Are European Cities Getting Warmer? Investigating Urban Heat Island Phenomenon in Europe from 1982-2018 through the Use of NOAA-AVHRR Data

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INTRODUCTION

- Urban Heat Island (UHI) effect describes the phenomenon of higher temperatures within urban locations as compared to surrounding rural areas of similar elevation [1].

- UHI is among the most evident aspects of human impact on the Earth system

- UHI prolongs and intensifies heat waves, hence, negatively impacting the quality of city life[2].

- With 73% of the population living in cities, a figure like to increase by 2050, Europe is vulnerable to the harmful effects of UHI[3].

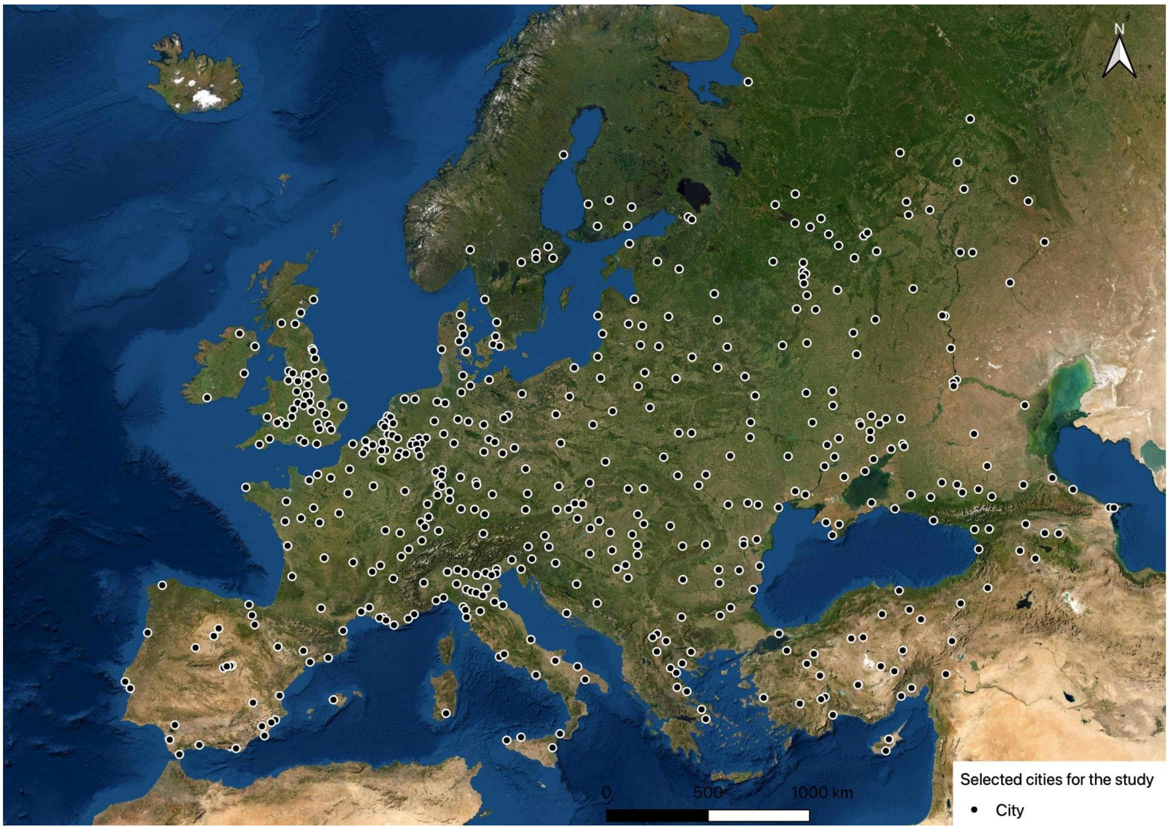


Fig 1 : Study area and the European cities selected for this study

- Noticeable knowledge gaps persists while analysing UHI, especially **Surface Urban Heat Island (SUHI)**, over a long time series and on a regional or Continental scale[4].

- The **TIMELINE** project ("Time Series Processing of Medium Resolution Earth Observation Data Assessing Long-Term Dynamics in our Natural Environment") of the Earth Observation Center (EOC) of the German Aerospace Center (DLR) aims to generate a consistent database of almost 40 years of daily **AVHRR**(Advanced Very High Resolution Radiometer) data from NOAA(National Oceanic and Atmospheric Administration) satellites at 1.1 km spatial resolution over the continent of Europe.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1639410233/agu-fm2021/20-6D-06-C3-11-31-C2-36-2E-05-82-4D-EF-D9-CE-98/Video/LST_online-video-cutter.com_uqfhv3.mp4

Fig 2 : Brief snippet of TIMELINE LST product

- This study uses TIMELINE LST product to analyze SUHI in the cities of Europe from 1982 to 2018

METHODOLOGY

- Determining the LST and extracting the Urban areas are two primary parts of the study

