Soil Compaction and Plant Biodiversity in Green Spaces Along Dublin's Urbanisation Gradient

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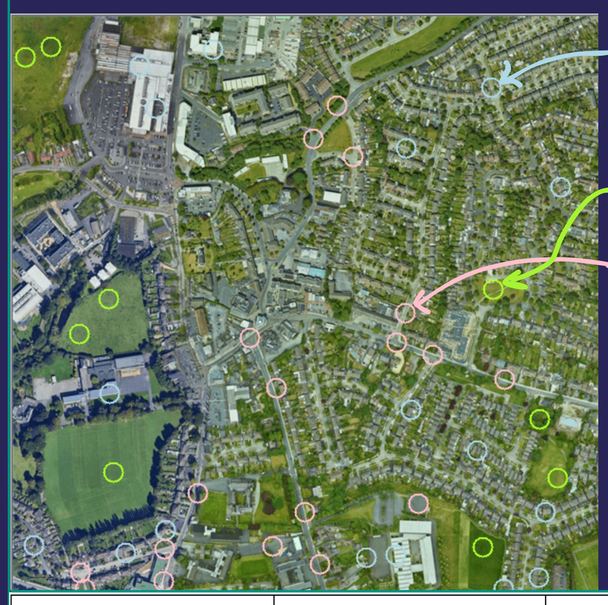
Abstract

In an age of increased awareness about environmental health, urban green spaces are lauded as bastions of biodiversity and habitat restoration. Many of these spaces experience some level of disturbance, like parks and sports fields experience heavy foot traffic, and others are formerly developed either by roads or buildings. When soil is compacted by human activities or structures, the individual grains of soil are closer together, creating less space between the soil grains for water and air, essential ingredients for plant life. Despite the evident links between these factors, no studies exist relating urban soil structure and urban land's capacity to support a diverse and robust ecosystem. Here we show that there is no statistically significant correlation between the level of urbanisation, bulk density of the soil, and plant biodiversity. Taking the average of the bulk density, a measure of compaction, for rural, peri-urban, and urban samples, we see that the higher average bulk density in urban samples supports our hypothesis. However, due to the high standard deviation, a correlation could not be established. This contradicts previous assumptions and indicates that more rigorous experimentation is needed.

Example of UrbanIndex Site Analysis



Site L16, with an urbanisation score of 2.48, 3 unique species, and a soil bulk density of 3.625 g/cm^3

Rural			Peri-Urban			Urban		
Urbanisation Score	Bulk Density (g/cm^3)	# of Unique Species	Urbanisation Score	Bulk Density (g/cm^3)	# of Unique Species	Urbanisation Score	Bulk Density (g/cm^3)	# of Unique Species
-3.43501	1.648	5	-0.792318	2.637	6	1.70052	2.637	6
-3.33694	3.296	6	-0.567818	0.989	5	1.96225	4.285	6
-2.89431	4.944	7	-0.31932	2.637	8	2.4407	3.296	8
-2.85859	1.978	10	-0.0587186	4.614	7	2.54149	3.626	3
-2.49259	1.978	6	0.313867	3.955	9	2.68344	4.944	6
-2.32105	1.648	6	0.561342	0.659	4	2.96527	6.592	6
-1.12554	3.296	6	1.60024	2.966	3	3.28794	6.592	1
Average Density (g/cm^3)	2.684		Average Density (g/cm^3)	2.637		Average Density (g/cm^3)	4.567	
Standard Deviation	1.225		Standard Deviation	1.437		Standard Deviation	1.563	
Average # of Unique Species	6.571		Average # of Unique Species	6.000		Average # of Unique Species	5.143	
Standard Deviation	1.618		Standard Deviation	2.160		Standard Deviation	2.340	

Methodology

Sites were selected using Random.org to generate true random coordinates between the latitudes 53.636018 and 53.179926, and longitudes -5.998313 and -6.547433, encompassing County Dublin.

Each generated coordinate pair was checked against the Copernicus Urban Atlas Land Use map, and 21 pairs falling within zones designated as Green Urban Areas (14100), Forests (31000), or Herbaceous Vegetation (32000) were selected for survey.

Each selected site was analysed by the Keplab UrbanizationScore software, a semi-automated scoring system using a 1 kilometre squared area of satellite imagery. An urbanisation score was calculated using principal component analysis. As the parameters of urban, peri-urban, and rural locations are largely subjective, the locations were divided into 3 groups of 7 by urbanisation score, with the highest scores being designated as urban, the middle 7 scores as peri-urban, and the lowest being rural.

