Spatial interaction model of energy demand of buildings and satellite thermal imageries using Geographically Weighted Regression analysis

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Background

- Building sector is important to meet the energy and climate goals of European countries (climate neutral by 2050)

- Energy management strategies, e.g. energy renovations, require information about current state of building and energy use

- Energy performance certificate (EPC) of buildings is an information tool for homeowners and prospective buyers. But,
  - In Sweden, EPC for one and two-family houses are mandatory during sales; not available for houses sold before 2008
  - Quality and reliability of EPC data is an issue
  - EPC data is usually old

- Energy use data from energy suppliers is difficult to obtain due to GDPR

Aim and Objectives

The overall aim is to understand if satellite images can be used to identify energy performance of a building. The objectives are

- To analyse relationship between energy performance of (EP) buildings (dependent variable) and (independent variables like)- Land Surface Temperature (LST), land use characteristics (built-up and open land neighbours), and building characteristics (building type, category, complexity and year of construction)
- To identify the variation in spatial relation of LST on the EP of buildings during spring (March-May) and summer (June-August) of 2020 in the study region

Methodological Framework

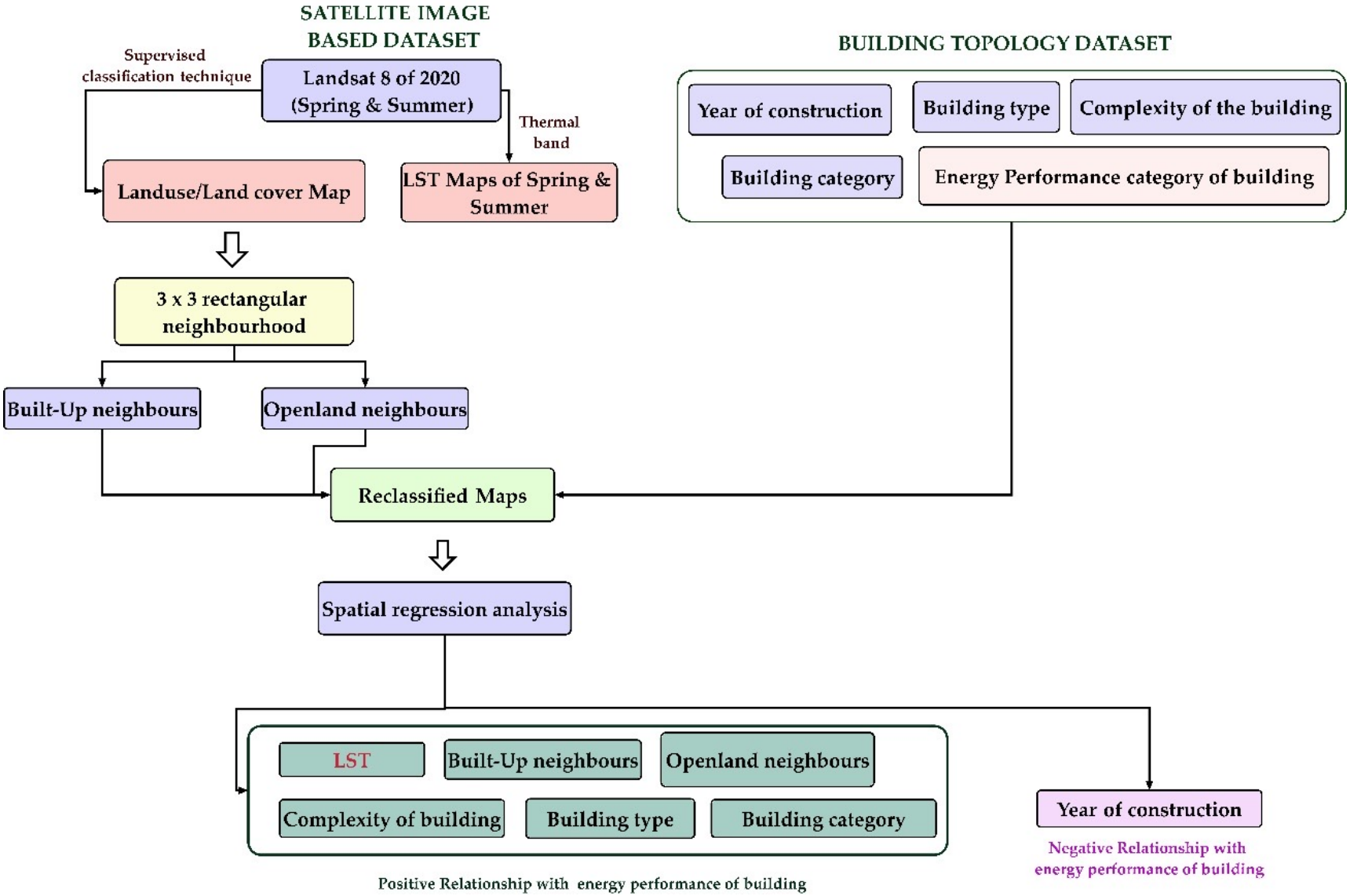


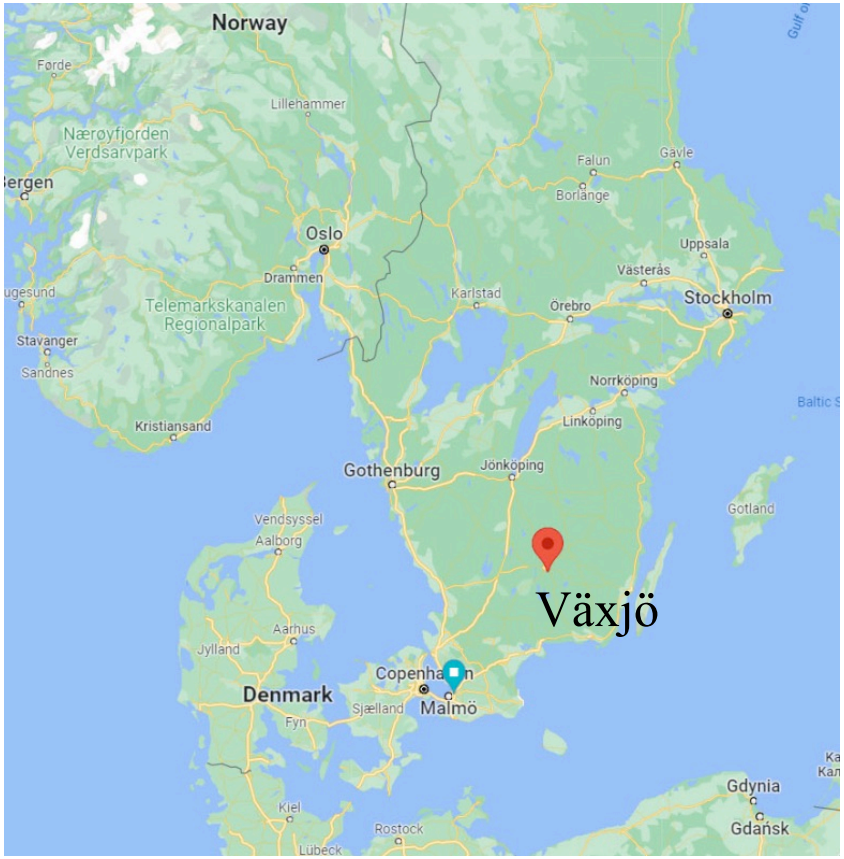
Figure 1. Methodological framework adopted in the study

Methodological Framework

- Selected 4541 buildings within Växjö municipality, Sweden for which building data was available (EPC dataset)

- Spatial regression analysis technique

Energy Performance =f (LST; no. of built-up neighbours, no. of openland neighbours; building type, category, complexity and year of construction)



