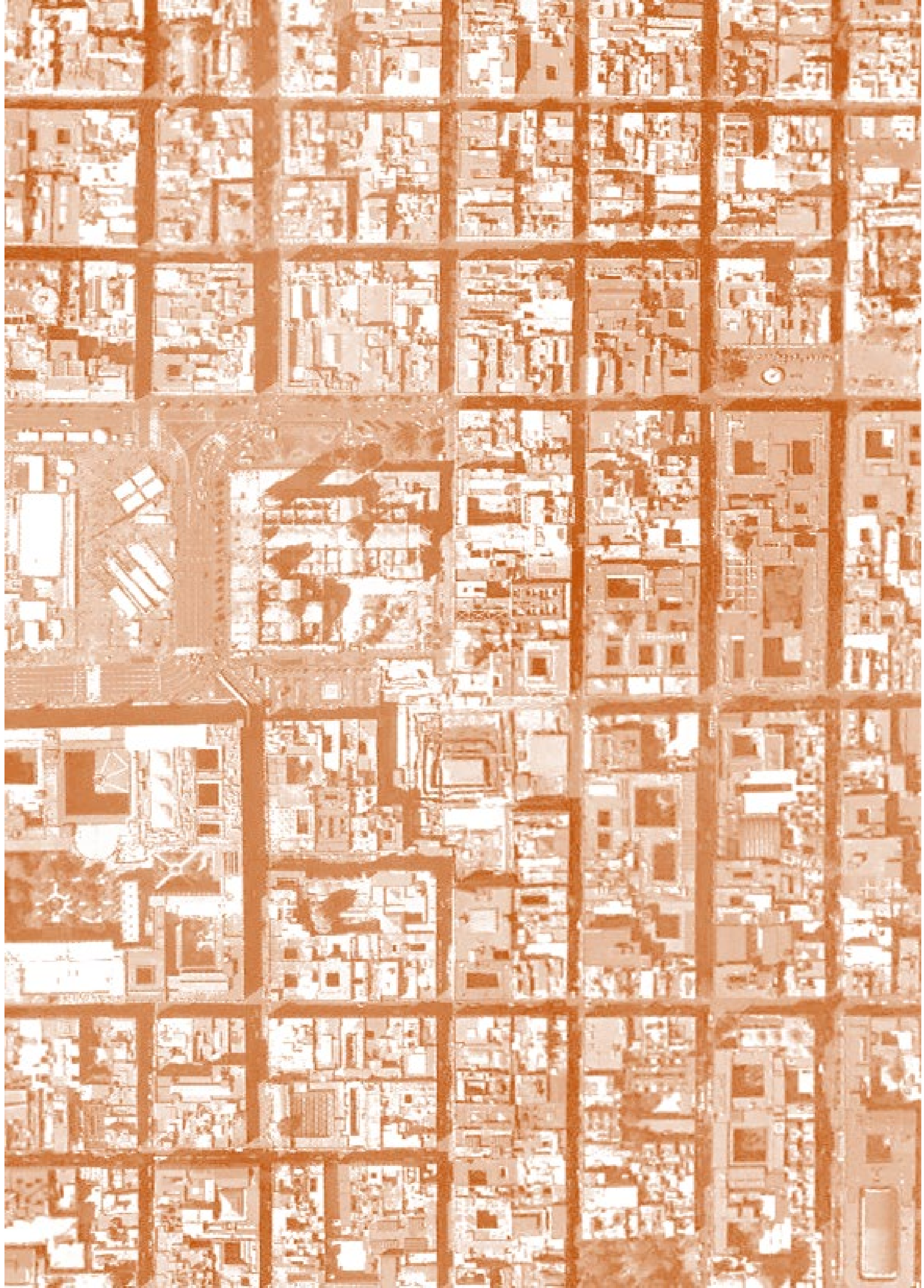
Remote Sensing for Urban Contexts: Addressing the UHI and Climate Impacts

Metropolitan Landscape Research Lab (MLRL)
Yaser Abunnasr & Mario Mhawej
May 2022

Contents



1 MLRL Background

About MLRL

MLRL is a research unit at AUB that addresses the need for a comprehensive approach that is **design, planning, and management** based to shape the future of cities, landscapes, and ecosystems in the face of global transformations.

- Established in **2018**, the MLRL addresses **challenges related to climate change and its impacts on cities, ecosystems and the metropolitan landscapes**.
- The lab applies remote sensing in an interactive manner to **incorporate ecological and regenerative approaches to urban planning to address urban climates, and consequently contribute to the Climate Change discussion**.

Mission

MLRL is committed to **empower communities with adaptive design and planning strategies for urban regions and ecosystems** to face the challenges posed by the effects of global transformations.

Urban Climate Change Objectives

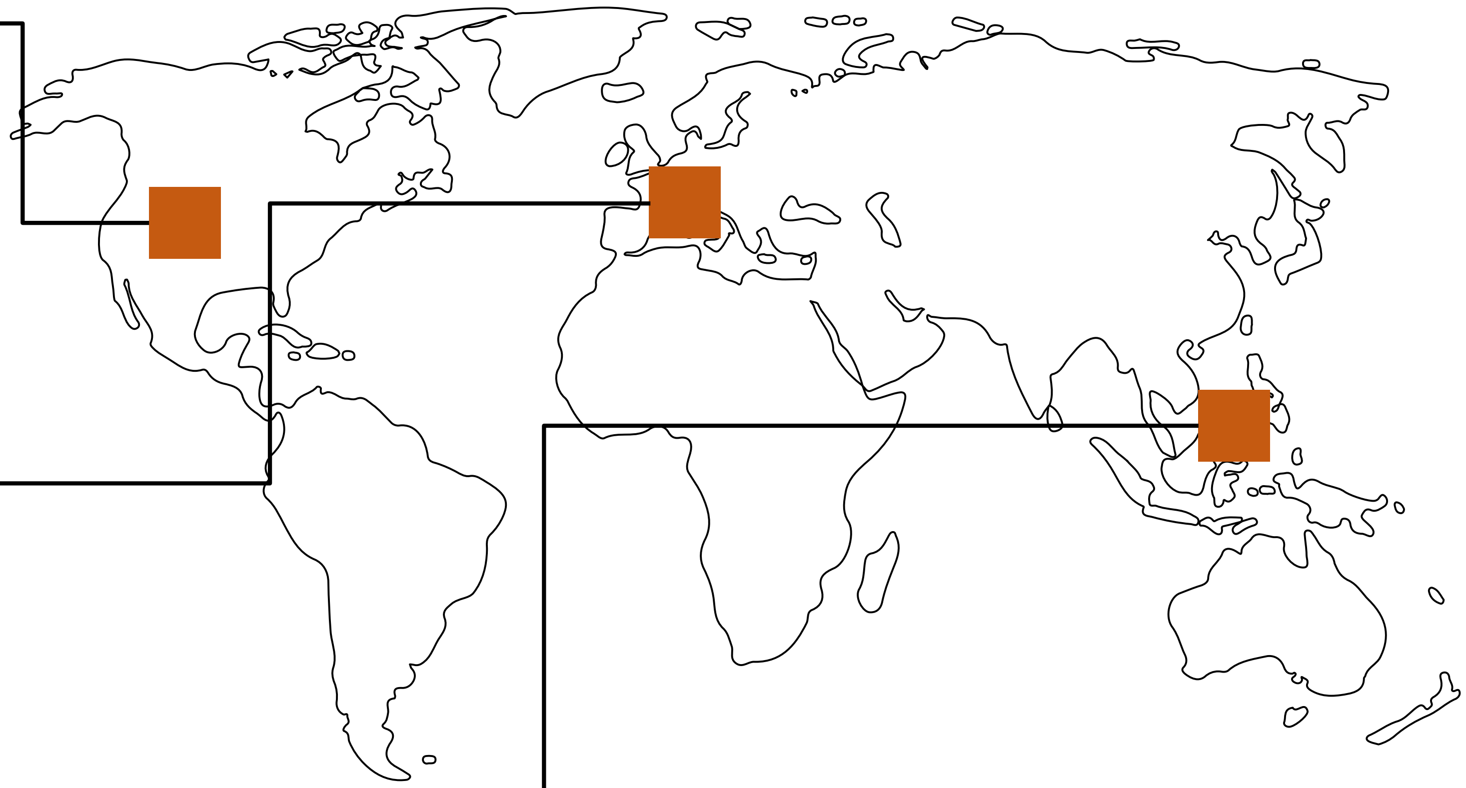
- Incorporate Remote Sensing (RS) in planning studies;
- Produce baselines for urban heating;
- Conduct easy comparable urban climate studies;
- Decision support system (DSS) tools to assist policy makers and planners designing cities of tomorrow;
- Combating climate change impacts.