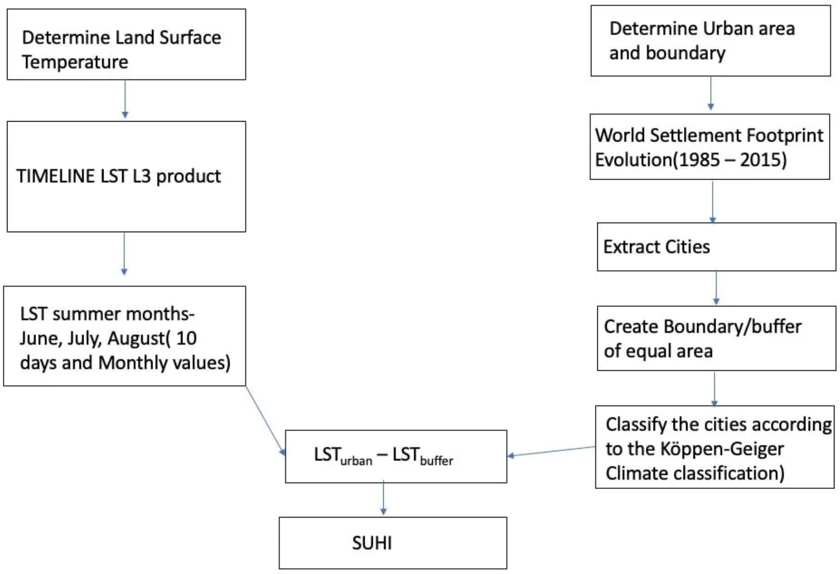


Fig 2 : Workflow for the study

- **470 cities** are extracted form the **World Settlement Footprint Evolution**[5], a repository containing the global settlement extent on a yearly basis from 1985 to 2015.

- Extracted cities are then classified according the **Köppen-Geiger** classification system[6].

