Flood Hazard Analysis in Fort Bend County, Texas

Luke Zaruba

GIS 5577: *Spatial Database Design & Administration*

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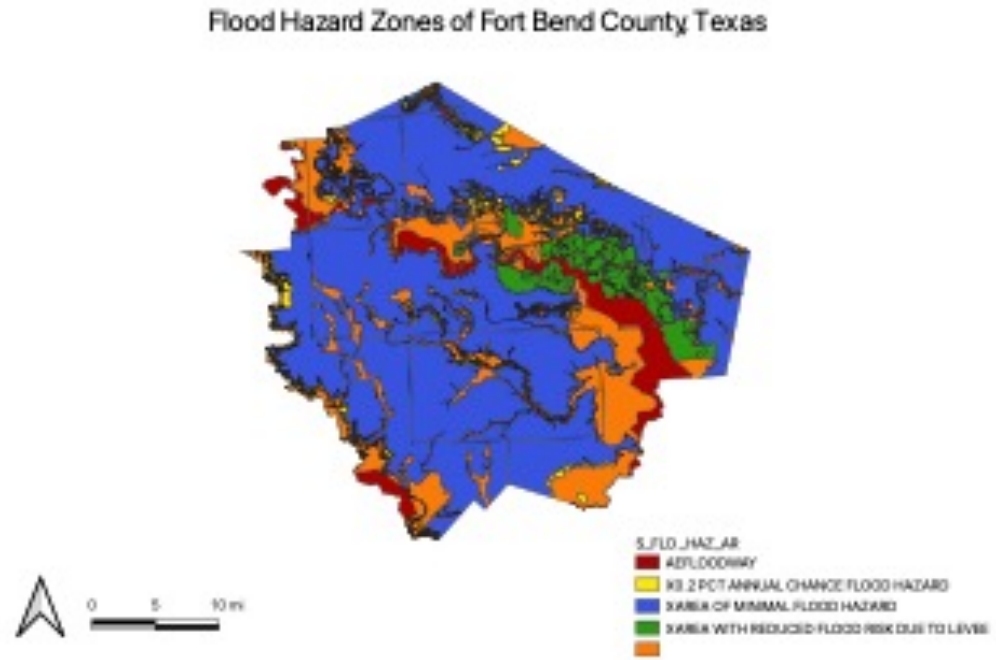
Project Motivation and Goals

Motivations

- Climate Change → Increase in extreme meteorological events
- Category IV Hurricane Harvey in 2017 → 2nd costliest hurricane in U.S. history[1]

Goals

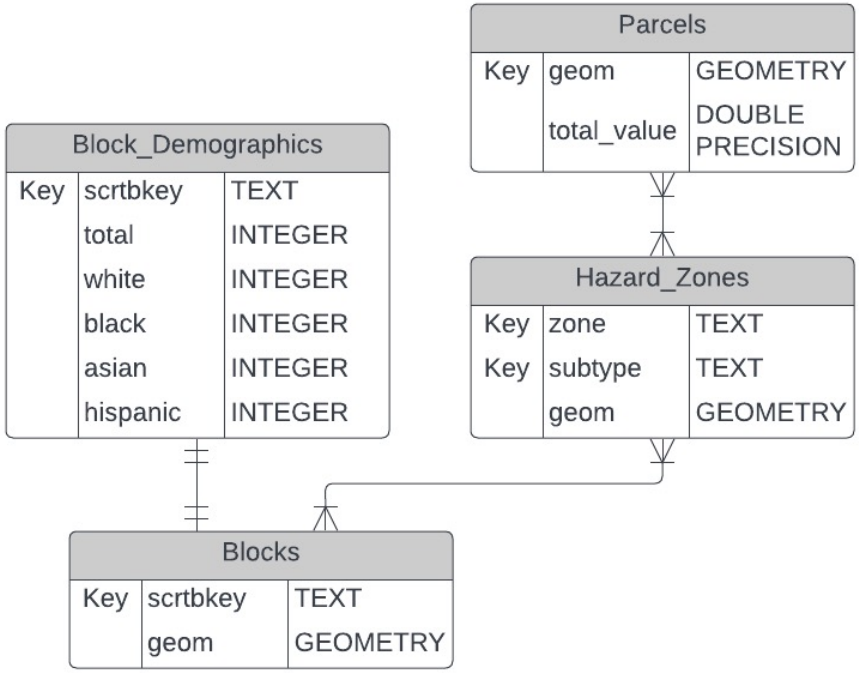
- Understand the disproportionate effects of flood hazards across different demographic groups
- Gain a broad understanding of the relationship between flood hazard and land/home values



1 “Costliest U.S. Tropical Cyclones - National Climatic Data ...,” Costliest U.S. Tropical Cyclones (NOAA), accessed February 21, 2022, https://www.ncdc.noaa.gov/billions/dcmi.pdf.