Main Global Research Collaborations

- NASA, USA
- USDA, USA
- USGS, USA
- MIT, USA

- ETH Zürich
- FORTH, Greece
- CESBIO, France
- University of Perugia, Italy
- Technical University of Crete , Greece
- NINR, Norway
- University of Basel, Switzerland

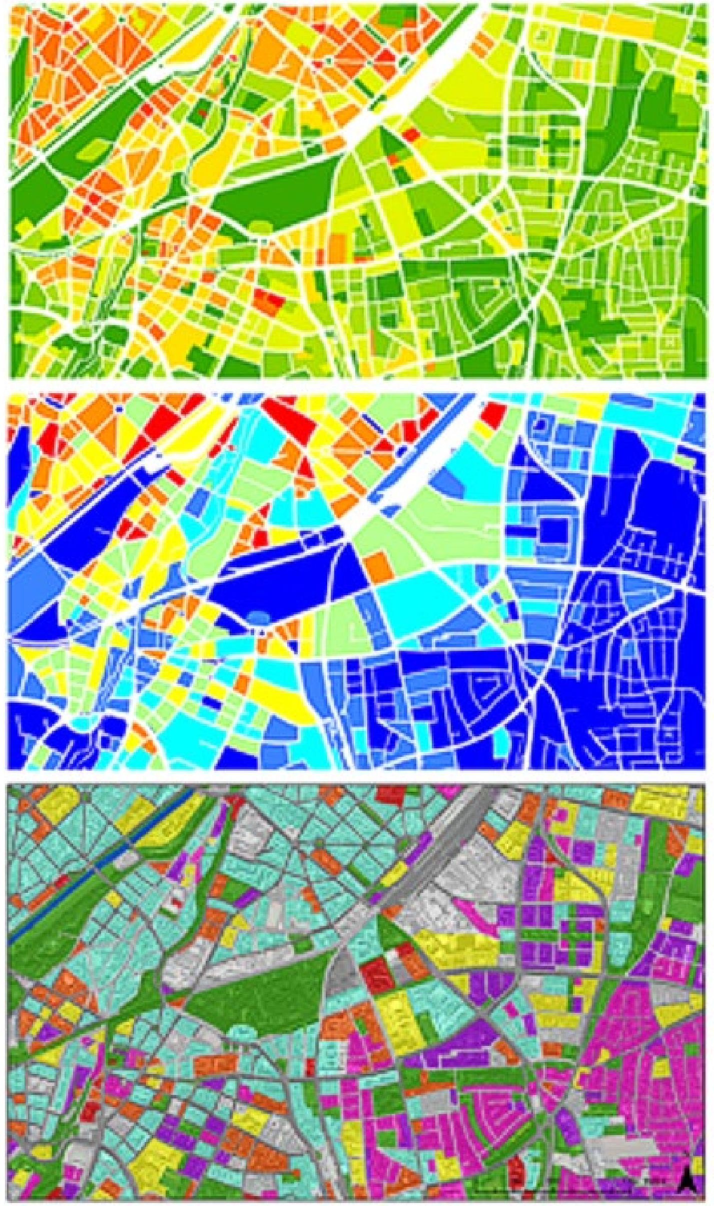
- CSIRO, Australia
- CAS, AIR, China



2 RS & Urban Planning

Cities: The Next Frontier for RS

- Driven by advances in technology and societal needs, **the next frontier in remote sensing is urban areas (IPCC, 2022)**.
- **Urban Remote Sensing** serves as a platform to provide **evidence-based theoretical and practical knowledge** that contributes to solving or better understanding the problems of urban issues and formulating relevant policies for sustainable urban systems.



Urban RS studies can include:

- Unmanned Aerial Vehicle data processing and analysis;
- Data mining and machine learning in urban applications;
- 3D and 4D urban modeling from satellite, airborne, and terrestrial sensors;
- Space-time analysis of urban environmental parameters.

Why studying cities is critical?

Population Increase

Today, 55% of the world's population lives in urban areas

→ **68% by 2050**

Climate Change

Cities are a key contributor to climate change

→ **75% of global CO_2 emissions**

Lack of plans

Many cities lack mitigation and/or adaptation plans

→ **70% dealing with effects of climate change**

Cities are the cause & the solution

the cause

- Increasing population
- Increasing temperatures
- Increasing pollution
- Increasing boundaries and taking over natural and agricultural areas

the solution

- Push for renewable energy
- NBS and EBA
- Sustainable water management
- Better science-backed planning and design for future cities

The small window is closing fast!

Why Remote Sensing is Good for Cities?

Wealth of Information

on land features, land use, built up areas, city structure, physical aspects of environment etc.

Cost and Time Effectiveness

covering very large areas, even the inaccessible one, in a much-reduced resources and efforts

Consistency and Rapidity

Human errors are eliminated, and the generated outputs require less time for further processing

Gaps in Urban Remote Sensing Studies

Limited Integration
between urban planning, remote sensing and ecology

→ **only 12% of the studies**

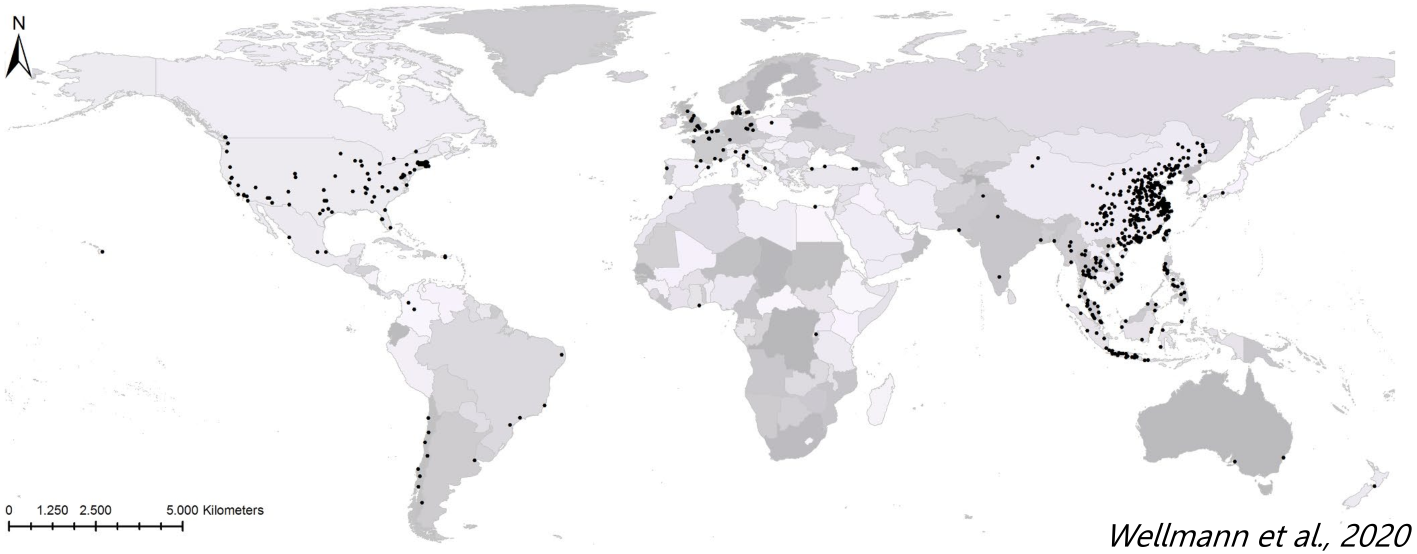
Limited Accessibility

as proprietary software and data are frequently used

→ **only 14% are open access**

Limited Knowledge
as only few are making specific design suggestions

→ **only 10% of the studies**



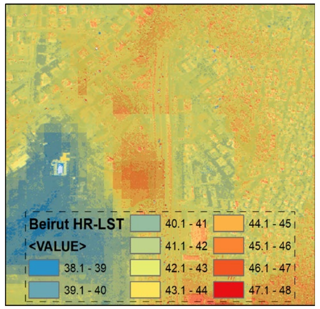
Wellmann et al., 2020

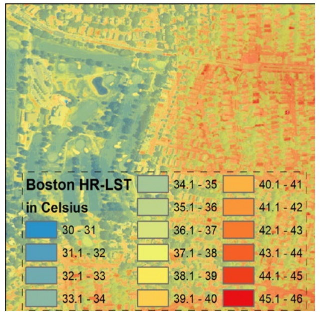
MLRL Main Urban RS axes – Answering the current gaps