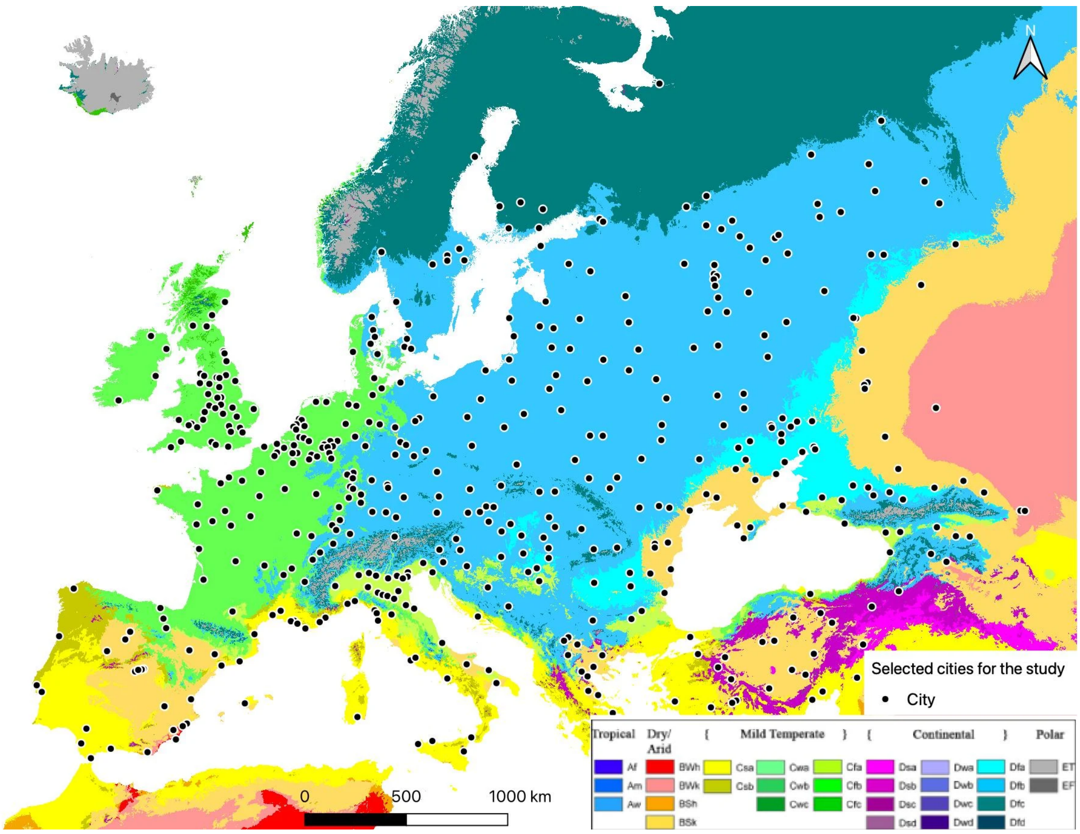
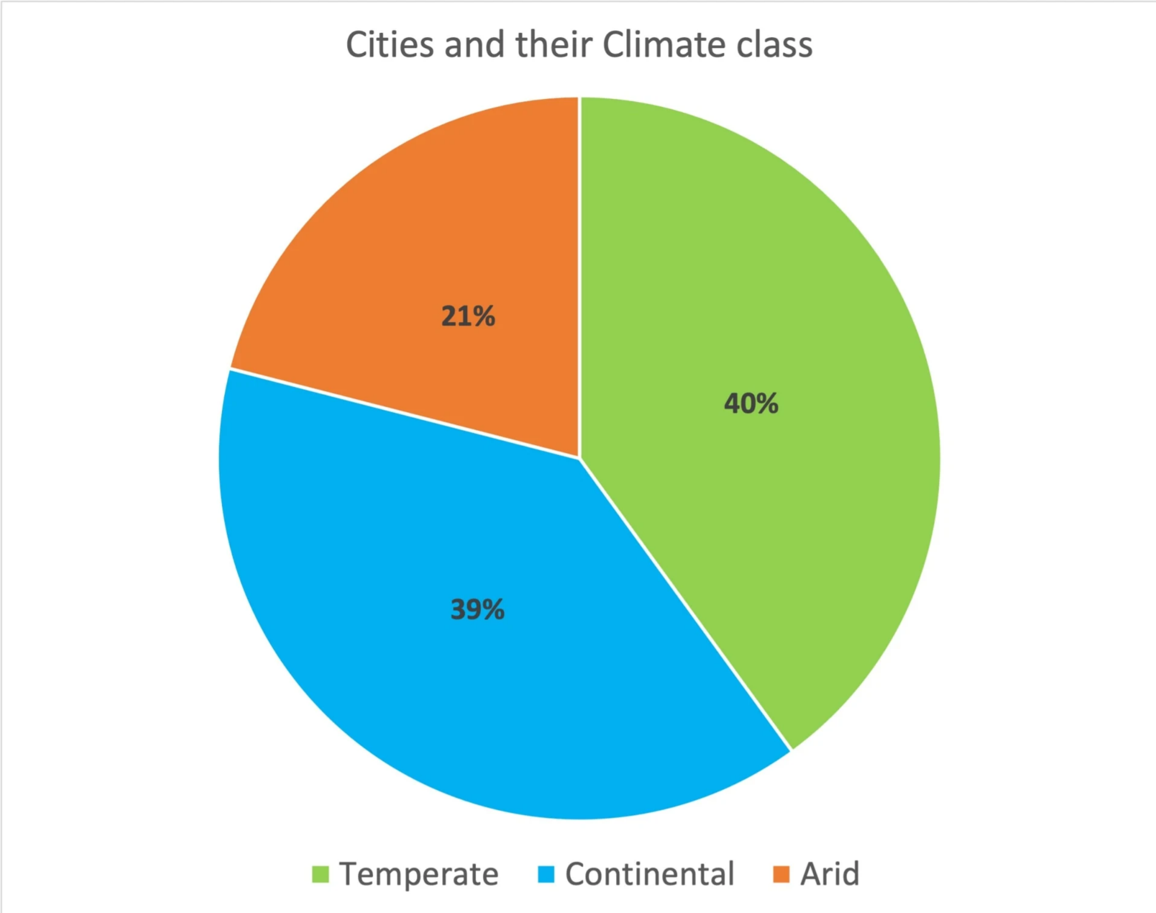
