Plant Resilient USA

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Miami needs trees.

And so does everywhere else.

Motivation

- In 20 years, the Miami climate will not be suitable for many plants native to Miami that are planted at this moment.
- For Miami citizens, trees and shades are crucial to their activities around the city, providing them necessary coolness in extreme hot weather.
- However, these trees may soon be gone as climate change alters the hardiness zones they normally grow in.

We present -

Climate-Ready Planting: Interactive Map of Future Hardiness Zones

Plant Native, Plant Resilient

Collecting Baseline Data

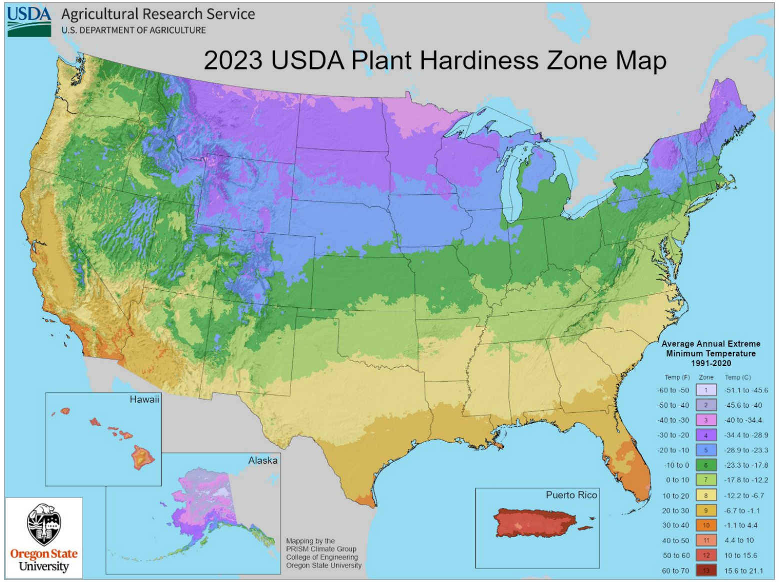
These are the current hardiness zones in USA as of 2023.

```
df = prepare_data()
df
```

	zipcode	zone	trange	zonetitle	t_low	t_high
0	501	7b	5 to 10	7b: 5 to 10	5	10
1	544	7b	5 to 10	7b: 5 to 10	5	10
2	1001	6b	-5 to 0	6b: -5 to 0	-5	0
3	1002	6a	-10 to -5	6a: -10 to -5	-10	-5
4	1003	6a	-10 to -5	6a: -10 to -5	-10	-5
...	...	...	...	...	...	...
39916	99363	7b	5 to 10	7b: 5 to 10	5	10
39917	99371	7a	0 to 5	7a: 0 to 5	0	5
39918	99401	7a	0 to 5	7a: 0 to 5	0	5
39919	99402	7a	0 to 5	7a: 0 to 5	0	5
39920	99403	7b	5 to 10	7b: 5 to 10	5	10

39921 rows × 6 columns

Quite a lot of data!



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Oregon State University

Extract Southeastern USA Data

```
[33] def extract_zipcodes():
       # read in USPS zipcode database
       zipcodes = pd.read_csv('/content/drive/My Drive/hardiness-zone-data/zip_code_database.csv')

       # Southeastern States: North Carolina, South Carolina, Tennessee, Mississippi, Alabama, Georgia, Florida
       # State abbreviations: NC, SC, TN, MS, AL, GA, FL
       # Extract southeatern US zipcodes
       southeastern_zipcodes = zipcodes[zipcodes['state'].isin(['NC', 'SC', 'TN', 'MS', 'AL', 'GA', 'FL'])]['zip']

       return southeastern_zipcodes
```

```
[34] def extract_original_zones(df):
       df.drop(columns=['trange', 't_low', 't_high'])
       df.to_csv('/content/drive/My Drive/hardiness-zone-data/original_zones.csv', index=False)
```

```
[35] southeastern_zipcodes = extract_zipcodes()

     # Keep only southeastern states in the dataframe
     southeastern_df = df[df['zipcode'].isin(southeastern_zipcodes)]

     extract_original_zones(southeastern_df)

     print(len(southeastern_df))
     southeastern_df.head()
```

6091 Still plenty data!

	zipcode	zone	trange	t_low	t_high
10190	27006	7b	5 to 10	5	10
10191	27007	7b	5 to 10	5	10
10192	27009	8a	10 to 15	10	15
10193	27010	7b	5 to 10	5	10
10194	27011	7b	5 to 10	5	10

The scale of our project covers the 7 Southeastern states

The project is easily scalable to continental US, Alaska, Hawaii, and Puerto Rico, given the available USDA data.

