Advanced GIS

Raphaëlle ROFFO

Sciences Po - Urban School

Session 5

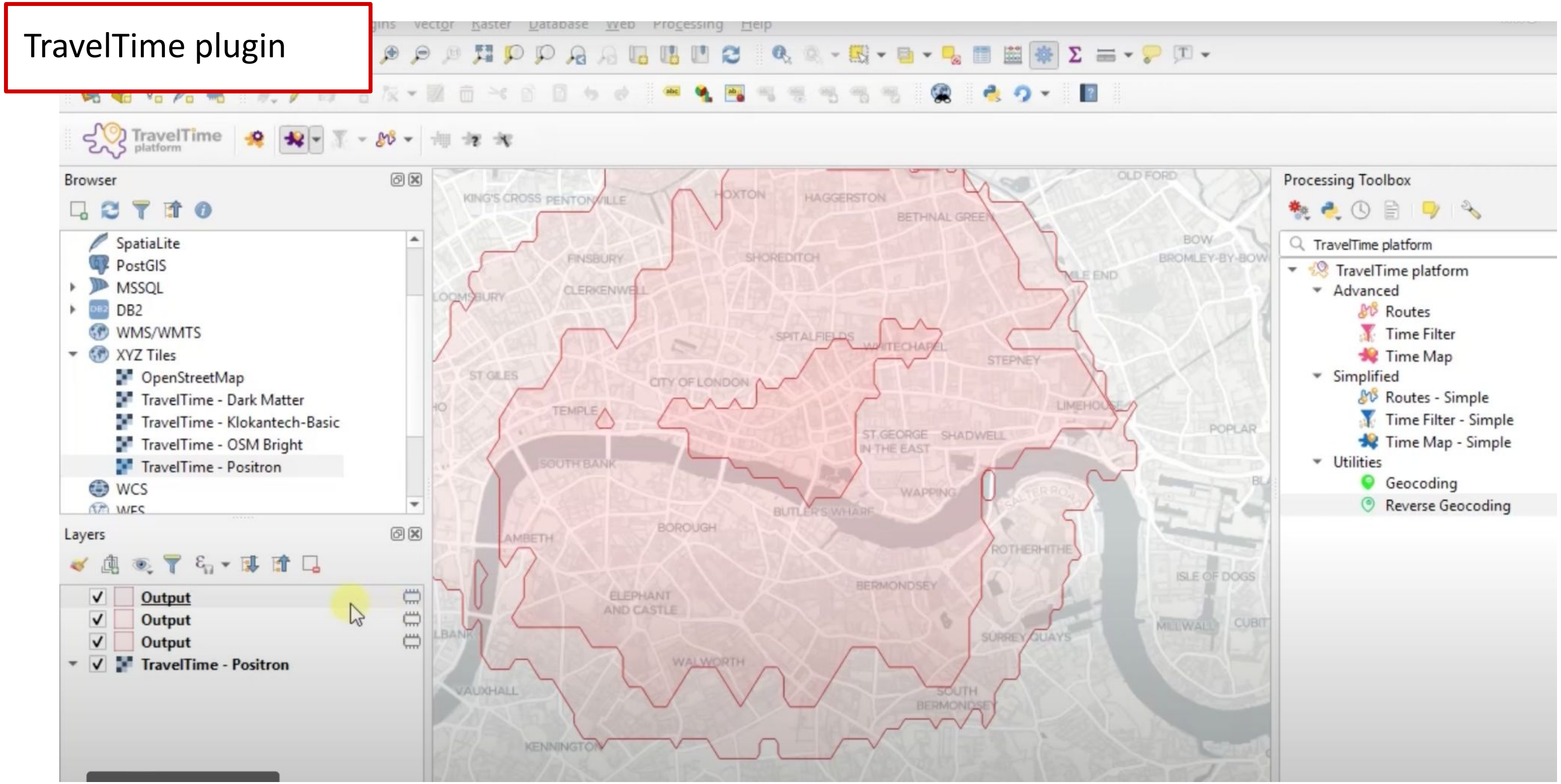
Multi-Criteria Decision Analysis in GIS

Today’s plan

1. Isochrones / Cartogram tutorial: Feedback, Q&A
2. Environmental Justice in GIS
3. Multi criteria decision analysis

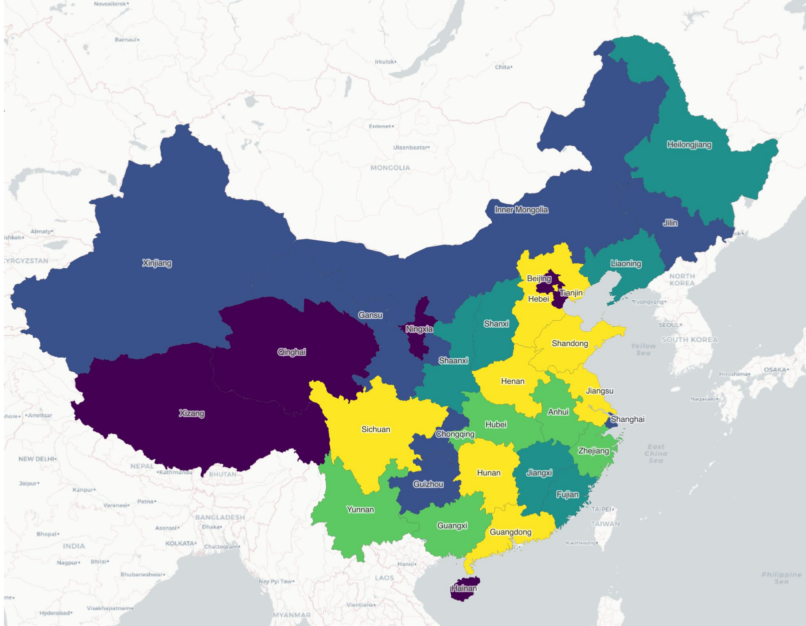
Session 5 Tutorial

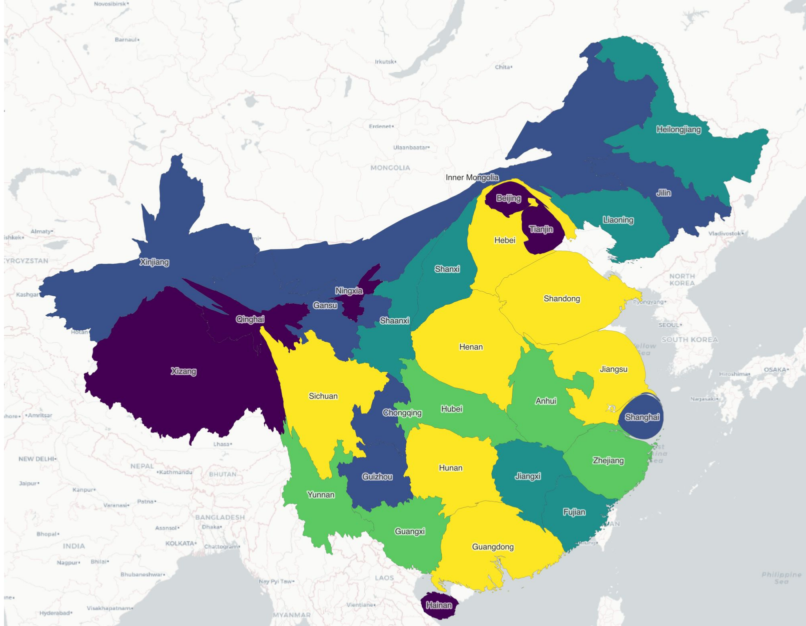
Isochrones using TravelTime



Population density cartogram

You can now see how combining a **cartogram of population density** with a **choropleth of absolute population numbers** can provide a finer understanding of population trends across China (look at large metropolitan areas such as Shanghai, Beijing, Guangdong, Hainan!)





Questions

Environmental Justice & GIS

Environmental Justice in GIS

GIS provides powerful tools to question the links between social and environmental variables, especially under an environmental justice framework.

By now you have acquired enough skills to be able to combine social and environmental datasets, and explore their spatial patterns.

Asthma and air pollution in the Bronx: Methodological and data considerations in using GIS for environmental justice and health research

Juliana Maantay

Show more

Share Cite

https://doi.org/10.1016/j.healthplace.2005.09.009

Abstract

This paper examines methods of environmental justice assessment with Geographic Information Systems, using research on the spatial correspondence between asthma and air pollution in the Bronx, New York City as a case study. Issues of spatial extent and resolution, the selection of environmental burdens to analyze, data and methodological limitations, and different approaches to delineating exposure are discussed in the context of the asthma study, which, through proximity analysis, found that people living near (within specified distance buffers) noxious land uses were up to 66 percent more likely to be hospitalized for asthma, and were 30 percent more likely to be poor and 13 percent more likely to be a minority than those outside the buffers.

Environmental Justice in GIS

A GIS–Environmental Justice Analysis of Particulate Air Pollution in Hamilton, Canada

Michael Jerrett, Richard T Burnett, Pavlos Kanaroglou, , , , more... Show all authors

First Published June 1, 2001 | Research Article
https://doi.org/10.1068/a33137

Abstract

The authors address two research questions: (1) Are populations with lower socioeconomic status, compared with people of higher socioeconomic status, more likely to be exposed to higher levels of particulate air pollution in Hamilton, Ontario, Canada? (2) How sensitive is the association between levels of particulate air pollution and socioeconomic status to specification of exposure estimates or statistical models? Total suspended particulate (TSP) data from the twenty-three monitoring stations in Hamilton (1985–94) were interpolated with a universal kriging procedure to develop an estimate of