Source: Google maps

Landuse/land cover (LULC) map of the study region

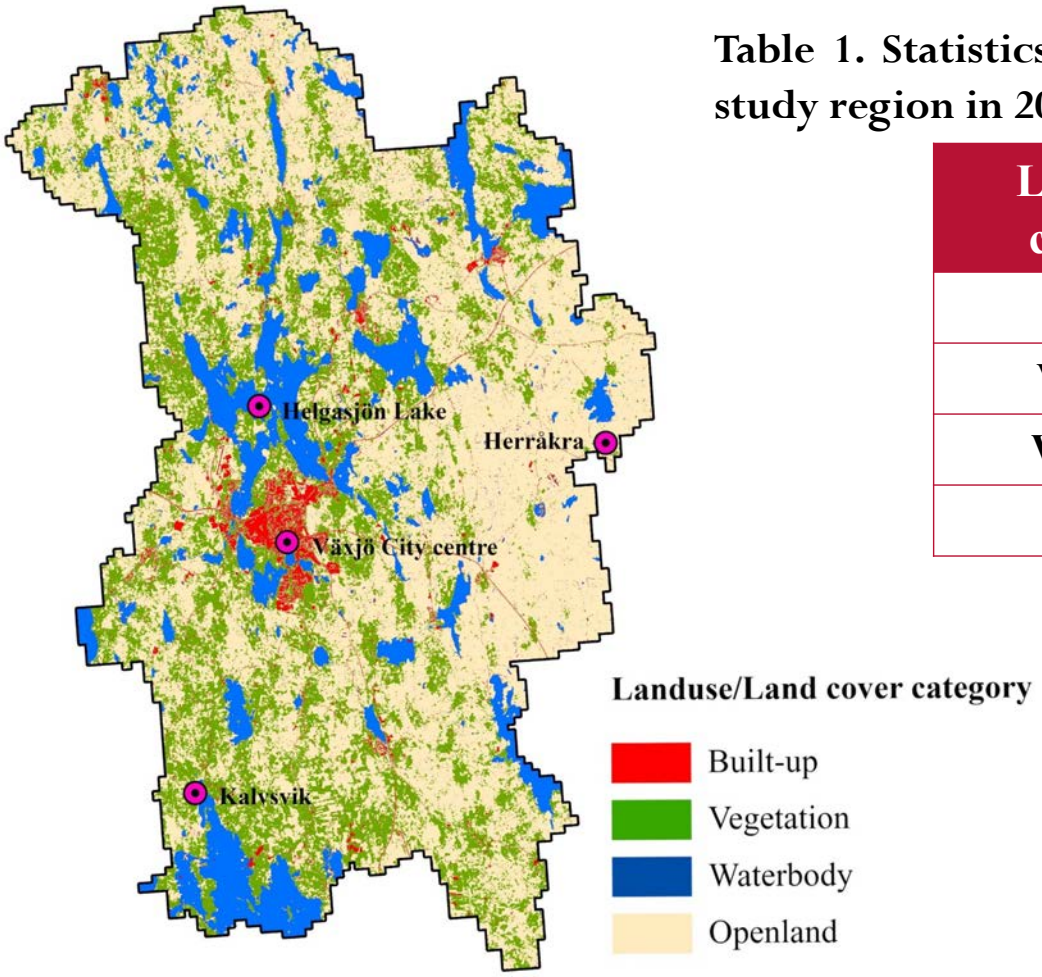


Table 1. Statistics of landuse/land cover categories of the study region in 2020 (Landsat 8; 15 m resolution)

Land cover categories	Area (km^2) of each category
Built-Up	64.34
Vegetation	506.25
Waterbody	252.99
Openland	1103