Grid and Metadata
CONUS
Alaska
Hawaii
Puerto Rico

Collecte Climate Forecast

USDA reported projected climate change in early-, mid-, and late-century.

Oregon State University

	Midwest			Northeast			Southeast		
Change	Early Century	Mid-century	Late Century	Early Century	Mid-century	Late Century	Early Century	Mid-century	Late Century
Min Temp (Low)									
-3	0	0	0	0	0	0	0	0	0
-2	0	0	0	0	0	0	0	0	0
-1	0	0	0	0.8	0	0	0	0	0
0	7.0	0	0	79.3	0	0	46.5	0	0
1	77.1	0	0	19.9	0.2	0	53.2	4.3	0
2	16.0	13.3	0.2	0	55.7	7.8	0.3	77.7	10.8
3	0	75.4	5.0	0	41.4	54.5	0	18.0	55.5
4	0	10.9	60.8	0	2.6	34.4	0	0	30.7
5	0	0.4	34.0	0	0	3.3	0	0	3.1
6	0	0	0.1	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0

Source: Assessing Potential Climate Change Pressures across the Conterminous United States: Mapping Plant Hardiness Zones, Heat Zones, Growing Degree Days, and Cumulative Drought Severity throughout this Century
Early: 2010-2039. Mid: 2040-2069. Late: 2070-2099.

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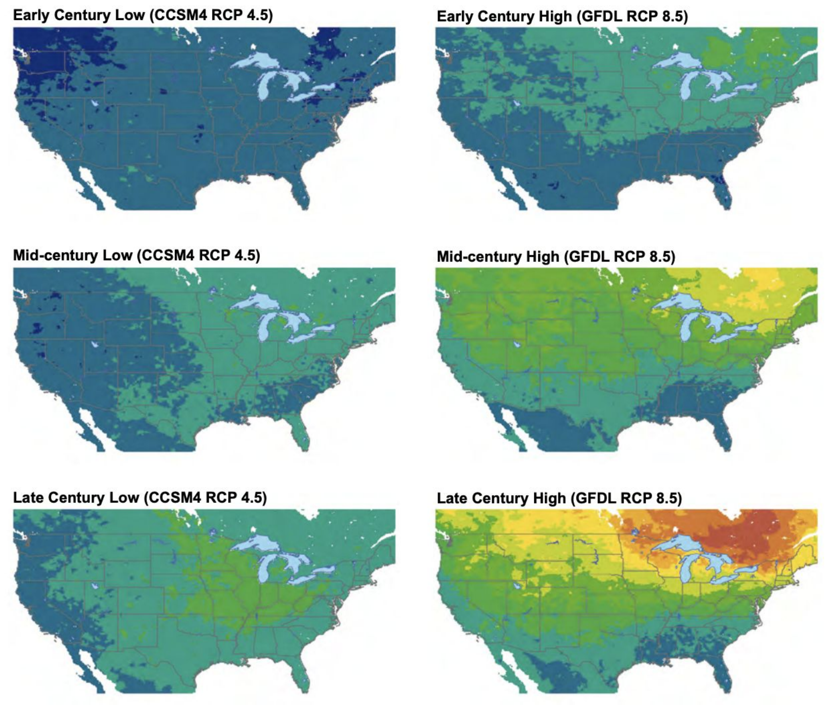

Change in Minimum Temperature (°C)

Update Temperatures By Sampling

Oregon State University

	temp_change	early_century	mid_century	late_century
0	0	0.403	0.009	0.001
1	1	0.428	0.328	0.168
2	2	0.136	0.434	0.427
3	3	0.033	0.162	0.199
4	4	0.000	0.058	0.112
5	5	0.000	0.009	0.069
6	6	0.000	0.000	0.023
7	7	0.000	0.000	0.010

13.6% of land in Southeastern USA will experience a 2˚C temperature rise by early-century (~2039)

5.8% of Southeastern USA will experience a 4˚C temperature rise by mid-century (2040~2069)

