Humans Structure The Ecosystem Properties of Cities: Findings from Survey 200

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Abstract

We did an extensive integrated inventory to answer the question: "To what extent do human variables contribute to explaining spatial variation in the basic ecological properties of an urban ecosystem?" Geophysical, geographic and human characteristics from the field survey, supplemented with geographic and socio-economic variables were used to model two key dependent variables: plant diversity and soil NO_3-N content. In the desert variation in both plant diversity and soil nitrate-N was relatively low and spatially auto-correlated. Plant diversity and soil nitrate-N in urban plots showed no spatial autocorrelation and huge between-site variation. Urban soil N was significantly higher than in the desert and was best modeled by human population density and impervious surface cover. Plant diversity was highest in the desert and urban areas and lowest for agricultural sites. Desert plant diversity was best modeled by including elevation, average age of housing, and distance from urban center. Urban plant diversity was best explained by housing age, median family income and whether the site was ever in agriculture. The positive plant diversity-income relationship is particularly interesting - neighborhoods with a median family income level above $50,000 per year had on average 2.3 times the plant diversity of less wealthy areas. Distance from urban center was largely unimportant in explaining system-wide patterns.

Further Work:
Additional analyses have already shown that there is an **inverse** correlation between soil N and plant diversity at the urban sites which is not present in desert plots.

Soil N → *Plants* → *Insects & Birds*

Future work will focus on:
- developing allometric relationships to convert plant volume to biomass estimates for the survey data
- examining how urbanization affects the trophic links between the soil-plant-animal system

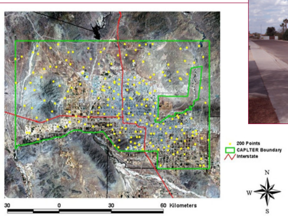
Key Question:
"To what extent do human variables contribute to explaining spatial variation in the basic ecological properties of an urban ecosystem?"

INPUT DATA

The predictor variables were: latitude, longitude, elevation, housing density, distance from the site to the center of the study area, distance to nearest major highway, percent impervious surface, whether the site had ever been farmed, land use, average housing age, average family income and human population density – the latter three from the appropriate US Census block group.

STATISTICAL ANALYSES

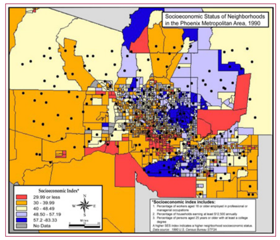
Field Survey



Typical survey site: A synoptic integrated field inventory of key biotic, abiotic and some human variables was carried out in 30m x 30m field plots over a 3-month period in spring 2000 at the 204 survey locations.

Field sampling scheme: We used a dual-density randomized tessellation stratified design (above) to obtain a spatially dispersed, representative and unbiased sample of the study area. There was a sampling density inside:outside the developed urban core of 3:1. The application of probability-based sampling at this scale across an urban area is unique.

Additional data



Geographic and socioeconomic variables were obtained from existing CAP LTER databases and from the US Census block group immediately surrounding each of the survey sites.

Soil nitrogen

SOIL N Log transform → Gaussian distribution → Plotted semi-variogram to test for spatial auto-correlation

- YES → DESERT Ordinary least squared model applied → DESERT Spherical semivariogram fitted → URBAN Generalized least squares used to make inferences → DESERT NO variables significant
- NO → URBAN Ordinary least squared regression applied → DESERT Backward elimination used to id significant variables → URBAN TWO explanatory variables

SPATIAL AUTOCORRELATION?

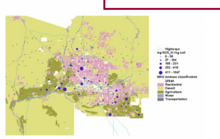
Plant diversity

PLANT DIVERSITY Square root transformed → Poisson distribution → Used Pearson residuals to test for spatial auto-correlation

- YES → DESERT Ordinary least squared model applied → DESERT Spherical semivariogram fitted to residuals → DESERT Generalized least square techniques used to make inferences → DESERT THREE explanatory variables
- NO → URBAN Generalized linear model fitted → URBAN Quasi-likelihood techniques applied → URBAN THREE (different) explanatory variables

SUMMARY STATISTICS

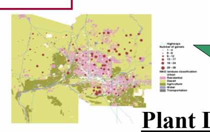
Soil nitrogen



Soil N

(mg/kg extractable NO_3-N)

Plant diversity



Plant Diversity

(number of woody genera per plot)

Table 1

All Sites	*Urban*	*Desert*		*All Sites*	*Urban*	*Desert*
38.2	42.2	6.8	*Mean*	6.8	8.0	8.4
101.7	91.6	7.7	*Std. Dev.*	6.5	7.1	5.5
0.1 – 1046.8	0.1 – 647.6	0.4 – 36.2	*Range*	0 to 39	0 to 39	1 to 24

Conclusions

1) **Urbanization** appears to **replace** a **'neighboring' dependence** in the desert with **'local' dependence** on in the city, the latter comprising a combination of deliberate and inadvertent human activities. These **site-specific factors** operate at a very local scale & show **very high spatial variation**.
2) This **spatial complexity in cities is** not 'noise' but rather **a basic characteristic generated by the intensive human management**; this complexity is attenuated by capital resources and shaped by social forces.
3) The **linear urban-rural gradient paradigm is inappropriate** for more recent urban developments exemplified by the new multi-centered 'Sun-belt' cities of the south western US such as Phoenix.

BEST FIT MODELS

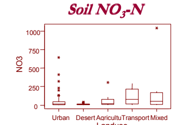
Table 2. Model results for soil N and plant diversity. Significant variables are listed in order of importance as judged by the test statistic (t value, Chi-square or F value) and level of significance denoted by asterisks (*** = P<0.0001; ** = P<0.001; * = P<0.01; no asterisk P<0.05). Where independent variables have a negative relationship with the dependent variable in the model is denoted by (-ve).

	All Sites	*Urban sites only*	*Desert sites only*
Soil N	Land use - desert*** (-ve) - urban** (-ve) - agriculture (-ve) Population density** Latitude* (-ve) Impervious surface* (-ve)	Populations density*** Impervious surface* (-ve)	None
Plant Diversity	Land use - urban*** - agriculture * (-ve) Elevation *** Family income ** Ever farmed (-ve)	Family income* Mean housing age* (-ve) Ever farmed (-ve)	Elevation*** Distance from urban center * (-ve) Mean housing age

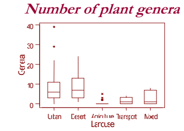
Main Findings:

1) Across the **whole study area**, spatial variation in soil nitrate and plant diversity was best explained by a **combination** of both geophysical and human-related variables (Table 2).
2) In **desert** plots, spatial variation in plant diversity and soil nitrate-N was low (Table 1); **both variables** showed **spatial auto-correlation.**
3) In **urban** plots, plant diversity and soil nitrate-N showed **no spatial autocorrelation** and **large between-site variation**, suggesting a **finer-scale patterning** of soil N and plant diversity in **urbanized areas** than in the desert.
4) The highest **soil N** pools were found in more **heavily populated neighborhoods** with **a high pervious surface area**, as well as besides major roads and in some of the mixed land use plots.
5) **Urban plant diversity** was best explained by **human variables**, in particular **median family income** - neighborhoods with a median family income level **above $50,000** per year had on average **2.3 times** the plant diversity of less wealthy areas.
6) **Distance from urban center** was **largely unimportant** in explaining system-wide patterns.

Soil NO_3-N



Number of plant genera



Plant diversity vs income