Examining the association of land cover with life satisfaction using deep learning

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1 OBJECTIVE

Urbanization and the resulting change in land use put green spaces under pressure. Since 1985 residential areas in Switzerland increased by 61% at the cost of meadows and agricultural land [1]. A growing body of literature suggests that green spaces positively affect residential life satisfaction [2, 3, 4]. Research also finds a beneficial association between greenness and health [5]. Prior studies have measured greenness by surveys or satellite imagery, while the latter mainly used Landsat 8 images with a 30m per pixel resolution combined with the NDV index to obtain green cover. This procedure does not allow distinguishing between different categories of green cover, e.g. trees vs. meadows. This work uses satellite images with a 0.5m pixel resolution combined with deep learning segmentation models. This allows to extract features at the tree level, distinguish between green and gray space, and their subclasses as trees, meadows, agricultural land, roads, developed space, and buildings. This should result in a more reliable evaluation of green and gray space in the urban setting.

2 METHODOLOGY

Data

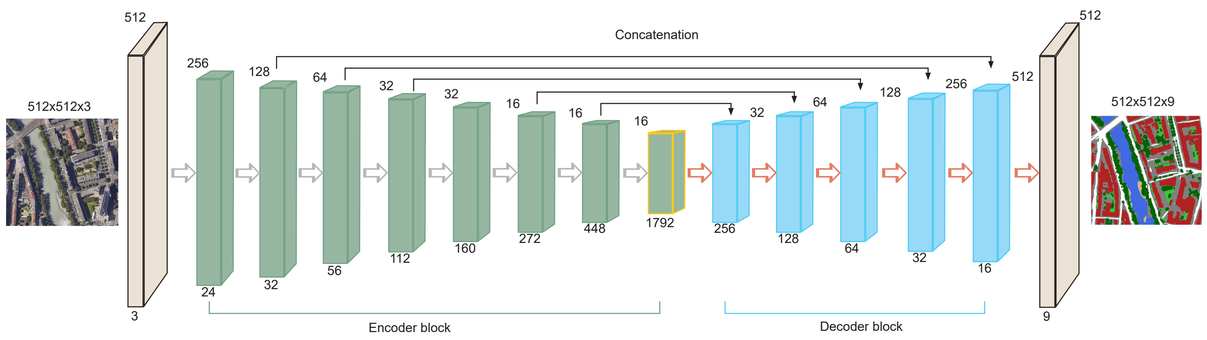
For every Swiss Household Panel (SHP) survey household living at a postcode with at least 10,000 inhabitants, satellite images of their neighborhoods are scraped from Google Static Maps API. The images surrounding the household are sized 420m x 420m or 1260m x 1260m. This allows to use 4,272 observations out of 15,675 located in 141 cities and municipalities.

Methods

A bagged U-Net ensemble with an Efficient-Net B4 encoder was trained on the OpenEarthMap [6] dataset to segment the input image into eight land cover classes. The Efficient-Net B4 model weights were initialized with ImageNet weights. For the final prediction, as for inference test time augmentation (TTA) was applied.

For every tile (e.g. 420m x 420m) the proportion covered by each land cover class was calculated. An OLS regression was estimated with life satisfaction as endogenous and the land cover classes as exogenous variables. Furthermore, the OLS regression contains control variables such as equivalized household income, age, gender, children, civil status, occupation, education, community type, residence type, and tenure. The analysis is based on individuals. Since Swiss cities are relatively small and less urbanized than large European cities, the analysis is repeated for highly urbanized postcodes with more than 20,000 inhabitants.

U-Net with Efficient-Net B4 encoder



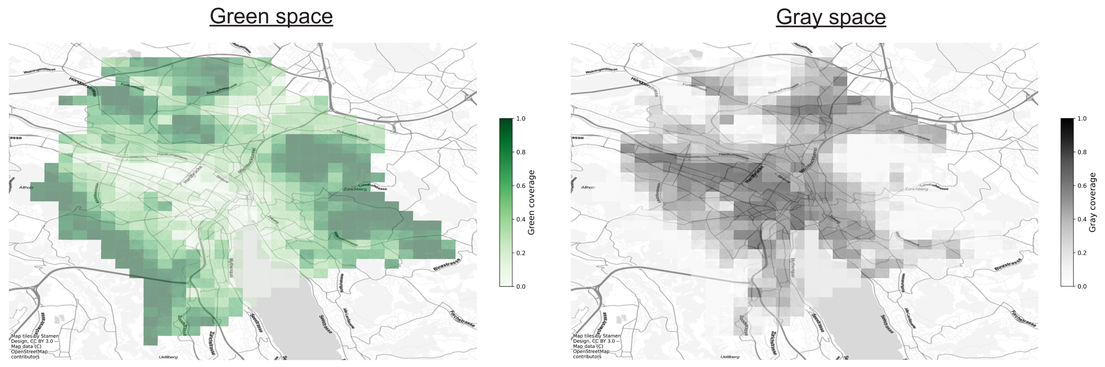
Model performance

Metric	Bareland	Rangeland	Agriculture	Trees	Water	Roads	Dev. space	Buildungs	Average
IoU	45.59	54.96	83.42	73.73	88.62	64.72	55.19	80.54	68.31
F1 score	0.604	0.709	0.909	0.847	0.940	0.786	0.711	0.892	0.800