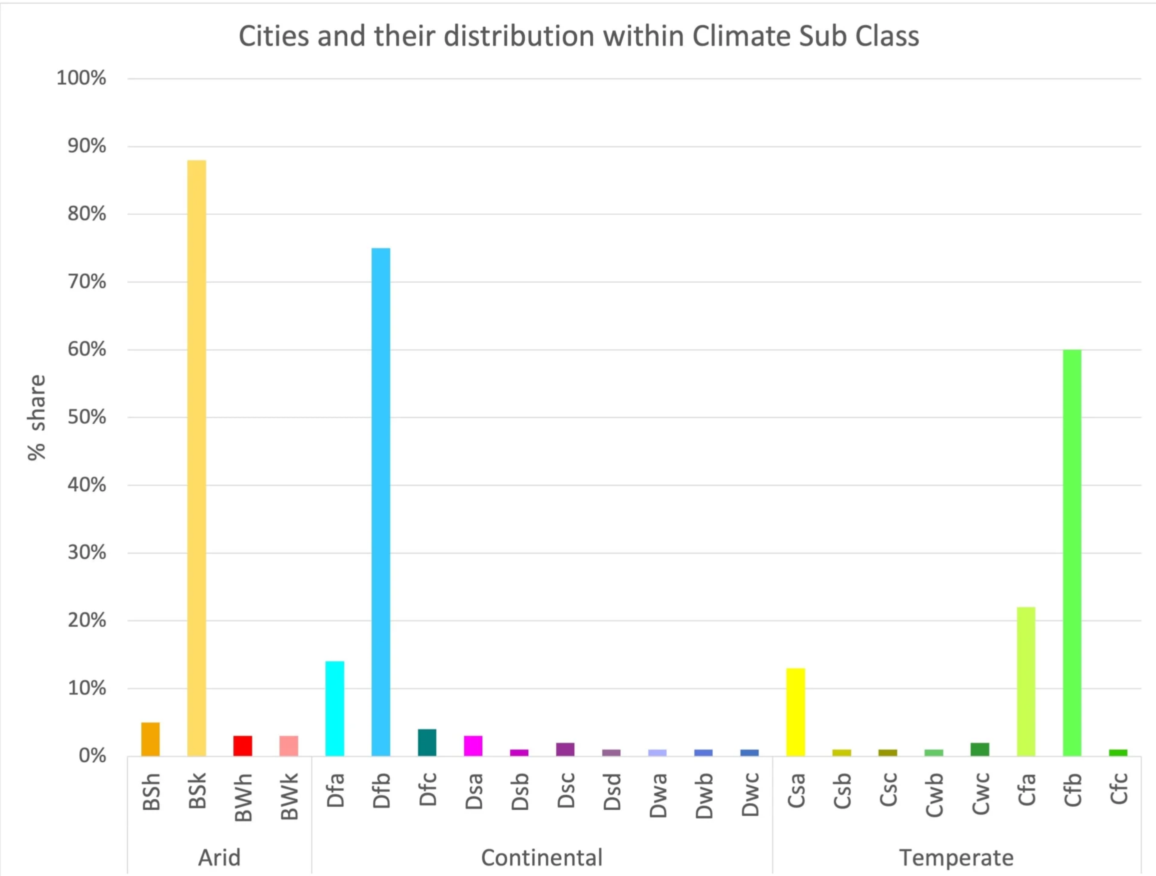