Figure 2. Landuse/land cover map of the study region in 2020

Land surface tempertaure (LST) map of the study region

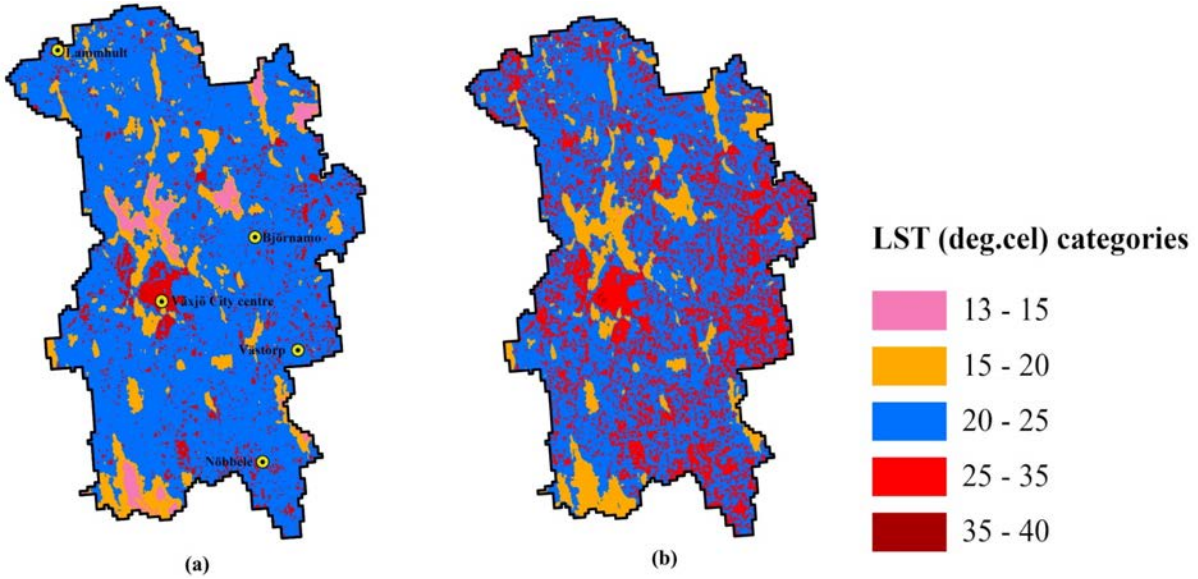
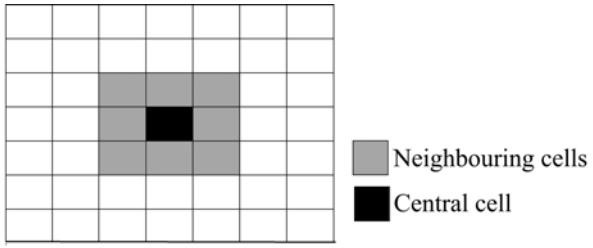


Figure 3. LST Maps of 2020 of the study region in (a) Spring; (b) Summer (Landsat 8; 100 m resolution)

