Megacities and Climate Change: An Environmental Implication of Urbanization on Big Cities in Different Climatic Regions.

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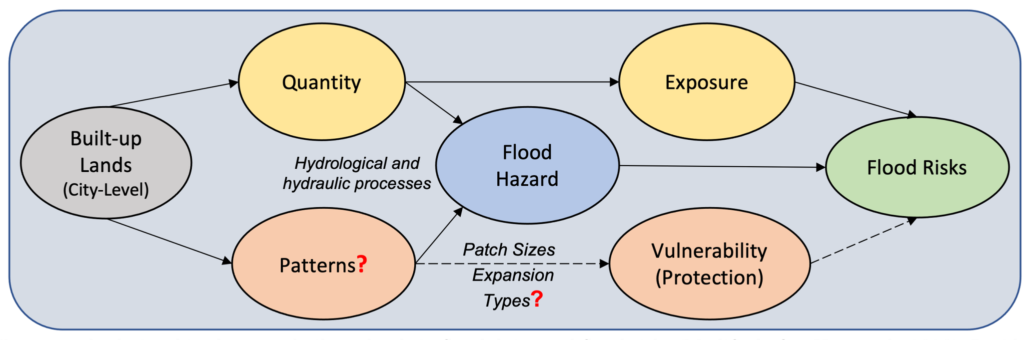
Problem Statement

Globally, more people are impacted by floods than all other forms of natural disasters combined. In global megacities, defined by the United Nations as cities with a population of over ten million, increased human exposure to flooding is both ubiquitous and extremely difficult to characterize which consequently affect flood protection measures and policies.

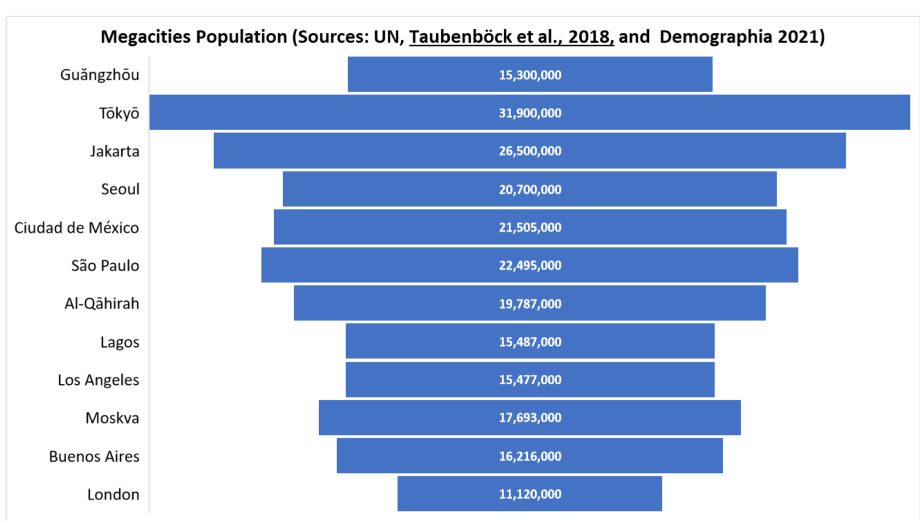
Over the past three decades, most of these cities have experienced a gradual or very rapid growth as the global population continues to urbanize. As both urban expansion and global climate change contribute to hydrologic intensification, and as globally more people live in urban areas than rural ones, the need to assess both the drivers and magnitude of flood risk associated with rapid growth in big cites is of critical humanitarian concern.

Generally, Built-up Land in Floodplains (BLF) which often result in changes in hydrologic processes within a floodplain is a strong driver for flood risk. This is accurate for river and urban (pluvial) flooding. Extensive work has been conducted on the level of flood risks considering the BLF quantity and exposure.

However, little is known as to how built-up land growth mode types (Infilling, Leapfrogging and Edge Expansion) influences flood vulnerability.