likely pollution values across the city based on annual geometric means and extreme events. Comparing the highest with the lowest exposure zones, the interpolated surfaces showed more than a twofold increase in TSP concentrations and more than a twentyfold difference in the probability of exposure to extreme events. Exposure estimates were related to socioeconomic and demographic data from census tract areas by using ordinary least squares and simultaneous autoregressive (SAR) models. Control for spatial autocorrelation in the SAR models allowed for tests of how robust specific socioeconomic variables were for predicting pollution exposure. Dwelling values were significantly and negatively associated with pollution exposure, a result robust to the method of statistical analysis. Low income and unemployment were also significant predictors of exposure, although results varied depending on the method of analysis. Relatively minor changes in the statistical models altered the significant variables. This result emphasizes the value of geographical information systems (GIS) and spatial statistical techniques in modelling exposure. The result also shows the importance of taking spatial autocorrelation into account in future justice – health studies.

Using GIS to Assess the Environmental Justice Consequences of Transportation System Changes

Jayajit Chakraborty, Lisa A. Schweitzer, David J. Forkenbrock

First published: 17 December 2002 | https://doi.org/10.1111/1467-9671.00020 | Citations: 31

Abstract

Although environmental justice research has typically focused on locations of industrial toxic releases or waste sites, recent developments in GIS and environmental modeling provide a foundation for developing measures designed to evaluate the consequences of transportation system changes. In this paper, we develop and demonstrate a workable GIS-based approach that can be used to assess the impacts of a transportation system change on minorites and low-income residents. We focus specifically on two adverse affects: vehicle-generated air pollution and noise. The buffer analysis capabilities of GIS provide a preliminary assessment of environmental justice. We integrate existing environmental pollution models with GIS software to identify the specific locations where noise and air pollution standards could be violated because of the proposed system change. A comparison of the geographic boundaries of these areas with the racial and economic characteristics of the underlying population obtained from block level census data provides a basis for evaluating disproportionate impacts. An existing urban arterial in Waterloo, Iowa, is used to illustrate the methods developed in this research.

Environmental Justice in GIS

NIH Public Access
Author Manuscript
Appl Geogr. Author manuscript; available in PMC 2010 January 1.

Published in final edited form as:
Appl Geogr. 2009 January 1; 29(1): 111–124. doi:10.1016/j.apgeog.2008.08.002.

