Provisioning of urban ecosystem services and the benefit distribution under climate change

Case study of Prague

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Aims:

Explore the relationship among urban ecosystem services, their distribution and climate change in space and time, and thus, support equity and equality in ES benefitiaries.

→ To analyse the distribution of ES supply and demand in Prague.

→ To identify the areas with population vulnerable to risks of climate.

→ To identify the areas threatened by current and future risks of climate change.

→ To evaluate the areas with unequal distribution of ES benefits and areas with the need of ES benefits.

Research questions:

→ Are ES benefits supplied equally in all Prague areas?

→ What ES are the most demanded in which areas?

→ What areas include the most vulnerable population?

→ What areas are in need of ES benefits?

Motivation behind the project

Increasing number of population in urban areas, urbanization, land competition and increasing magnitude and frequency of climate change impacts

→An urgent need to maintain and increase urban ecosystem services in urban areas

Combination of mapping and modelling ES with a vulnerability analysis

→ bringing new perspectives and evidence on a problem of ecosystem services-urbanization-climate change.

Identification of spatial mismatches between ecosystem service (ES) supply and societal demand

→ informing and guiding governance, and policy- and decision-makers in the sustainable management of areas important for the provision of ecosystem services and urban planning

Literature review

Methods for mapping, modelling and assessment of supply-demand urban ecosystem services

Systematic approach

Search engines: Scopus and Web of Science

Keywords: ecosystem service* and mismatch* in tiitle, abstract, keywords; English; articles; all years

→ 167 returns after removing duplicates

→ 58 articles after title-abstract screening→18 articles for full screening

→ 10 articles passed to review through inclusion/exclusion criteria

Database creation

→ data for selected articles entered into the database (example of data entry in Table 1)

→ data entry in database served as a basis for comparison of frameworks and methods

Table 1: **Examples of database entries**

authors	year of publication	journal	type of study	location	country	framework	ES	reason for ES selection	LULC types	resolution of LULC	model/ analysis	supply	supply indicators	demand	demand indicators	EQS	mismatches	participation	year of data	note
Ortiz and Geneletti	2018	Sustainability	urban	Havana (two municipalities)	Cuba	Conceptual diagram; assessing unsustainable flow and unsatisfied demand; 1. the identification of services providing and demanding areas, 2. the quantification of mismatches by a spatial comparison between critical capacity and flow, and demand and flow.	recreation, food supply	Recreation frequently considered in planning processes, urban agriculture plays important in provision of service while representing a source of income for population of cities in low income countries.	woodland and trees, shrubland, grassland, bare soil, river, resiential areas, road network	1:1000 urban block resolution	GIS modelling, network analysis	service providing areas are considered sources of ES, including only public green spaces larger than 0.5 ha and having at least two of the features or facilities; es flow quantified as a number of inhabitants living within the distance of 400-3200 m	recreation - minimum area of green space; food - mean crop yield of vegetables and fruits in 2016 and mean annual crop yield	recreation - based on the quality standard for which everyone should be able to reach at least one recreational area within maxium distances, reliance coeficient	recreation - distance to recreational area food - minimum intake of fruits and vegetbles and the reliance coefficiet	recreation - inverse minimum value of green spaces per capita (cuban rule); food - 45% reliance coefficient	Unsustainable mismatch = converting number of inhabitants in benefiting residential areas to m2/inhabitantant, comparin value to the critical capacity; unsatisfied demand = % of people who travel over max. distance to recreational sites; % of people and for whom the production does not meet at least 45%.	no	2016	accounting for boundry effect
Chen et al.	2019	Science of the Total Environment	urban	Shanghai	China	comprehensive framework comprising of 4 steps for qunantifying ES S and S changes associated with land use changes on the basis of environmental quality standards and policy goals. Developed based on Baro et al (2015) but advanced by quantifying the mismatches between ES S and D associated with land use changes for optimal land management. 1. urbanisation related LULC (land composision, configuration and spatial transition) 2. selection of appropriate indicators reflecting stakeholder concerns and appropriate EQS and policy goals based on policy documents to assess coocurrence of ES S and D under alternative land use situations using spatially explicit models 3. assessment of ES mismatches and shortfalls on the basis of spatial visual results 4. inform future land management options	carbon sequestration, water retention, particulate (PM10) removal, recreation	ES classification framework (MEA and CICES), stakeholder concerns - ES reflect the particular interests and concerns of government and local residents, supply-demand connection - ES can reflect the coupling mechanism between suppliers and benefitiaries, good data availability	lake, reservoir, grassland, garden plot, coastal wetland, aquaculture, woodland, river, constructed land, arable land	100 m	GIS; balance thresholds od ES S and D derived by regression analysis between ES and LULC types	PM10 removal service is conditional - if absorption capacity of vegetation exceeds PM10 concentration, the PM10 removal service is equal to PM10 concentration -if PM10 absorption capacity by vegtegtation is smaller than PM concentration, the PM removal service supply = PM absorption capacity	Water retention - runoff air quality - absorption capacity climate regulation - carbon sequestration (absorbed carbon capacity recreation - average fraction of urban green space	PM removal demand is conditional: calculated as each subdistrict and the permitted PM concentration set by the local government target. The demand is the disperacy between the actual concentration and the permitted concentration if the actual concentration exceeds the permitter PM concenration. Otherwise the demand = 0. carbon sequestration = the difference between actual emissions and permitted CO2 emissions set by local government	water retention - water demand air quality - concentration PM10 climate regulation - emissions carbon recreation - population density (and the local guidance on green space per capita	considered in demand	same as above	yes - stakehodlers and residents needs included in the choise of Ess	2000-2014	
Parsa et al.	2019	PlosONE	urban	Tabriz	Iran	a methodological approach based on indicators 1. assessing the supply 2. selecting environmental quality standards 3. assessing demand 4. identifying mismatches	air quality, global climate regulation		trees, shrubs	city scale	iTree Eco model	supply = ES flows or biophysical impact of the ES on the environment in or surrounding the area	air quality - aanually removed pollutants (PM2.5, O3, NO2, SO2, CO) climate regulation - annual carbon sequestration	the required or desired amount of ES delivered by the society, EQS used as an indicator for demand	air quality - concentration in reference to values selected standards climate regulation - annual GHG emissions (downscaled global CO2 emissions to Tabriz based on the number of inhabitants.	the environmental quality standards (EQS) as an amenable indicator 4 air quality standards and GHG reguction targets (Iranian reguction target GHG, WHO air quality guidelines, EU air quality directive, National ambient aur quality standards for the EPA of the US and the Iran air quality standard)	difference between S and D, if demand is met without any decrease in the future capacity of regulating provision, it is sustainable; otherwise it is unsustainable (also if it involves losing or degrading other ES - traddeoffs)	no	2015	not spatial distribution - whole city assessment

