Population Exposure to Rising Heat Stress and Pollution Risks: Evidence from Selected Asian Countries

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Motivation and Research Question

Who is more exposed to heat stress and air pollution risks?

- **Asia** faces high exposure to climatic and environmental hazards, with climate change exacerbating risks to human development

- **Short-run cognitive performance** can be impaired by elevated temperatures (Park et al. 2021, Hu and Li 2019); **Health** can be cumulatively affected by **extreme temperatures** (Hu and Li 2019)

- **Pollution exposure** negatively affects **educational outcomes, labor market productivity, and health** (Brabhukumr et al. 2020, Gakidou et al. 2017)

Motivation and Research Question

Are certain population groups simultaneously exposed to both shocks?

- Interactions between air quality, extreme heat, and their health outcomes remain unclear (Chowdhury et al. 2024)

1. **Interaction between high temperature and air pollution increases mortality rates** (Rainham and Smoyer-Tomic 2003, Willers et al. 2016, Qin et al. 2017, Lee et al. 2019, Zhou et al. 2023) **and affects human health** (Piracha and Chaudhary 2022, De Vita et al. 2024)

2. **Directions of interaction are uncertain**
   - Higher temperature increases harmful air pollutant levels, such as ozone (Chowdhury et al. 2024)
   - When air pollution levels are lower, temperature increases (He et al. 2023)

Data on Climate Factors

Heat tress

- **Universal Thermal Climate Index (UTCI)** from ERA5-HEAT dataset, derived from 5th generation of ECMWF atmospheric reanalyses
- Describes how human body experiences atmospheric conditions: air temperature, humidity, ventilation, and radiation
- **Hourly, gridded, 0.25X0.25 resolution, 1940 -**

Air pollution risk

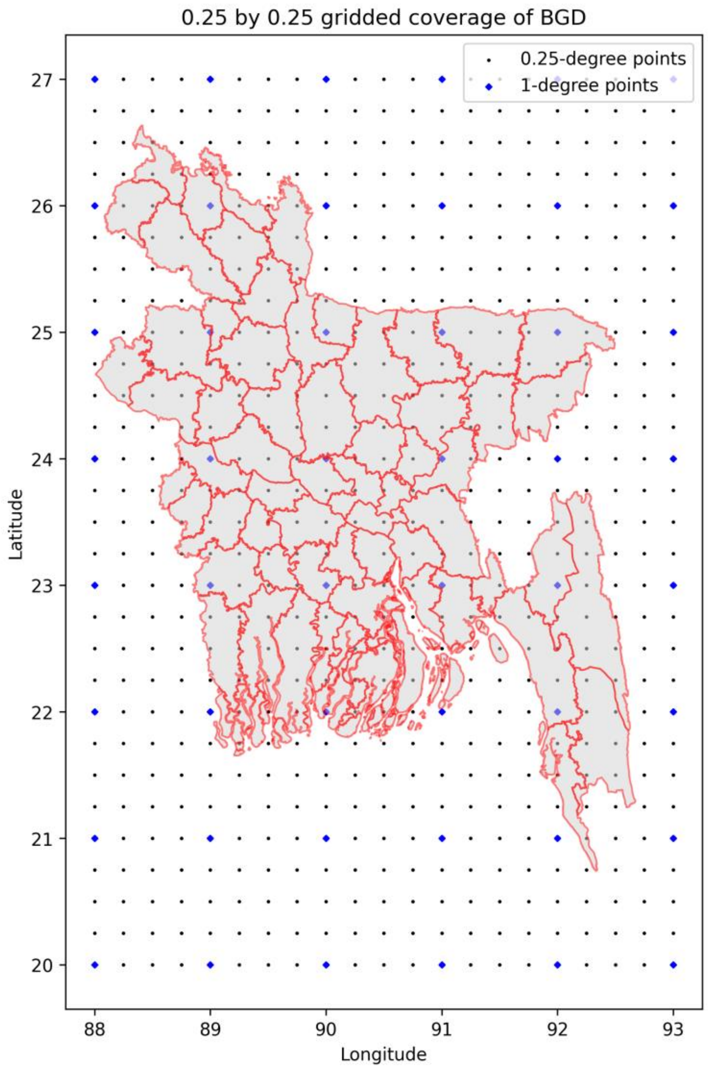
- **Global PM2.5 data** by Washington University in St. Louis, integrating satellite, simulation, and monitor-based sources
- Provides geophysical estimates that explain most of variance in ground-based PM2.5 measurements
- **Monthly mean, gridded, 0.01X0.01 resolution, 1998 -**