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Sampling Algorithm

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```
def sample_zipcodes(southeastern_zipcodes, time_period, mode):
  if mode == 'low':
    proportions = list(temp_changes_low_df[time_period])
  elif mode == 'high':
    proportions = list(temp_changes_high_df[time_period])

  sampled_zipcodes = []

  for prop in proportions:
    sampled_zipcodes.append(southeastern_zipcodes.sample(frac=prop, random_state = 14, replace=False))

  return sampled_zipcodes
```

```
[46] def update_temperatures(df, sampled_zipcodes):
  df['new_t_low'] = df['t_low']
  df['new_t_high'] = df['t_high']

  temp_change = 0
  for zipcode_list in sampled_zipcodes:
    # 1 degree celcius increase = 1.8 degree F increase

    df.loc[df['zipcode'].isin(zipcode_list), 'new_t_low'] += temp_change * 1.8
    df.loc[df['zipcode'].isin(zipcode_list), 'new_t_high'] += temp_change * 1.8
    temp_change += 1

  return df
```

We sampled Southeastern zip codes according to the temperature change distribution given by USDA.

Since the USDA Plant Hardiness Zone Map (PHZM) dataset is in Fahrenheit, but their climate report is in Celsius, a conversion is necessary when calculating temperature changes.

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Forecasting Future Hardiness Zones

```python
def update_hardiness_zones(df):
  df['new_trange'] = 'null'

  for index, row in df.iterrows():
    left_zone = None
    right_zone = None

    for zone in hardiness_zones:
      left_bound, right_bound = zone

      if left_bound <= row['new_t_low'] <= right_bound:
        left_zone = zone

      if left_bound <= row['new_t_high'] <= right_bound:
        right_zone = zone

      if left_zone and right_zone:
        if left_zone == right_zone:
          southeastern_df.at[index, 'new_trange'] = right_zone
          break

    if left_zone and right_zone and left_zone != right_zone:
        left_diff = abs(row['new_t_low'] - left_zone[1])
        right_diff = abs(row['new_t_high'] - right_zone[0])

        if left_diff > right_diff:
          df.at[index, 'new_trange'] = left_zone
        else:
          df.at[index, 'new_trange'] = right_zone