Mapping Urban Risk: Flood Hazards, Race, & Environmental Justice In New York”

Juliana Maantay[a] and **Andrew Maroko**[b]

[a]Corresponding Author, Associate Professor, Urban Environmental Geography, Director of GISc Program and Urban GISc Lab, Department of Environmental, Geographic, and Geological Sciences, Lehman College, City University of New York, 250 Bedford Park Blvd. West, Bronx, NY 10468, (718) 960-8574 (tel), (718) 960-8584, Juliana.maantay@lehman.cuny.edu

[b]Research Fellow, NOAA-CREST, Lehman College, City University of New York, The Graduate Center, City University of New York

Abstract

This paper demonstrates the importance of disaggregating population data aggregated by census tracts or other units, for more realistic population distribution/location. A newly-developed mapping method, the Cadastral-based Expert Dasymetric System (CEDS), calculates population in hyper-heterogeneous urban areas better than traditional mapping techniques. A case study estimating population potentially impacted by flood hazard in New York City compares the impacted population determined by CEDS with that derived by centroid-containment method and filtered areal weighting interpolation. Compared to CEDS, 37 percent and 72 percent fewer people are estimated to be at risk from floods city-wide, using conventional areal weighting of census data, and centroid-containment selection, respectively. Undercounting of impacted population could have serious implications for emergency management and disaster planning. Ethnic/racial populations are also spatially disaggregated to determine any environmental justice impacts with flood risk. Minorities are disproportionately undercounted using traditional methods. Underestimating more vulnerable sub-populations impairs preparedness and relief efforts.

Keywords

dasymetric; population mapping; environmental justice; flood hazard; New York City; cadastral; urban; 100-year flood

ELSEVIER

International Journal of Disaster Risk Reduction
Volume 43, February 2020, 101394

A place-based socioeconomic status index: Measuring social vulnerability to flood hazards in the context of environmental justice

Liton Chakraborty, Horatiu Rus, Daniel Henstra, Jason Thistlethwaite, Daniel Scott

Show more

Share Cite

https://doi.org/10.1016/j.ijdrr.2019.101394 Get rights and content

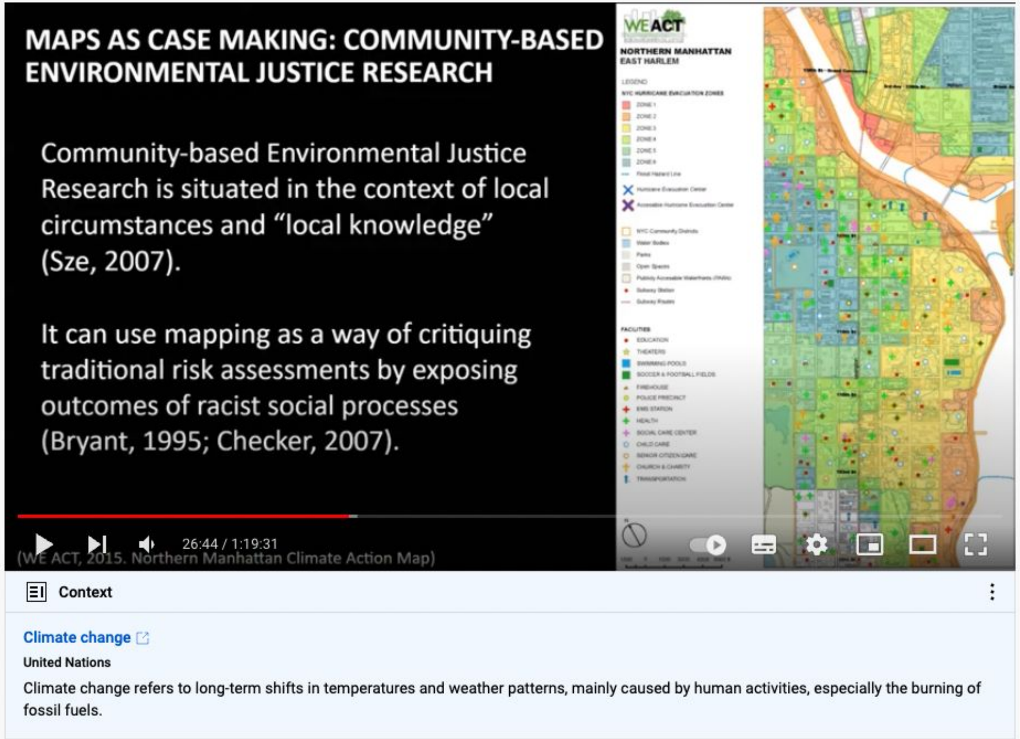
Abstract

This paper proposes a national-level socioeconomic status (SES) index to measure place-based relative social vulnerability and socioeconomic inequalities across Canada. The aim is to investigate how disparities in overall socioeconomic status influence environmental justice outcomes for Canadian flood risk management planning and funding structures. A micro-dataset of the 2016 Canadian census of population was used to derive a comprehensive SES index over 5739 census tracts. The index comprises 49 theoretically-important and environmental policy-relevant indicators of vulnerability that represent diverse aspects of socioeconomic, demographic, and ethnicity status of Canadians. Bartlett's test of sphericity, Kaiser-Meyer-Olkin measure of sampling adequacy, Cronbach's alpha scale reliability, and goodness-of-fit for factor's solution were employed to assess validity, reliability, and consistency in the dataset before applying principal components analysis. Our data revealed 11 statistically-significant multidimensional factors, which together explained 80.86% of the total variation. Levene's homogeneity of variance test disclosed a considerable socioeconomic disparity across census tracts, census metropolitan areas (CMAs), and provinces/territories in Canada. Social vulnerability tends to be geographically stratified across Canada. For example, Drummondville, Saguenay, and Granby CMAs (all in Quebec) had the lowest SES scores, whereas Vancouver and Toronto CMAs had the highest SES scores. Prevalence of spatial variations in the SES scores has significant implications for appraising overall social well-being and understanding the relative social vulnerability of population subgroups. The new place-based SES index has potential for assessing environmental justice outcomes in flood risk management at the census tract level.