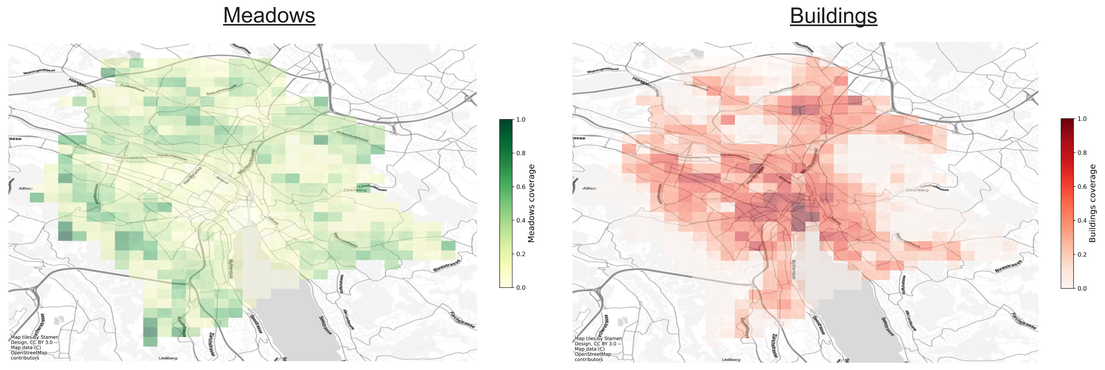
Observed life satisfaction values and neighborhood land cover for Zurich

3 RESULTS

Proportion covered by green and gray space for Zurich

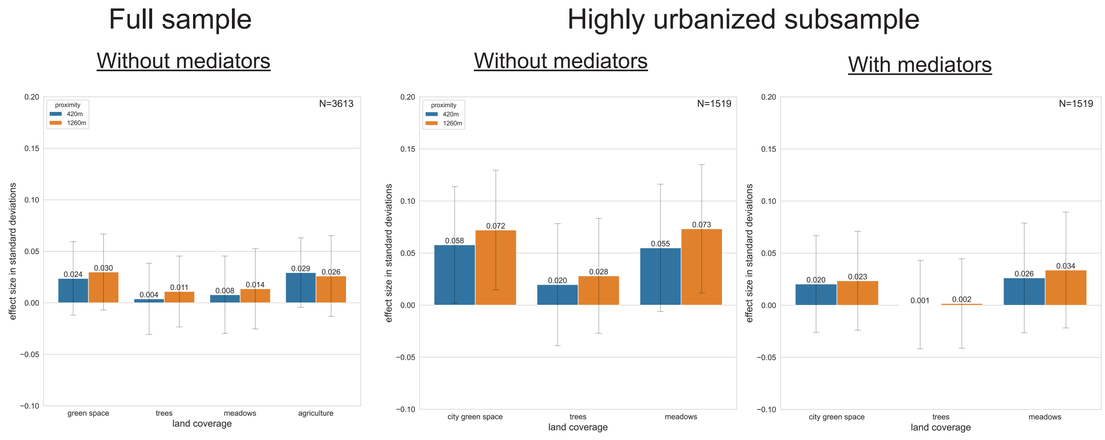


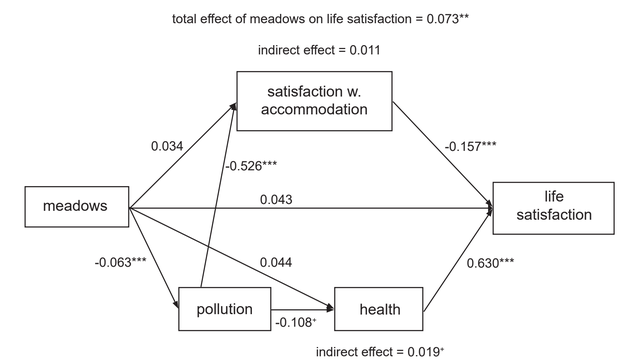
Proportion covered by meadows and buildings for Zurich



Note: Land coverage values range from 0 to 1 and correspond to the proportion covered by a land cover class. Green coverage is the sum of the proportion of trees, meadows, and agriculture. Gray coverage is the sum of the proportions of roads, developed space, and buildings. The depicted tiles have a size of 420m x 420m.

Associations of land cover classes with life satisfaction by proximity





Note: Selected estimates from OLS regression. Individual-demographic, socio-economic, household, and neighborhood characteristics are added but are not displayed. The coefficients can be interpreted as the effect a one standard deviation change in the proportion of a land cover class on standardized life satisfaction. Cluster and heteroskedasticity robust standard errors are applied. Green space is the sum of the proportion of trees, meadows, and agriculture. City green space is the sum of the proportion of trees and meadows. The proximity indicates the distance from the household to the border of the tile. Only observations located in a postcode with at least 20,000 inhabitants are included in the highly urbanized subsample.

4 CONCLUSION

General finding

This work finds no general association between greenness and life satisfaction. A positive association is found only in a subsample focusing on highly urbanized postcodes. This effect is mainly driven by meadows and not by tree coverage. However, it is small (0.055, respectively 0.073) for a standard deviation change in meadow coverage.

Mediation analysis

A mediation analysis reveals that meadows do not directly affect life satisfaction. The satisfaction with the accommodation seems not to mediate this effect. However, there is an indirect effect of meadows on self-reported pollution, affecting health and life satisfaction.

Limitations

The analysis is conducted with cross-sectional data, and causal interpretations should be cautiously made. The research focuses on land cover classes; however, cover does not imply usage. However, usage can be a decisive factor in the relationship of greenness on life satisfaction.

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Selected References

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