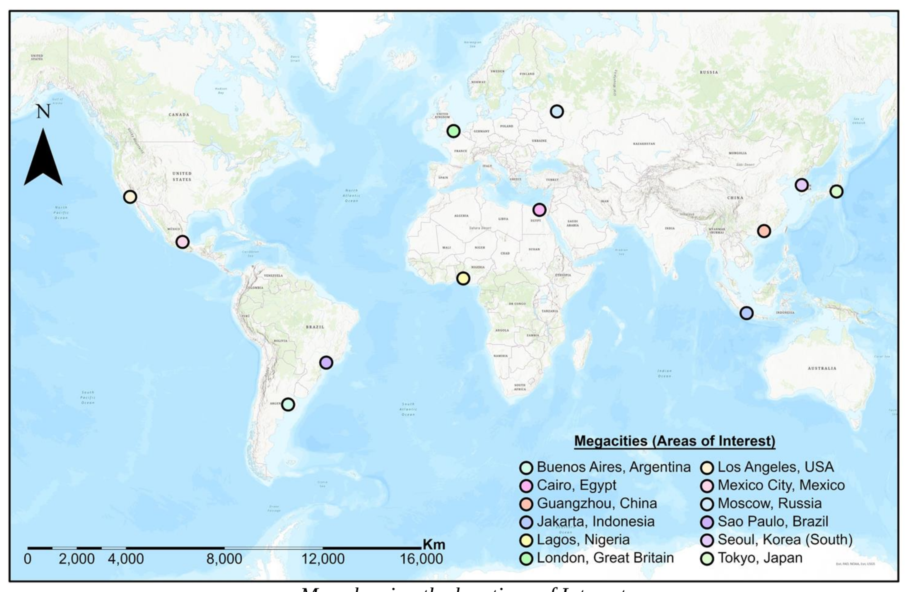
Conceptual relationships between built-up lands in floodplains and flood risks (Modified after Han et al., 2020). Besides affecting flood hazard through altering hydrological and hydraulic processes, Built-up land can impact flood risk through two ways: (i) changing flood exposure because of its changes in quantity and (ii) changing flood vulnerability or the protection level due to its spatial patterns. However, the latter issue is still to be elucidated



Project Objectives/Goals

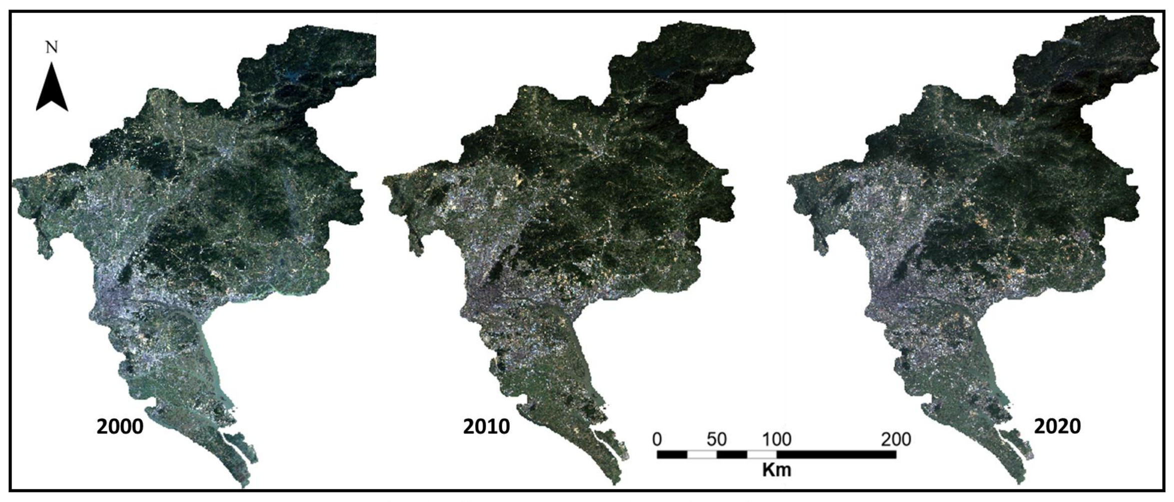
In terms of flood protection measures for flood prone regions, since increasing built-up land could sometimes imply changes or modification to existing infrastructure (e.g., existing flood protection measures needs to be modified to accommodate new developments – for regions/cities with existing flood protection measures) and whether a new built-up land falls within an existing flood protection boundaries, it is important to assess how urban expansion type influence flood risks. This project seeks to investigate;

- Urban expansion types for 12 megacities
- Relationship between urban expansion types and flood vulnerability for these cities
- Urban growth mode(s) associated with flood risks and most dominant among the cities



Map showing the locations of Interest

Data and Methods



Landsat Satellite Imageries for Guangzhou, China.

