POSTER - vP3.12

Surface Urban Heat Island in Bolzano (Italy): Evaluating the Role of Morphometric and Biophysical Characteristics

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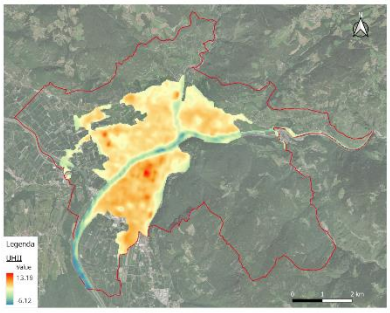
Introduction

Urbanization alters land cover, affecting heat exchange and causing cities to be warmer than rural areas, a phenomenon known as Urban Heat Island (UHI). This study focus on Surface UHI (SUHI). SUHI is influenced by surface properties, human activities, vegetation, and urban morphology. This study analyzes the relationship between SUHI and various urban and biophysical indices in Bolzano, a town in the North of Italy.

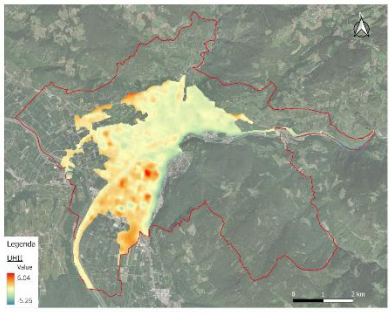
Materials and Methods

- Bolzano elevation varies from 232 to 1616 m a.s.l.
- Buildings and land cover data were collected.
- Two Landsat 8/9 satellite images were selected based on extreme temperature records from 2020 and 2024. One for the summer and one for the winter.
- Building Coverage Ratio, Building Volume Density, Mean Building Height, Green Space Ratio, Sky View Factor, Albedo, Normalized Difference Built-up Index, Normalized Difference Vegetation Index, Land Surface Temperature and Urban Heat Island Intensity are calculated on a 30x30 m grid.

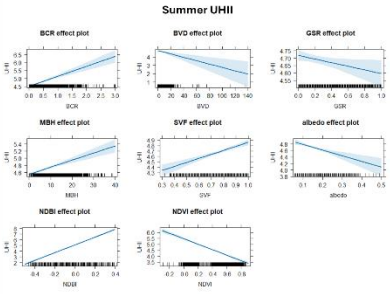
Results



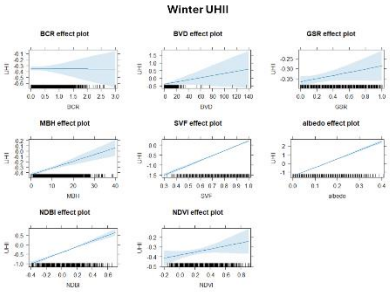
Min value: -6.12 °C; Max value: 13.12 °C; Date: 07/19/2022



Min value: -5.26 °C; Max value: 6.04 °C; Date: 02/14/2021



R2 = 0.367



R2 = 0.199

Discussion and Conclusion

- Summer: all indices, with the exception of GSR, are significant.
- Winter: significant indices are MBH, SVF, albedo and NDBI.
- BVD could decrease UHII because of increased shadows on surface.
- SVF could increase UHII because of reduced shadows on surface.
- Positive relation with albedo could be due to other parameters influence.
- It is important to keep under consideration urban morphology when planning.

References

D. Gerçek and T. Güven. Assessment of mutual variation of near-surface air temperature, land surface temperature and driving urban parameters at urban microscale. Sustainability, 15(22), 2023. ISSN 2071-1050. doi: 10.3390/su152215710.
Y. Xu, C. Ren, P. Ma, J. Ho, W. Wang, K. K.-L. Lau, H. Lin, and E. Ng. Urban morphology detection and computation for urban climate research. Landscape and Urban Planning, 167:212–224, 2017. ISSN 0169-2046. doi: https://doi.org/10.1016/j.landurbplan.2017.06.018
W. Liao, T. Hong, and Y. Heo. The effect of spatial heterogeneity in urban morphology on surface urban heat islands. Energy and Buildings, 244:111027, 2021. ISSN 0378-7788. doi: https://doi.org/10.1016/j.enbuild.2021.111027.
S. E. Pappalardo, C. Zanetti, and V. Todeschi. Mapping urban heat islands and heat-related risk during heat waves from a climate justice perspective: A case study in the municipality of Padua (Italy) for inclusive adaptation policies. Landscape and Urban Planning, 238:104831, 2023. ISSN 0169-2046. doi: https://doi.org/10.1016/j.landurbplan.2023.104831.