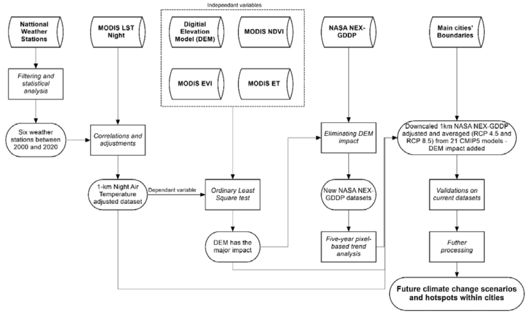
Urban Climate and Urban Morphology

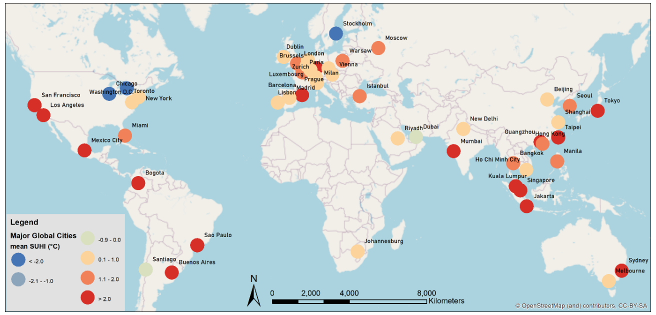
Downscaling and Planning for CC

Energy Exchange and NBS









MLRL Main Urban RS axes – Answering the current gaps

Urban Climate and Urban Morphology

1. A fully automated 1-km/30-m GEE LST OLS Model is proposed over multiple cities: SUHI-GEE
2. Heat Performance Assessment of Vegetation Configuration in Low-density Residential Developments to Mitigate Urban Heat Islands in Dryland Cities
3. Urban Heat Island Behaviors in Dryland Regions
4. Pervious Area Change as Surrogate to Diverse Climatic Variables Trends in the CONUS: A County-scale Assessment
5. Mitigating Urban Heating in Dryland Cities: A Literature Review

Downscaling and Planning for CC

1. A Google Earth Engine 10-m Land Surface Temperature was proposed: True-ST-GEE
2. A dynamic approach to retrieve HSR Land Surface Temperature is introduced: HSR-LST
3. Windows of Opportunity: Addressing Climate Uncertainty through Adaptation Plan Implementation
4. Planning for climate change: A reader in Green Infrastructure and Sustainable Design for Resilient Cities

Energy Exchange and NBS

1. A dynamic fully automated GEE urban Surface Energy Balance Model is proposed: SEBU
2. Assessing Deeper Levels of Participation in Nature-based Solutions in Urban Landscapes – A Literature Review of Real-world Cases
3. The Green Infrastructure Transect
4. Pathways to Coastal Resiliency: The Adaptive Gradients Framework
5. A Rapid Assessment Method of Green Infrastructure Space Opportunities: An Application to The Boston Metropolitan Area

3 Current Research Studies

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Approach

Pervious Area Change as Surrogate to diverse Climatic Variables Trends in the CONUS: A County-scale Assessment

Contents lists available at ScienceDirect

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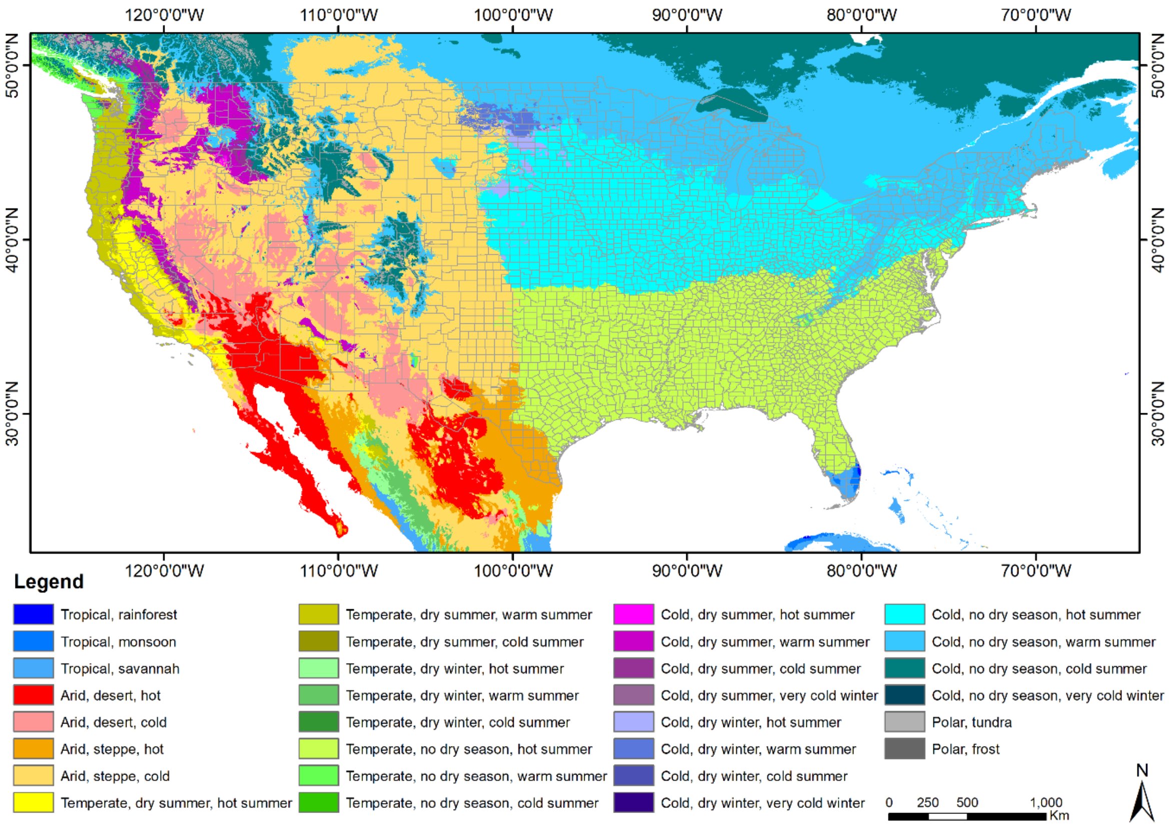
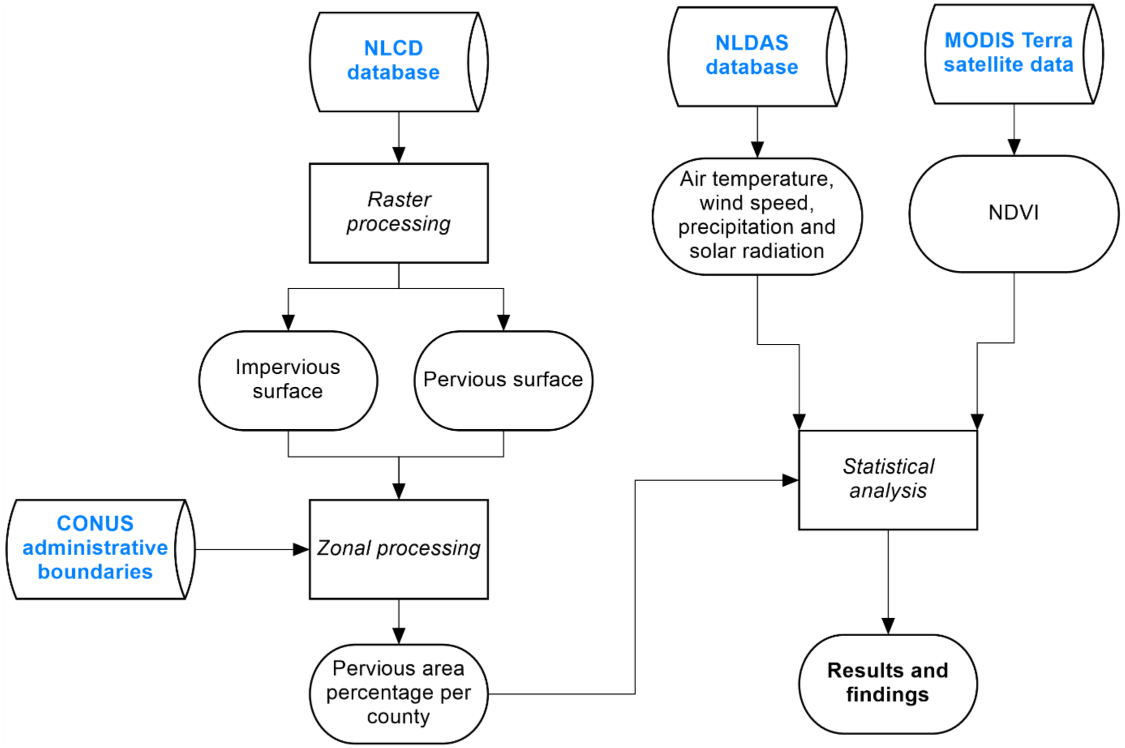
journal homepage: www.elsevier.com/locate/uclim