Data	Years	Source
Landsat 7 ETM + and OLI	2000, 2010 and 2020	Earth Engine data catalog (provided by the USGS)

Methods

➢ Image Classification and Change Detection

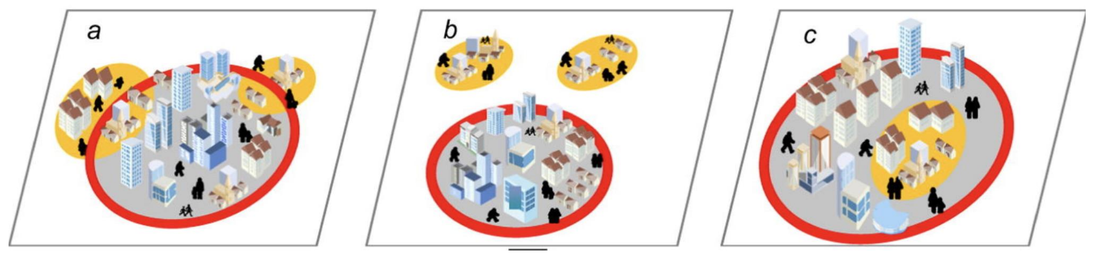
A multitemporal image classification and change detection analysis to estimate the area of built-up land and a pair-wise evaluation of temporal changes was conducted in Google Earth Engine and the ArcGIS Pro environment.

- Unsupervised Image Classification
- Change Detection

➢ Urban Expansion Index

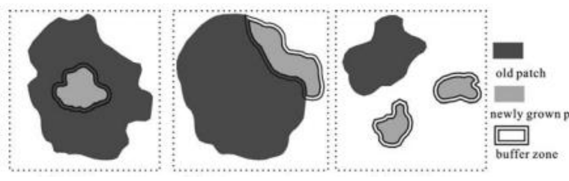
The growth modes for Guangzhou, China was estimated using the equation below;

- Infilling
- Edge Expansion
- Leapfrogging



Example Urban Expansion Types (a) Edge Expansion (b) Leapfrogging (c) Infilling (Han et al., 2020)

$$S = 100 * \frac{A_o}{A_o + Av}$$



Where;

S - Landscape expansion index for a newly grown patch,

A_o - Intersection between the buffer zone and the occupied category,

A_v - Intersection between the buffer zone and the vacant category.

S =

Infilling S > 50

Edge-expansion 0 < S ≤ 50

Leapfrogging S = 0

Preliminary Findings

➢ Flooding in megacities mostly as a result of heavy rainfall as shown in the table below.

Table showing Megacities and Past Flood Information. Years of Flooding from the Dartmouth Flood Observatory and other Online Sources.