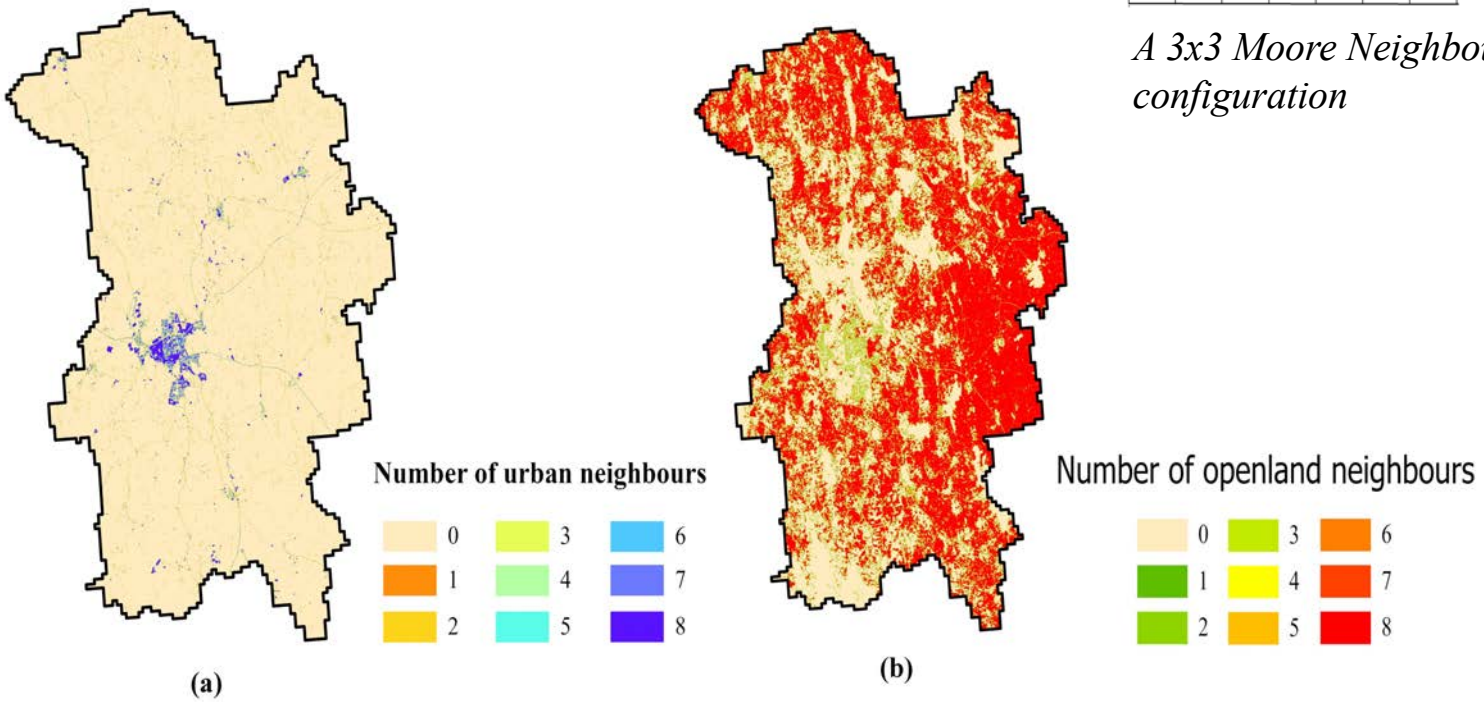
Table 2. Statistics of LST in spring and summer of 2020 in Växjö municipality

LST Categories (°C)	Area (km^2) under each LST category in	
	Spring 2020	**Summer 2020**
13 – 15	58.97	0.21
15 – 20	220.17	224.39
20 – 25	1499.57	1188.72
25 – 35	149.02	514.16
35 - 41	0.27	1.20