Pervious area change as surrogate to diverse climatic variables trends in the CONUS: A county-scale assessment

Yaser Abunnasr [a], Mario Mhawej [a,b,*]

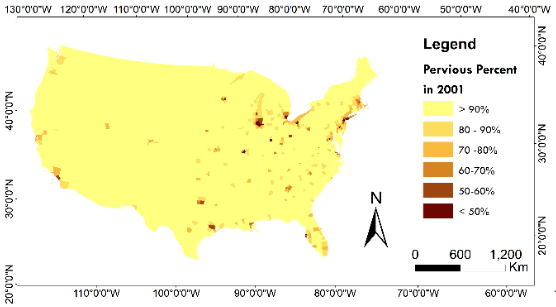


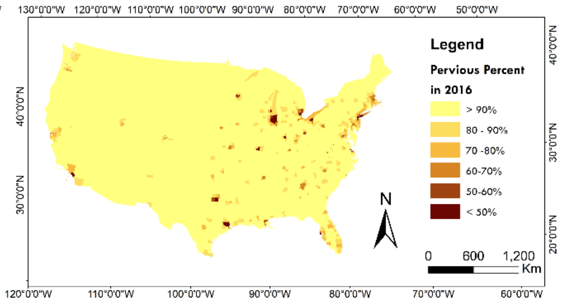


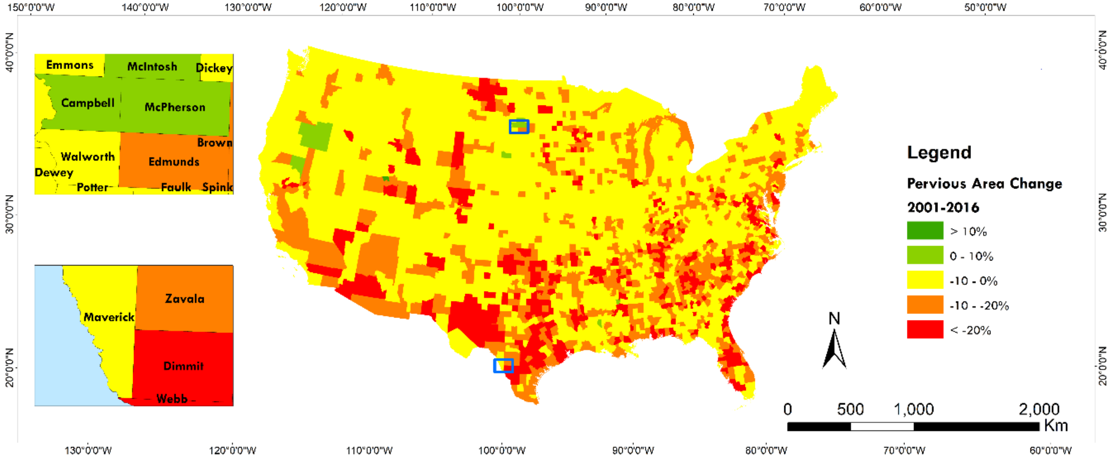
From the **Urban Climate and Urban Morphology** ax

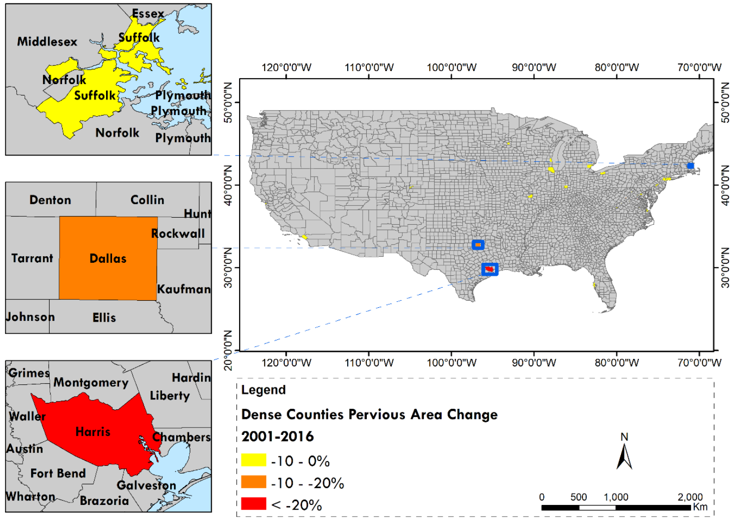
Outputs

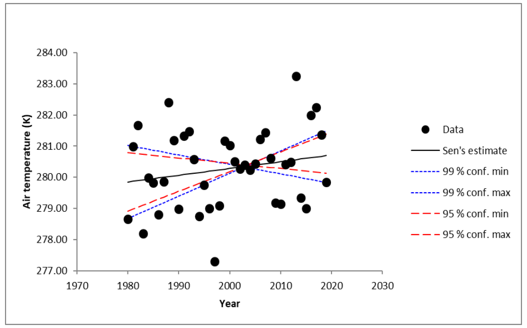
Pervious Area Change as Surrogate to diverse Climatic Variables Trends in the CONUS: A County-scale Assessment