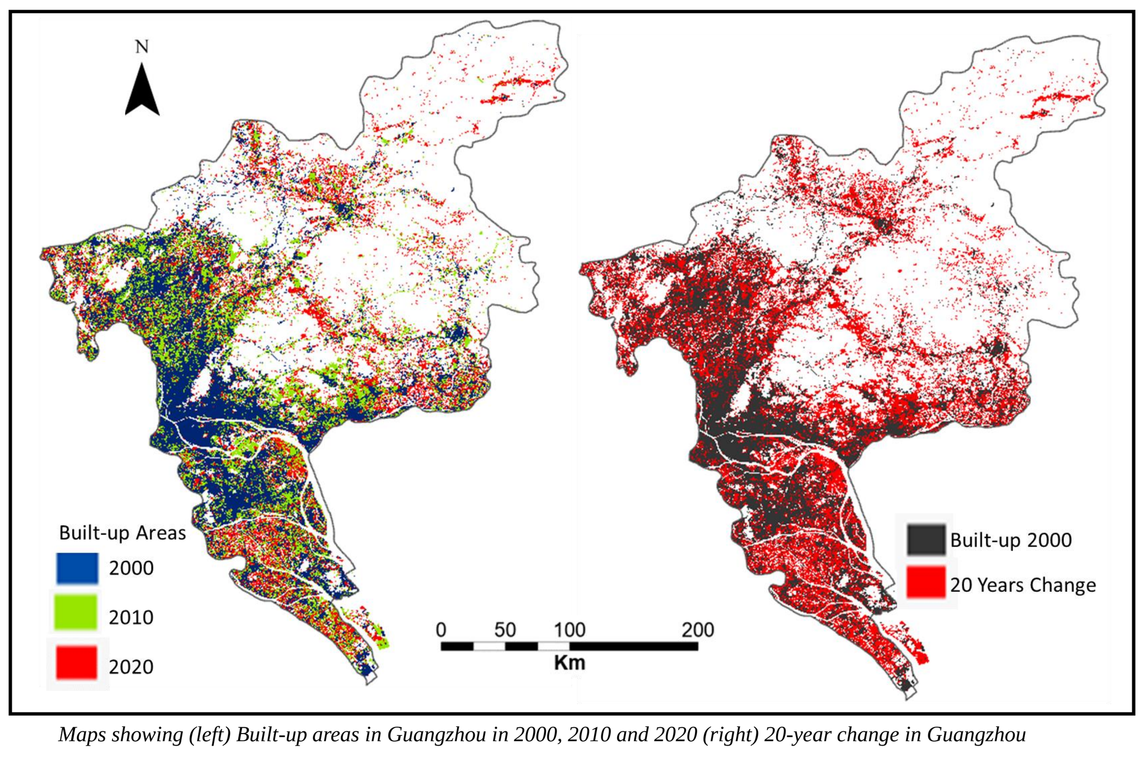
ID	Megacity	Other Name	Country	Population	Climate	Flood (Y/N)	Year	Flood_Source
1	Guăngzhōu	Canton	China	15,300,000	Humid subtropical to tropical cimate	Y	2010, 2020	Heavy Rainfall
2	Tōkyō	Tokyo	Japan	31,900,000	Humid subtropical	Y	1910, 2000, 2019	Heavy Rainfal, Typhoon
3	Jakarta	Jakarta	Indonesia	26,500,000	Tropical humid	Y	1960,1996, 2007, 2013, 2014 2020, 2021	Heavy Rainfall
4	Seoul	Seoul	Korea (South)	20,700,000	Temperate	Y	1984, 1987, 1990,1998, 2001, 2010, 2011	Heavy Rainfall
5	Ciudad de México	Mexico City	Mexico	21,505,000	Subtropical	Y	2011, 2021	Heavy Rainfall
6	São Paulo	São Paulo	Brazil	22,495,000	Temperate	Y	2016, 2018, 2019, 2022	Heavy Rainfall
7	Al-Qāhirah	Cairo	Egypt	19,787,000	Subtropical desert	Y	2011, 2018, 2019, 2020, 2021	Heavy Rainfall
8	Lagos	Lagos	Nigeria	15,487,000	Tropical	Y	2012, 2019, 2020, 2021	Heavy Rainfall
9	Los Angeles	Los Angeles	United States of America	15,477,000	Subtropical	Y	1938, 2005, 2021	Heavy Rainfall, Storms
10	Moskva	Moscow	Russia	17,693,000	Continental	Y	2020, 2021	Heavy Rainfall
11	Buenos Aires	Buenos Aires	Argentina	16,216,000	Temperate	Y	1993, 1995, 2013	Heavy Rainfall
12	London	London	Great Britain	11,120,000	Temperate	Y	1990, 1991, 1992, 1993, 2000, 2003, 2020, 2021	Heavy Rainfall

➢ Image classification and change detection analysis

Year	Area (km^2)	% Change of Guangzhou Total Area
2000	1652	23
2010	2214	31
2020	2853	40

Pairwise Changes in Built-Up Areas in Guangzhou

2000 - 2010	2010 - 2020	2000 - 2020
25	23	43



Maps showing (left) Built-up areas in Guangzhou in 2000, 2010 and 2020 (right) 20-year change in Guangzhou

➢ Urban Expansion Index

- Guangzhou has experienced rapid urbanization and between 2000 and 2020, the city built-up areas increased to 40% of its total area. Much of the developments are around the Pearl River and its tributaries.
- Flooding in the city is mostly as a result of heavy rainfall which is likely to intensify because of climate change.
- The most occurring expansion pattern found in the area is infilling which implies new development occurring within existing developed areas.
- Flood protection measure and policy in the city should account for the different growth types.