Fig 3 : Cities of the study with Köppen-Geiger classification system

- Cities under the study area fall under 3 main Climate classes(Arid, Continental, Temperate) and 19 subsequent sub-classes.



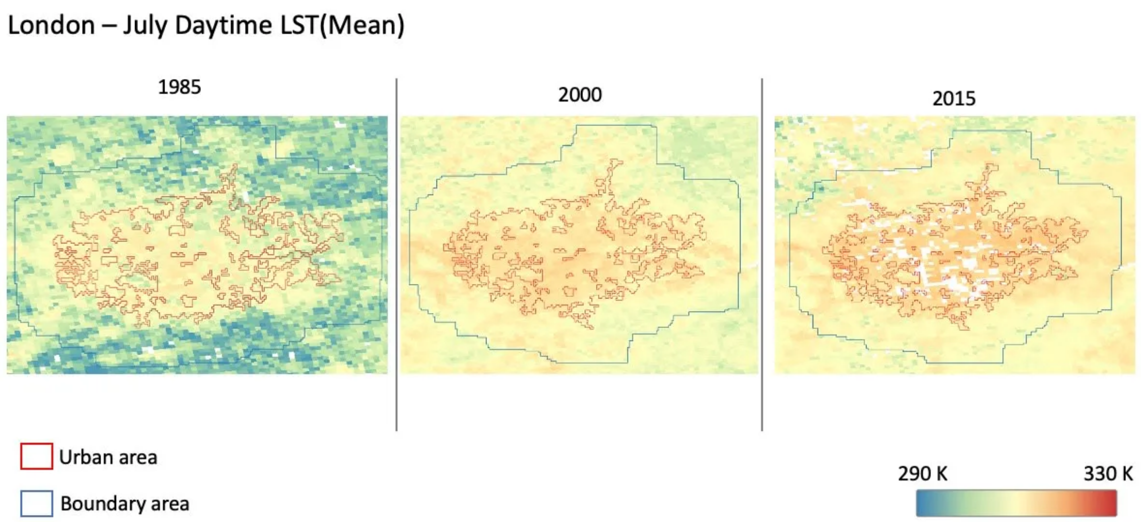


Class	Subclass	Precipitation type	Level of heat	Prominent Cities
Arid	BSh	Steppe	Hot	Almeria, Cartagena
	BSk	Steppe	Cold	Elche
	BWh	Desert	Hot	Mallorca, Nicosia
	BWk	Desert	Cold	Lisbon, Madrid, Marseille
Temperate	Csa	Dry summer	Hot summer	Rome,Seville,Florence
	Csb	Dry summer	Warm summer	Porto
	Csc	Dry summer	Cold summer	Tbilisi
	Cwb	Dry winter	Warm summer	Halle
	Cwc	Dry winter	Cold summer	Brighton,Sochi
	Cfa	Without dry season	Hot summer	Lyon,Zagreb,Milan,Southampton
	Cfb	Without dry season	Warm summer	London,Paris,Amsterdam, Glasgow
	Cfc	Without dry season	Cold summer	Stuttgart, Krasnodar
Continental	Dsa	Dry summer	Hot summer	Helsinki, Magdeburg
	Dsb	Dry summer	Warm summer	Zurich
	Dsc	Dry summer	Cold summer	Aarhus, Rostok
	Dsd	Dry summer	Vert cold summer	Aalborg
	Dwa	Dry winter	Hot summer	Leipzig
	Dwb	Dry winter	Warm summer	Pecs
	Dwc	Dry winter	Cold summer	Tagang
	Dfa	Without dry season	Hot summer	Budapest,Prage,Copenhagen
	Dfb	Without dry season	Warm summer	Moscow, Stockholm, Oslo
	Dfc	Without dry season	Cold summer	Pori, Umea, Volgoda