Environmental Justice in GIS

1 hour Webinar by the Tishman environment & design centre

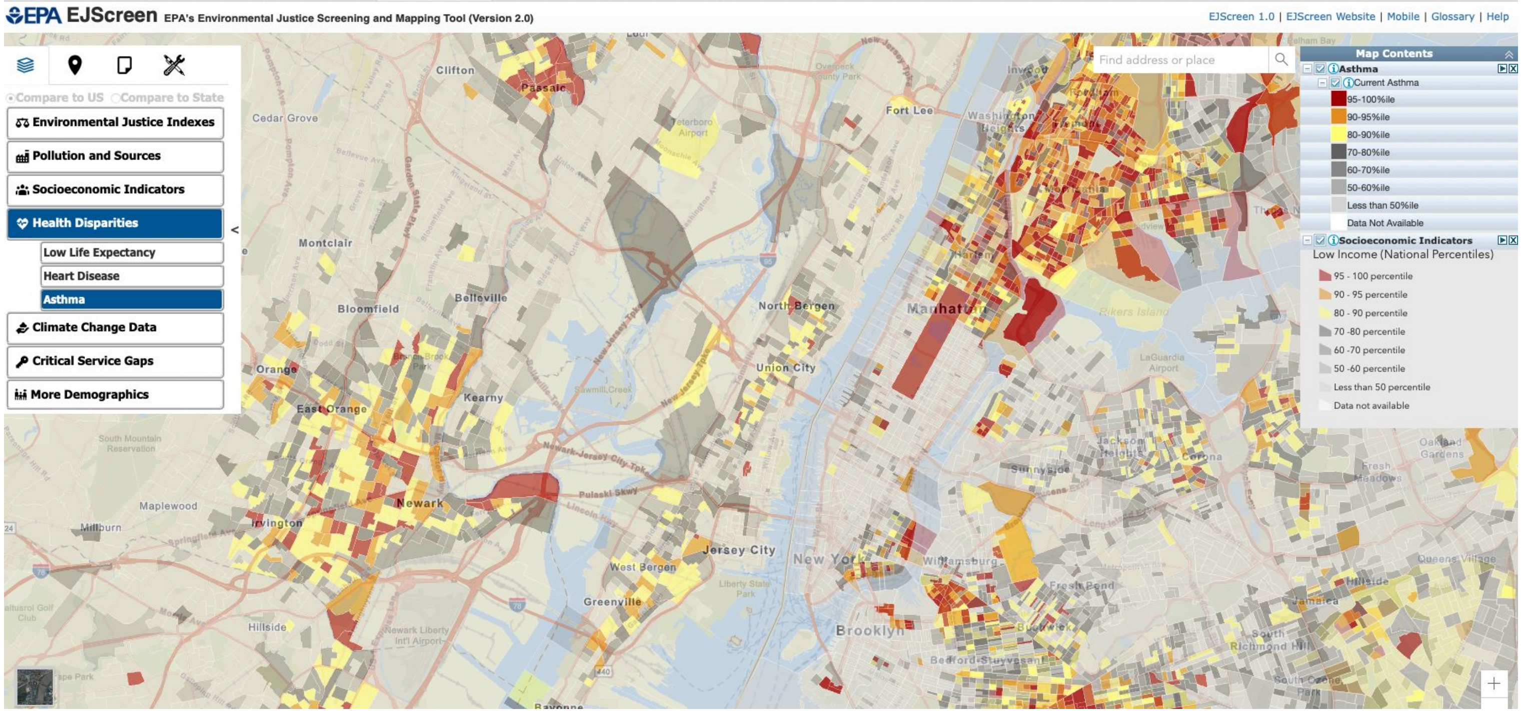
[Who Does Mapping Serve? GIS in Environmental Justice and Climate Change Research]



Who Does Mapping Serve? GIS in Environmental Justice and Climate Change Research

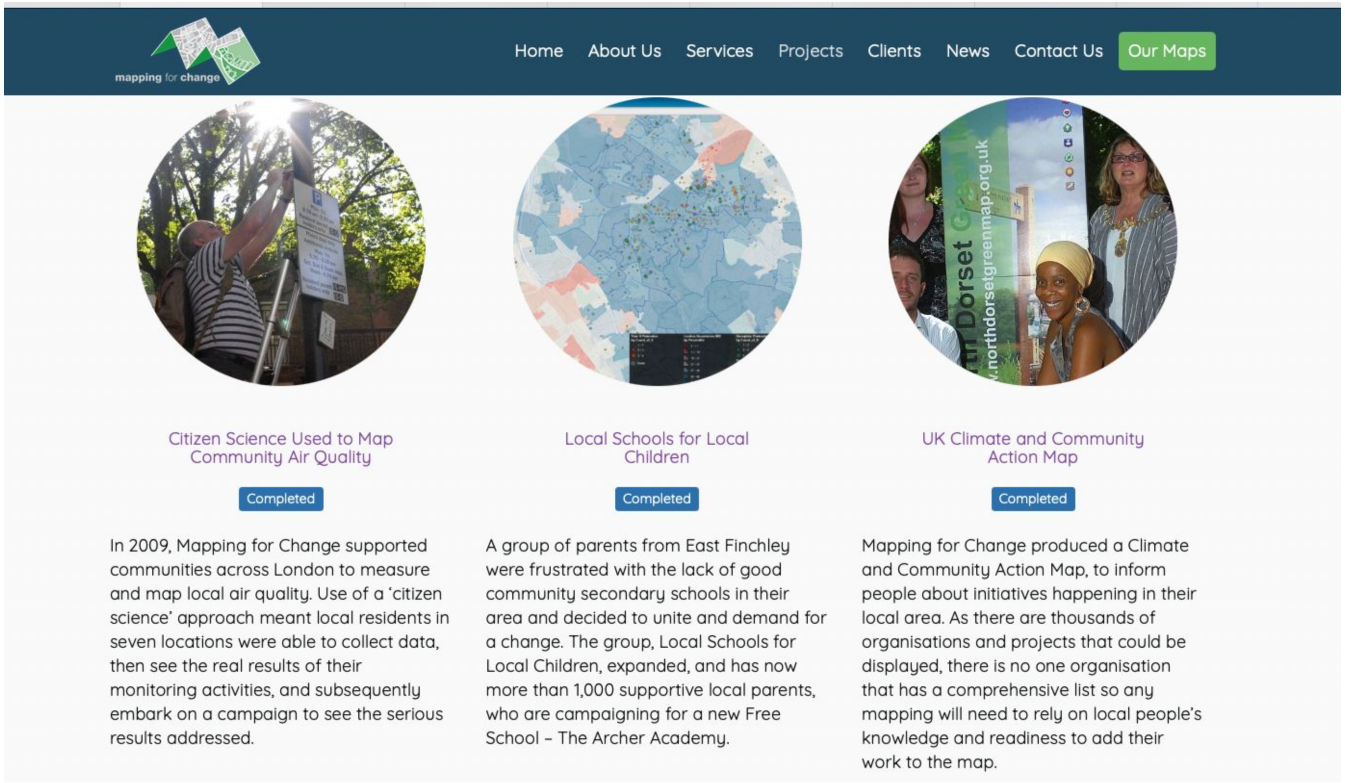
Environmental Justice in GIS

[EPA Environmental Justice tool]



Environmental Justice in GIS

[Mapping for Change UK Project]


mapping for change

Home About Us Services Projects Clients News Contact Us Our Maps

Citizen Science Used to Map Community Air Quality

Completed

In 2009, Mapping for Change supported communities across London to measure and map local air quality. Use of a 'citizen science' approach meant local residents in seven locations were able to collect data, then see the real results of their monitoring activities, and subsequently embark on a campaign to see the serious results addressed.