Data

- Special Flood Hazard Area (SFHA) Definitions[2]
  - Zones A & AE → Area in 100-year floodplain
  - Zone X
    - 0.2-Percent Annual Chance → Area in 500-year floodplain
    - Area of Minimal Flood Hazard & Area with Reduced Risk due to Levee→ Area that is outside of the 100- and 500-year floodplains (due to natural or manmade causes, respectively)



2 “National Flood Insurance Program Terminology Index,” FEMA.gov (FEMA, June 1, 2021), https://www.fema.gov/flood-insurance/terminology-index.

Methods & Solutions

```
-- CREATING A TABLE W/ PERCENTAGES OF COVER FOR EVERY HAZARD TYPE AND EVERY BLOCK
CREATE TABLE hazard_percentage_blocks as (
     SELECT
          block.sctbkey, haz.fld_zone as zone, haz.zone_subty as subtype, ST_Area(ST_Intersection(block.geom, haz.geom)) /
ST_Area(block.geom) as pcover
     FROM (
               SELECT sctbkey, ST_Transform(geom, 4326) as geom
               FROM studyarea_blocks
          ) as block,
          (    SELECT fld_zone, zone_subty, ST_Transform(geom, 4326) as geom
               FROM studyarea_hazard_validgeom
          ) as haz
     WHERE
          ST_Intersects(block.geom, haz.geom)
);
-- CREATING VIEW WITH THE HAZARD THAT COVERS THE LARGEST AREA OF THE BLOCK
CREATE VIEW max_block_pcover as (
     WITH max_coverages as (
          SELECT
               sctbkey, MAX(pcover) as coverage
          FROM
               hazard_percentage_blocks
          GROUP BY
               sctbkey
     )
     SELECT
          mc.sctbkey, mc.coverage, hp.zone, hp.subtype,
          CASE
               WHEN zone = 'A' AND subtype IS NULL THEN 1
               WHEN zone = 'X' AND subtype = 'AREA OF MINIMAL FLOOD HAZARD' THEN 2
               WHEN zone = 'X' AND subtype = 'AREA WITH REDUCED FLOOD RISK DUE TO LEVEE' THEN 3
               WHEN zone = 'AE' AND subtype IS NULL THEN 4
               WHEN zone = 'AO' AND subtype IS NULL THEN 5
               WHEN zone = 'AE' AND subtype = 'FLOODWAY' THEN 6
               WHEN zone = 'X' AND subtype = '0.2 PCT ANNUAL CHANCE FLOOD HAZARD' THEN 7
          END AS category
     FROM
          max_coverages mc
     INNER JOIN
          hazard_percentage_blocks hp
     ON
          mc.sctbkey = hp.sctbkey AND mc.coverage = hp.pcover
);

-- CALCULATING DEMOGRAPHIC INFO AND JOINING TO MAX HAZARD COVERAGE VALUES
WITH joined_demo_data as (
     SELECT
          pc.sctbkey, pc.category, (d.anglo::float / d.total::float) as anglo_pct, (d.asian::float/ d.total::float) as
asian_pct, (d.hisp::float / d.total::float) as hisp_pct, (d.black::float / d.total::float) as black_pct
     FROM
          max_block_pcover pc
     INNER JOIN
          studyarea_blocks_demo d
     ON
          pc.sctbkey = d.sctbkey
     WHERE
          d.total <> 0
)
SELECT
     category, AVG(anglo_pct) as anglo_avg, stddev_samp(anglo_pct) as anglo_sd, AVG(asian_pct) as asian_avg,
stddev_samp(asian_pct) as asian_sd,
     AVG(hisp_pct) as hisp_avg, stddev_samp(hisp_pct) as hisp_sd, AVG(black_pct) as black_avg, stddev_samp(black_pct) as
black_sd, COUNT(*)
FROM
     joined_demo_data
GROUP BY
     category;
```

Steps:

(1) Spatial Join Parcel Centroids to Hazard Zones, then aggregate

(2) Calculate % coverage of every hazard type for every block

(3) Find max % coverage value for every block and add column with the hazard type that best represents the block

(4) Join results to demographics

Results

- ANOVA → All statistically significant significant ($p < 0.05$, very close to 0)
- Tukey HSD Post-Hoc Test
  - Total Land Value, % Asian, % Hispanic → Many low p-values
  - % White, % Black → Low p-values with pairs including X – Area of Minimal Hazard zone/subtype