Brief scientometrics

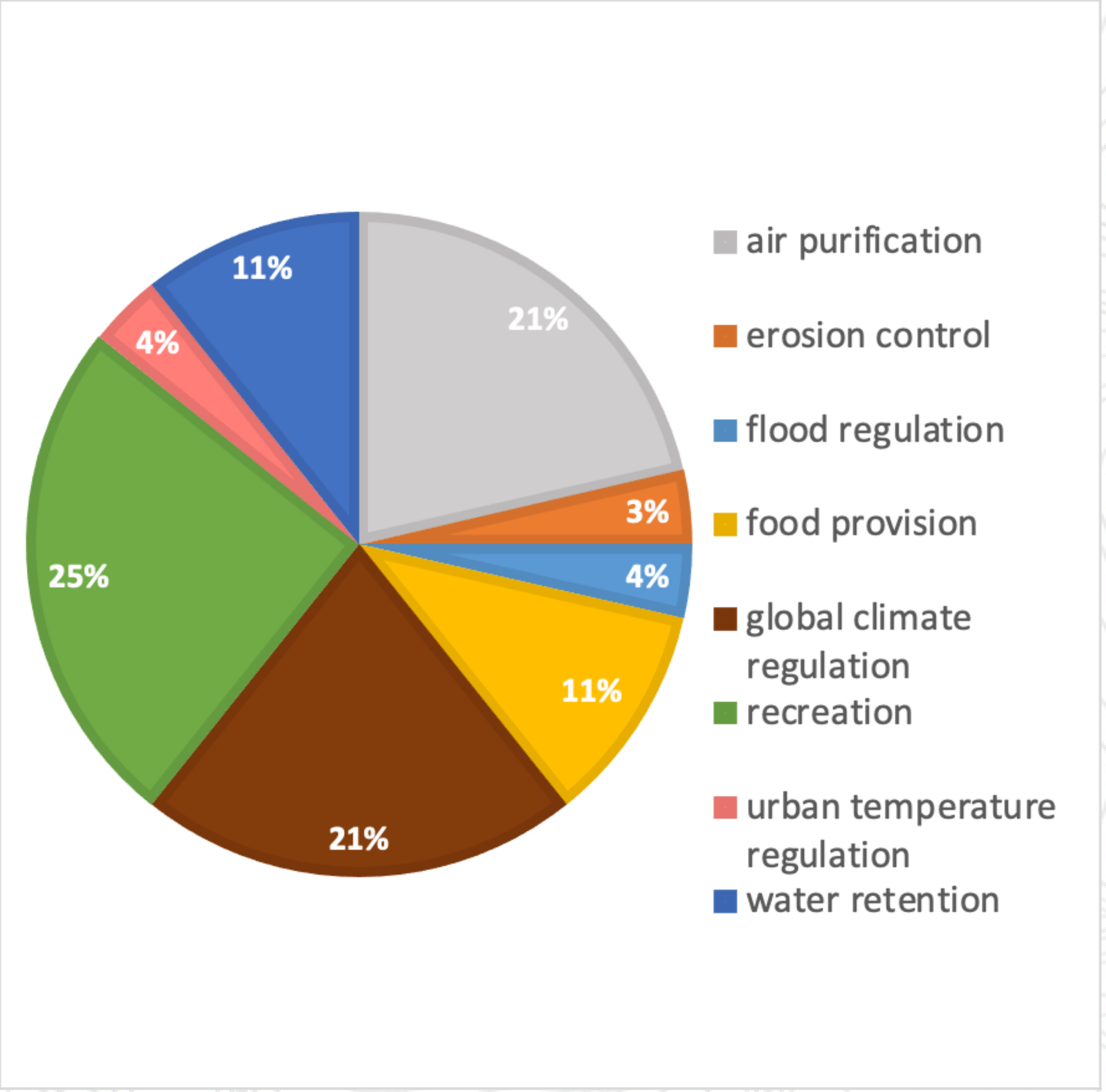
→No pattern in publication journal

→Oldest included article from 2015 (despite no restrictions to timespan in search)

→Recreation and global climate regulation are the most assessed services (Fig. 1)

→Most assessments from China (4) and Spain (3)

→Only one attempt to assess supply and demand of urban climate temperature (unsuccesful in mismatch assessment on the demand side)



Advances in ES supply and demand coupling

The innovative approaches appearing in reviewed literature:

→ Approach for regulating ES based on environmental quality standards

→Advances in framework expresing 2 mismatches – unsatisfied demand and unsatisfied sustainability

→ Advances in framework to assess ES bundles from supply-demand approach

→ Demand assessed as a function of vulnerability

→ Inclusion of alternative scenarios

→ Advances in framework by assessing mismatches between supply and demand linked to land use changes

→ Predicting change in ES mismatches based on 1 baseline and 3 stakeholder defined scenarios

Findings

- The assessment of ES supply and demand coupling mechanisms in urban areas is an emergent topic in urban planning and ecosystem service literature
- Indicators for ES supply and demand differ across papers even if the same ES is assessed
- No assessments of noise attenuation, habitat quality and urban temperature regulation, which are also important services in urban environment
- There is a gap in an assessment of socio-demographics of population living in areas of matches and mismatches → a need to address a question who are the beneficiaries and losers, (not only where they are located) while considering the equity of distribution and future planning

Limitations of the literature search

Including only city-scale studies

→Needs to be extented to all urban studies (e.g. regional study of urban areas)

Keyword limitation

→Needs to be expanded to other keywords in search (e.g. coupling mechanisms, supply and demand,..)

Including only original studies

→A need to take a look at review studies (snowballing)

Methodology

Overview

Selection of ES services:

- →**Urban temperature regulation**
- →**Urban flood mitigation**
- →Recreation
- →Air purification
- →Stormwater runoff retention
- →Carbon sequestration
- →Noise attenuation
- →Habitat quality

Methods:

- →**Remote sensing and GIS (and literature search) for data preparation**
- →**Urban InVEST software for modelling**
- →**GIS for mapping and modelling**

Urban cooling model (InVEST)

→ estimates the cooling effect of vegetation based on commonly available data

natural capital PROJECT

InVEST
integrated valuation of ecosystem services and tradeoffs

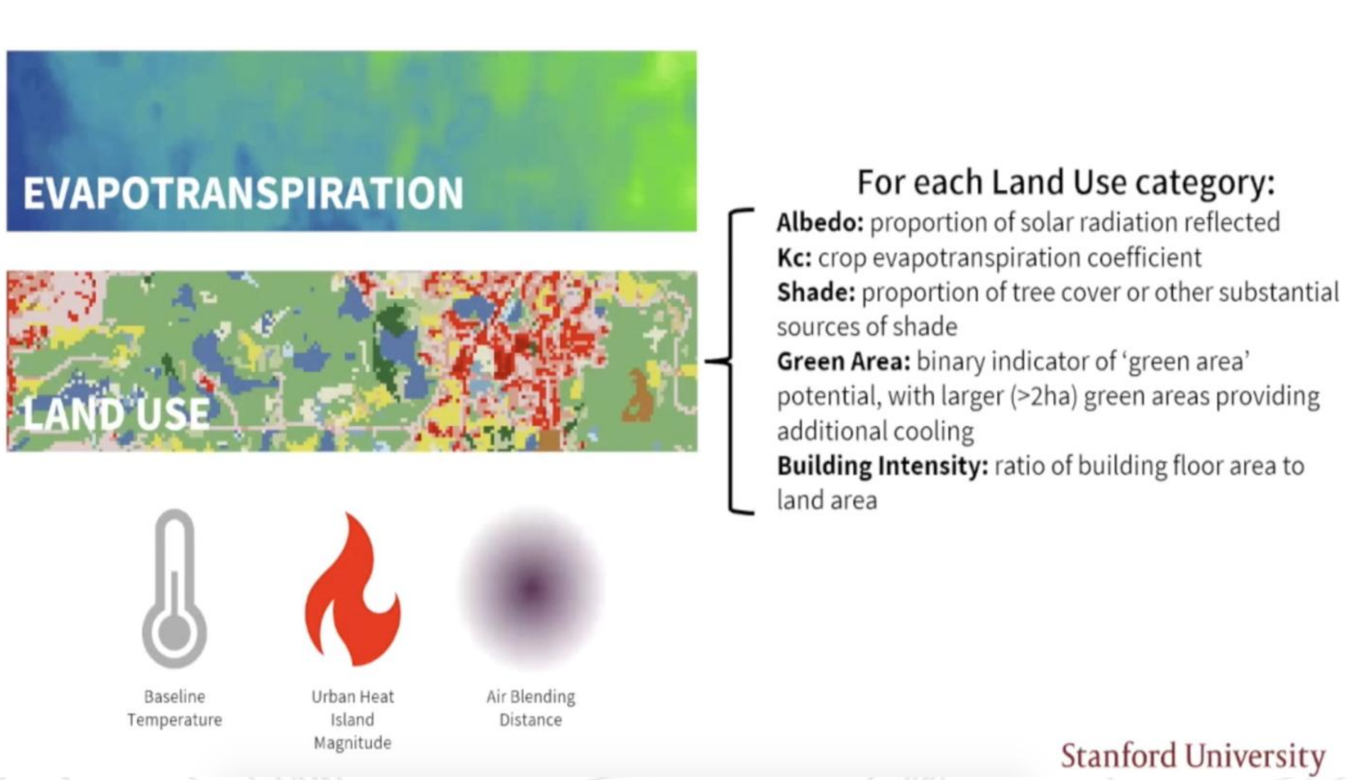
Model inputs:

Area of interest
- Neighborhood or city

Climate
- Background temperatute
- Reference evapotranspiration
- Maximal UHI effect

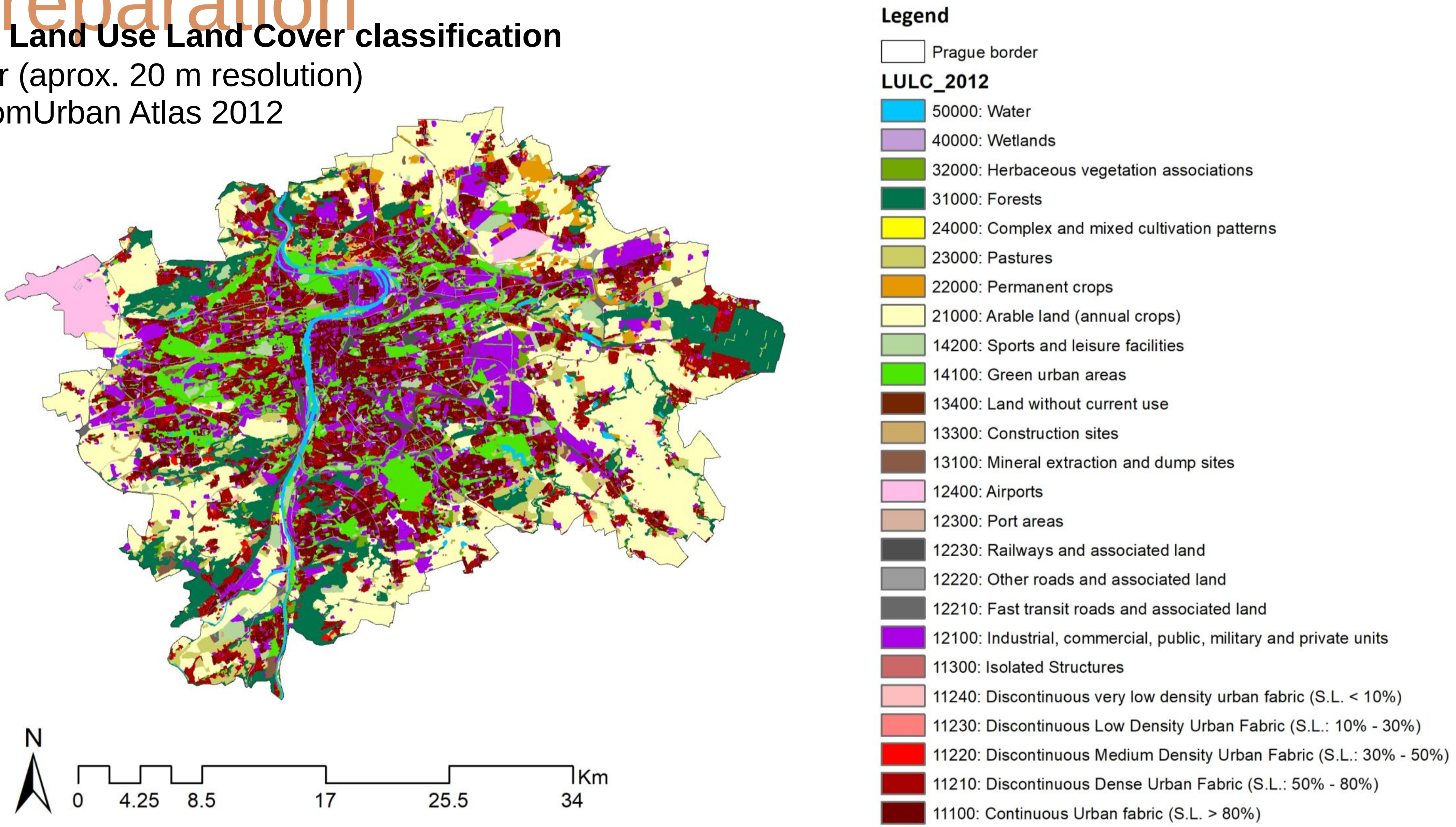
Land Use/Land Cover
- Raster data
- Associated biophysical parameters

Buildings (optional)
- Footprints and energy use



Data preparation

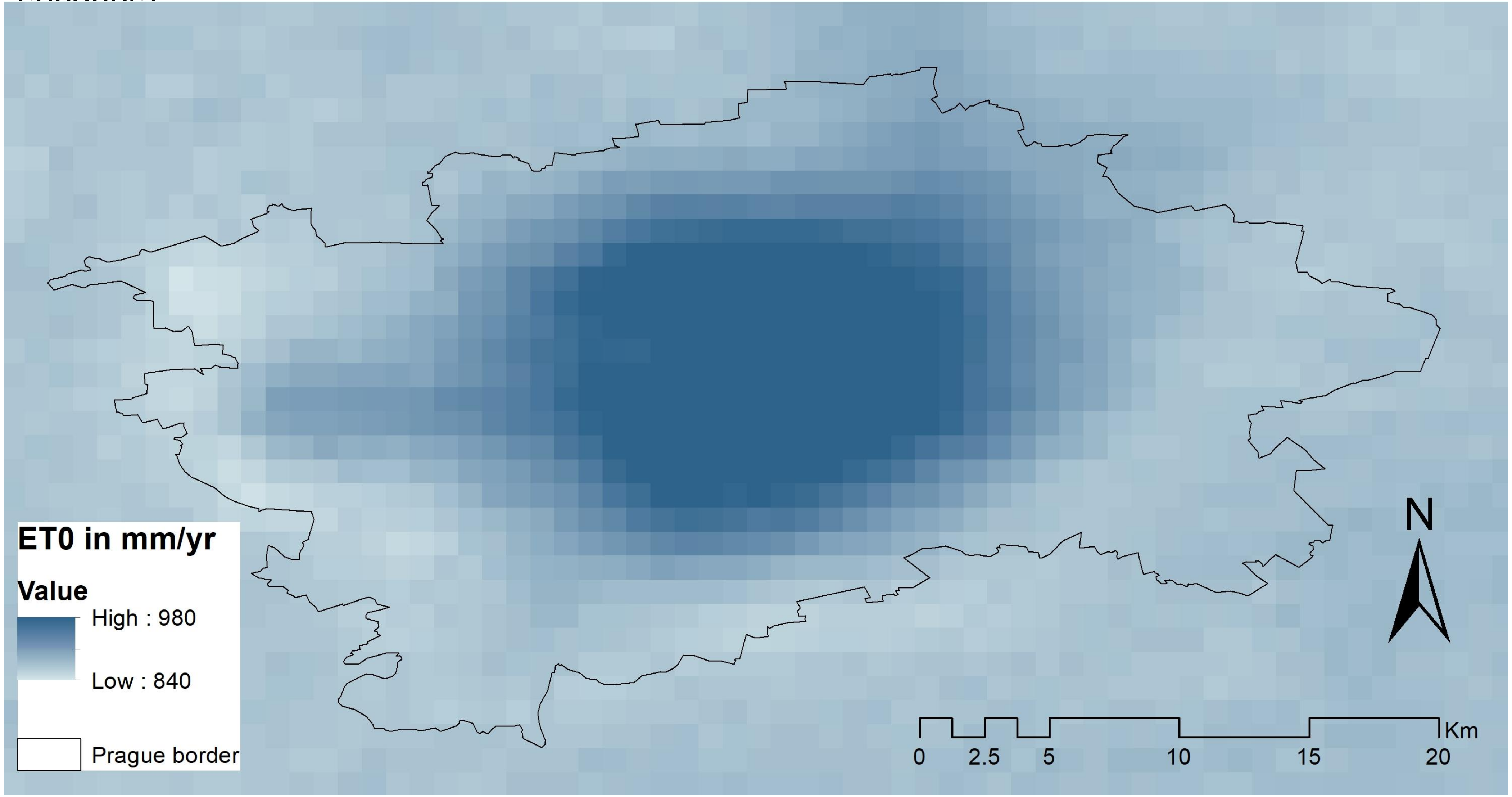
Prague Land Use Land Cover classification
In raster (aprox. 20 m resolution)
Data fromUrban Atlas 2012