The work is conducted within the framework of the RETURN Extended Partnership (European Union Next-Generation EU, National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investment 1.3 – D.D. 1243 2/8/2022, PE0000005).

Sharing is encouraged

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INDICES CALCULATION FORMULA

Building Coverage Ratio $$BCR = \frac{\sum_{i=1}^{N} C_i}{S_L}$$

where C_i is the coverage area of building *i*, S_L is the size of the cell and N is the total number of buildings in a cell.

Building Volume Density $$BVD = \frac{\sum_{i=1}^{N} C_i H_i}{S_L}$$

where C_i is the coverage area of building *i*, H_i is the height of building *i*, S_L is the size of the cell and N is the total number of buildings in a cell.

Mean Building Height $$MBH = \frac{\sum_{i=1}^{N} H_i}{N}$$

where H_i is the height of building *i* and N is the total number of buildings in a cell.

Green Space Ratio $$GSR = \frac{\sum_{i=1}^{n} A_i}{S_L}$$

where A_i is the area of green space *i* and S_L is the size of the cell.

Sky View Factor

It was calculated using the SAGA (9.3.1 version) Sky View Factor algorithm included in Terrain Analysis – Lighting.

Albedo $$albedo = \frac{0.356\alpha_2 + 0.130\alpha_4 + 0.373\alpha_5 + 0.085\alpha_6 + 0.072\alpha_7 - 0.0018}{0.356 + 0.130 + 0.373 + 0.085 + 0.072}$$

where α represents Landsat 8/9 OLI-TIRS Collection 2 Level 2 Surface Reflectance bands 2, 4, 5, 6 and 7.

Normalized Difference Built-up Index $$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

Normalized Difference Vegetation Index $$NDVI = \frac{NIR - R}{NIR + R}$$

Urban Heat Island Intensity $$UHII = T_u - T_r$$

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Land Surface Temperature $$LST = \frac{BT}{1 + \lambda(BT/\rho)ln(\varepsilon)} - 273.15$$

where λ is the wavelength of emitted radiance, ρ is a constant, calculated as $\rho = hc / \sigma$.

For the other parameters in the formula:

- Brightness Temperature $$BT = \frac{K_2}{ln(\frac{K_1}{L_\lambda} + 1)}$$
- Spectral Radiance $$L_\lambda = M_\lambda Q + A_\lambda$$
- Emissivity $$\varepsilon = 0.004Pv + 0.986$$
- Proportion of Vegetation $$Pv = \frac{(NDVI - NDVI_s)^2}{NDVI_v + NDVI_s}$$
- NDVI $$NDVI = \frac{TOA_{B5} - TOA_{B4}}{TOA_{B5} + TOA_{B4}}$$
- Top of Atmosphere Reflectance $$TOA = \frac{MQ + A}{sin\Theta_{SE}}$$

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SUMMARY OF MORPHOLOGICAL AND BIOPHYSICAL INDICES

	Summer				Winter			
Index	Min	Max	Mean	SD	Min	Max	Mean	SD
BCR	0.00	3.00	0.27	0.32	0.00	3.00	0.28	0.32
BVD $[m^3/m^2]$	0.00	136.05	3.20	4.49	0.00	136.05	3.28	4.58
GSR	0.00	1.00	0.22	0.26	0.00	1.00	0.22	0.26
MBH [m]	0.00	41.83	7.14	4.83	0.00	41.83	7.25	4.85
SVF	0.32	1.00	0.77	0.15	0.32	1.00	0.77	0.15

Figure 1: Minimum, Maximum, Mean and Standard Deviation value of morphological indices