Fig 4 : Cities and their Class and sub-class

- Urban area and the buffer is then applied to the **TIMELINE LST** product

- **SUHI = LST_{urban} - LST_{buffer}**



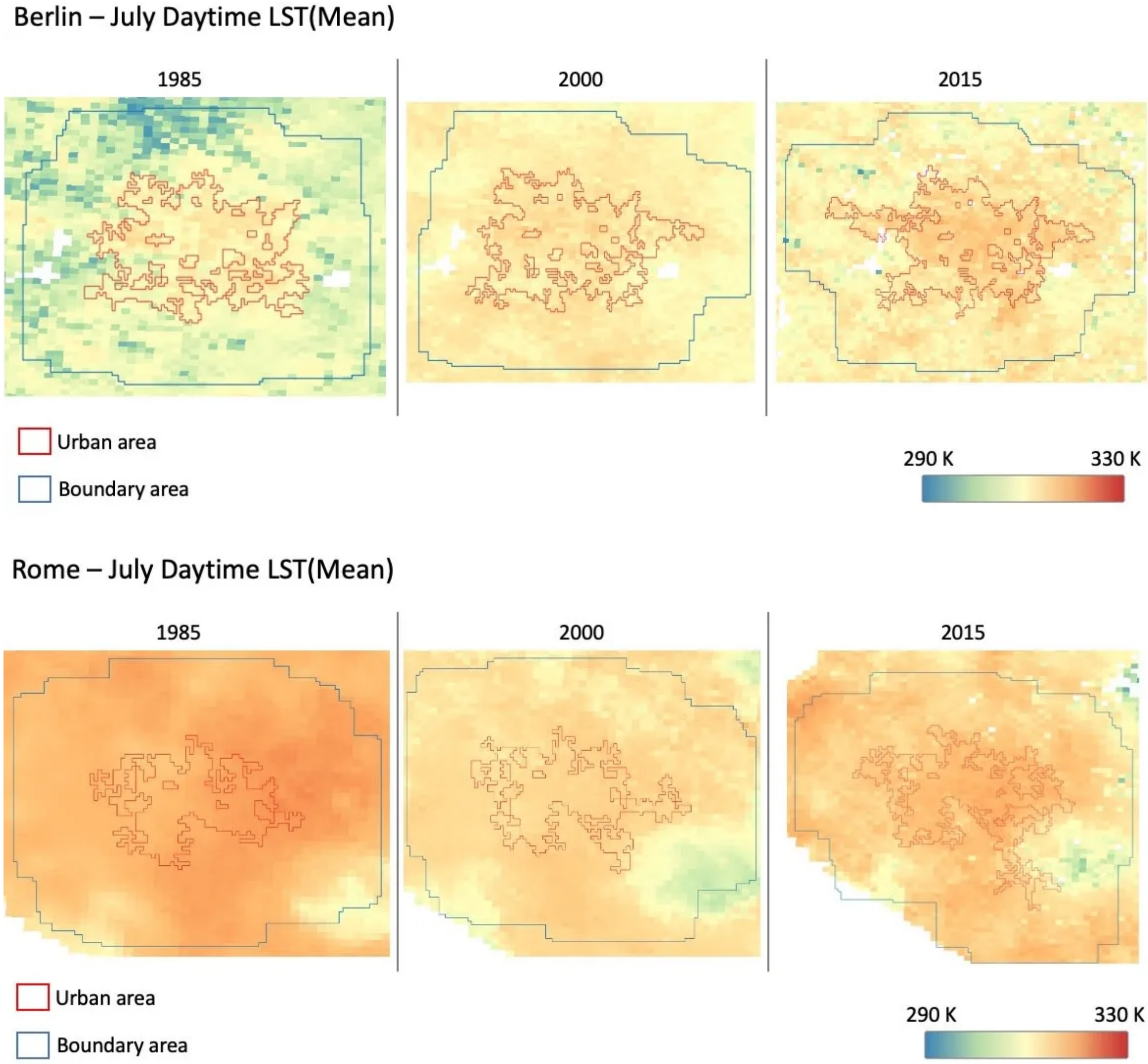


Fig 5 : Sample Cities and buffer area after applying TIMELINE LST

RESULTS

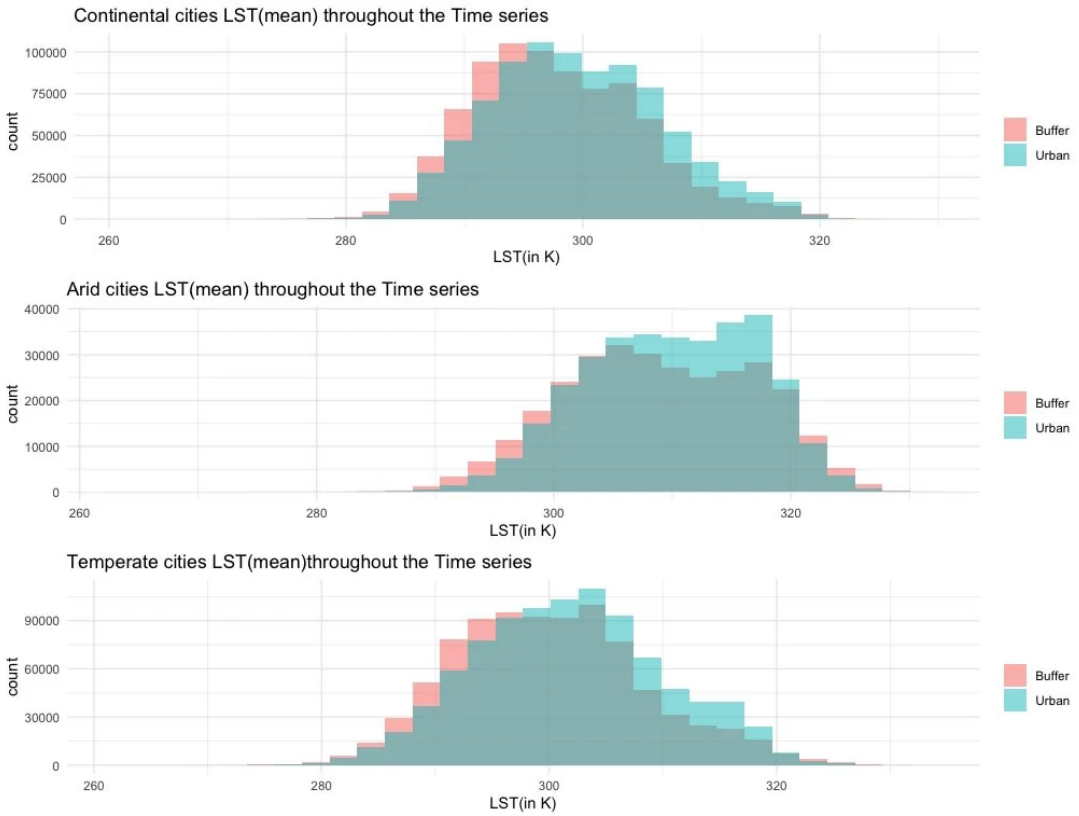
- Significant differences in Urban and buffer areas is observed
- 

Fig 6: Histogram showing Urban vs Buffer LST across the whole time series for Arid, Continental and Temperate cities

- SUHI shows an increasing trend. This is observed among all 3 main climate classes

