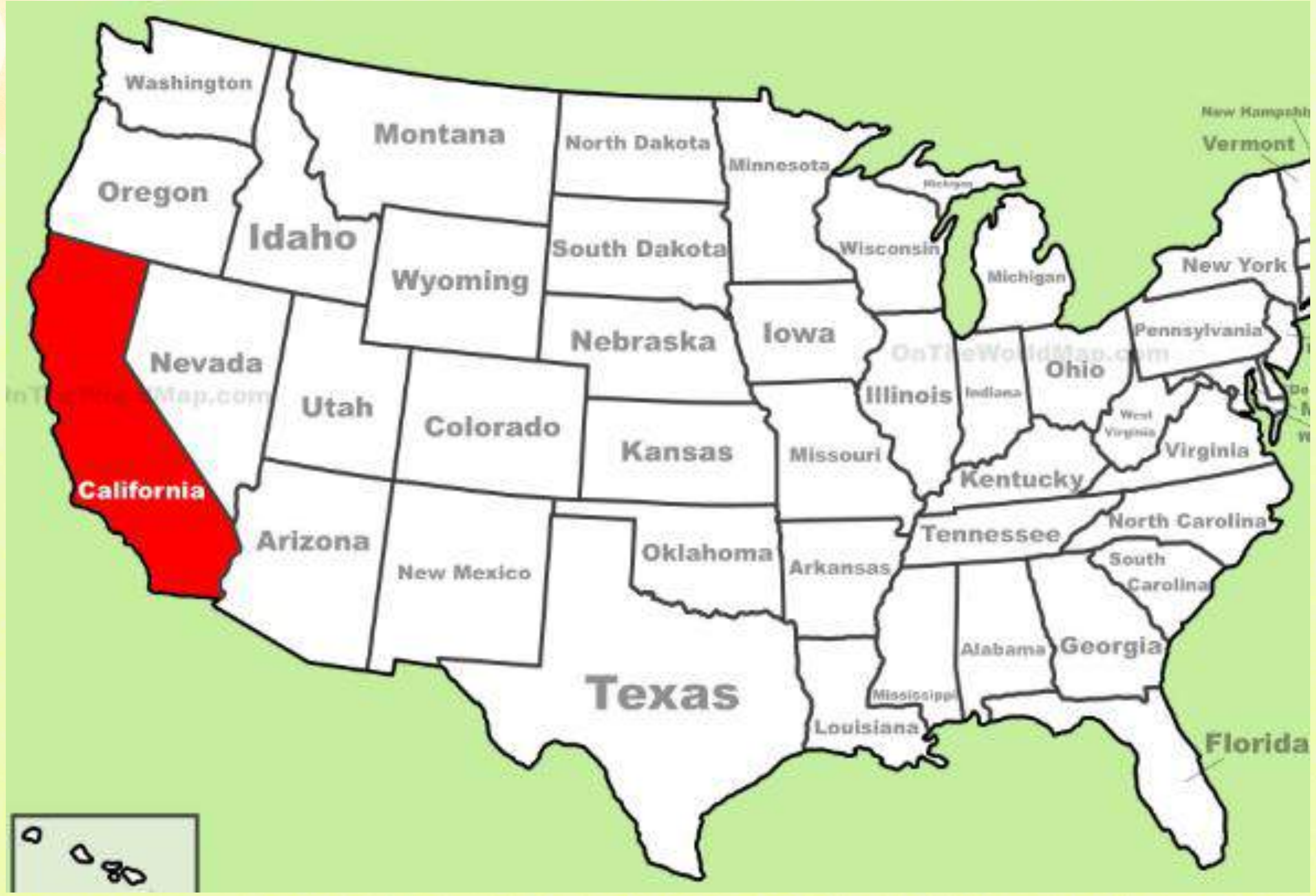


REGION OF INTEREST- CALIFORNIA