Potential evapotranspiration

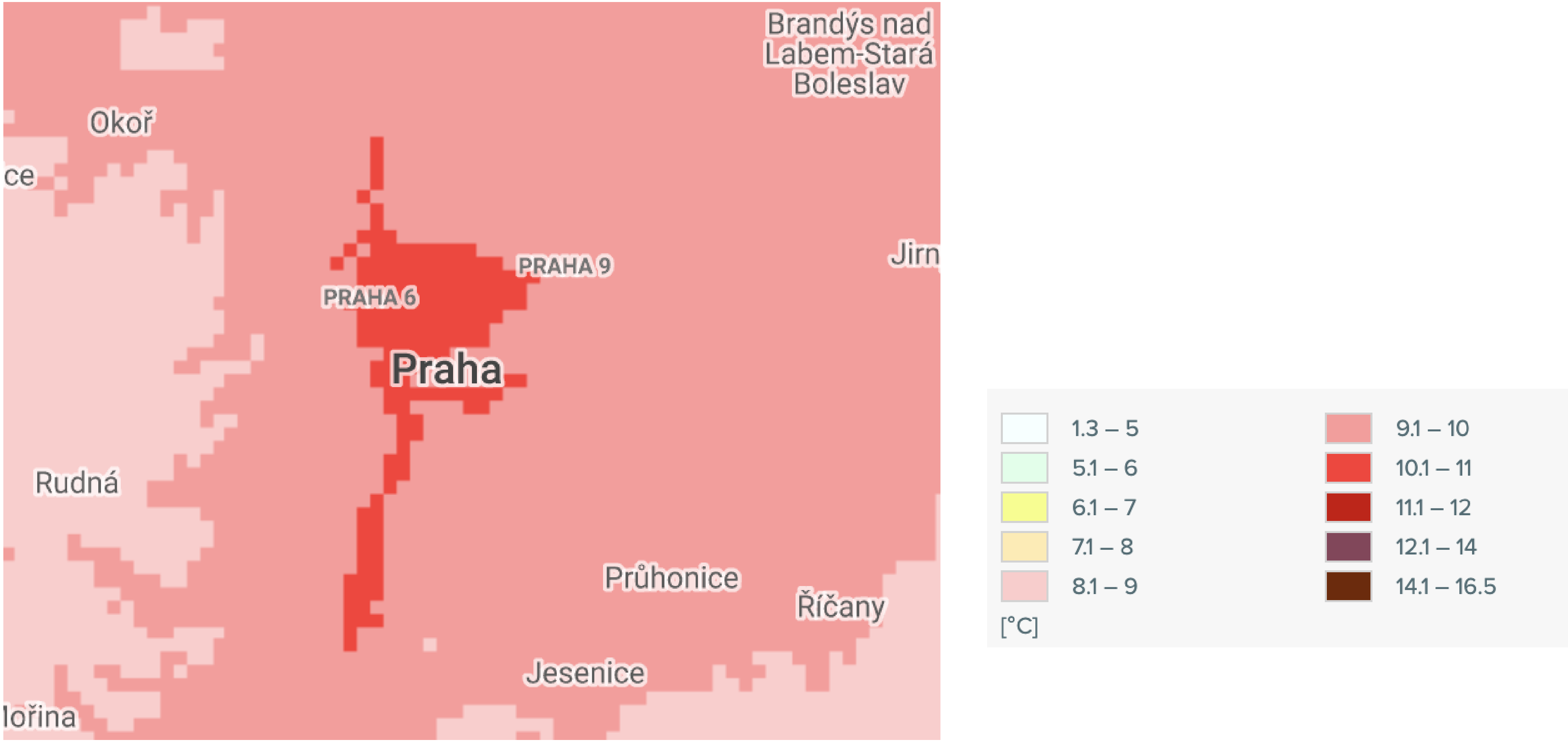
raster climate data for the 1970-2000 (resolution 30-arc seconds)

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\left(\frac{C_n}{(T + 273.16)}\right)u_2(e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}$$



Data from CGIARCSI

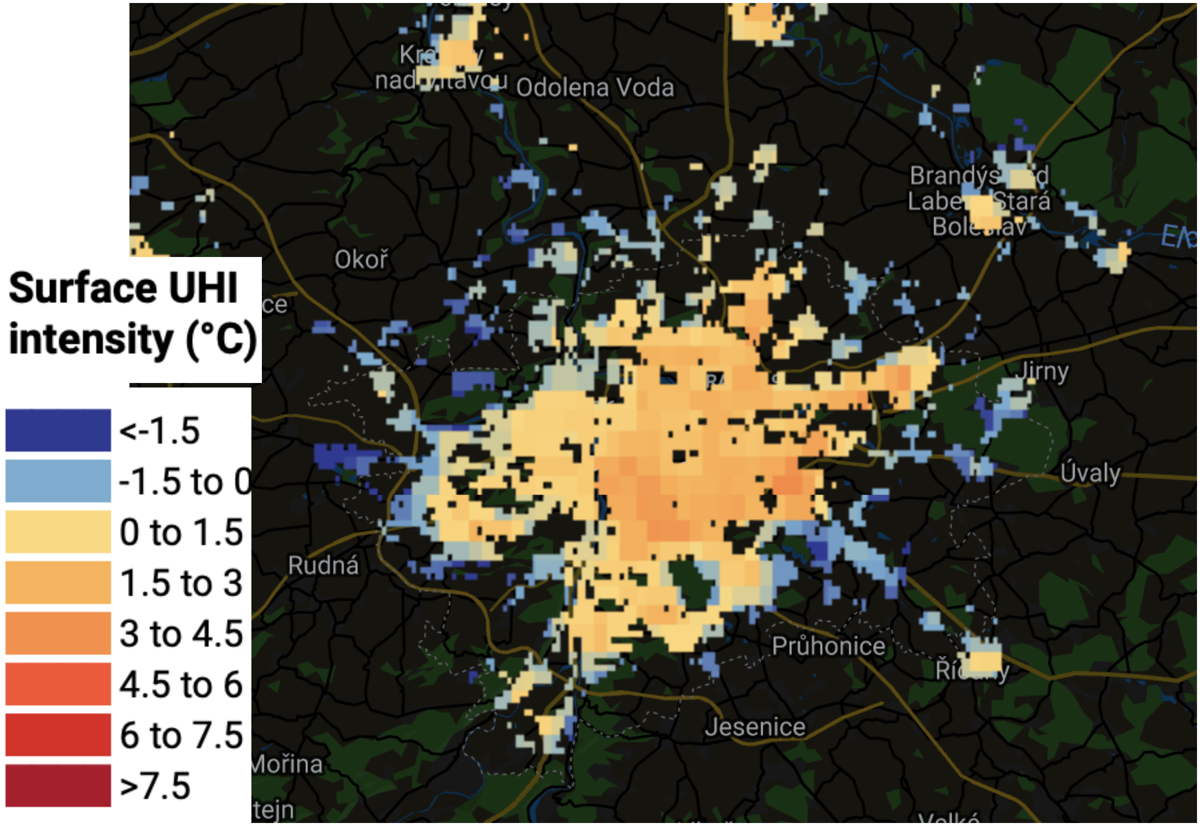
Mean average temperature (1981 – 2010)