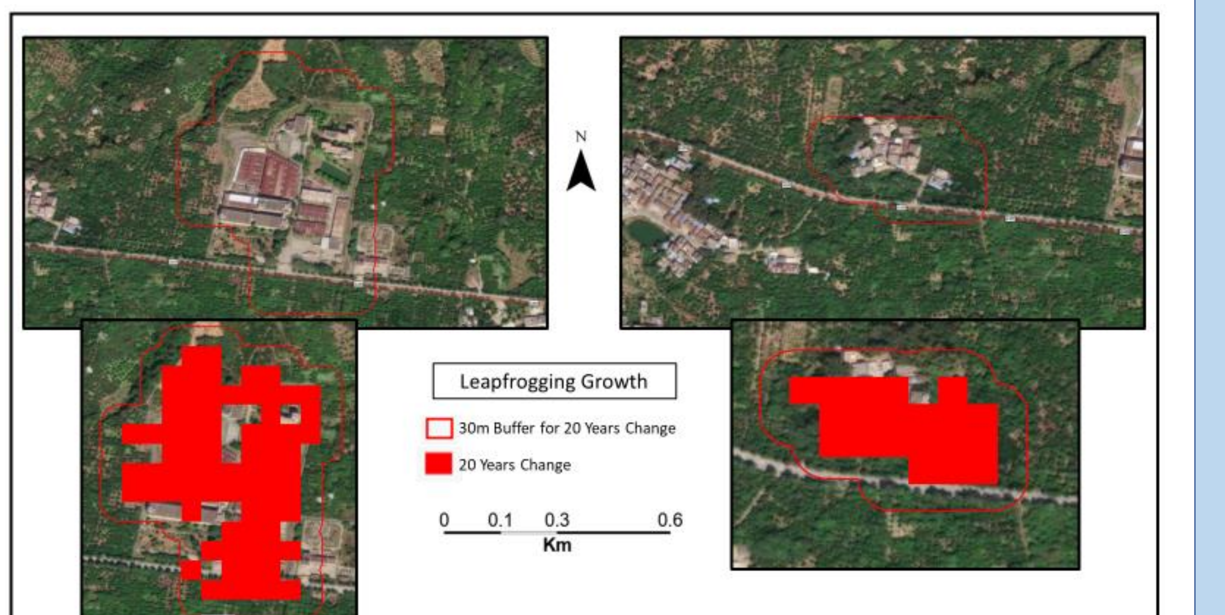


Figure displaying an example of a leapfrogging growth in Guangzhou China

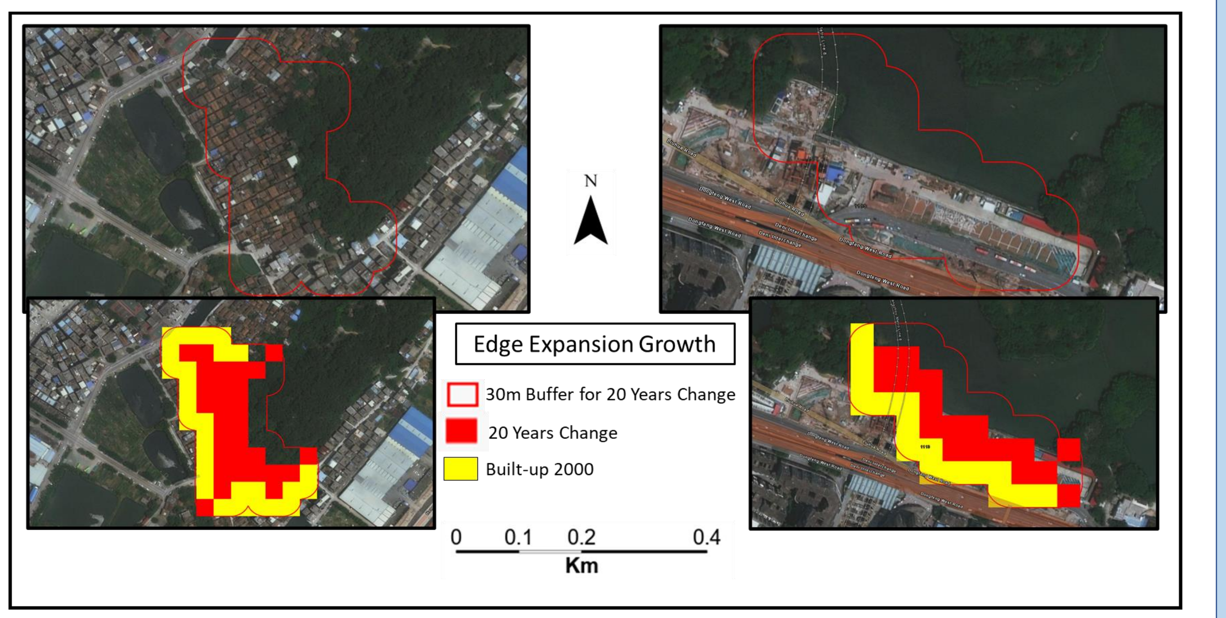


Figure displaying an example of an edge expansion growth in Guangzhou China

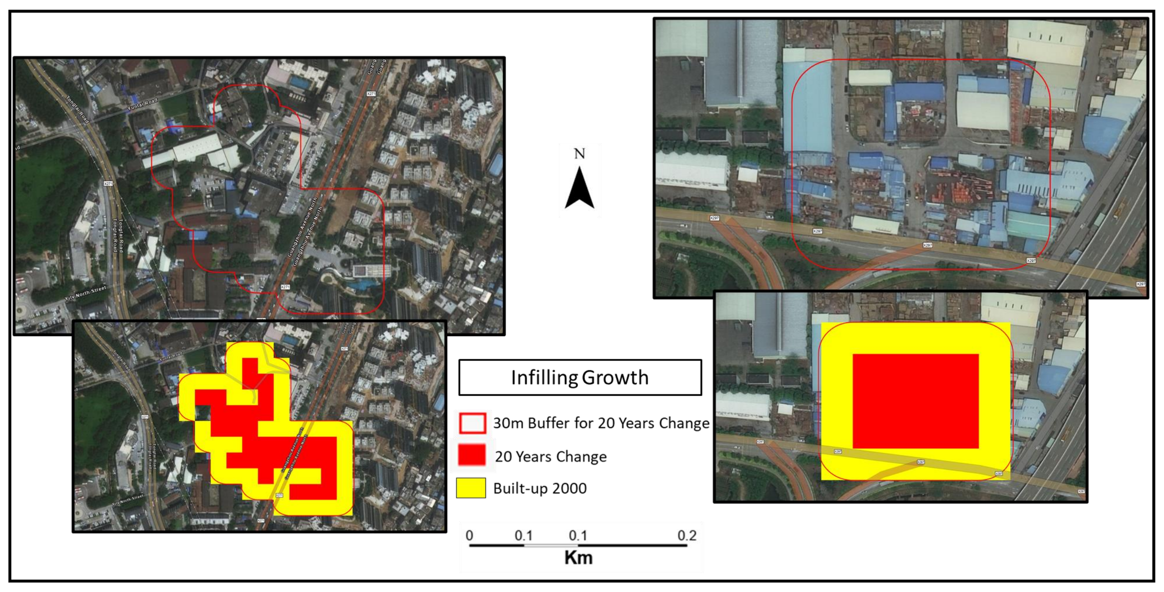
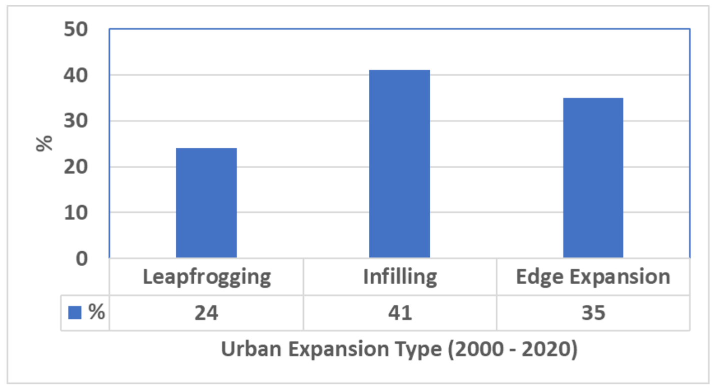


Figure displaying an example of an infilling growth in Guangzhou China

Table showing the percentage of each growth type in Guangzhou China.



Future Work

- Estimate the urban growth mode for other megacities.
- Determine the most occurring expansion index for the megacities and establish the growth mode(s) associated with flood risk.
- Assess which urban expansion index values are associated with high values of the GRACE Flood potential Index

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