Zone/Subtype	AVG - Parcel Value	Count - Parcel	AVG - Anglo %	AVG - Asian %	AVG - Black %	AVG - Hisp %	Count - Block
A	1304137.12	81	46.46%	6.65%	9.38%	35.24%	22
AE - Floodway	142089.26	165	30.36%	13.61%	17.12%	37.38%	49
AE	312305.03	439	37.42%	6.86%	14.54%	39.96%	276
X - 0.2 Pct Chance	350764.92	297	36.53%	22.65%	13.17%	26.97%	213
X - Area of Minimal Hazard	413176.49	6078	27.40%	15.35%	21.83%	35.16%	4933
X - Area w/ Reduced Risk due to Levee	440922.62	1379	35.48%	36.28%	12.86%	14.78%	1196
	493899.24		35.61	16.90	14.82	31.58	

```
ANOVA RESULTS - TOTAL LAND VALUE
    Tukey HSD Post-hoc Test...
    A vs AE - Floodway:          Diff=-1162047.8560, 95%CI=-1812773.5454 to -511322.1667,   p=0.0000   ****
    A vs AE - NULL:              Diff=-991832.0910,  95%CI=-1571850.5064 to -411813.6757,   p=0.0000   ****
    A vs X - LEVEE:              Diff=-863214.4998,  95%CI=-1411575.6334 to -314853.3662,   p=0.0001   ****
    A vs X - 0.X - MIN HZRD PCT: Diff=-953372.1955,  95%CI=-1554601.3694 to -352143.0217,   p=0.0001   ****
    A vs X - MINIMAL:            Diff=-890960.6228,  95%CI=-1427432.7032 to -354488.5424,   p=0.0000   ****
ANOVA RESULTS - HISP PCT
    Tukey HSD Post-hoc Test...
    A - NULL vs X - MIN HZRD:      Diff=-0.0008,  95%CI=-0.1480 to 0.1465,   p=1.0000
    A - NULL vs X - LEVEE:         Diff=-0.2046,  95%CI=-0.3528 to -0.0563,  p=0.0012   **
    A - NULL vs AE - NULL:         Diff=0.0472,   95%CI=-0.1055 to 0.1998,   p=0.9511
    A - NULL vs AE - FLOODWAY:     Diff=0.0214,   95%CI=-0.1554 to 0.1982,   p=0.9994
    A - NULL vs X - 0.2 PCT:       Diff=-0.0827,  95%CI=-0.2370 to 0.0716,   p=0.6471
    X - MIN HZRD vs X - LEVEE:     Diff=-0.2038,  95%CI=-0.2260 to -0.1816,  p=0.0000   ****
    X - MIN HZRD vs AE - NULL:     Diff=0.0480,   95%CI=0.0053 to 0.0906,    p=0.0169   *
    X - MIN HZRD vs AE - FLOODWAY: Diff=0.0222,   95%CI=-0.0768 to 0.1211,   p=0.9881
    X - MIN HZRD vs X - 0.2 PCT:   Diff=-0.0819,  95%CI=-0.1301 to -0.0337,  p=0.0000   ****
    X - LEVEE vs AE - NULL:        Diff=0.2518,   95%CI=0.2057 to 0.2978,    p=0.0000   ****
    X - LEVEE vs AE - FLOODWAY:    Diff=0.2260,   95%CI=0.1255 to 0.3264,    p=0.0000   ****
    X - LEVEE vs X - 0.2 PCT:      Diff=0.1219,   95%CI=0.0706 to 0.1731,    p=0.0000   ****
    AE - NULL vs AE - FLOODWAY:    Diff=-0.0258,  95%CI=-0.1326 to 0.0810,   p=0.9833
    AE - NULL vs X - 0.2 PCT:      Diff=-0.1299,  95%CI=-0.1927 to -0.0670,  p=0.0000   ****
    AE - FLOODWAY vs X - 0.2 PCT:  Diff=-0.1041,  95%CI=-0.2132 to 0.0051,   p=0.0720
ANOVA RESULTS - WHITE PCT
    Tukey HSD Post-hoc Test...
    A - NULL vs X - MIN HZRD:      Diff=-0.1906,  95%CI=-0.3375 to -0.0438,  p=0.0029   **
    A - NULL vs X - LEVEE:         Diff=-0.1098,  95%CI=-0.2577 to 0.0381,   p=0.2795
    A - NULL vs AE - NULL:         Diff=-0.0904,  95%CI=-0.2427 to 0.0619,   p=0.5374
    A - NULL vs AE - FLOODWAY:     Diff=-0.1611,  95%CI=-0.3375 to 0.0154,   p=0.0969
    A - NULL vs X - 0.2 PCT:       Diff=-0.0993,  95%CI=-0.2532 to 0.0546,   p=0.4411
    X - MIN HZRD vs X - LEVEE:     Diff=0.0809,   95%CI=0.0587 to 0.1030,    p=0.0000   ****
    X - MIN HZRD vs AE - NULL:     Diff=0.1002,   95%CI=0.0577 to 0.1427,    p=0.0000   ****