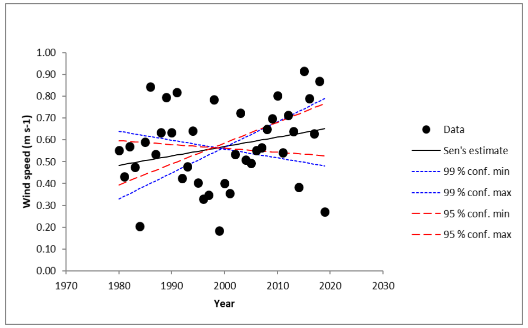


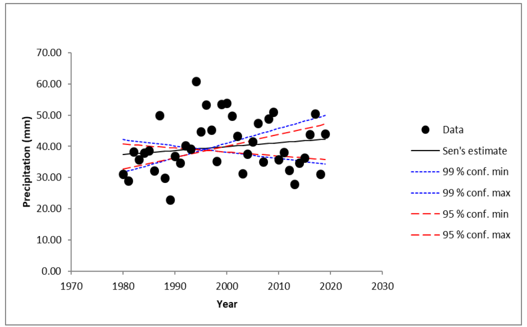


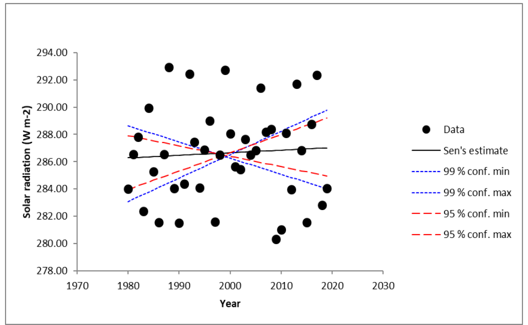












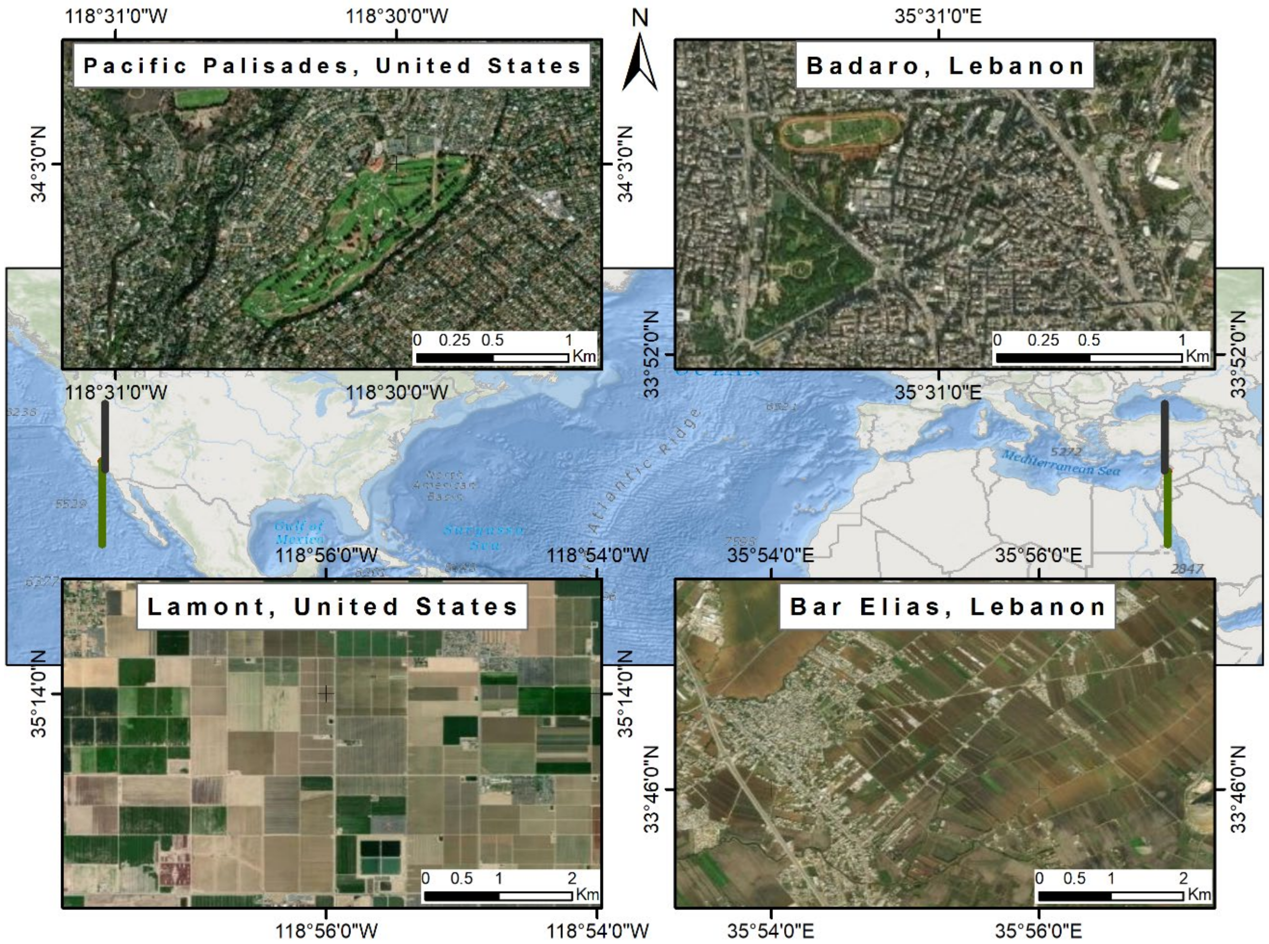
Main Findings

Pervious Area Change as Surrogate to diverse Climatic Variables Trends in the CONUS: A County-scale Assessment

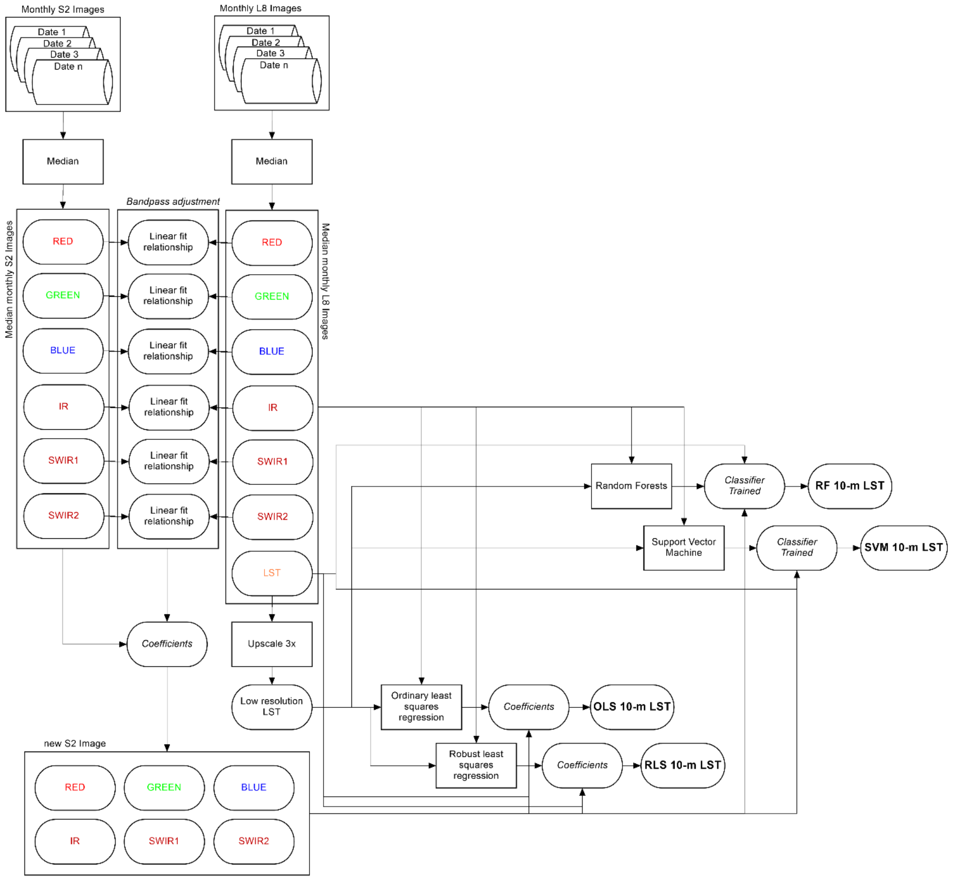
- The significant increase at α=0.95 in **air temperatures between 1980 and 2019 is alarming**;
- The other considered factors (e.g. precipitation, wind speed and solar incoming radiation) appear to show no effect on the pervious area percentage change and nor on the air temperatures' trends;
- **No direct relation between LST and NDVI;**
- **Climate's type is the most dominant factor.**

Approach

Combined Landsat-8 and Sentinel-2 for 10-m Land Surface Temperature Products: the Ten-ST-GEE System



Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors



From the **Downscaling and planning for CC** axe

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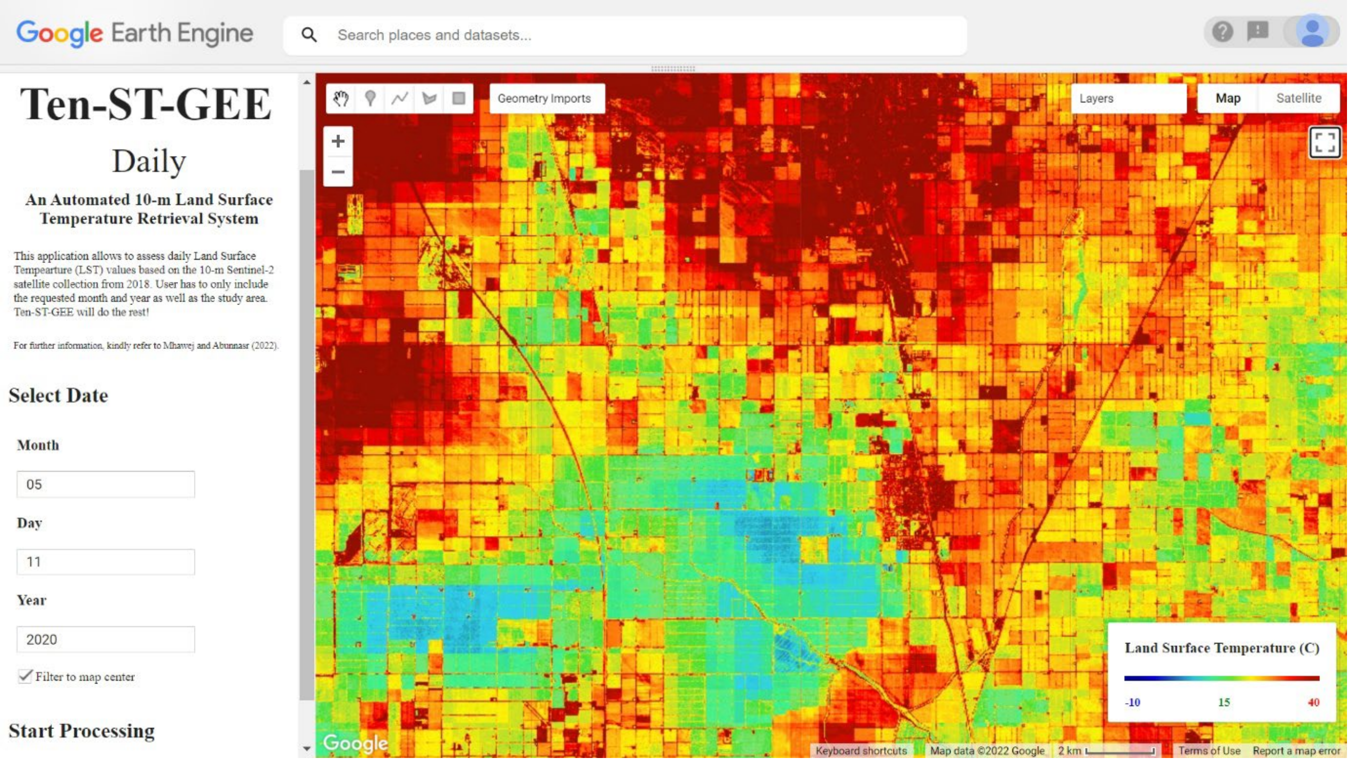

