Master of Science in Sustainability Science

Environmental Sustainability Indicators: Construction and Use – SUSCPS5210 – Fall 2022
Monday, 6-8pm
3 credits

Instructor: Alex de Sherbinin, Associate Director for Science Applications
Office Hours: Mon-Fri 9-5pm, 201a Geoscience, Lamont Campus
Response Policy: Weekdays only, within 12 hours

Facilitator/Teaching Assistant, if applicable: N/A
Office Hours: N/A
Response Policy: N/A

Course Overview

Aggregated (composite) sustainability indicators reduce complexity in policy-relevant ways, providing an important link between science and policy and helping to point decision makers towards potential solutions to environmental problems. The number and type of indicators used for assessing environmental sustainability around the world have proliferated dramatically within the last few years. From a count of nearly zero just two decades ago, environmental indexes now number in the hundreds – including the Environmental Performance Index (EPI), the Ecological Footprint, the Ocean Health Index, Global Adaptation Index, green accounting, carbon indices and the Sustainable Development Goals (SDGs). This course will present students with the architecture, data, methods, and use cases of environmental indicators, from national-level indices to spatial indices that present sub-national variation. The course will draw on the instructor's experience in developing environmental sustainability, vulnerability and risk indicators for the Yale/Columbia EPI as well as for a diverse range of clients including the Global Environmental Facility, UN Environment, and the US Agency for International Development. Visiting lecturers will also provide exposure to the use of sustainability indicators in decision making, Lamont experience with air pollution metrics, and use of indicators for measuring environmental justice. The course will explore alternative framings of sustainability, vulnerability and performance, as well as aggregation techniques for creating composite indicators (e.g., hierarchical approaches vs. data reduction methods such as principal components analysis). The course will examine data sources from both in-situ monitoring and satellite remote sensing, and issues with their evaluation and appropriateness for use cases and end users. During in-class "lab" sessions, the students will use pre-packaged data and basic statistical packages to understand the factors that influence index and ranking results, and, as a class exercise, will construct their own comparative index for a thematic area and region or country of their choice. They will learn to critically assess existing indicators and indices, and to construct their own. The course will also examine theories that describe the role of scientific information in decision-making processes, and factors that influence the uptake of information in those processes. The course will present best practices for designing effective indicators that can drive policy decisions.

This elective course will provide a basic introduction to the rationale for environmental indicators, the strengths and limitations of data that contribute to their development, the methods for their normalization and aggregation into indices, and their use in policy settings. Knowledge of descriptive and inferential statistics is a requirement, but students can develop their own indices using the software they are most comfortable using (e.g., Excel, SPSS, Stata, R, Python, etc.).

Learning Objectives

By the end of this course, students will be able to:

L1: Explain the role and relevance of environmental indicators in policy processes, and the basic elements that are important to the use of information in policy processes: credibility, salience and legitimacy.

L2: Describe the importance of frameworks for constructing environmental indices, and be able to develop a basic framework for an index of their own construction encompassing multiple environmental and other parameters to be developed in lab exercises.

L3: Evaluate the strengths and limitations of raw environmental monitoring data from in situ and remote sensing sources and explain choices made for data selection and processing.

L4: Understand and apply statistical methods for data reduction for index construction, and be able to evaluate the strengths and weaknesses of approaches commonly applied.

L5: Effectively present the results of their own index in written and oral formats, defending the choice of raw data, normalization, indicator weights, and aggregation methods.

Diversity Statement

It is our intent that students from all diverse backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that the students bring to this class be viewed as a resource, strength and benefit. It is our intent to present materials and activities that are respectful of diversity: gender identity, sexuality, disability, age, socioeconomic status, ethnicity, race, nationality, religion, and culture.

Readings

There is no comprehensive textbook on the subject of environmental sustainability, vulnerability and risk indicators. Therefore, this course builds off a carefully selected list of peer reviewed articles and reports. These are listed in the

Resources

Columbia University Library

Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online: http://library.columbia.edu/.

SPS Academic Resources

The Office of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: http://sps.columbia.edu/student-life-and-alumni-relations/academic-resources.

Programming

Students should be familiar with standard office software and at least one statistical package (e.g., R, SPSS, or Stata) to support their completion of course assignments, and should have completed past course work or self-study in inferential statistics. Students may use any statistical package in the course, and those without an up-to-date license may use GNU PSPP.