	Summer				Winter			
Index	Min	Max	Mean	SD	Min	Max	Mean	SD
LST	27.36	43.96	35.46	1.97	-3.21	8.09	1.70	1.36
UHII	-3.41	13.19	4.69	1.97	-5.26	6.04	-0.35	1.36
Albedo	0.06	0.49	0.16	0.03	0.00	0.41	0.11	0.04
NDBI	-0.46	0.42	-0.06	0.11	-0.44	0.66	0.04	0.09
NDVI	-0.29	0.87	0.34	0.16	-0.16	0.92	0.22	0.15

Figure 2: Figure 1: Minimum, Maximum, Mean and Standard Deviation value of biophysical indices

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SUMMER BIOPHYSICAL INDICES MAPS

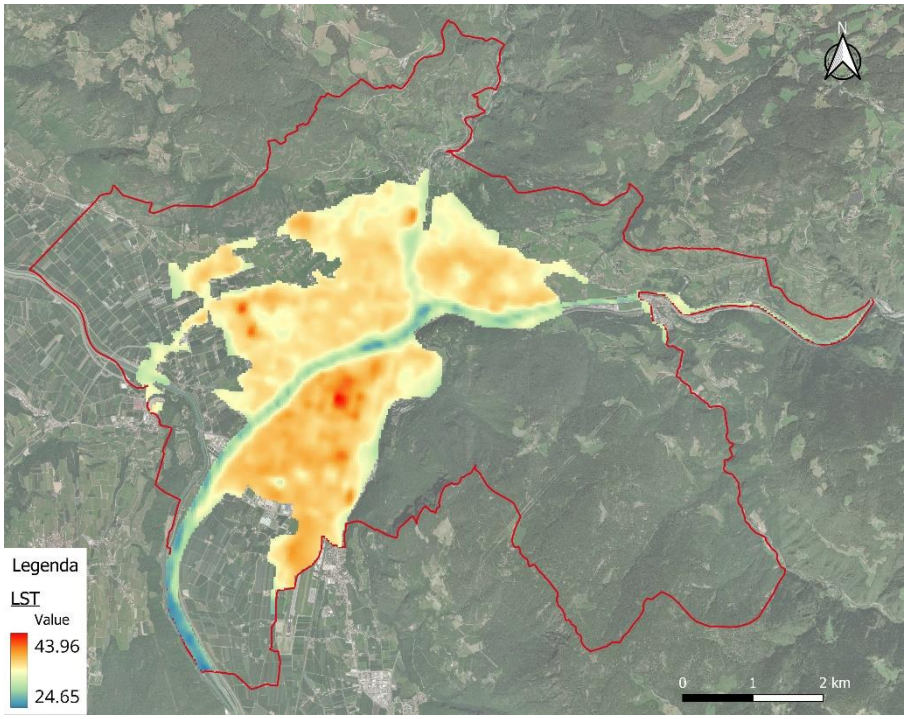

Figure 3: Summer LST

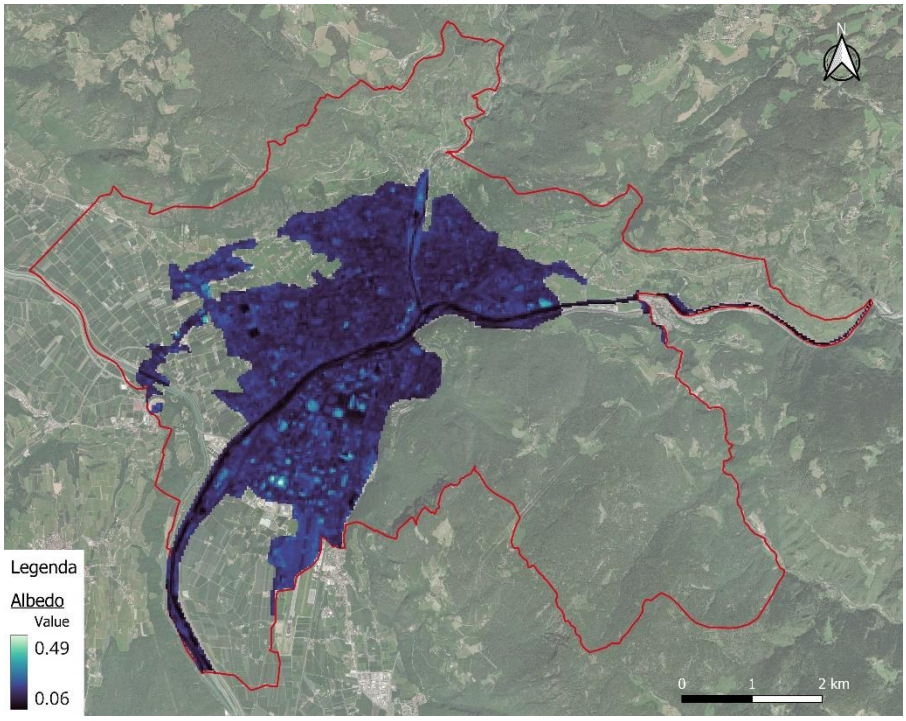

Figure 4: Summer Albedo

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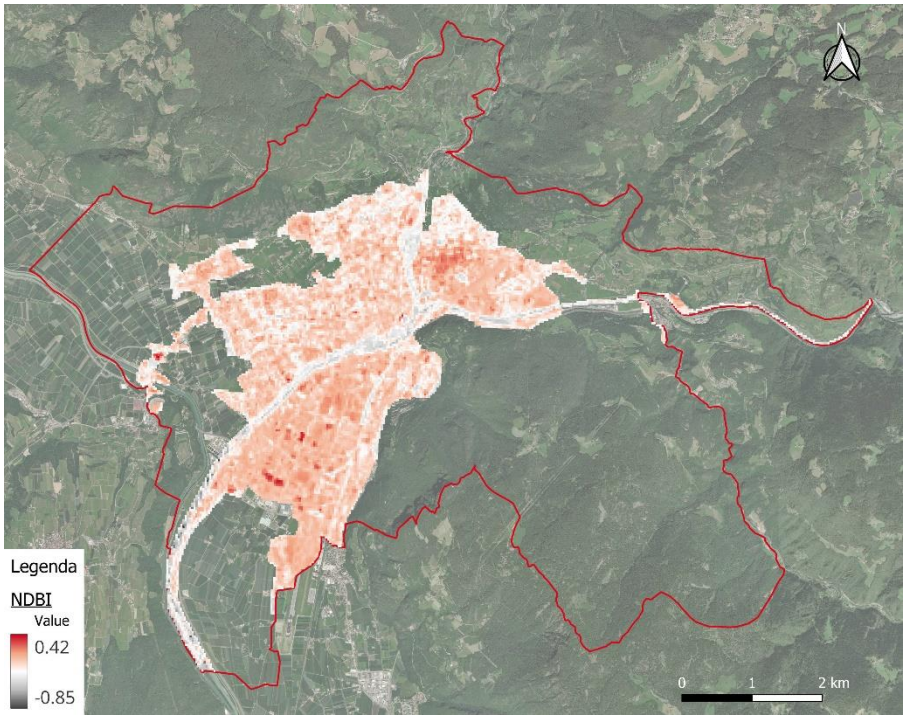