Local Schools for Local Children

Completed

A group of parents from East Finchley were frustrated with the lack of good community secondary schools in their area and decided to unite and demand for a change. The group, Local Schools for Local Children, expanded, and has now more than 1,000 supportive local parents, who are campaigning for a new Free School – The Archer Academy.

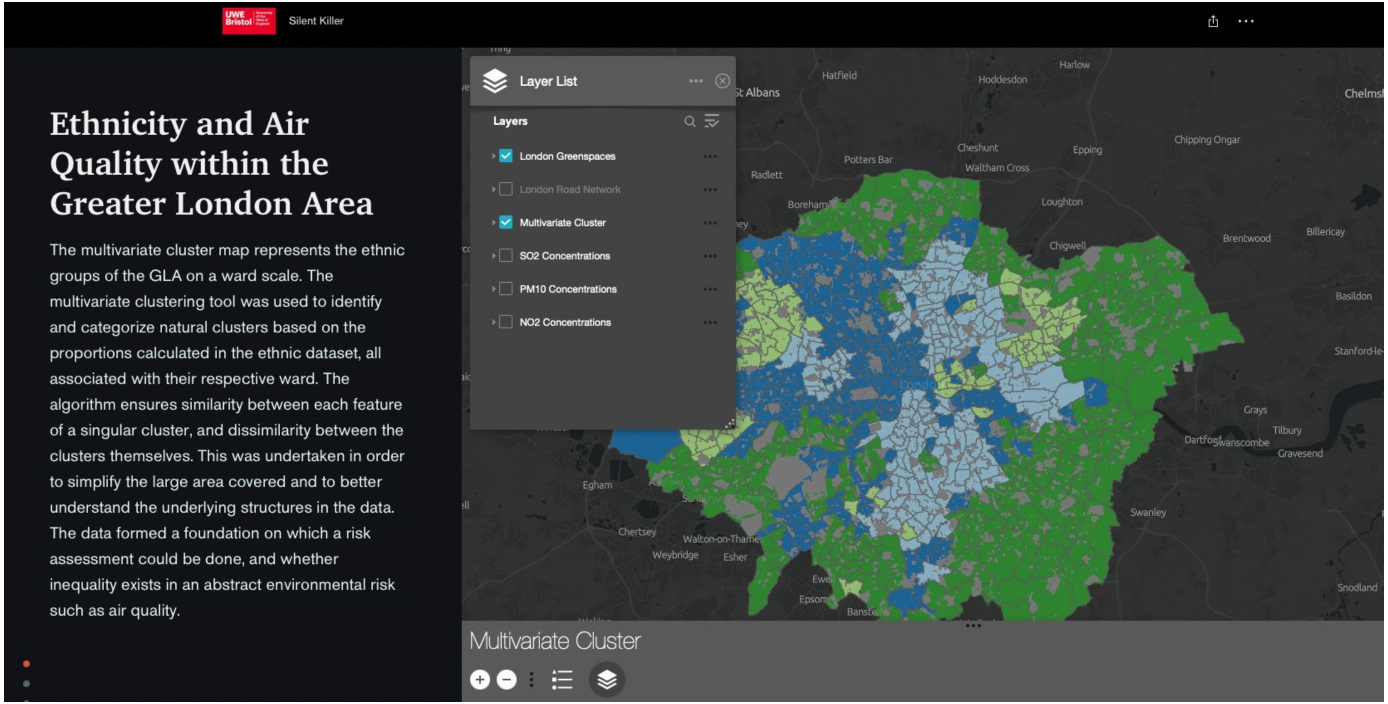
UK Climate and Community Action Map

Completed

Mapping for Change produced a Climate and Community Action Map, to inform people about initiatives happening in their local area. As there are thousands of organisations and projects that could be displayed, there is no one organisation that has a comprehensive list so any mapping will need to rely on local people's knowledge and readiness to add their work to the map.

Environmental Justice in GIS

[Air pollution in London: silent killer]



Critical Theory & GIS

GIS and Critical Theory

Critical theory seeks to challenge existing power structures, and questions how our cultural and social practices are the product of power dynamics.

Geographic Information Science has only recently and relatively marginally started to question the role of cartographic representations and the "scientific" status of GIS in supporting securitization of mainstream ideologies, including racist, colonialist, military and discriminatory practices.

Quantitative Limits to Qualitative Engagements: GIS, Its Critics, and the Philosophical Divide*

Agnieszka Leszczynski
University of Washington

Heated exchanges between critical theorists and GIScientists over geographic information systems (GIS) in 1990s geography gave rise to calls for increased communication between critics and practitioners of the technology and most recently for "hybrid" qualitative–quantitative GIS practices. Although GIS scholars have successfully addressed mid-1990s critiques of the technology by developing a series of critical GIS practices that involve nuanced and reflexive deployments of GIS and assessments of its visual products, theoretical critiques of GIS remain fixated on the epistemological deficiencies of the technology. Despite references to loosening metaphysical tensions across the discipline, this difference in assessments reveals the discourses of critical-theoretic geography and GIScience to remain separated by a trenchant philosophical divide, across which ontological and epistemological commitments are inviolable. The inability to fully reconcile a critical–theoretic epistemology with the explicitly ontological metaphysics of GIS further complicates qualitative engagements with the technology by addressing a series of inconsistencies into GIS praxis arising from the quantitative limits to representation encountered in the formal universe of computing. The persistence of metaphysical tensions in critical engagements with the technology questions the degree to which qualitative methods can be seamlessly hybridized with the quantitative architectures of GIS. **Key Words: critical geography, formal ontology, GIS, hybrid geographies, philosophical divide.**