Spatial Merging

- Example: Bangladesh
- Each dot represents one coordinate
- Boundaries show districts

- **District-level hourly UTCI**: average UTCI across merged coordinates

- **District-level monthly PM2.5**: average PM2.5 across merged coordinates



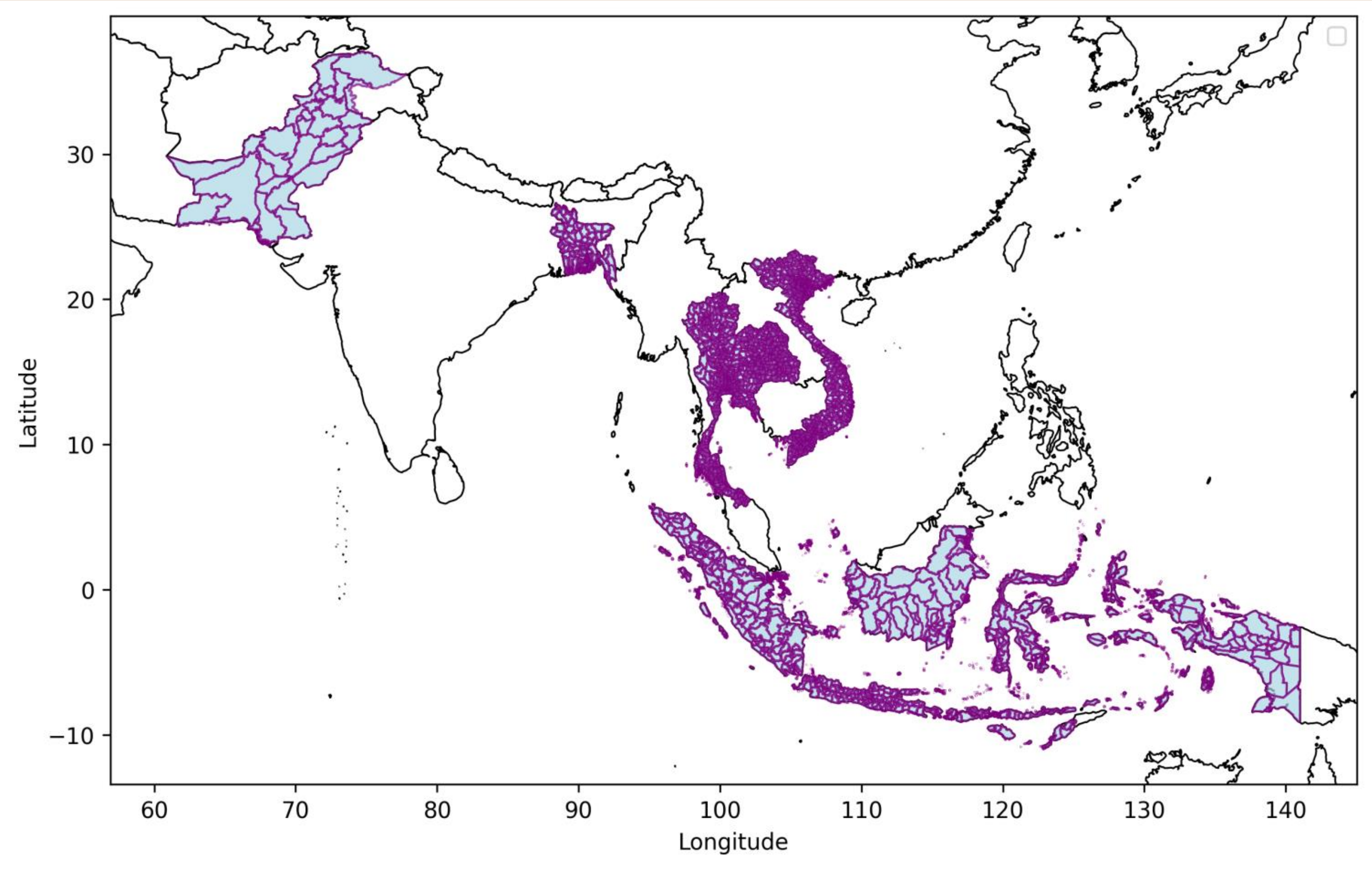
Data on Population

- **Census** from IPUMS
- Around 1990 and most recent year for each country
- Geo-location: state/province (admin 1) & district (admin 2) levels
- **Population categories: 2 X 3 X 4 = 24 groups**
    - Gender: male, female
    - Age range: children (0-14), working-age (15-59), elderly (60+)
    - Employment status: employed, unemployed, inactive, housework