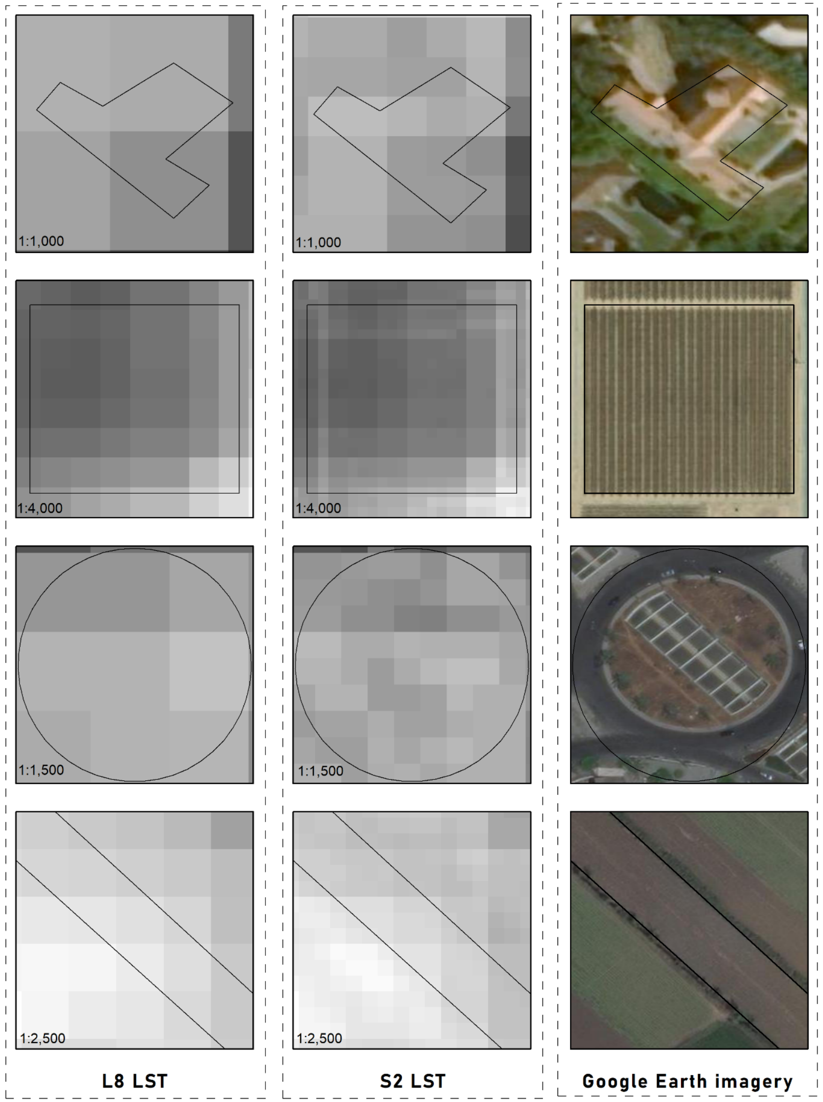

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics,

Main Findings

Combined Landsat-8 and Sentinel-2 for 10-m Land Surface Temperature Products: the Ten-ST-GEE System

- **Ten-ST-GEE** is a user-friendly, much-needed, **open-access 10-m LST** retrieval system;
- OLS and RLS showed an **RMSE of ~1.1°C** compared to ~2.4°C for DisTrad and ~2.5°C for RF and SVM in three different climatic regions and four different locations;
- The Ten-ST-GEE system is freely available from the authors for research and educational purposes at https://bit.ly/3n6koz9.

Approach

SEBU: A novel fully automated Google Earth Engine Surface Energy Balance Model for Urban areas

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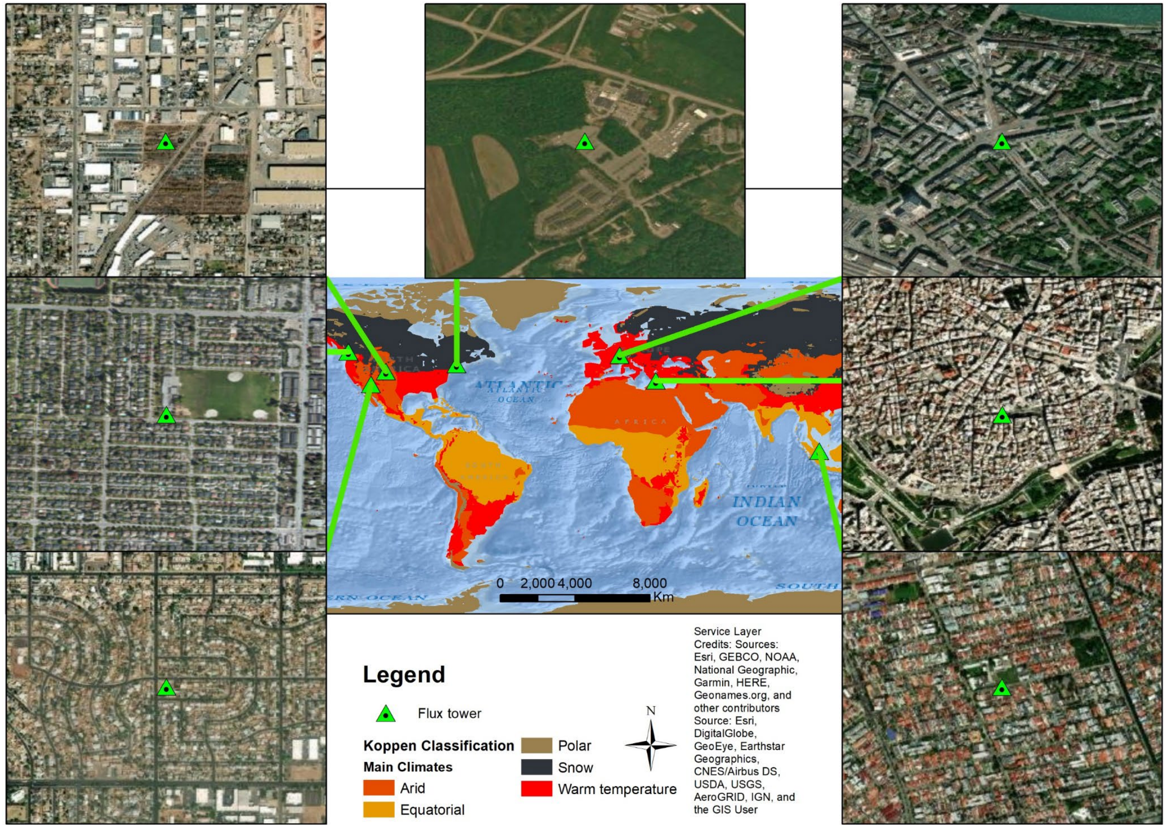
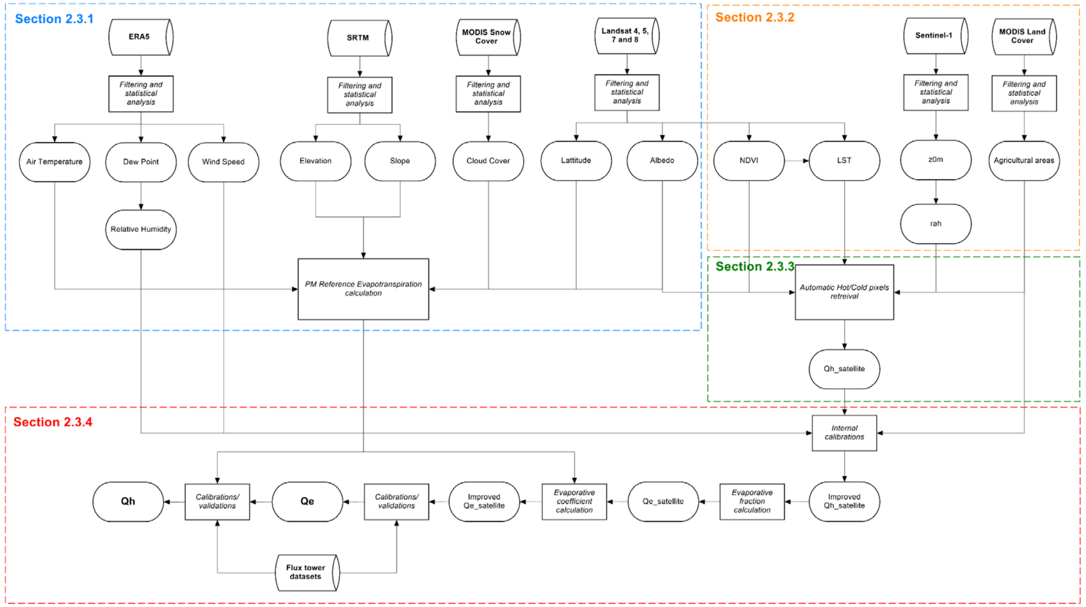
SEBU: A novel fully automated Google Earth Engine surface energy balance model for urban areas