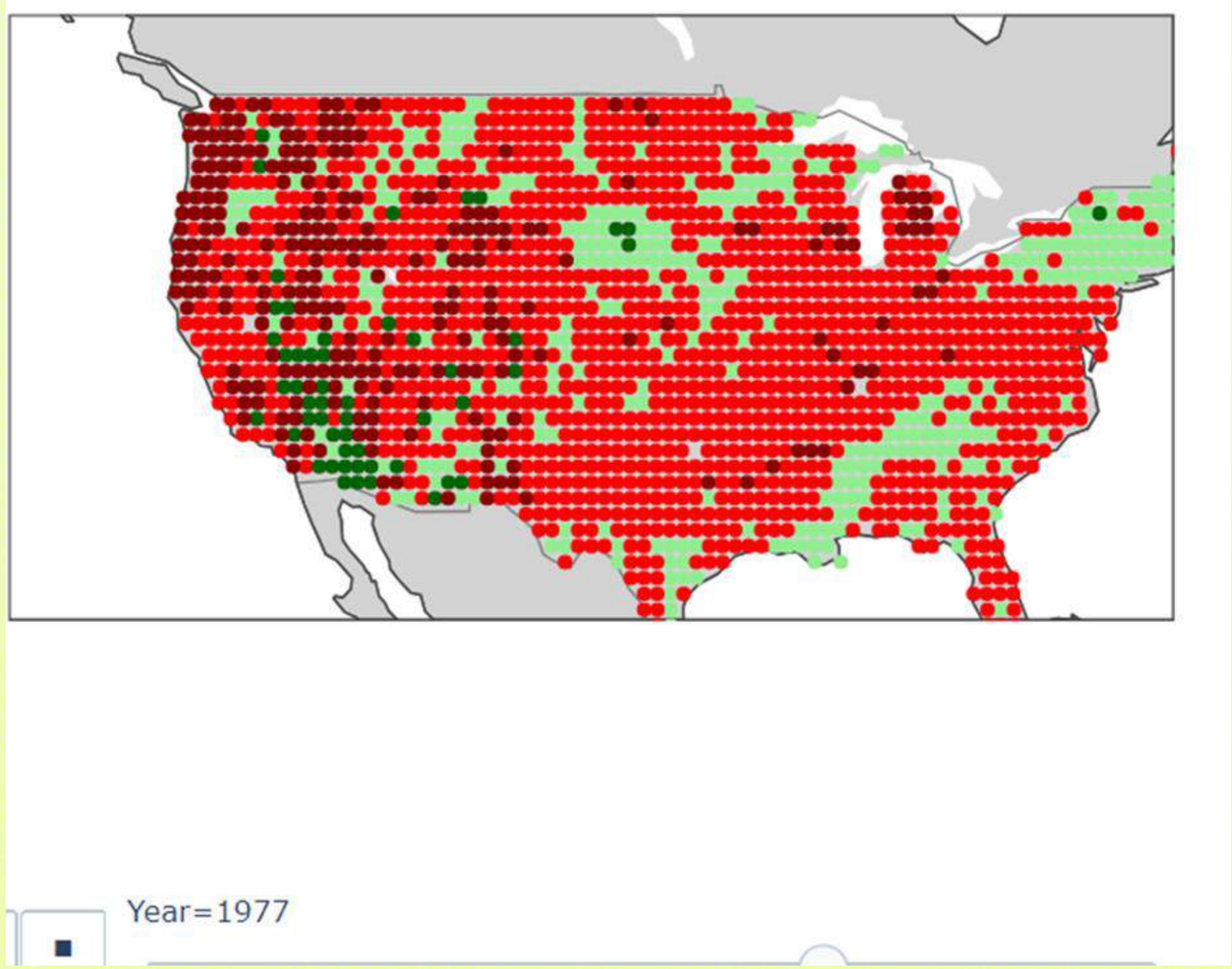
YEAR 1976

HISTORICAL DROUGHT CASE:STUDY 2

1970S DROUGHT (1976 - 1978)