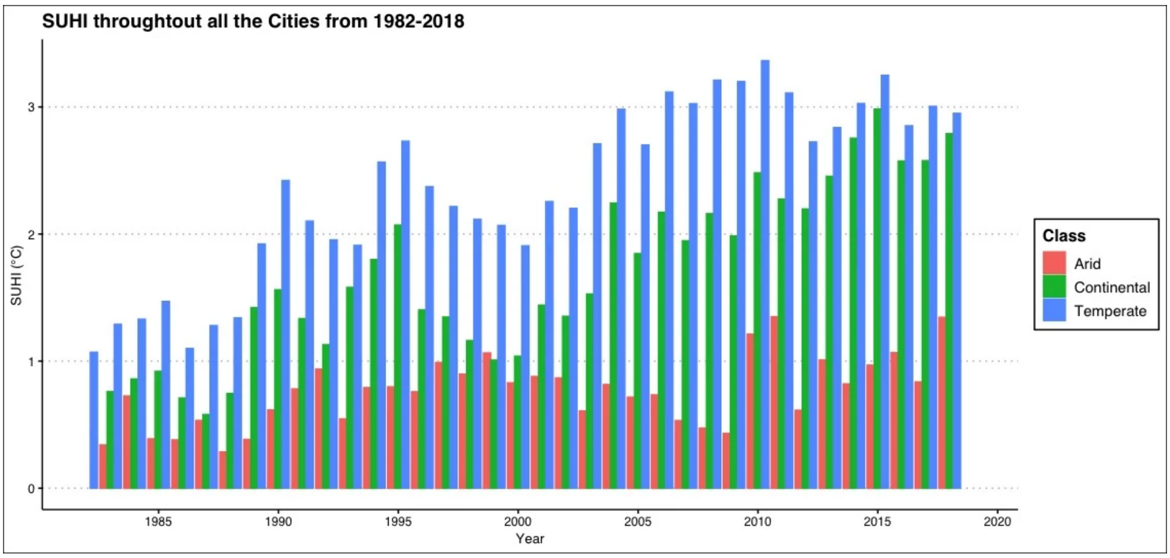


Fig 7 : SUHI trend throughtout the time series

- Temperate cities show the highest warming among the 3 main classes

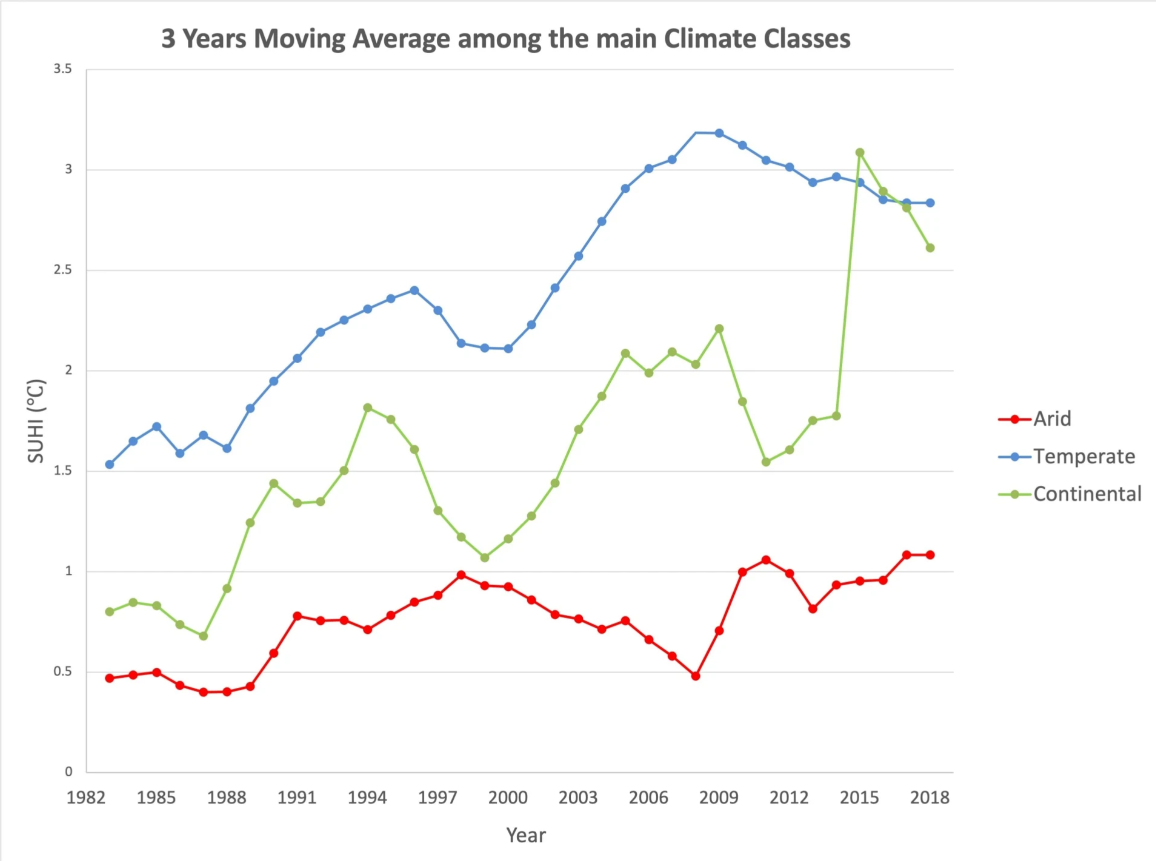


Fig 8 : 3 years moving average of SUHI among the main Climate classes

- Among the Sub-classes, Csc showed the higest warming.However, there are limited no.of cities in this category