  return df
```

For each new temperature range, we used a simple variant of the sliding window technique to determine where it falls in the hardiness zones.

Temp (F)	Zone	Temp (C)
-60 to -55	1a	-51.1 to -48.3
-55 to -50	1b	-48.3 to -45.6
-50 to -45	2a	-45.6 to -42.8
-45 to -40	2b	-42.8 to -40
-40 to -35	3a	-40 to -37.2
-35 to -30	3b	-37.2 to -34.4
-30 to -25	4a	-34.4 to -31.7
-25 to -20	4b	-31.7 to -28.9
-20 to -15	5a	-28.9 to -26.1
-15 to -10	5b	-26.1 to -23.3
-10 to -5	6a	-23.3 to -20.6
-5 to 0	6b	-20.6 to -17.8
0 to 5	7a	-17.8 to -15
5 to 10	7b	-15 to -12.2
10 to 15	8a	-12.2 to -9.4
15 to 20	8b	-9.4 to -6.7
20 to 25	9a	-6.7 to -3.9
25 to 30	9b	-3.9 to -1.1
30 to 35	10a	-1.1 to 1.7
35 to 40	10b	1.7 to 4.4
40 to 45	11a	4.4 to 7.2
45 to 50	11b	7.2 to 10
50 to 55	12a	10 to 12.8
55 to 60	12b	12.8 to 15.6

Not good!

zipcode	zone	trange	new_t_low	new_t_high	new_trange	new_zone
27006	7b	5 to 10	15.8	20.8	(15, 20)	8b
27007	7b	5 to 10	8.6	13.6	(10, 15)	8a
27009	8a	10 to 15	13.6	18.6	(15, 20)	8b
27010	7b	5 to 10	8.6	13.6	(10, 15)	8a
27011	7b	5 to 10	5.0	10.0	(5, 10)	7b

With these data, here's our solution –