Country	Year	Year
Bangladesh	1991	2011
Indonesia	1990	2010
Thailand	1990	2000
Vietnam	1989	2019

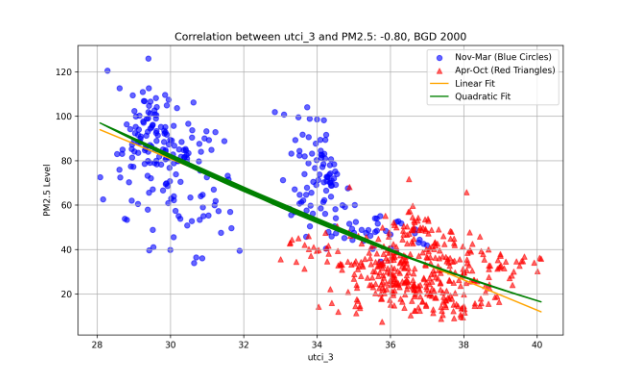
- *Pakistan Census is only available for 1973, 1981, 1998, and does not contain employment status information

District-Level Analysis

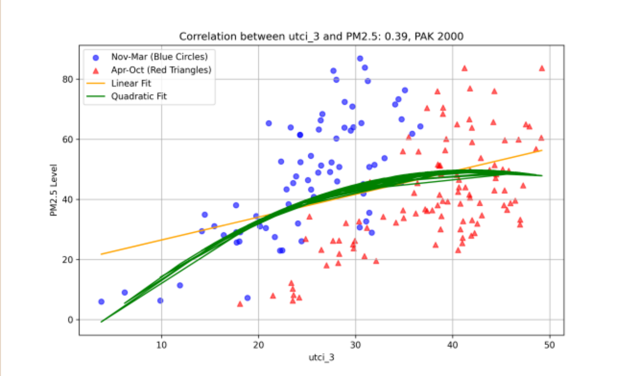


Correlation: UTCI & PM2.5

Bangladesh

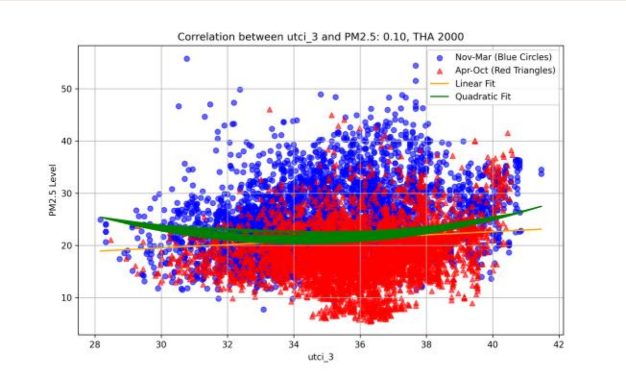


Pakistan

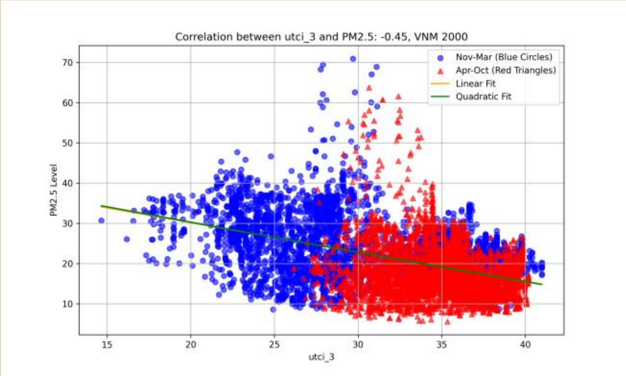


- Each fig: one country-year
- Dots: district-month
- Blue circles – cold months
- Red triangles – hot months
- Linear & quadratic fit lines