Neighbourhood Maps of (a) Built-up; (b) Openland



A 3x3 Moore Neighbourhood configuration



Correlation between input variables and the energy performance of the buildings

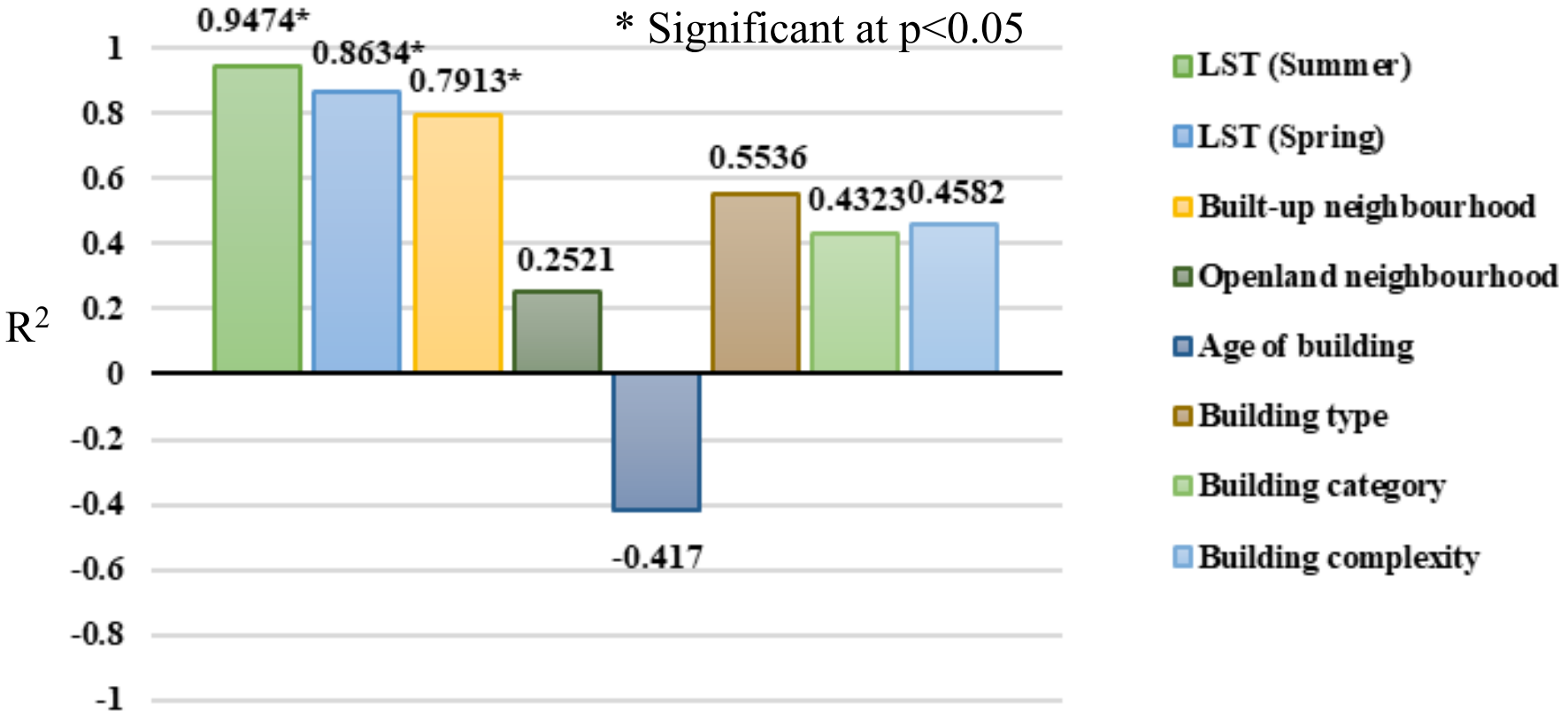


Figure 4. Relation between the EP of buildings and the input variables based on spatial regression analysis in the study region in 2020

Results

- LST and built-up neighbourhood exhibit maximum positive relation with the energy consumption of buildings in the study region
- Irrespective of the season, regions with LST more than the average value indicate buildings with poor EP
  - Of the total 4541, **67% (EPC category E), 71% (F category), 87% (G category)** of buildings had LST greater than average value in summer
- Buildings in the proximity of higher number of built-up neighbours (8, 7, 6, 5) exhibit lower EP (concentrated around the city)
  - Almost 50% of the total building with energy class G had maximum number of built-up neighbours

Conclusion

- LST maps from satellite imageries can provide information on the EP of buildings of a region
  - Identify the hotspots where EP of buildings are poor - appropriate renovation techniques could be implemented
  - Useful to homeowners, investment bankers, real estate companies - selling and purchasing of buildings

Future Research Scope

- Winter and fall season dataset - provide a detailed insight on the relation between LST and the EP of buildings
- Two-stage least squares (2SLS) regression analysis - to identify the dependency of input variables on EP of buildings
- Inclusion of year and the type of renovation carried out – influence on the EP of buildings

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