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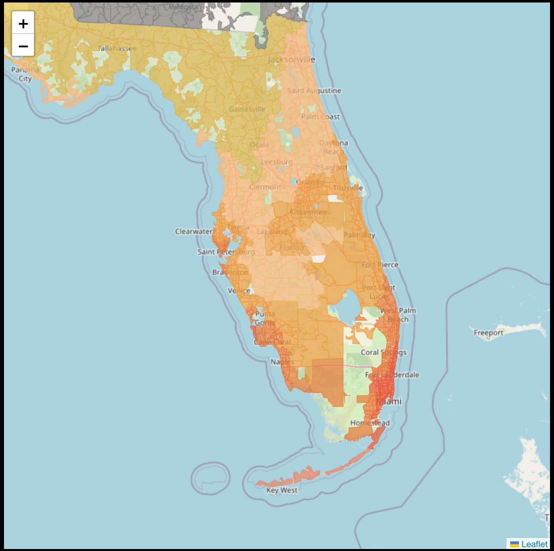
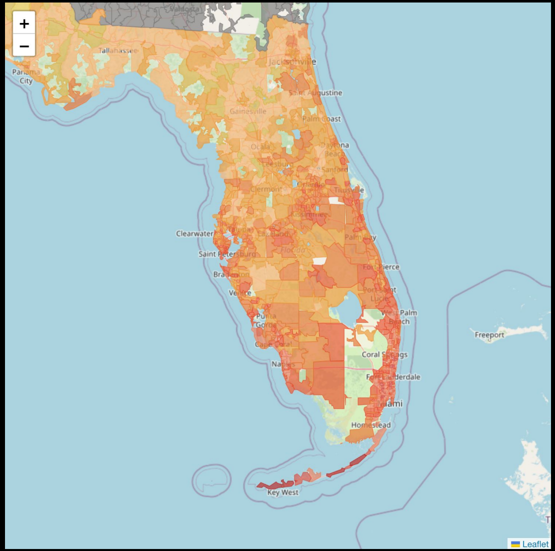
Our Solution

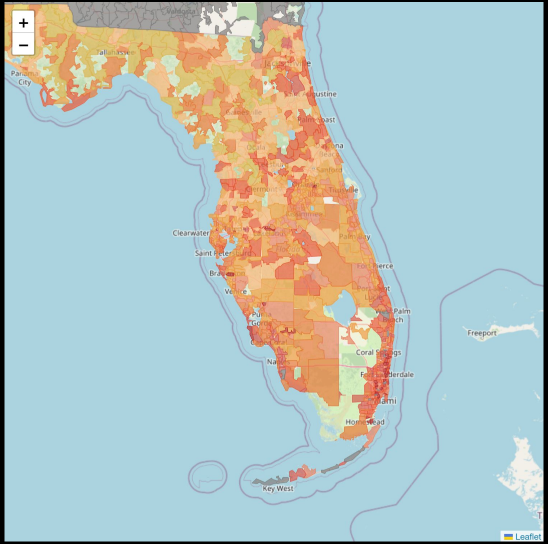
CCSM4 RCP 4.5: Low



Early-century low
(2010 - 2039)



Mid-century low
(2040 - 2069)



Late-century low
(2070 - 2099)

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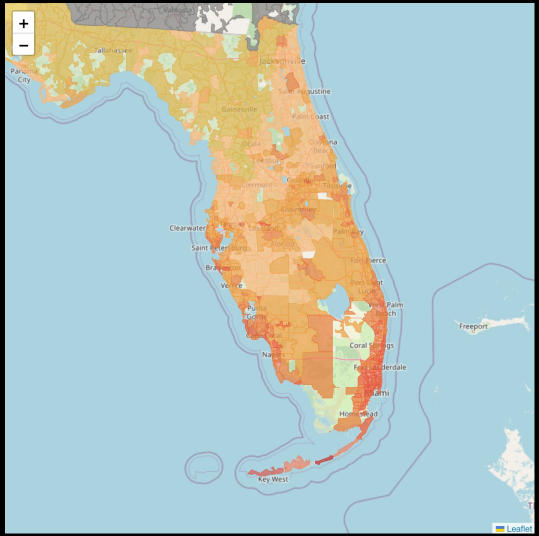
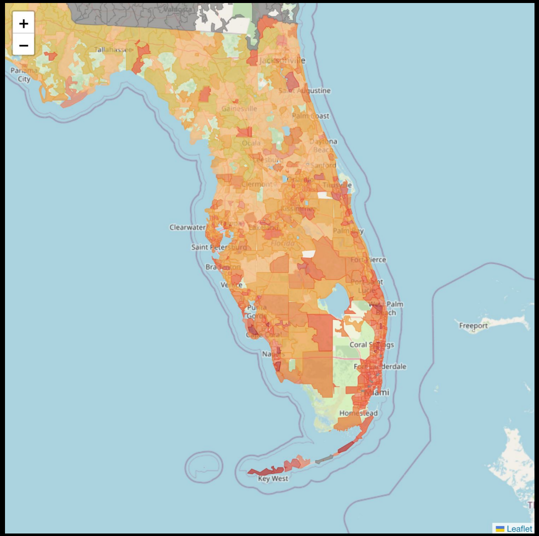
Our Solution

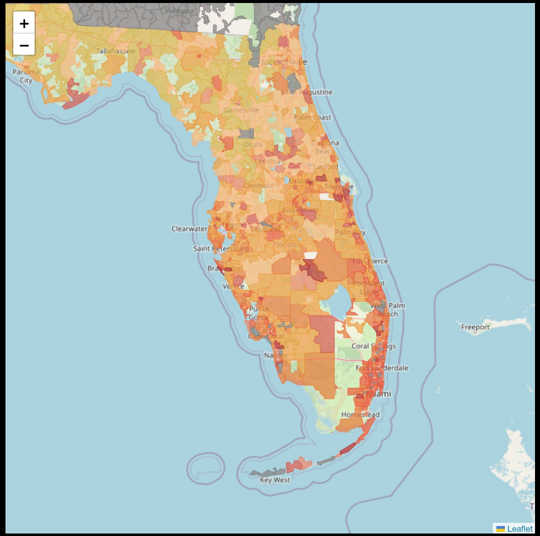
GFDL RCP 8.5: High



Early-century high
(2010 - 2039)



Mid-century high
(2040 - 2069)



Late-century high
(2070 - 2099)

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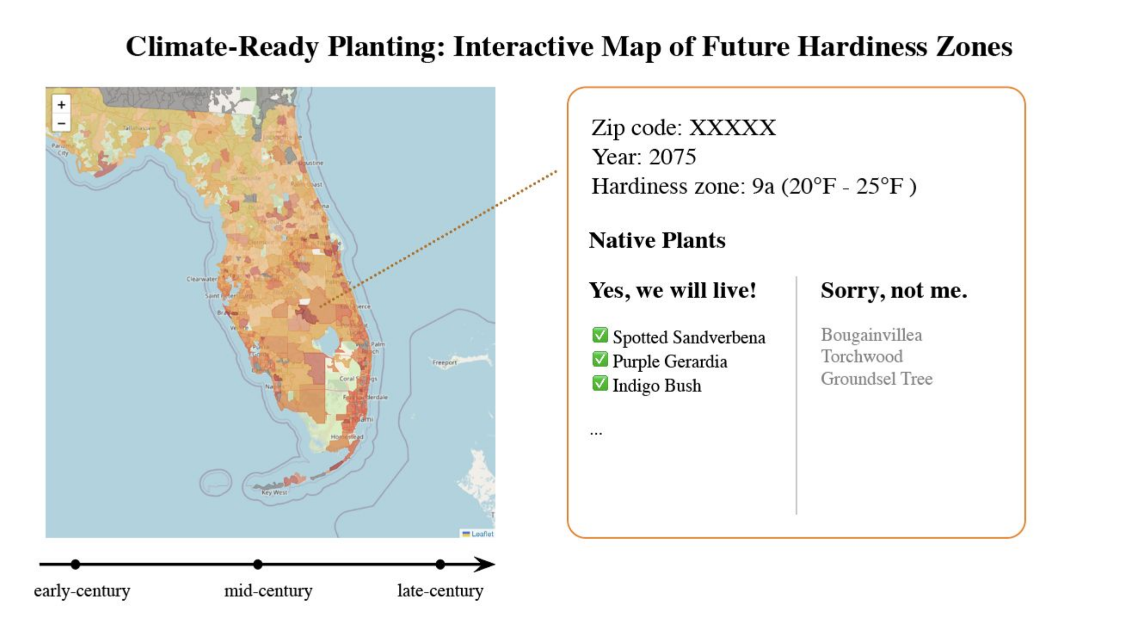
Future Directions: Connect Plant Database

With our current scalable interactive map, we plan to connect our data to a plant database that details the plants native to a region and their favorable hardiness zones.



With our scalable interactive map,
gardeners and city planners can plant smarter
for a changing climate –

***native, resilient, and built to last*.**