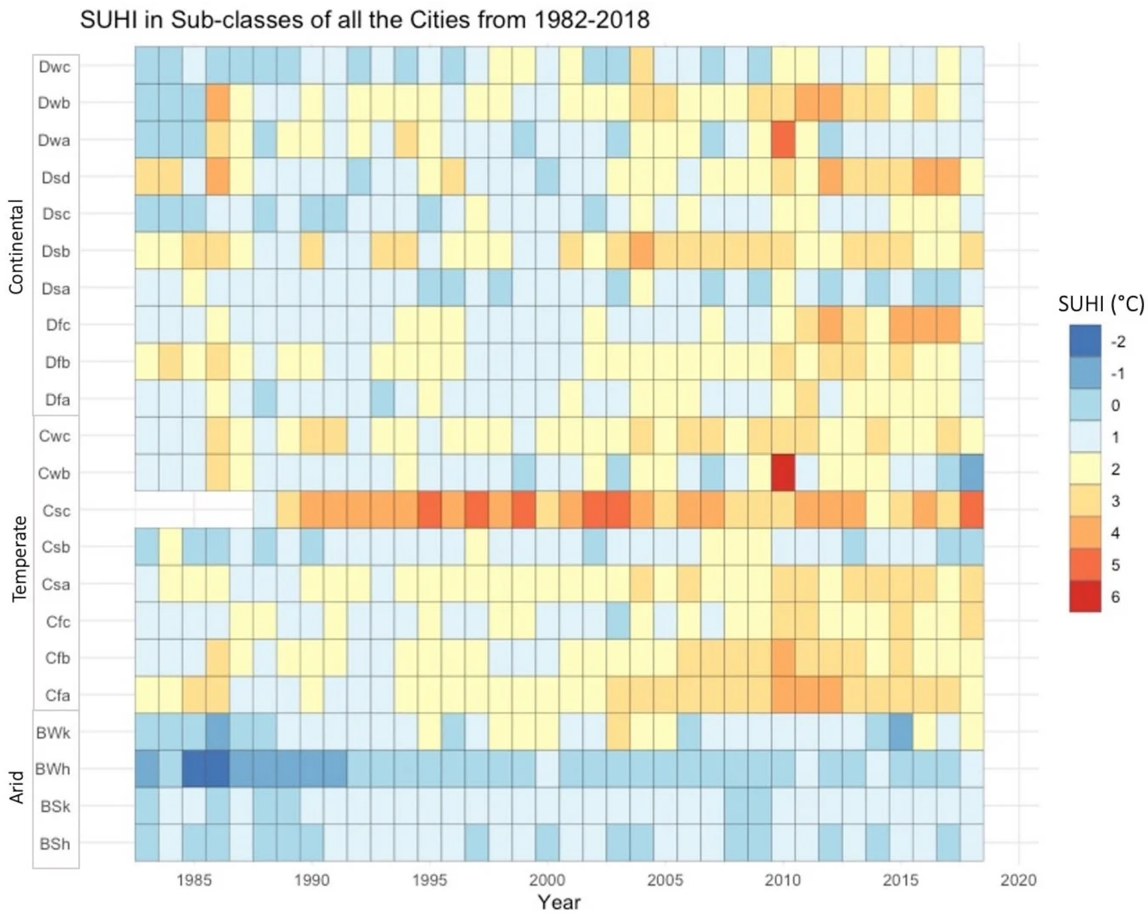


Fig 9 : Heatmap showing SUHI across sub-class throughout the time period

- Analysing a more representative sample of cities in a sub-class, Cfa subclass shows the strongest warming(2.38 ± 0.3 °C)

- Zooming into the City level

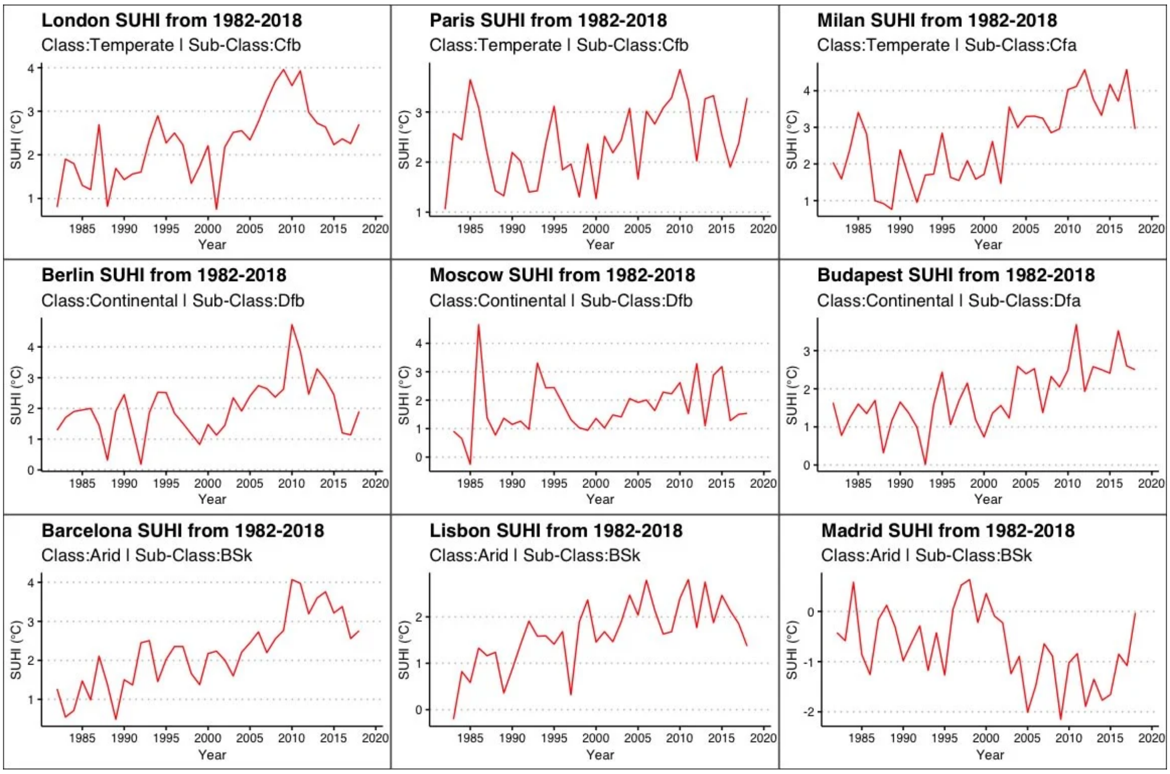


Fig 10: SUHI across some sample cities throughout the whole time period

KEY TAKEAWAYS

- Significant LST differences in Urban and rural are found
- There is an increasing warming trend throughout Europe from 1982 to 2018
- Intensity of SUHI has increased among all major climate classes of European cities
- Temperate cities have undergone the strongest warming
- Cfa climate subclass, which includes cities like Milan, Lyon, Zagreb , have witnessed the highest SUHI intensity over the time series

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