Course Requirements (Assignments)

Class Participation (15%) (L1, L2, L3, L5)

Class participation, including oral and written communication, exercises important job skills. Weekly readings must be completed before class and will help contextualize class discussions. We will assign weekly readings and we will start each class collecting questions from the students to get us started. Please come to class having read the material, having written down one or more questions, and ready to participate in classroom discussions. Classroom participation makes up 15% of your final grade. Most importantly, it gives us a window on your interests and grasp of the material.

Midterm Paper (35%) and Final Paper/Presentation (50%) (L1, L2, L3, L4, L5)

Students will write a short midterm paper and prepare a paper and presentation on a semester-long project. The midterm paper requires that the student critically evaluate a global or regional environmental sustainability, vulnerability or risk index, including reference to assigned readings. The mid-term paper will also help students to prepare for their final project, which is to develop an environmental sustainability, vulnerability or risk index of their own construction. The paper needs to detail the purpose, framework, data, data transformation, and construction/aggregation methods, and present the final results and their implications. Students will prepare both a written description of the project results (approximately 20 pages plus references and figures) and a formal oral presentation (15 minutes) delivered to the class.

Evaluation/Grading

Participation (15%)

Participation will be graded on a scale of 0-100. Participation includes class attendance, contribution of written questions, and active discussions in class. The students are expected to show critical thinking, respectful interactions with classmates and a positive attitude towards learning and freely discussing the topics proposed. Students are encouraged to share the critical questions from their assignments with their peers.

Index Construction Class Project (15%)

Students will engage in a group project to develop the index on a given theme. Groups will be expected to search for and evaluate data, process data, create a framework, normalize and aggregate indicators, and conduct a sensitivity analysis.

Midterm Paper (30%)

The midterm paper will be judged on a scale of 0-100. Students will be evaluated on their ability to critically assess an existing environmental sustainability, vulnerability or risk index based on their own reasoning and citing relevant literature from course reading assignments and beyond. Approximately one-third of the evaluation will be based on the clarity of the written work, and two-thirds will be based on an evaluation of the student's reasoning and presentation of arguments. Students are required to discuss their choice of index with the instructor(s) beforehand. Instructor comments will be returned with the graded work and should be incorporated in the final project paper and presentation.

Final Term Paper and Presentation (40%)

Both the written final project report (three-quarters of the final project grade) and the class presentation (one-quarter of the final project grade) will be graded on a scale of 0-100. The written report on the student's own indicator project will be graded based on completeness (i.e., including background and motivation, data, methods, correct use of statistics, results, conclusions and references) and interpretation of the results. The class presentation will be graded based on clarity, quality of the presentation materials, finishing in a timely manner, and responses to audience questions.

The final grade will be calculated as described below:

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %

B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

ASSIGNMENT	% Weight
Midterm Paper	30
Final Project	40
Participation	15
Class Exercise	15

Course Policies

Participation and Attendance
You are expected to come to class on time and thoroughly prepared. Your participation will require that you answer questions, defend your point of view, and challenge the point of view of others. The instructors will keep track of attendance and look forward to an interesting and lively discussion. If you miss an experience in class, you miss an important learning moment and the class misses your contribution. More than one absence will affect your grade. If you need to miss a class for any reason, please discuss the absence with me in advance.

Late work
Work that is not submitted on the due date noted in the course syllabus without advance notice and permission from the instructor will be graded down 1/3 of a grade for every day it is late (e.g., from a B+ to a B).

Citation & Submission
All written assignments must cite sources and be submitted in person or to the course website (not via email).

School Policies

Copyright Policy
Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity
Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It

is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at http://sps.columbia.edu/student-life-and-alumni-relations/academic-integrity-and-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

Accessibility
Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: http://health.columbia.edu/services/ods/support.