GIS and Critical Theory

Critical GIS: Distinguishing critical theory from critical thinking

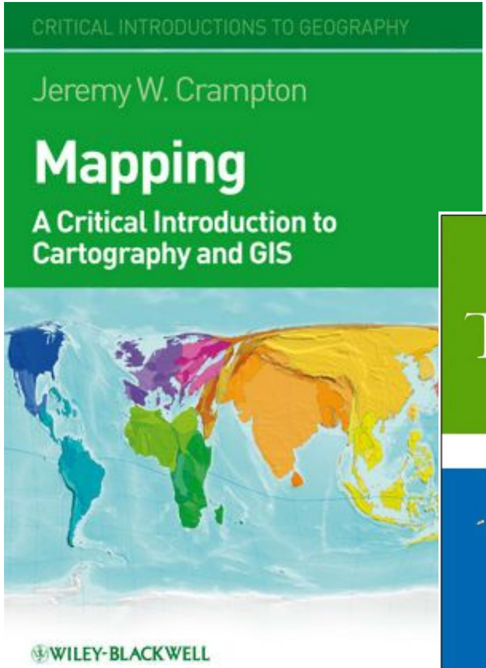
Francis Harvey
Leibniz Institute for Regional Geography

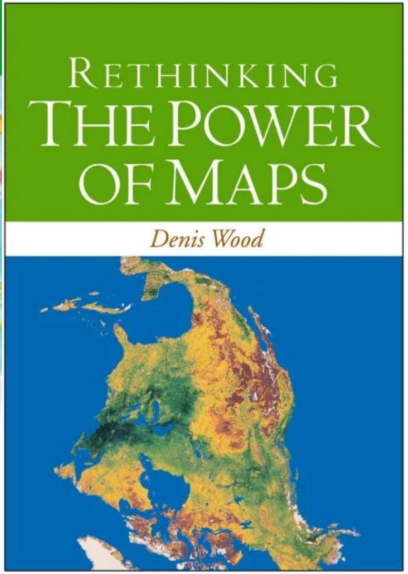
Key Messages

- Critical GIS benefits from distinguishing critical theory from critical thinking.
- This distinction speaks to the importance of integrity.
- Hybrids of critical theory and critical thinking continue to hold relevance.

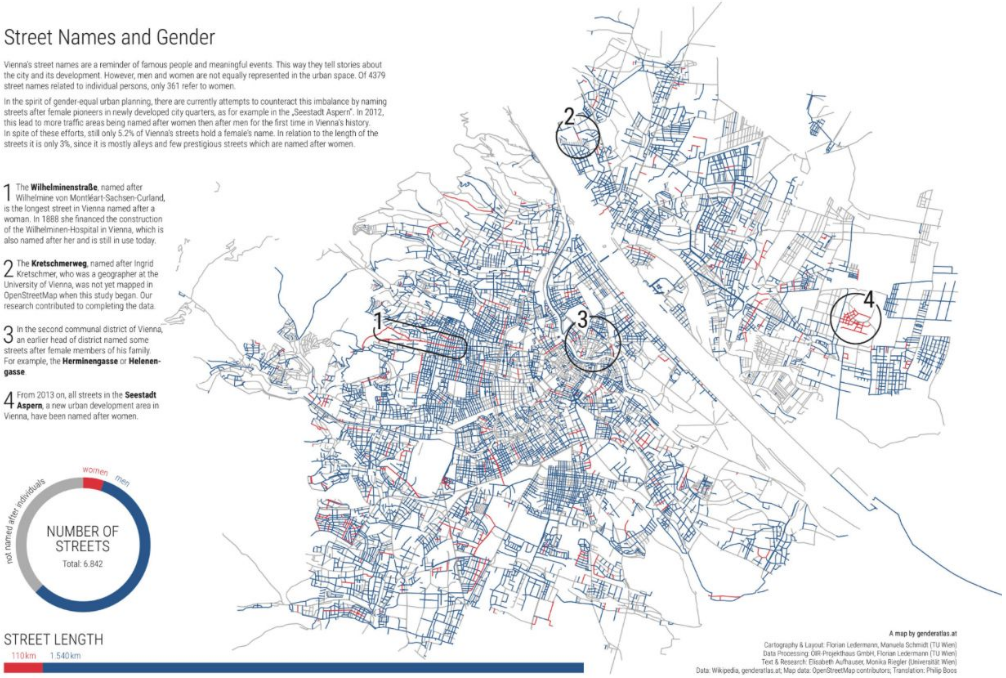
This viewpoint offers a perspective on how critical GIS and critical GIScience can develop and go further in times of widespread concern and unease around the world. The basis for this is the distinction between critical theory and critical thinking. Revisiting this difference, especially in the many hybrids involving theories and applications with geographic information technologies, is important for thinking and reflecting on broader issues and assuring the integrity of our work.