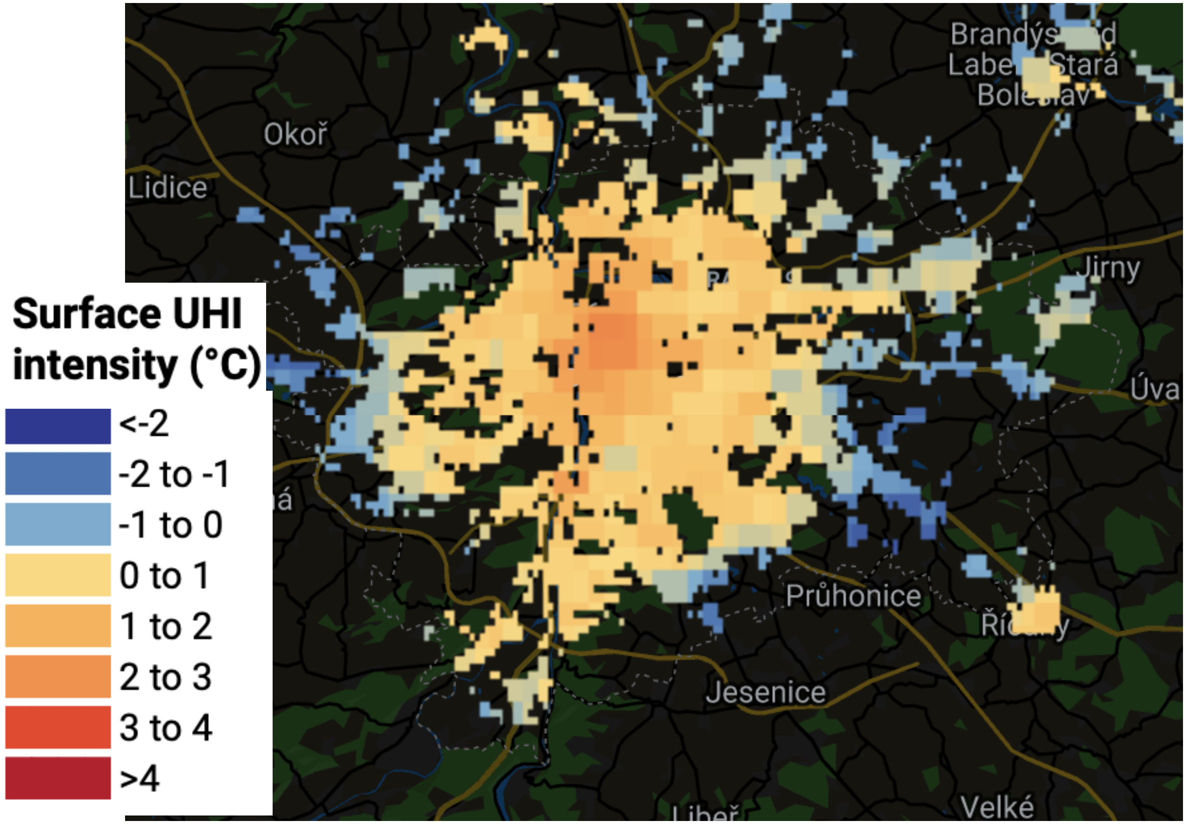
Data from klimatickazmena.cz

Urban heat island effect

Daytime intensity



Nightime intensity

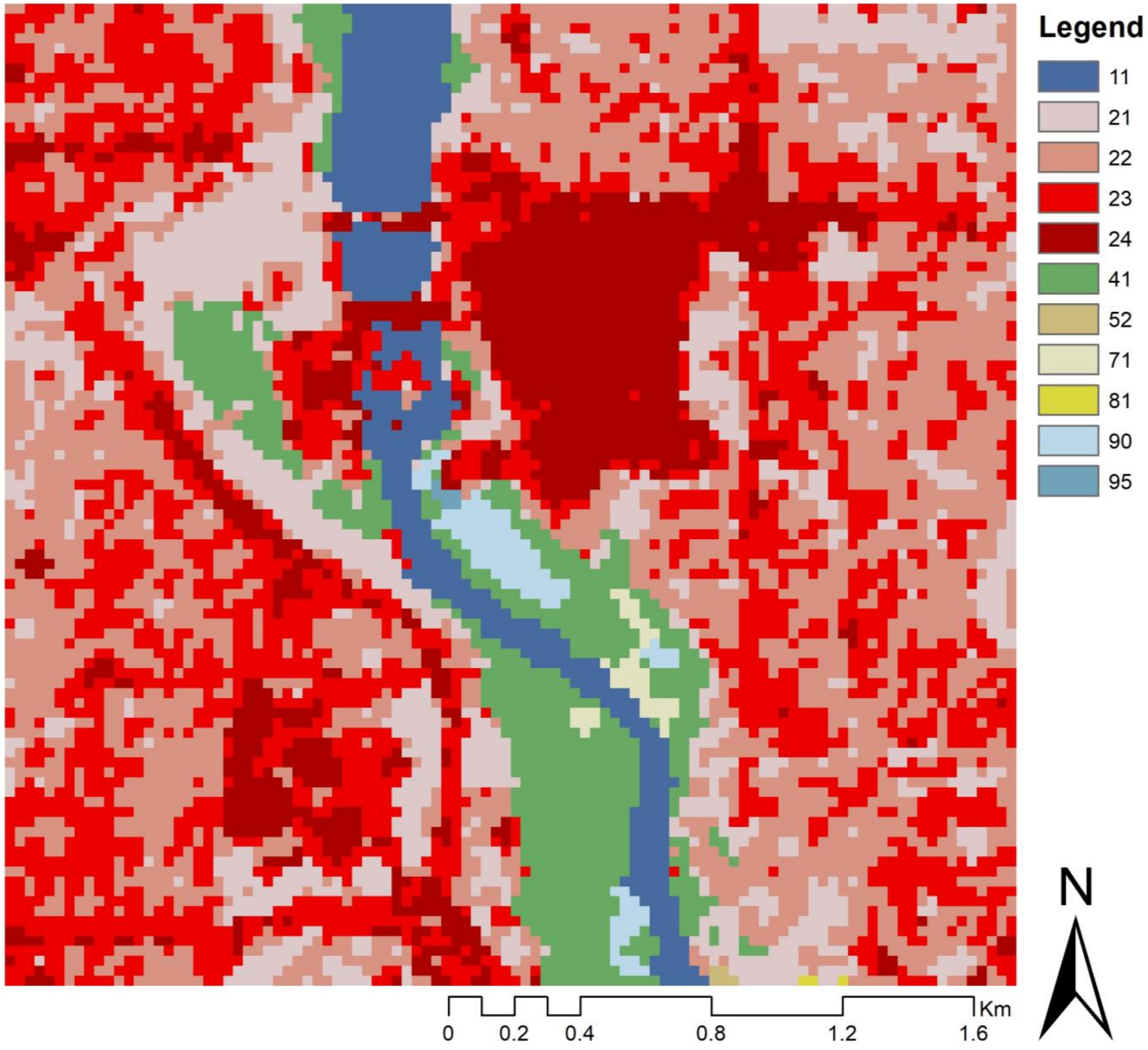


Yceo earth engine, 2020

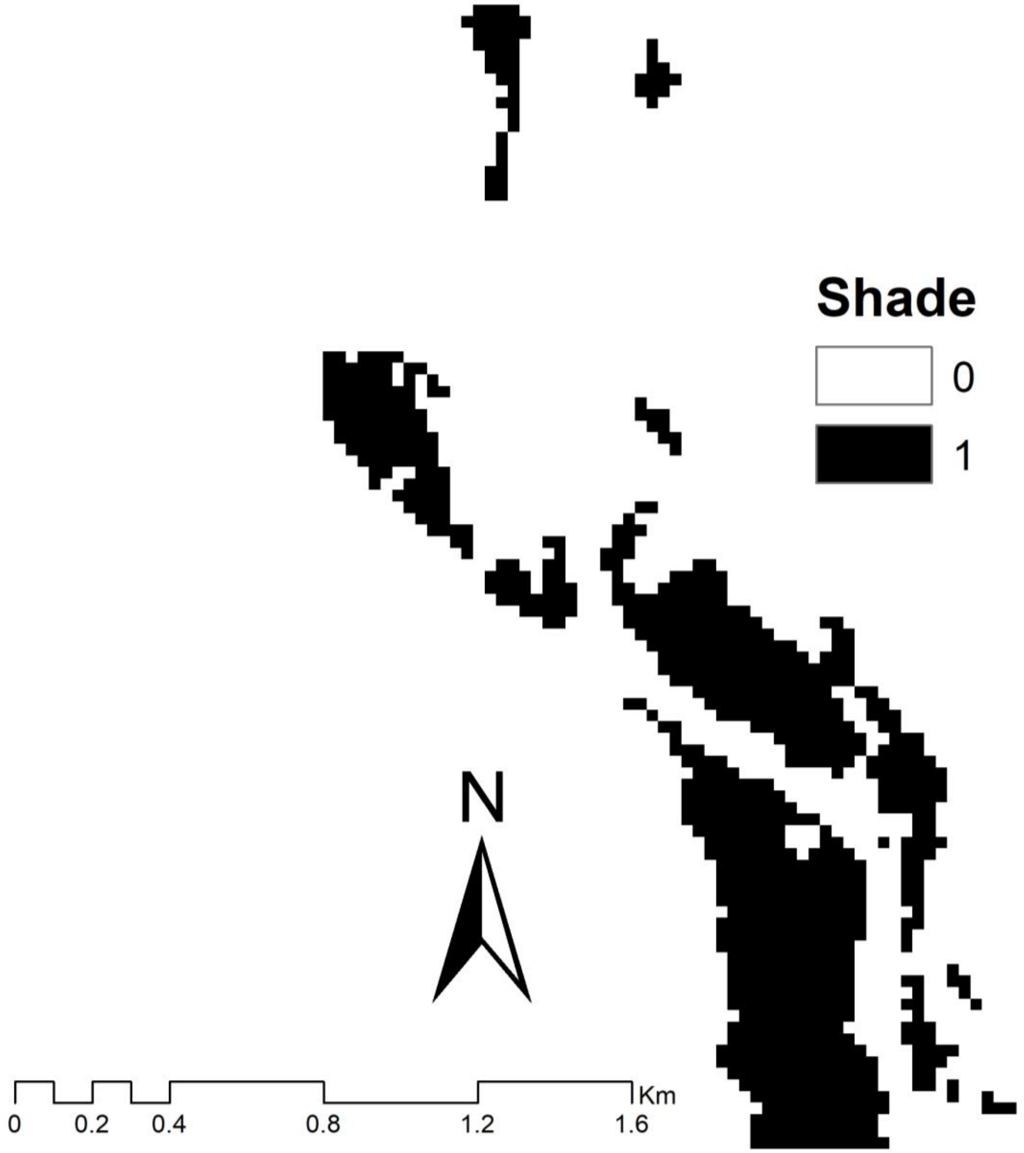
Model testing
Urban Cooling

- Testing the model on the data provided from Natural Capital Project during the online workshop
- Results from Minneapolis case study (area 3x3 km)