COLUMBIA UNIVERSITY
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Master of Science in Sustainability Science
2022 Course Schedule/Course Calendar

Date	Topics and Activities	Readings (due by class time)	Assignments	In Class Activities
9/12	Week 1: Rationale and motivation for sustainability indicators	Moldan, B., S. Janouskova, and T. Hak. 2012. How to understand and measure environmental sustainability: Indicators and targets, *Ecological Indicators*, 17:4–13. Parris, T.M. and Kates, R.W., 2003. Characterizing and measuring sustainable development. *Annual Review of environment and resources*, 28(1), pp.559-586. McNie, E. 2007. Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science & Policy*, 10:17-38. *Optional on history of sustainability indicators:* Dahl, A. 2018. “Chapter 3: Contributions to the emerging theory and practice of indicators of sustainability.” In: Bell and Morse (eds), *Routledge Handbook of Sustainability Indicators.* New York: Routledge. (pgs. 42-58)		
9/19	Week 2: Environmental justice and social vulnerability indicators (Guest lecturers: Ben Preston, Office of Science and Technology Policy (OSTP), The White House, and Eric Tate, University of Iowa	Cutter, S, BJ Boruff, WL Shirley. 2012. Social vulnerability to environmental hazards. In: *Hazards vulnerability and environmental justice*, 143-160. Tedesco, M., C.G. Hultquist, and A. de Sherbinin. 2021. A New Dataset Integrating Public Socioeconomic, Physical Risk, and Housing Data for Climate Justice Metrics: A Test-Case Study in Miami. *Environmental Justice* https://doi.org/10.1089/env.2021.0059 (An updated version of the SEPHER data available here: https://www.ciesin.columbia.edu/data/sepher/) *Optional:* Tellman, B., C. Schank, B. Schwarz,, P.D. Howe and A. de Sherbinin. 2020. Using Disaster Outcomes to Validate Components of Social Vulnerability to Floods: Flood Deaths and Property Damage across the USA. *Sustainability*. 12(15). https://doi.org/10.3390/su12156006		

Date	Topics and Activities	Readings (due by class time)	Assignments	In Class Activities
		Explore the following: RAND's EJ tool (Environmental Racism: A Tool for Exploring the Enduring Legacy of Redlining on Urban Environments | RAND (Links to an external site.)) as well as USG things like EJ Screen (Links to an external site.), CDC's SVI (Links to an external site.), and the CEJST tool.		
9/26	Week 3: Overview of construction of aggregated sustainability indicators	Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A., & Giovannini, E. 2008. *Handbook on constructing composite indicators*. Paris: OECD. (pp. 1-43). Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological indicators*, 9(2), 189-212. (Sections 3 and 4 only) UNDP. 2022. Human Development Report 2021/22: Technical Notes. New York: UNDP (Read Technical Note 1 and 6) Sachs, J., G. Lafortune, C. Kroll, G. Fuller and F. Woelm. 2022. *SDG Index and Dashboards Report 2022*. New York: Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN) (skim Part 2: The SDG Index and Dashboards at https://dashboards.sdgindex.org/chapters/part-2-the-sdg-index-and-dashboards).	In class: use HDI to assess alternative aggregation approaches	Provide the data for the HDI. Explore: - Geometric mean - Arithmetic mean - Weighted mean
10/3	Week 4: Elements of sustainability – the importance of frameworks	Niemeijer, D. and de Groot, R.S., 2008. A conceptual framework for selecting environmental indicator sets. *Ecological Indicators*, 8(1):14-25. Bell, S., and S. Morse. 2018. "Chapter 12. Participatory approaches for the development and evaluation of sustainability indicators." In: Bell and Morse (eds), *Routledge Handbook of Sustainability Indicators.* New York: Routledge. (*skim* pgs. 188-203) Holsten, A., & Kropp, J. P. 2012. An integrated and transferable climate change vulnerability assessment for regional application. *Natural Hazards*, 64(3), 1977-1999. https://doi.org/10.1007/s11069-012-0147-z (read pp. 1977-1982 only) *Optional*	In class: Present chosen indicator/ index for assignment 1	Develop framework and indicator list for an EJ Index designed by students