Yaser Abunnasr [a], Mario Mhawej [a,*], Nektarios Chrysoulakis [b]

[a] Department of Landscape Design and Ecosystem Management, Faculty of Agricultural and Food Sciences, American University of Beirut, Bliss St., Beirut 2020-1100, Lebanon

[b] Foundation for Research and Technology - Hellas, Institute of Applied and Computational Mathematics, rslab.gr, Greece





From the **Energy Exchange and NBS** axe

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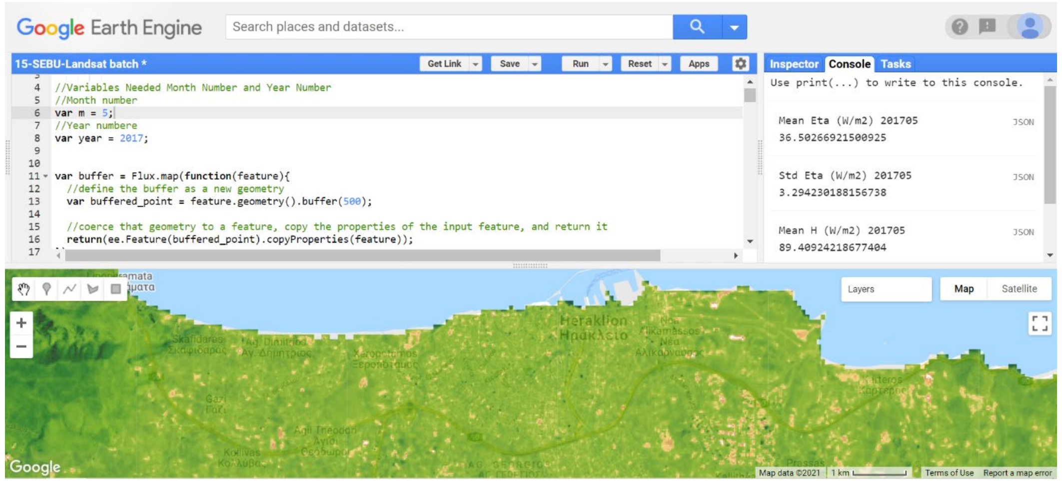
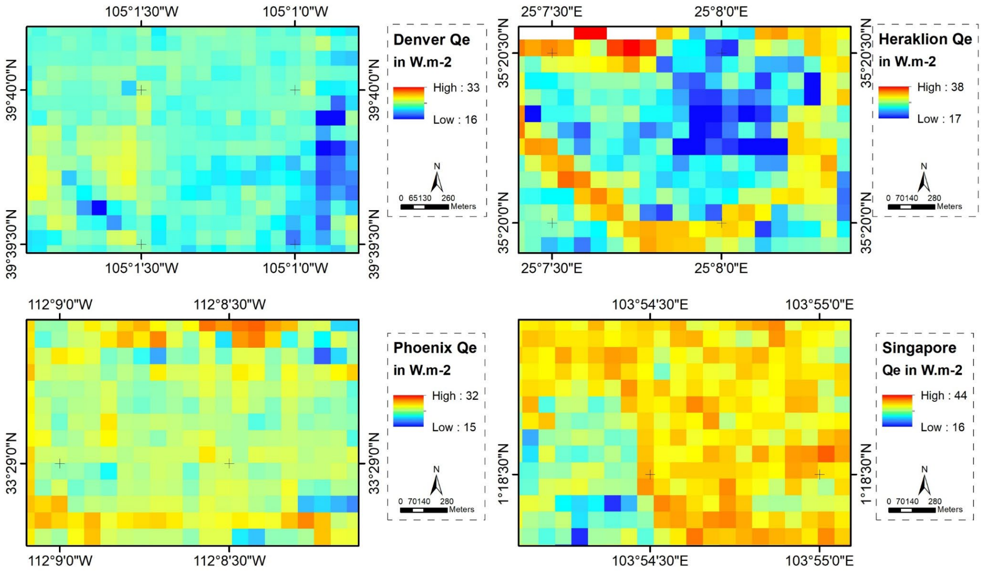
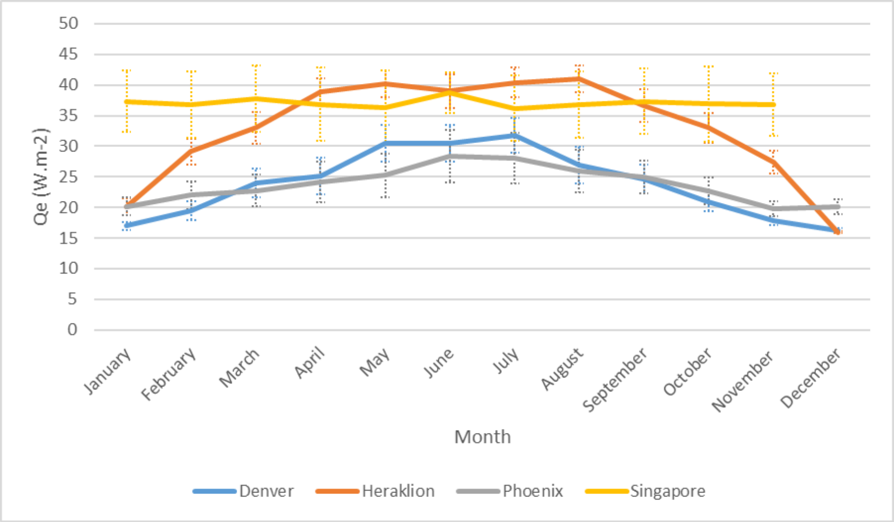






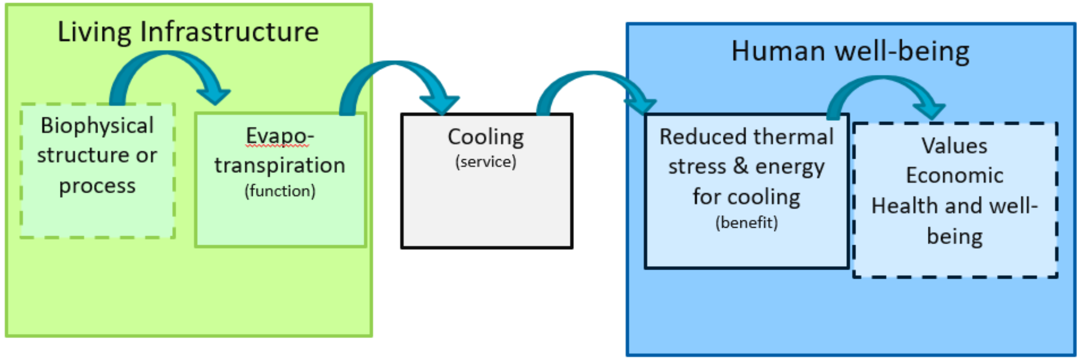
Main Findings

SEBU: A novel fully automated Google Earth Engine Surface Energy Balance Model for Urban areas

- SEBU is proposed, benefitting from both the remote sensing satellite images and the GEE platform and providing **100-m monthly Qe and Qh images in different climates across the globe;**
- It was validated in seven locations with different climates according to Koppen classification. **Qe and Qh accuracies were very promising;**
- The monthly change of values is characteristic for each city;
- **Singapore seemed unique**, similar to other tropical cities, with somehow steady Qe and Qh values across the year.