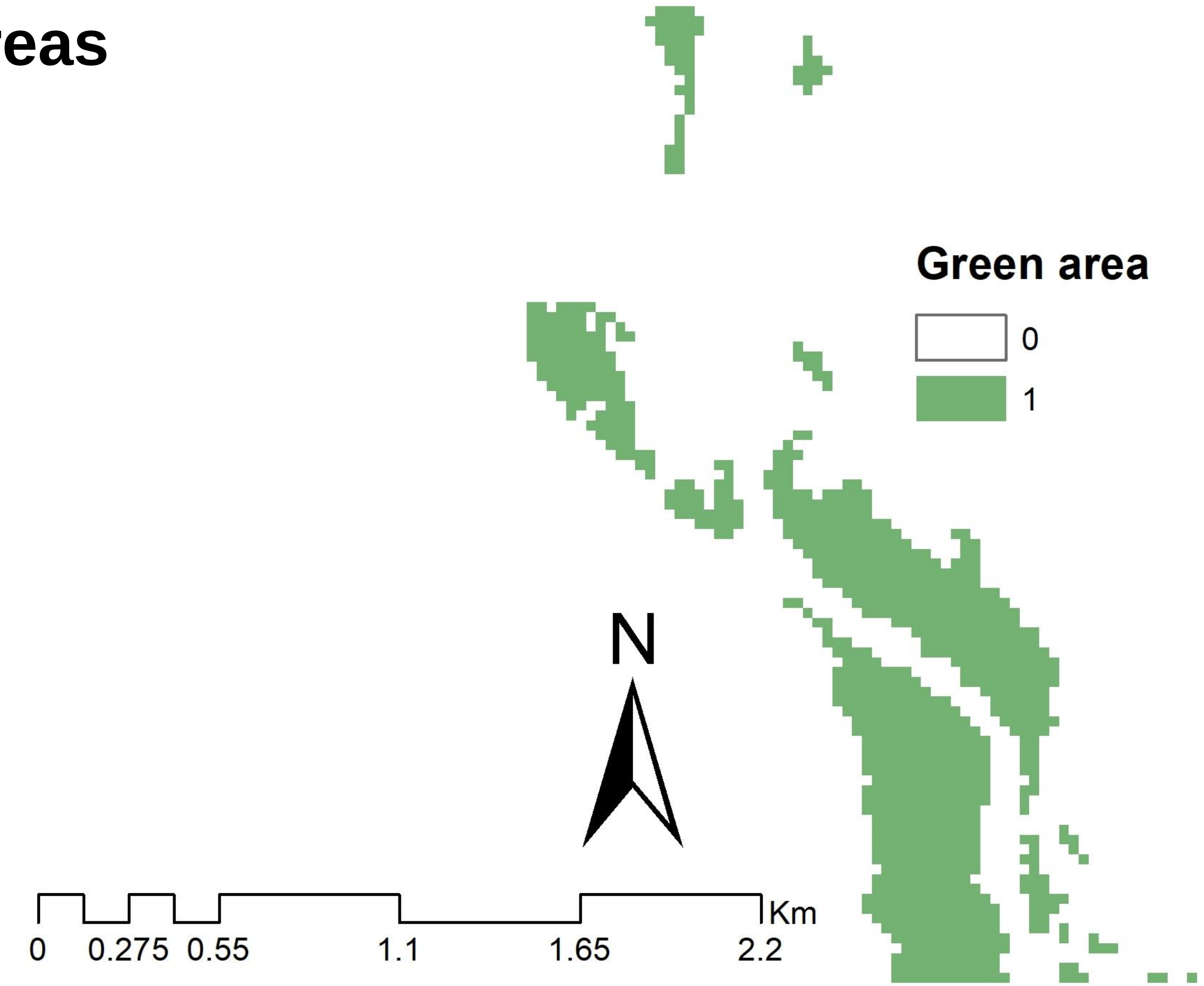
Land Use Land Cover classes



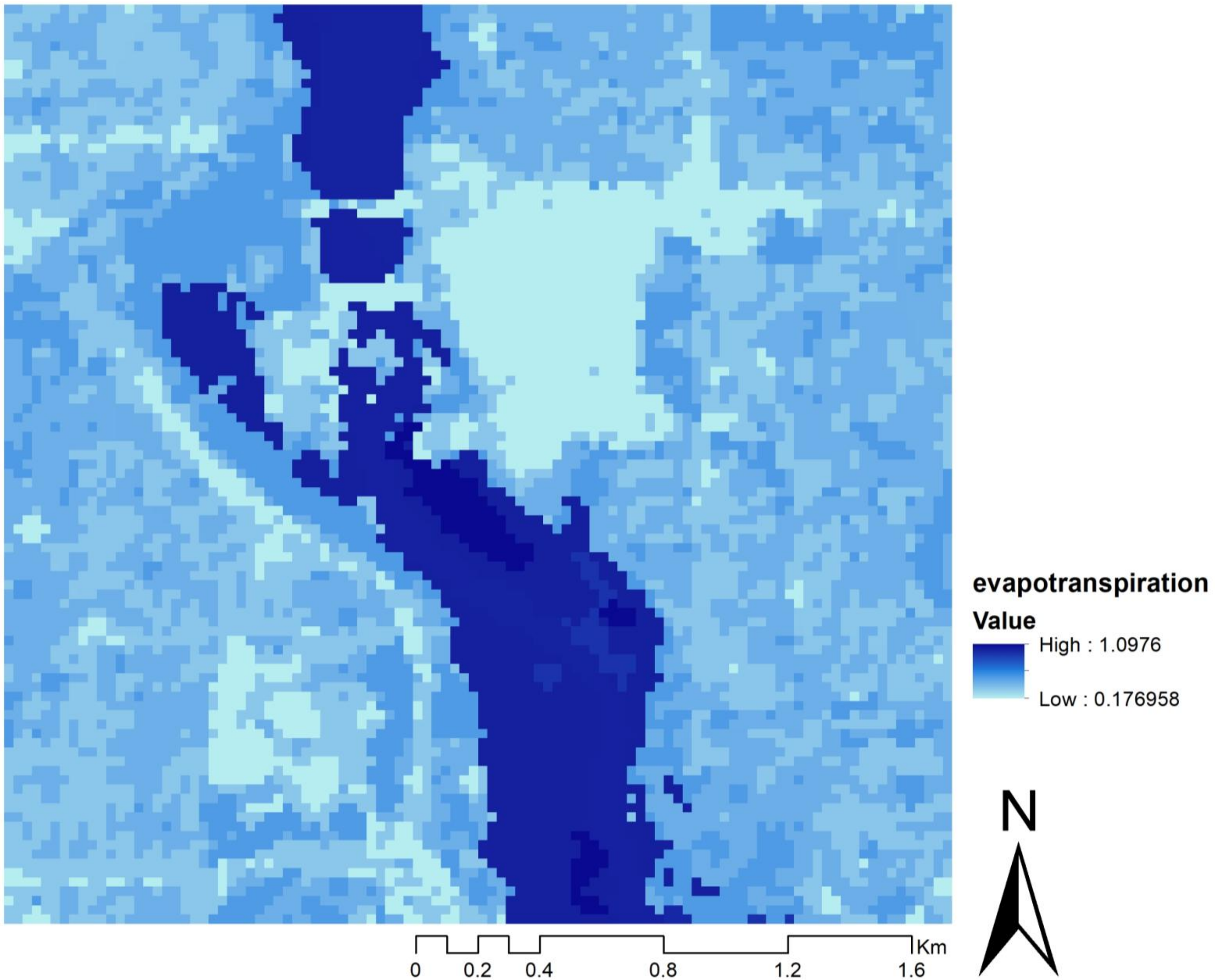
Shade areas



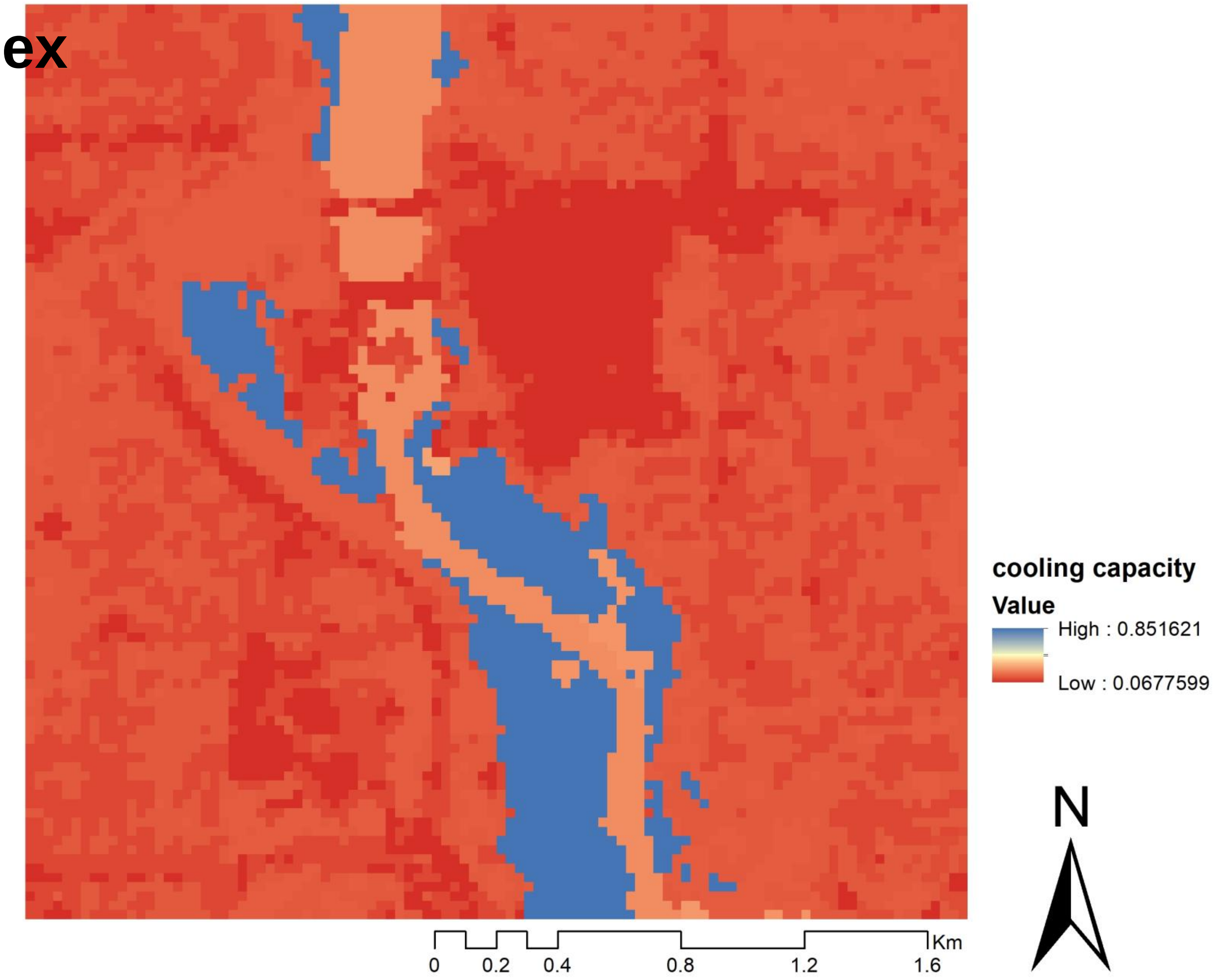
Green areas



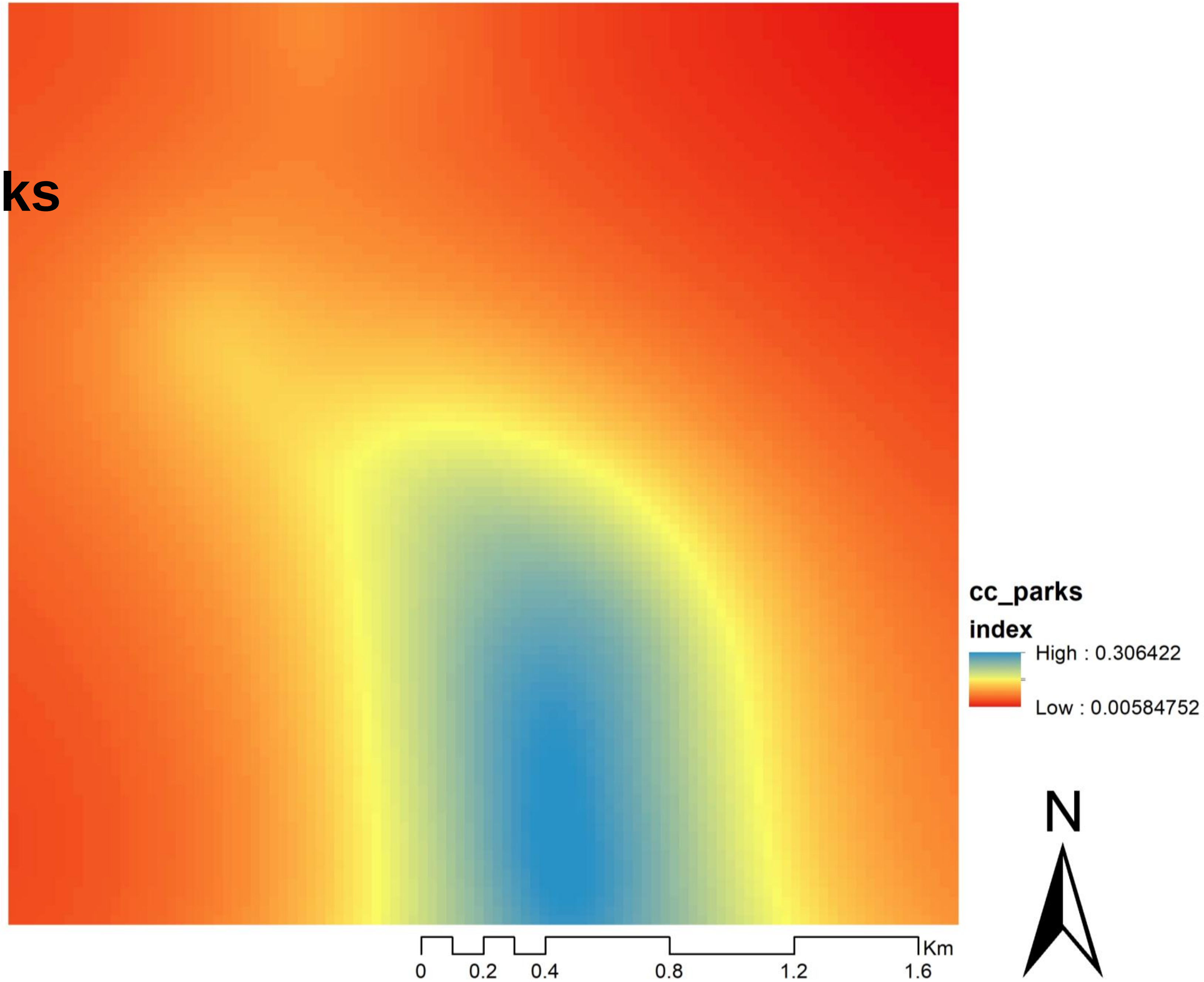
Actual evapotranspiration



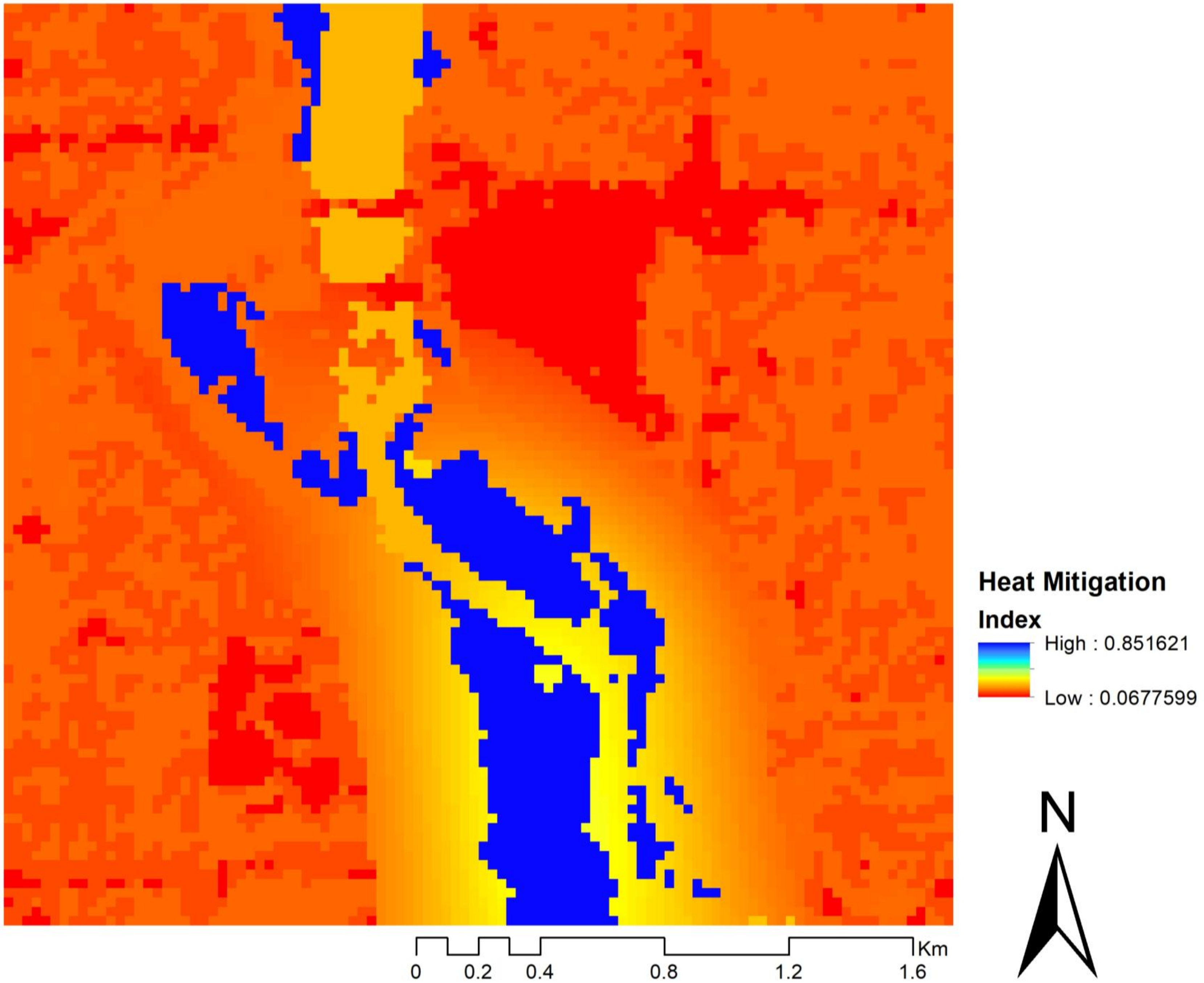
Cooling capacity index



Additional cooling capacity index of parks



Heat mitigation index



Follow up and next steps

- Finishing the collection/preparation of data (albedo, crop coeficients for all LULC classes)
- Validation of urban cooling model's outputs
- Continuing with other ES supply mapping/modelling
- Selection the indicators for the demand side assessment (e.g. EQS)
- Analysis of mismatches
- Vulnerability analysis
- Design of various scenarios of urban greenery development