Keywords: critical GIS, theory, thinking, GIS2





GIS and Critical Theory

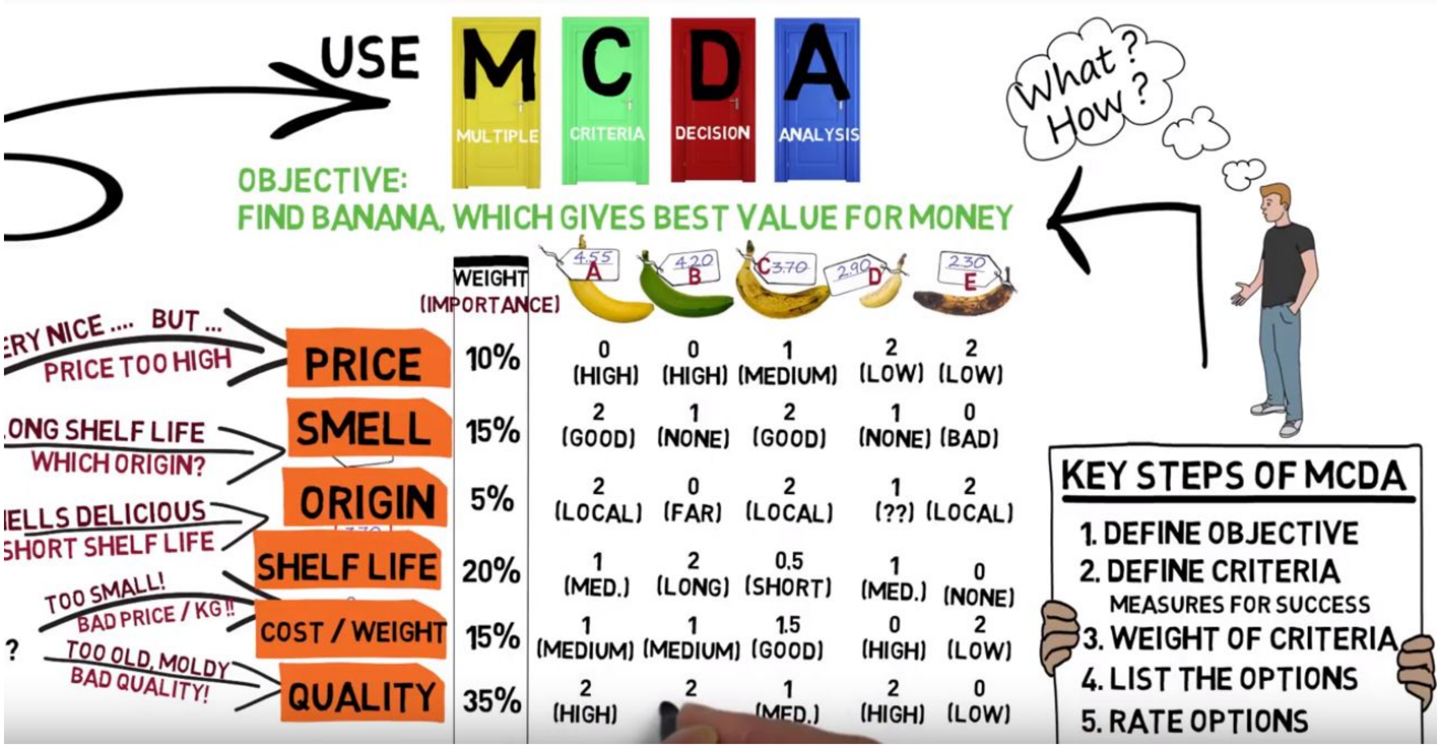


Three collectives that are very active in the critical cartography space:

- Counter cartographies (US)
- Bureau d'Etudes (France)
- Not an Atlas

Multi Criteria Decision Analysis
&
Weighted Overlays

Multi-Criteria Decision Making (MCDM)



GIS Multi-Criteria Decision Making

- Multi-Criteria Decision Making (MCDM), also known as Overlay Analysis, Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Analysis (MCA), is a framework for taking multiple variables into account when making a decision. It can be applied to spatial decisions using GIS-MCDM methodologies.

- The basic logic is that "*Many decisions depend on identifying relevant factors and adding their appropriately weighted values.*" (Longley, Goodchild et al, 2015). Obviously, different stakeholders will have different perspectives on which factors to take into account and their importance. In policy-making, public consultations can help determine the perspective of each stakeholder, and come up with a set of weights that is acceptable to all parties.

- GIS-MCDM method is especially useful when trying to solve problems such as land use suitability, site selection, etc. Please note that "suitability analysis" can also be carried out using vector geoprocessing (buffers, intersection tools, clipping etc), but typically when we talk about GIS-MCDM or Overlay analysis we refer to a raster data analysis method.

Suitability analysis: Vector vs Raster

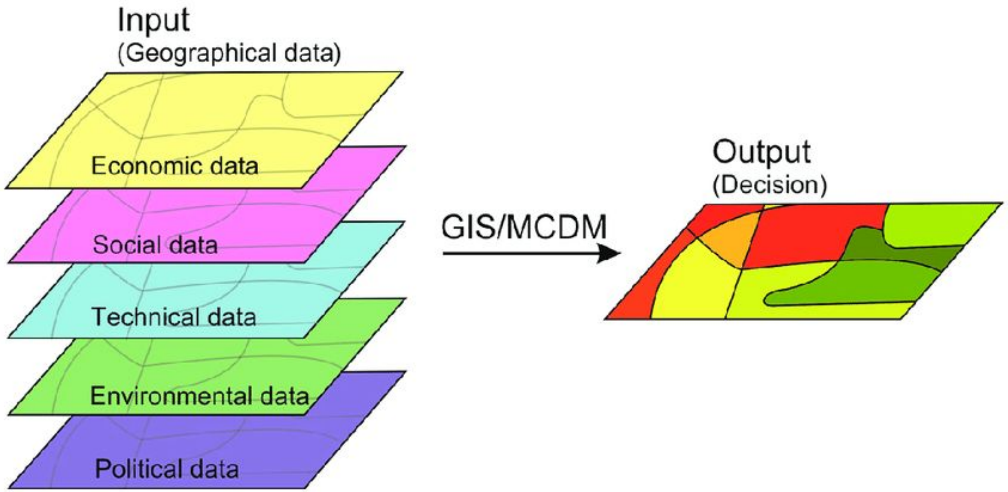
The following table summarizes the main geoprocessing stages, advantages, and pitfalls of suitability assessment with vector and raster data:

	Vector data	Raster data
Main geoprocessing and analysis operations	Buffering Clip overlay Intersection overlay Union overlay	Vector data rasterization Proximity raster creation Raster reclassification Raster algebra addition Raster algebra multiplication Raster algebra subtraction
Advantages	Workflow quickness Workflow simplicity Good representation of man-made features	Simple data reclassification Good representation of continuous features Crisp and fuzzy classes are possible Possibility to weigh different coverages according to their importance Various assessments are possible, such as binary, ranked, and weighted
Limitations	Provide only crisp classes Usually provides binary (yes/no) assessments only	Reclassification and ranking subjectivity Workflow complexity

Source: Bruy, A. and Svidzinska, D., 2015. *QGIS by Example*. Packt Publishing Ltd.

(GIS) Multi-Criteria Decision Making

Applied to GIS, MCDM consists in crossing different variables to determine an output (the decision).



GIS MCDM models: mathematical framework

Let's say you want to identify the zones that are most vulnerable to flooding in a given region.