Figure 6: Summer NDBI

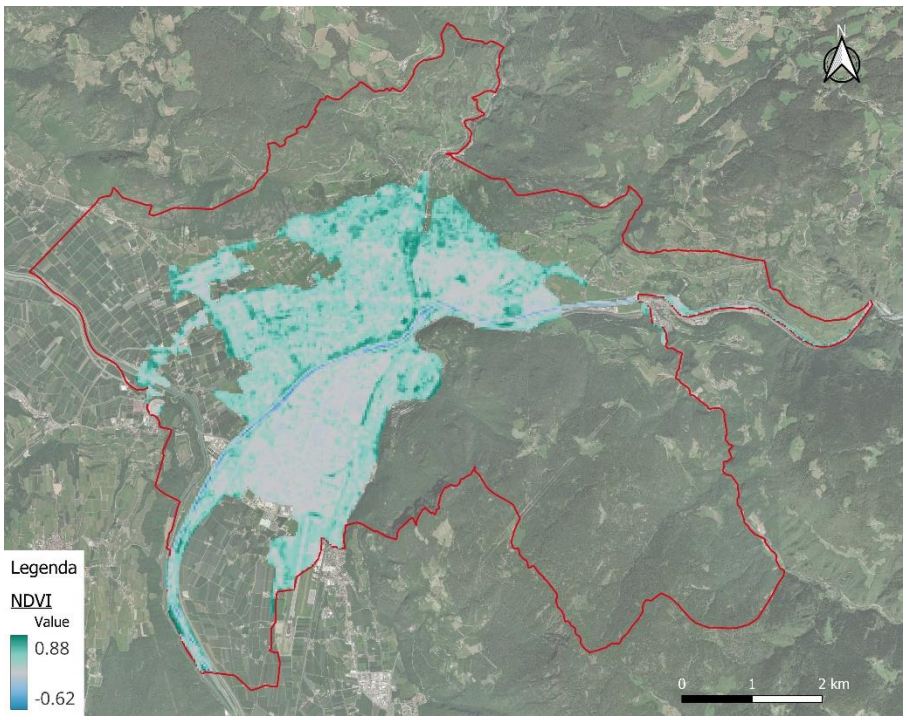

Figure 5: Summer NDVI

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WINTER BIOPHYSICAL INDICES MAPS