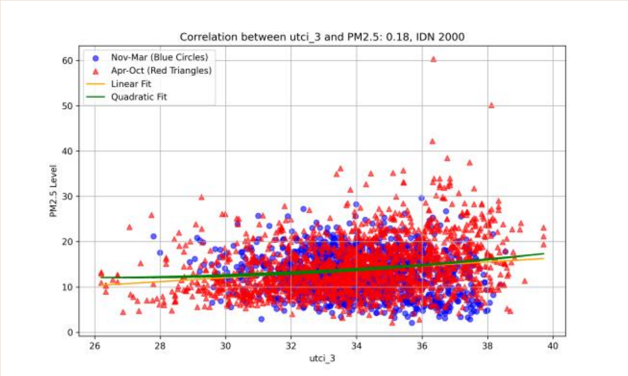
Thailand



Vietnam



Indonesia



Population Exposure Measure: SEIDT

Share of population in one category **E**xposed to heat stress by various **I**ntensity and **D**urations **T**hresholds

1. Set up thresholds:

$$I = temperature,\ H = share\ of\ time\ within\ a\ period$$

2. For each district d, calculate duration of time exposed to heat

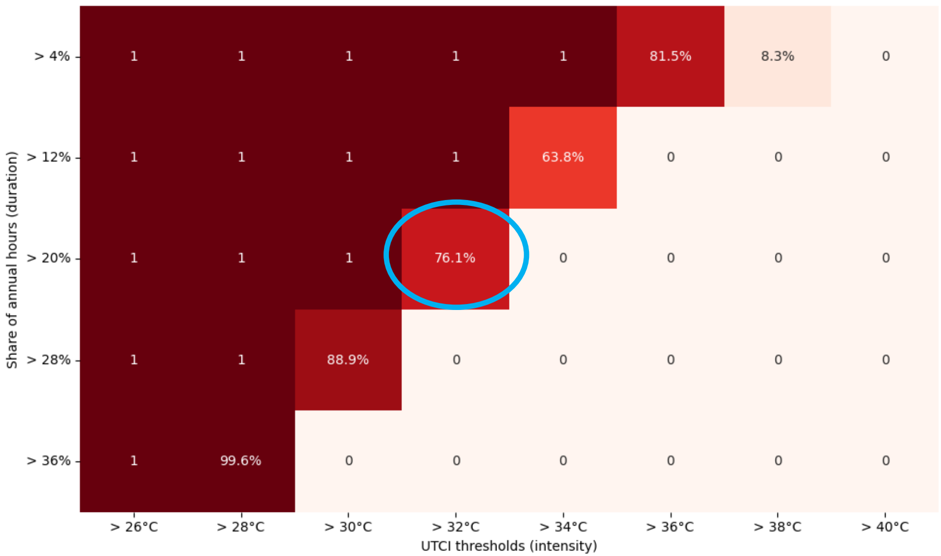
$$H_d = \frac{\#\ of\ hours\ where\ temperature\ exceeding\ I}{Total\ hours\ in\ period}$$

3. Sum the share of population for category m in districts where exposure time exceeds duration threshold

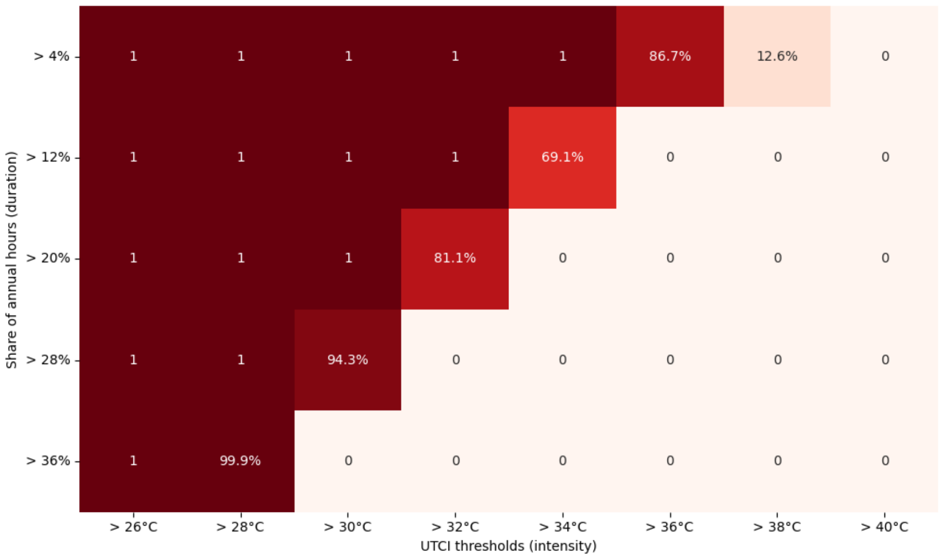
$$SEIDT_m = \sum_{d\ \in \{d:H_d > H\}} Population\ share_{d,m}$$