- A number of factors influence vulnerability **I**, denoted by **X1** through **Xn**. For instance slope, land use, distance from water stream.
- The impact of each factor on vulnerability is determined by a transformation of the factor **f(X)**. For example, the factor distance would be transformed so that its impact decreases with increasing distance, whereas the impact of slope would be increasing.
- Then the combined impact of all of the factors is obtained by weighting and adding them, each factor i having a weight **wi**, which is determined by the GIS specialist, based on stakeholders' inputs.

$$I = \sum_{i=1}^{n} w_i f(x_i)$$

Table 15.1 An example of the weights assigned to three factors by one stakeholder. For example, the entry "7" in Row 1 Column 2 (and the 1/7 in Row 2 Column 1) indicates that the stakeholder felt that Factor 1 (slope) is seven times as important as Factor 2 (land use).

	Slope	Land use	Distance from stream
Slope		7	2
Land use	1/7		1/3
Distance from stream	1/2	3	

GIS MCDM Steps

1. **Define the problem/research objective:** this would typically include literature review to understand the domain and the local context.
2. **Definition of criteria and constraints**, based on literature research, analysis of historical data and potentially interviews with domain experts and stakeholders
3. **Reclassify/Transform the values** onto a relative scale to ensure the criteria can be comparable. For instance, transform a vector layer of a road into a raster layer of distance ranges to the nearest road.
4. **Weight the criteria**: think about each criteria's relevance to the final result, and it's importance compared to the other criteria.
5. **Combine the criteria** into a single layer.
6. **Results analysis** and validation, leading to the decision

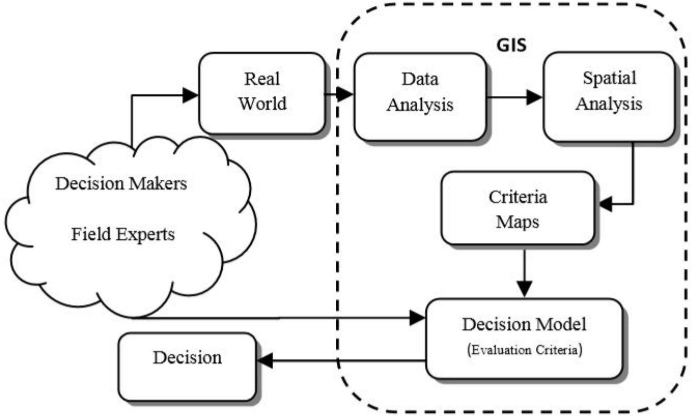
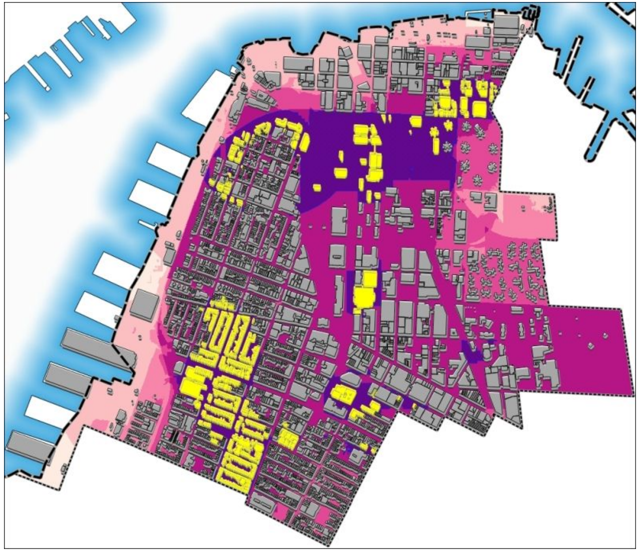


Figure 1. Integrated GIS/ MCDA approach

Extra readings on MCDM / weighted overlays

Please read these three resources to have a better understanding of the MCDM / overlay methodology

1. The ESRI page on overlay approaches
2. This tutorial, which covers an entire workflow for identifying buildings suitable for a family to move in, based on their preferences (close to green spaces, to primary schools, well-connected by public transport, etc.)
3. This research poster on agriculture in Vermont



Homework

Next session is in person

Homework

1. Do the QGIS tutorial on MCDM

2. Use Slack if you have questions (#help).

3. Spend time on your final coursework - next session is your last chance to share progress / concerns / challenges with the class!

Final Coursework

Final coursework: Policy brief (100%)

Deadline: Tuesday 2nd May, 23.59 Paris time.
If late: -1 point penalty for each day past the deadline.

- Groups of 2-3 students or individual report
- 3 pages minimum, 5 pages **maximum**
- **Policy brief** aimed at the Mayor of the large metropolis you're studying (*/!\ writing style !*)
- You may - and are encouraged to - build upon your first term report and push the methodology further. You can also pick a completely different topic and/or study area
- You **must** use at least one of the advanced techniques learnt in the Advanced module, while ensuring it's well suited to answer your research question.

Final coursework: Policy brief (100%)

Proposed outline

- Executive summary (maximum ½ page, bullet points are fine)
- Introduction / Problem / Context
- Data sources in a table
- High-level methodology. Keep it short but use precise terminology
- 2 to 4 maps. Careful, you only have 5 pages maximum in this report so these maps must be very relevant to answering your policy question *(i.e. for a suitability analysis, I don't need every step in your weighted overlay, just the final potential sites you've identified, which you can pair with a map of some key variables in your analysis)*
- Analysis of the findings
- Policy recommendations to decision makers

In this exercise, concision and precision are key! Your analysis must lead to actionable results.

Final Coursework: Marking Criteria

The marking criteria reflect the learning outcomes expected at the end of this module. Students should be able to:

- Formulate a research question suitable for GIS analysis
- Source relevant data and assess their relevance based on the metadata provided
- Be comfortable working with vector and raster datasets
- Design complex GIS workflows to combine multiple datasets, using at least one technique covered in the Advanced course (bivariate choropleths, raster processing, cartograms, digitization, isochrones, weighted overlays)
- Produce clean map exports that respect cartographic design principles, are colour-blind safe, and are complete with all key cartographic elements (title, legend, north arrow etc.)
- Justify all key methodology choices, focusing on key decisions (choice of datasets, geoprocessing steps, raster processing steps, class breaks chosen for a choropleth, etc.)
- Draw policy insights from their maps and translate those into applicable policy recommendations **or** future research outlooks. Please be very explicit!

Final Coursework: Marking Criteria

Criteria:

- Research question and whether your methodology adequately addresses it (10%)
- Methodology, choice of relevant datasets and design of your workflow (35%)
- Quality of the map outputs (35%)
- Quality of the writing, structure and visual clarity of the report (10%)
- Relevance of the recommendations / insights (10%)