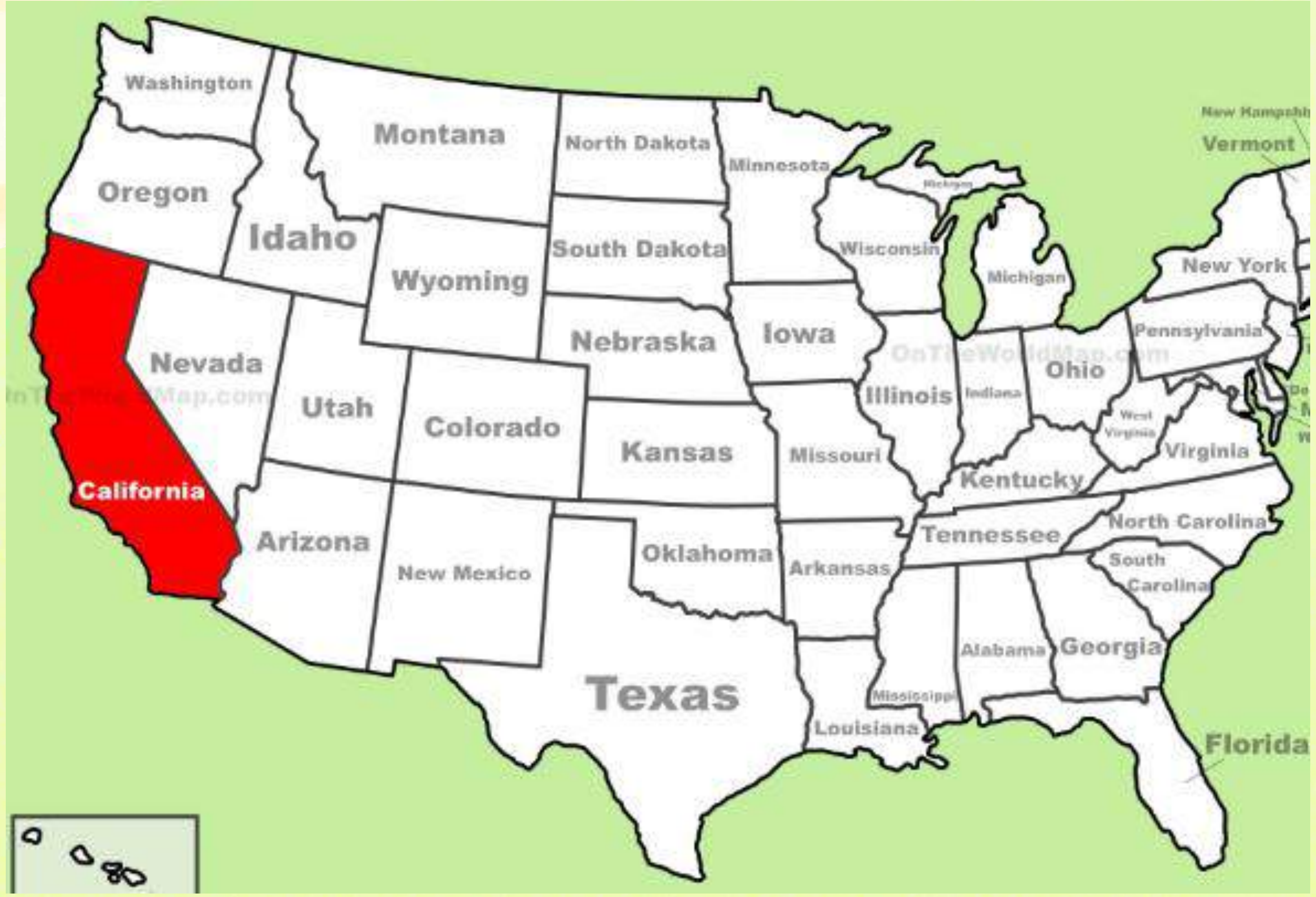


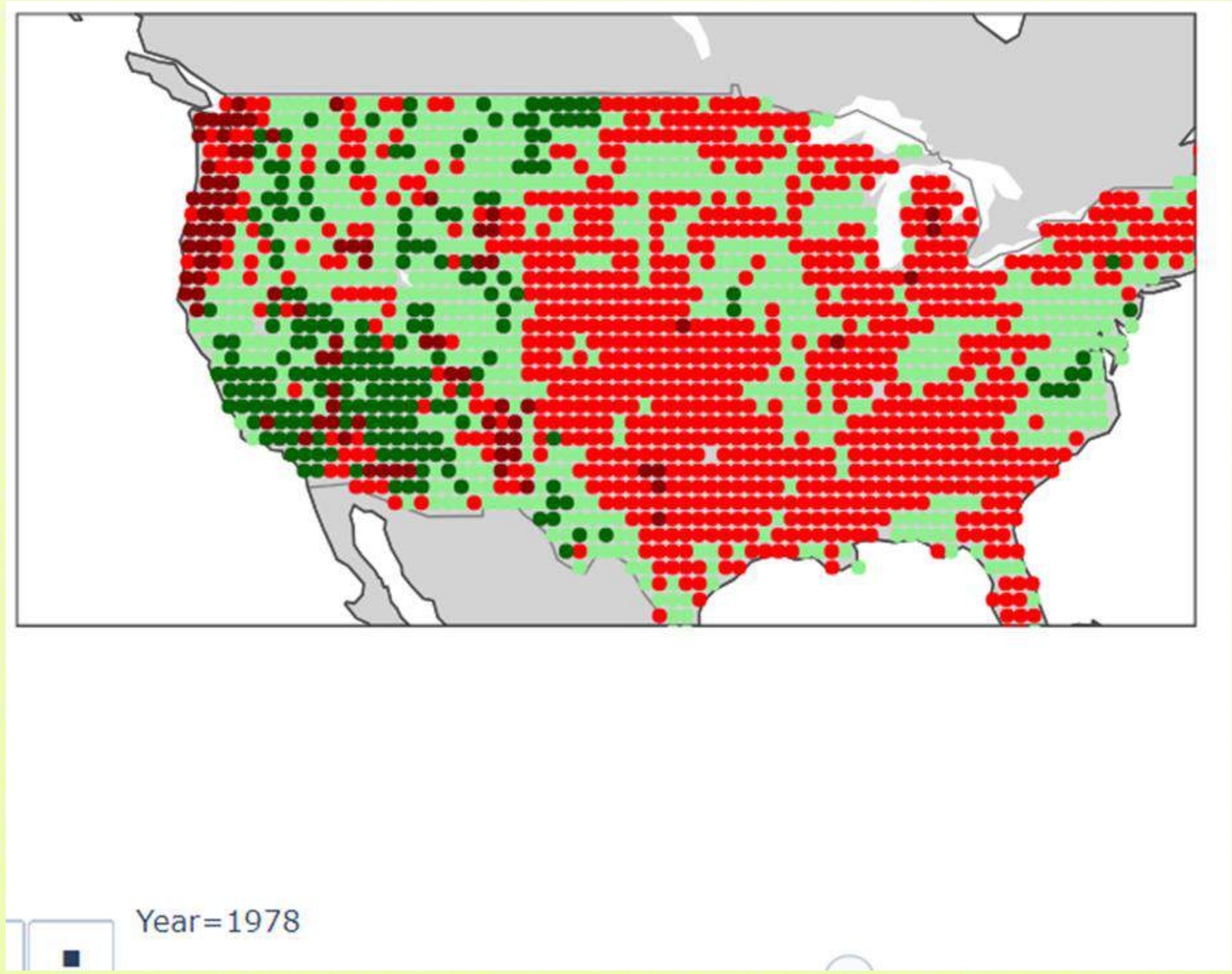
REGION OF INTEREST- CALIFORNIA



YEAR 1977

HISTORICAL DROUGHT CASE:STUDY 2





REGION OF INTEREST- CALIFORNIA

YEAR 1978

PDSI AND HISTORICAL CONSISTENCY

- Seen Strong alignment with historical drought events.
- Demonstrates spatial and temporal accuracy.

FUTURE DIRECTIONS FOR DROUGHT ASSESSMENT

- Enhanced Remote Sensing: Utilize satellite and drone technology for real-time data on soil moisture and evapotranspiration