Results from SEIDT: BGD 1991

Less exposed:
female, working-age, unemployed



More exposed:
female, elderly, housework



76.1% of working-age unemployed females experienced strong and very strong heat stress for more than 20% of total hours (equivalent to over 10 weeks)

Population Exposure Measure: STAC

Share of **T**ime the **A**verage individual in a **C**ategory exposed to heat stress

1. For each district d, obtain share of people in category m relative to the total population of that category across the entire country

$$Population\ share_{d,m} = \frac{Population\ of\ m\ in\ d}{Total\ population\ of\ m\ in\ the\ country}$$

2. For each district, calculate total hours above a threshold over a period

$$Share\ of\ time\ exposed_{d} = \frac{Hours\ with\ temperature > threshold}{Total\ hours\ in\ time\ period}$$

3. Calculate population-weighted STAC at national-level

$$STAC_m = \sum_{d=district1}^{district\ n} (Population\ share_{d,m} \times Share\ of\ time\ exposed_d)$$

Results from STAC: BGD 1991

Category	Gender	Age Range	Employment	> 36° C
1	Male	Children	Employed	6.35%
2	Male	Children	Unemployed	5.61%
3	Male	Children	Inactive	6.20%
4	Male	Children	Housework	5.65%
5	Male	Working Age	Employed	6.35%
6	Male	Working Age	Unemployed	5.67%
7	Male	Working Age	Inactive	6.14%
8	Male	Working Age	Housework	5.67%
9	Male	Elderly	Employed	6.18%
10	Male	Elderly	Unemployed	5.84%
11	Male	Elderly	Inactive	6.17%
12	Male	Elderly	Housework	5.42%
13	Female	Children	Employed	6.19%
14	Female	Children	Unemployed	5.74%
15	Female	Children	Inactive	6.22%
16	Female	Children	Housework	6.21%
17	Female	Working Age	Employed	6.24%
18	Female	Working Age	Unemployed	5.86%
19	Female	Working Age	Inactive	6.12%
20	Female	Working Age	Housework	6.30%
21	Female	Elderly	Employed	6.23%
22	Female	Elderly	Unemployed	6.08%
23	Female	Elderly	Inactive	6.25%
24	Female	Elderly	Housework	6.20%

- Column “> 36°C”: share of time on average for each category exposed to heat above 36°C in one year
- Compare STAC across categories at same threshold
- At > 36°C, male employed are heavily exposed

Results

- **Bangladesh – Heat:** In both 1991 and 2011, the elderly were more exposed than children and the working-age population. **Air pollution:** In 2011, both children and the elderly were more exposed

- **Indonesia – Heat:** In 1990, the unemployed were more exposed, while in 2010, the employed experienced greater exposure. **Air pollution:** In 2010, the employed were not exposed to higher risks than the unemployed

- **Thailand - Heat:** In 1990, the employed were more exposed, and females experienced higher exposure than males. In 2000, the unemployed was more exposed. **Air pollution:** In 2000, elderly males were the most exposed

- **Vietnam – Heat:** Among the employed, females were more exposed than males. **Air pollution:** In general, females were also more exposed than males.

Conclusions

- There are diverse patterns across countries

- There is an urgent need for targeted policies to mitigate the compounded effects of climate and pollution hazards on vulnerable populations

Next steps and future research

- Decompose the STAC measures to investigate if increasing exposure comes from changing demography or climate
- Explore migration due to heat stress and air pollution and what can mitigate such exposures

Thank you!

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