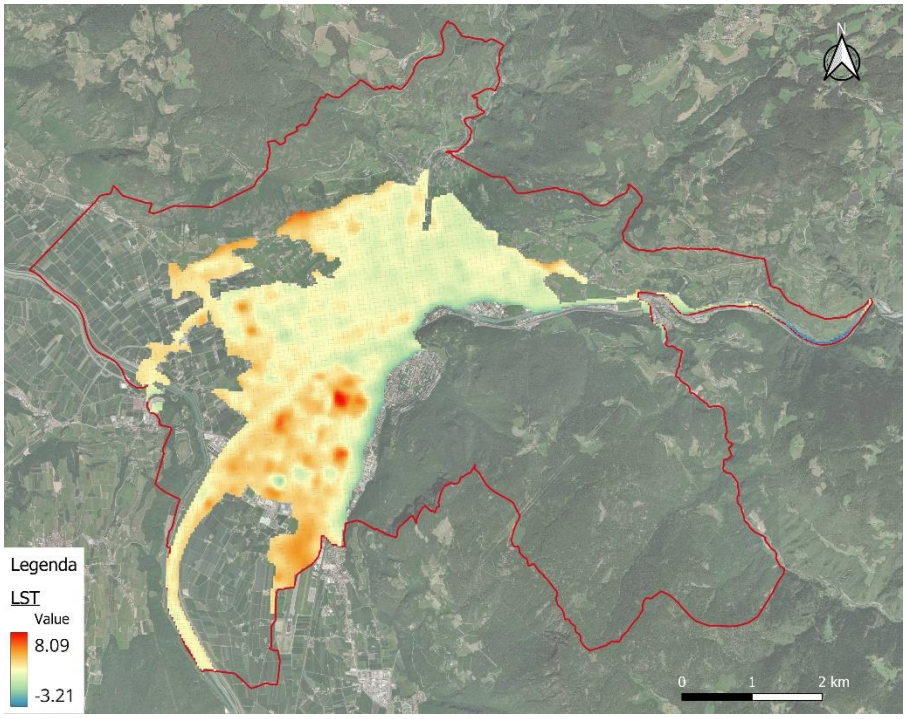

Figure 8: Winter LST

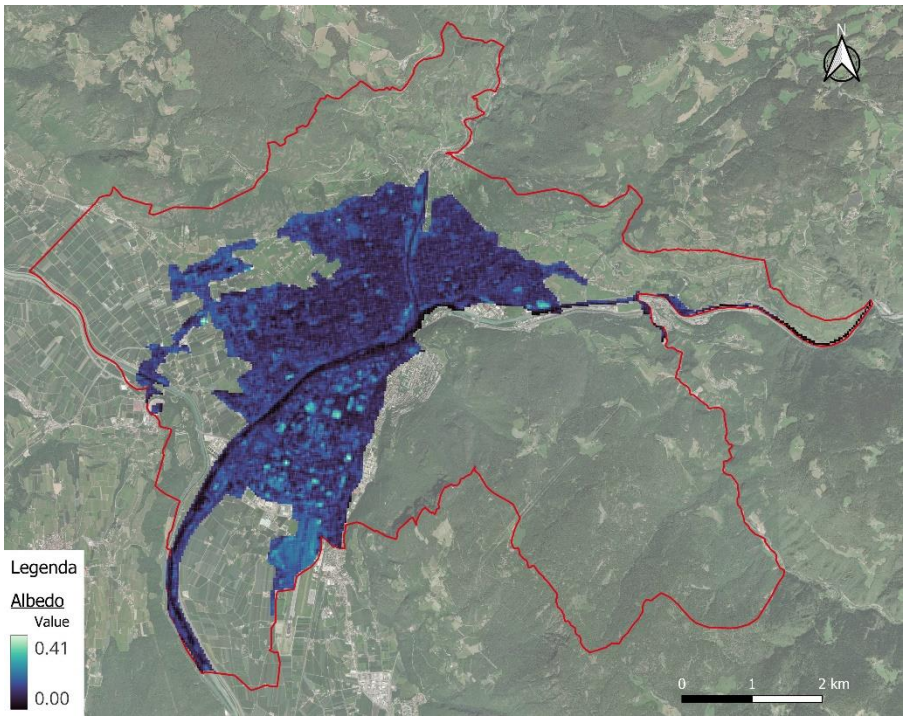

Figure 7: Winter Albedo

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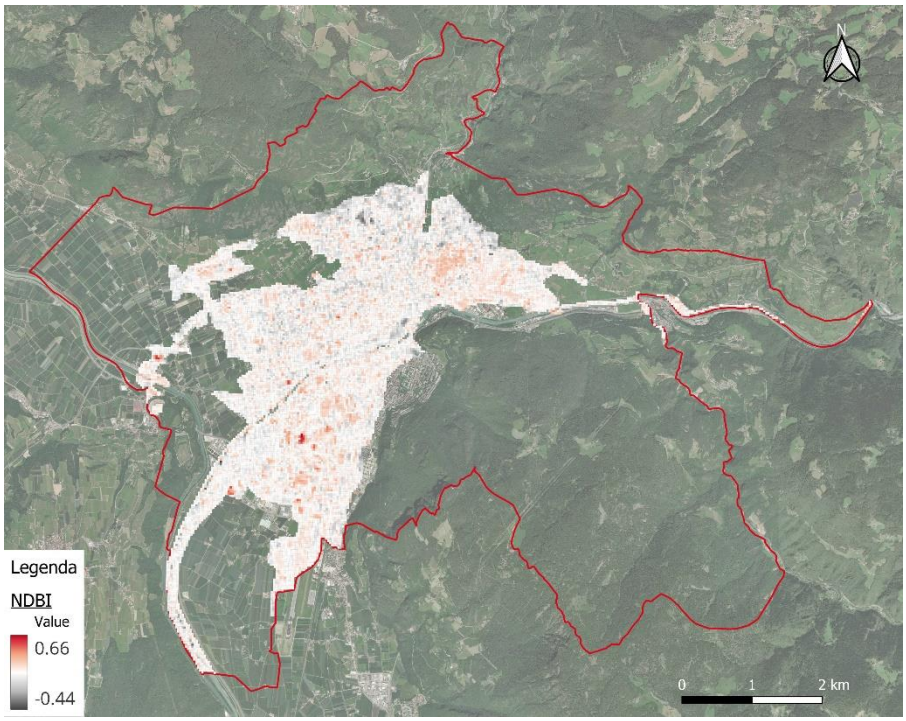