At each site, a 1 metre by 1 metre quadrat underwent a survey of plant species, and a soil sample was collected from within the quadrat. Using a trowel, a hole was dug and a sample cylinder with an internal volume of 15.17 g/cm3 was inserted into the soil parallel to and less than 1 centimetre from the surface. The sample was then weighed and dried in an oven at 105° Celcius for 24 hours. The dry weight was used to determine the bulk density of soil.

Results

The data showed that average soil bulk density was roughly the same between rural and peri-urban samples, and that the average soil bulk density was roughly 1.7 times higher in urban samples. The standard deviation for density increased in each subset of samples between rural and urban, indicating a higher variance in bulk density as urbanisation scores increased. The average number of unique plant species correlated negatively with each urbanisation score subset, while the standard deviation increased. There were several outliers.

Chi-squared tests were performed on the data as a whole, and on each urbanisation subgroup. Regardless of the configuration, none of the results met the α=0.05 threshold for statistical significance. Similarly, the f-test and Student's t-test results did not meet any threshold for statistical significance.

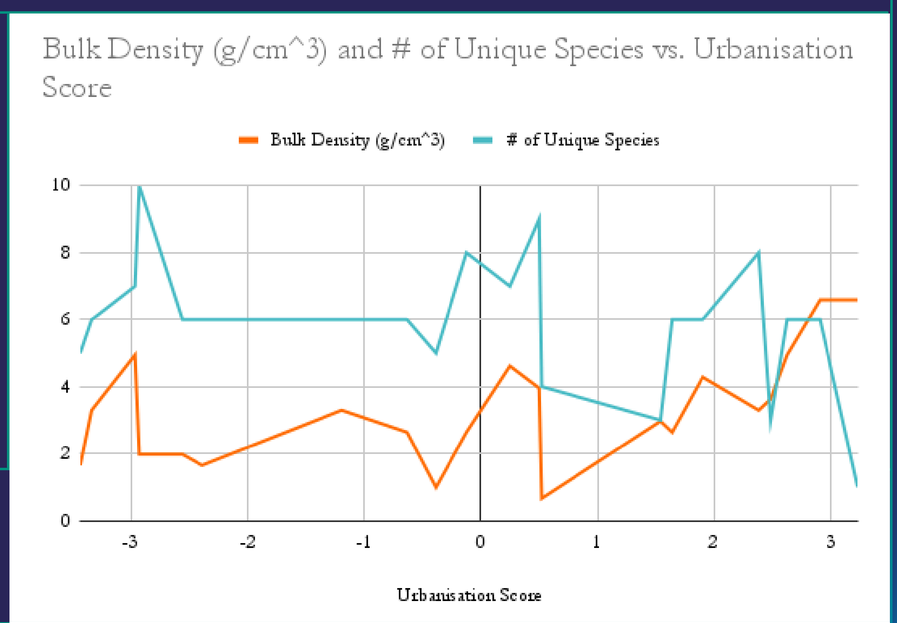
Discussion

This study found that none of the results were statistically significant. This may be due to the small sample size, where the few outliers could have skewed the data significantly. Additionally, there is practical significance in the data collected. The average results of each subset are in line with the hypothesis, despite not formally supporting it. The results also indicated that the difference between rural and peri-urban may be less than the difference between peri-urban and urban in both average soil bulk density and average number of unique species.

Interestingly, when visualising soil bulk density and number of unique species together, many of the peaks aligned for rural and peri-urban samples, but had no correlation for urban samples. This would suggest that for rural and peri-urban samples, there was a positive correlation between soil bulk density and number of unique species and an unclear correlation between urban soil bulk density and number of unique species. Ultimately, because the results were not statistically significant, further study needs to be done. An increased sample size in sites analysed, soil samples taken within the 1 km by 1 km location, and quadrats surveyed within the locations would likely provide more rigorous results.

Conclusion

This study aimed to quantify the impact of urbanisation on soil compaction levels and, in turn, plant biodiversity. The results did not indicate any statistically significant relationship between urbanisation scores, soil bulk density, and number of unique species per square metre. However, despite not meeting the criteria for statistical significance, the average density of urban soils was 1.7 times higher than that of peri-urban or rural samples and the average number of unique species correlated negatively with the urbanisation score and soil bulk density. This indicates that further study is needed, specifically with a larger sample group and with more factors taken into account. Sorting samples into subgroups based on current use and development history may provide the additional context needed to understand the way human activity impacts soil and ecosystem health. Furthermore, the role of soils in urban ecosystems must continue to be studied to create more sustainable cities.



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