    X - MIN HZRD vs AE - FLOODWAY: Diff=0.0296,   95%CI=-0.0691 to 0.1283,   p=0.9570
    X - MIN HZRD vs X - 0.2 PCT:   Diff=0.0913,   95%CI=0.0432 to 0.1394,    p=0.0000   ****
ANOVA RESULTS - BLACK PCT
    Tukey HSD Post-hoc Test...
    A - NULL vs X - MIN HZRD:      Diff=0.1245,   95%CI=0.0017 to 0.2473,    p=0.0447   *
    A - NULL vs X - LEVEE:         Diff=0.0348,   95%CI=-0.0888 to 0.1585,   p=0.9671
    A - NULL vs AE - NULL:         Diff=0.0516,   95%CI=-0.0758 to 0.1789,   p=0.8583
    A - NULL vs AE - FLOODWAY:     Diff=0.0774,   95%CI=-0.0701 to 0.2249,   p=0.6676
    A - NULL vs X - 0.2 PCT:       Diff=0.0379,   95%CI=-0.0908 to 0.1666,   p=0.9601
    X - MIN HZRD vs X - LEVEE:     Diff=-0.0897,  95%CI=-0.1082 to -0.0712,  p=0.0000   ****
    X - MIN HZRD vs AE - NULL:     Diff=-0.0729,  95%CI=-0.1085 to -0.0374,  p=0.0000   ****
    X - MIN HZRD vs AE - FLOODWAY: Diff=-0.0471,  95%CI=-0.1296 to 0.0354,   p=0.5808
    X - MIN HZRD vs X - 0.2 PCT:   Diff=-0.0866,  95%CI=-0.1268 to -0.0464,  p=0.0000   ****
ANOVA RESULTS - ASIAN PCT
    Tukey HSD Post-hoc Test...
    A - NULL vs X - MIN HZRD:      Diff=0.0870,   95%CI=-0.0338 to 0.2079,   p=0.3128
    A - NULL vs X - LEVEE:         Diff=0.2963,   95%CI=0.1747 to 0.4180,    p=0.0000   ****
    A - NULL vs AE - NULL:         Diff=0.0021,   95%CI=-0.1232 to 0.1274,   p=1.0000
    A - NULL vs AE - FLOODWAY:     Diff=0.0695,   95%CI=-0.0756 to 0.2147,   p=0.7478
    A - NULL vs X - 0.2 PCT:       Diff=0.1600,   95%CI=0.0333 to 0.2866,    p=0.0042   ***
    X - MIN HZRD vs X - LEVEE:     Diff=0.2093,   95%CI=0.1911 to 0.2275,    p=0.0000   ****
    X - MIN HZRD vs AE - NULL:     Diff=-0.0849,  95%CI=-0.1199 to -0.0500,  p=0.0000   ****
    X - MIN HZRD vs AE - FLOODWAY: Diff=-0.0175,  95%CI=-0.0987 to 0.0637,   p=0.9900
    X - MIN HZRD vs X - 0.2 PCT:   Diff=0.0729,   95%CI=0.0334 to 0.1125,    p=0.0000   ****
    X - LEVEE vs AE - NULL:        Diff=-0.2942,  95%CI=-0.3320 to -0.2565,  p=0.0000   ****
    X - LEVEE vs AE - FLOODWAY:    Diff=-0.2268,  95%CI=-0.3092 to -0.1444,  p=0.0000   ****
    X - LEVEE vs X - 0.2 PCT:      Diff=-0.1364,  95%CI=-0.1784 to -0.0943,  p=0.0000   ****
    AE - NULL vs AE - FLOODWAY:    Diff=0.0674,   95%CI=-0.0202 to 0.1551,   p=0.2415
    AE - NULL vs X - 0.2 PCT:      Diff=0.1579,   95%CI=0.1063 to 0.2095,    p=0.0000   ****
    AE - FLOODWAY vs X - 0.2 PCT:  Diff=0.0904,   95%CI=0.0008 to 0.1800,    p=0.0463   *
```

Notes: * denotes significance with $\alpha = 0.05$, ** denotes significance with $\alpha = 0.01$, *** denotes significance with $\alpha = 0.001$, **** denotes significance with $\alpha = 0.0001$

Conclusion & Challenges

- Challenges
  - Working with ”big data” in PostgreSQL – Use of indices sped up analysis greatly
  - Geometry Errors – Buffer by 0 to fix Ring Self-Intersections
  - Possible errors in data and/or effects from outliers in data
- Conclusions
  - Clear statistically significant differences in average values for the demographics and parcel values used in this analysis
  - Differences in size of groups for blocks and parcels within each hazard zone and subtype is inconsistent, which does affect the interpretation of the results