Figure 9: Winter NDBI

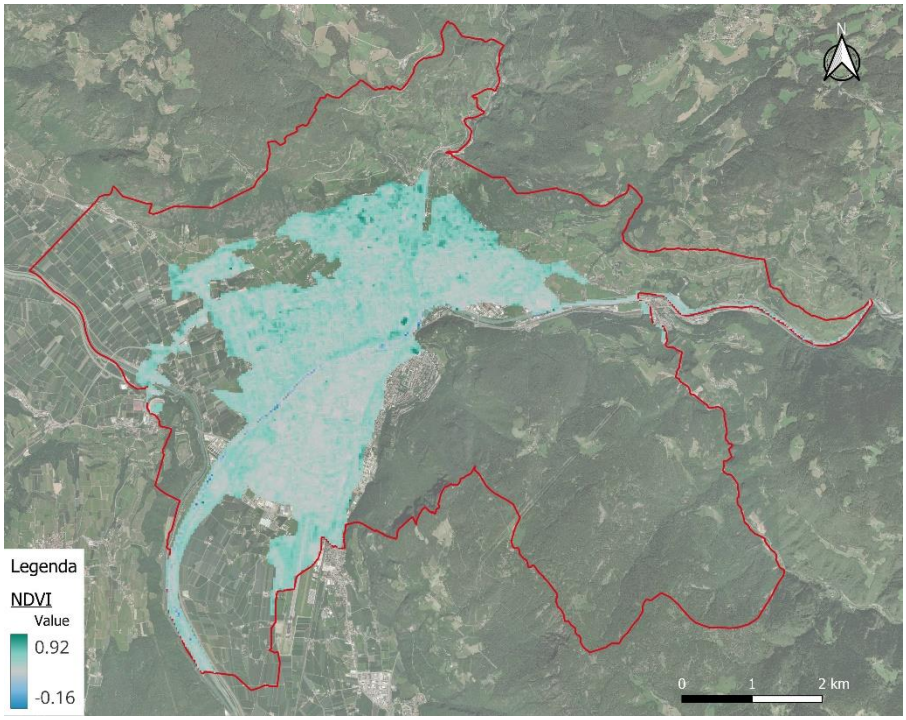

Figure 10: Winter NDVI

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References

A.-R. B. Ismaila, I. Muhammed, and B. Adamu. Modelling land surface temperature in urban areas using spatial regression models. Urban Climate, 44:101213, 2022. ISSN 2212-0955. doi: https://doi.org/10.1016/j.uclim.2022.101213. URL https://www.sciencedirect.com/science/article/pii/S2212095522001316.

W. Liao, T. Hong, and Y. Heo. The effect of spatial heterogeneity in urban morphology on surface urban heat islands. Energy and Buildings, 244:111027, 2021. ISSN 0378-7788. doi: https://doi.org/10.1016/j.enbuild.2021.111027. URL https://www.sciencedirect.com/science/article/pii/S037877882100311X.

B. Liu, X. Guo, and J. Jiang. How urban morphology relates to the urban heat island effect: A multi-indicator study. Sustainability, 15(14), 2023. ISSN 2071-1050. doi:10.3390/su151410787. URL https://www.mdpi.com/2071-1050/15/14/10787.

S. E. Pappalardo, C. Zanetti, and V. Todeschi. Mapping urban heat islands and heat-related risk during heat waves from a climate justice perspective: A case study in the municipality of padua (italy) for inclusive adaptation policies. Landscape and Urban Planning, 238:104831, 2023. ISSN 0169-2046. doi: https://doi.org/10.1016/j.landurbplan.2023.104831. URL https://www.sciencedirect.com/science/article/pii/S0169204623001500.

Y. Xu, C. Ren, P. Ma, J. Ho, W. Wang, K. K.-L. Lau, H. Lin, and E. Ng. Urban morphology detection and computation for urban climate research. Landscape and Urban Planning, 167:212–224, 2017. ISSN 0169-2046. doi: https://doi.org/10.1016/j.landurbplan.2017.06.018.

R. Zhu, X. Dong, and M. S. Wong. Estimation of the urban heat island effect in a reformed urban district: A scenario-based study in Hong Kong. Sustainability, 14(8), 2022. ISSN 2071-1050. doi: 10.3390/su14084409. URL https://www.mdpi.com/2071-1050/14/8/4409.

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