References

Baro, F., Gomez-Baggethun, E., and Haase, D. 2017. Ecosystem service bundles alon the urban-rural grandient: Insights for landscape planning and management. *Ecosystem Services,* 24:147-159.

Baro, F., Haase, D., Gomez-Baggethun, E. and Frantzeskaki, N. 2015. Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities. *Ecological Indicators,* 55:148-158

Baro, F., Palomo, I., Zilian, G., Vizcaino, P., Haase, D., and Gomez-Baggethun, E. 2016. Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. *Land Use Policy,* 57:405-417.

Chen, Y., Jiang, B., Bai, Y., Xu, X., and Alatalo, J., M. 2019. Quantifying ecosystem services supply and demand shortfalls and mismatches for management optimisation. *Science of the Total Environment,* 650:1426-1439.

Jian, B., Bai, Yang, Chen, J., Alatalo, J., M., Xu, X., Liu, G., and Wang, Q. 2020. Land management to reconcile ecosystem services supply and demand mismatches – A case study in Shanghai municipality, China. *Land Degradation and Development, 1-16.*

Klimaticka Zmena. 2020. Mean average temperature.

Marango, D., Galio, M., Robbi, M., Appiotti, F., Fano, E., A., and Gissi, E. 2018. Fine-scale analysis of urban flooding reduction from green infrastructure: An ecosystem service approach for the management of water flows. *Ecological Modelling,* 386:1-10.

Natural Capital. 2019. Users' guide. Stanford University.

Trabucco, A., Zomer, R. 2019. Global Aridity Index and Potential Evapotranspiration (ET0) Climate Database v2. figshare. Fileset.

Urban Atlas. 2012, Land Copernicus.