Approach

Estimating the cooling benefits of living infrastructure



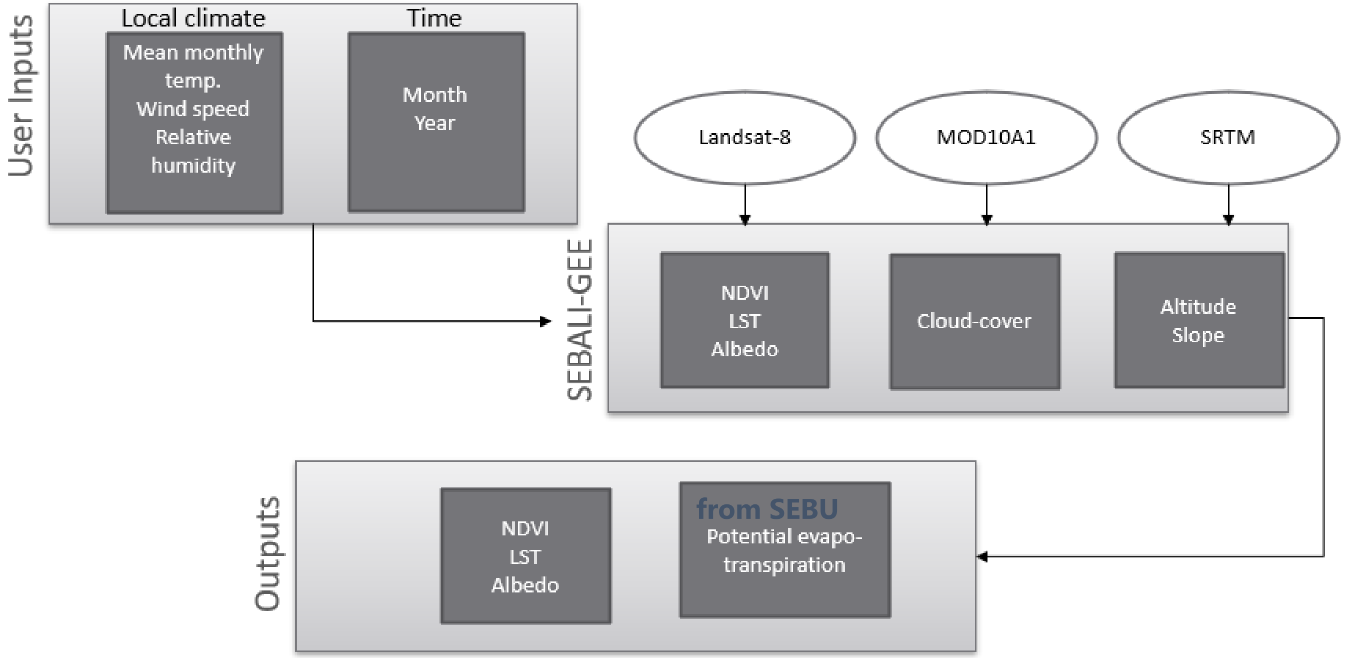
Australia's National Science Agency

Estimating the cooling benefits of living infrastructure

Ecosystem Services Assessment Tool addition

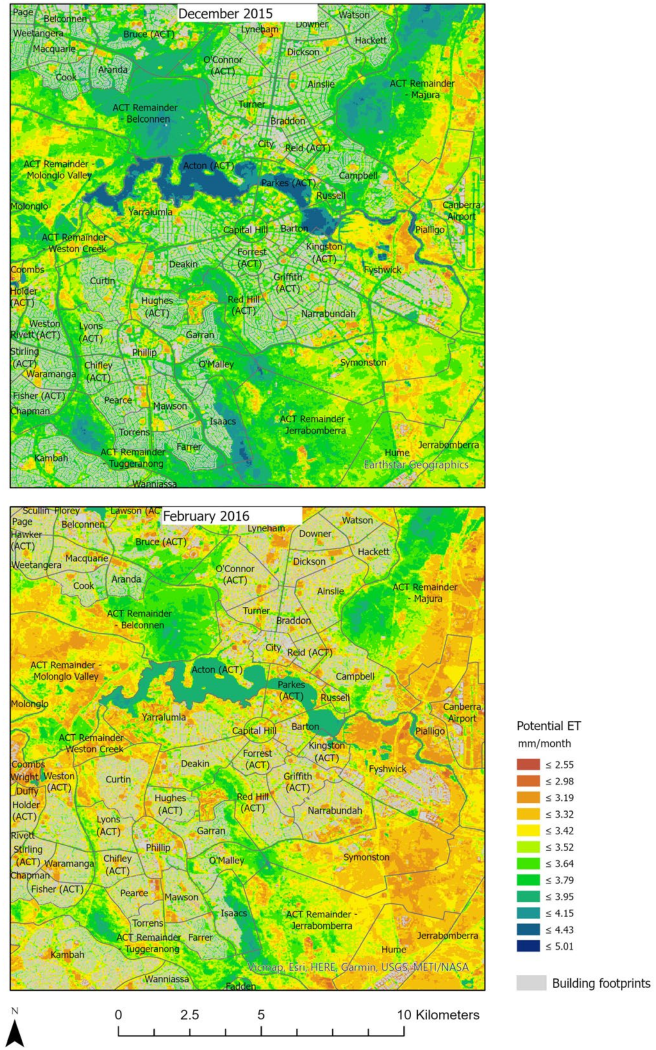
Stephen Cook, Natthanij Soonsawad, Raymundo-Marcos Martinez, and Sorada Tapsuwan

June 2021



Outputs

Estimating the cooling benefits of living infrastructure



CSIRO
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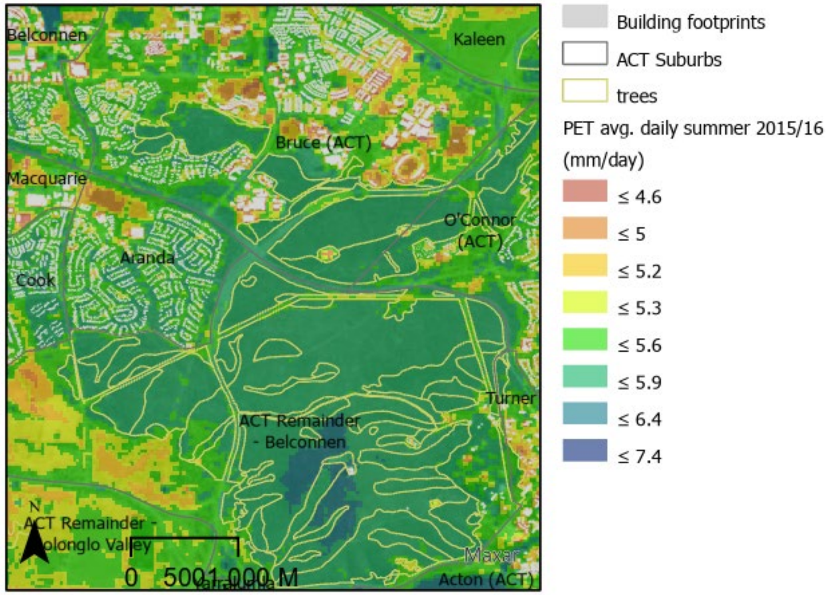

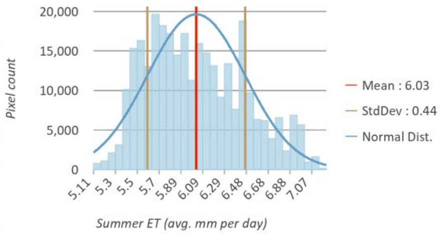

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June 2021

LIVING INFRASTRUCTURE TYPES	EVAPOTRANSPIRATION RATE -SUMMER (DEC - FEB) (mm/day per m^2)	LATENT HEAT FLUX ($kWH/m^2/day$)	TREE CANOPY EQUIVALENCE	CONFIDENCE
Trees & tall shrubs	6	4.09	1.00	HIGH
Shrubs	5.6	3.82	0.93	MODERATE
Grass, groundcover & herbaceous plants	5.1	3.48	0.85	MODERATE
Intensive green roof	5.6	3.82	0.93	LOW
Extensive green roof	5.1	3.48	0.85	MODERATE
Living wall	5	3.41	0.83	LOW
Constructed wetlands (<10 years)	5.5	3.75	0.92	MODERATE
Constructed wetlands (>10 years)	5.5	3.75	1.02	MODERATE
Constructed ponds (<10 years)	6.1	4.16	1.02	MODERATE
Constructed ponds (>10 years)	6.1	4.16	1.00	MODERATE
Bioretention basins	5.1	3.48	0.93	MODERATE

4 Concluding Remarks

Concluding Remarks

- Urban remote sensing is a **relatively new science,** especially for urban contexts. Much is still needed to answer threatening climate change impacts on cities.
- Developing **data that is downscaled and/or at finer resolutions** is necessary for urban planners to incorporate RS as a tool for inventory and analysis.
- There is still much to understand on applications of remote sensing in cities such as incorporating the **3-dimensional nature of cities** and their contribution to urban climate.
- RS for urban contexts allows the possibility to provide data and information that is **open-source, free-to-access and readily-available datasets** pivotal for city planning and management.
- Through RS, MLRL continue to develop approaches to **connect planners, environmentalists and modelers with decision- and policy- makers** to ensure that RS data is put to good use in combating urban climates and climate change.

Metropolitan Landscape Research Lab (MLRL)

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