Date	Topics and Activities	Readings (due by class time)	Assignments	In Class Activities
		Wendling et al. 2020. *2020 Environmental Performance Index*. New Haven, CT: Yale. (focus on Chapter 1, pages 1-5; *skim* Chapter 2-3, pages 6-47).		
10/10	Week 5: Data selection, exploratory analysis and imputation (partial guest lecture by Tanja Srebotnjak, director of the Zilkha Center at Williams College, on imputation methods)	Nardo et al. 2008. OECD Handbook. pp. 44-62. Wendling et al. 2020. *2020 EPI.* New Haven: Yale University. https://bit.ly/3qVpoIY (Chapter 15 on methodology, pp. 168-176). Skim: Srebotnjak, T., G. et al. 2011. "A global Water Quality Index and hot-deck imputation of missing data" *Ecological Indicators*, Volume 17, June 2012, Pages 108-119, http://dx.doi.org/10.1016/j.ecolind.2011.04.023. Hsu, et al. 2016. EPI Metadata. https://bit.ly/386dcwe (read 3-4 indicator definition pages)		In class: Conduct EDA for the Index
10/17	Week 6: Multivariate analysis (partial guest lecture by Tanja Srebotnjak, director of the Zilkha Center at Williams College, on multivariate analysis)	Nardo et al. 2008. OECD Handbook. pp. 63-88. Hsu, A., L.A. Johnson, and A. Lloyd. 2013. *Measuring Progress: A Practical Guide From the Developers of the Environmental Performance Index (EPI)*. New Haven:Yale Center for Environmental Law & Policy. (read Chapter 5, pp. 42-53) A Step-by-Step Explanation of Principal Components Analysis. https://builtin.com/data-science/step-step-explanation-principal-component-analysis Skim: Ramos, T.B. 2019. Sustainability assessment: Exploring the frontiers and paradigms of indicator approaches. *Sustainability* 11, 824 (*skim* pp 1-9).	Abstract for final paper due	In class: Conduct MVA and normalization for the Index
10/24	Week 7: Normalization, weighting and aggregation	Nardo et al. 2008. OECD Handbook. pp. 89-116. Becker, W., Saisana, M., Paruolo, P., & Vandecasteele, I. 2017. Weights and importance in composite indicators: Closing the gap. *Ecological Indicators*, 80, 12-22. (read sections 1, 5, and 6) *Optional:*	Mid-term paper due	In class: Weighitng & Aggregation for Urban Heat Risk Index

Date	Topics and Activities	Readings (due by class time)	Assignments	In Class Activities
		Böhringer, C., & Jochem, P. E. 2007. Measuring the immeasurable—A survey of sustainability indices. *Ecological Economics*, 63(1), 1-8.		
10/31	Week 8: Uncertainty and sensitivity assessment and data visualization	Nardo et al. 2008: revisit pp. 34-43, read pp. 117-139. Tate, E. 2012. Social vulnerability indices: a comparative assessment using uncertainty and sensitivity analysis. *Natural Hazards*, 63 (2), 325-347 Papadimitriou, E. et al., 2020. *JRC Statistical Audit of the 2020 Environmental Performance Index*. Ispra: Joint Research Centre. (*skim*) 10 Do's and Don'ts of Infographic Chart Design: https://venngage.com/blog/chart-design/ *Optional*: Roth, F. 2020. Visualizing Risk: The Use of Graphical Elements in Risk Analysis and Communications. *3RG Report.*	Final paper abstract with indicators and data sources table due	In class: Uncertainty and sensitivity analysis for Index Data viz handout
11/14	Week 9: Indicators in practice: The policy influence and use of indicators in real-world contexts (guest lecture by Terry Fletcher, Millennium Challenge Corporation)	de Sherbinin, A., et al. 2013. Indicators in Practice. New Haven: Yale Center for Environmental Law and Policy. (read main report and 2 case studies in appendix) The Bayswater Institute. 2011. A Synthesis of the Findings of the Policy Influence of Indicators (POINT) Project. Project report for the European Commission within the Seventh Framework Programme (2007-2013). (read sections 1 and 2). *Skim:* Millennium Challenge Corporation, country score cards: https://www.mcc.gov/who-we-select/scorecards *Optional* Lehtonen, M., Sébastien, L. and Bauler, T., 2016. The multiple roles of sustainability indicators in informational governance: between intended use and unanticipated influence. *Current Opinion in Environmental Sustainability*, 18:1-9.		

11/21	Week 10: The Sustainable Development Goals (SDGs) and measures off wellbeing (Guest lecture by Alainna Lynch and Zach Wendling, Sustainable Development Solutions Network (SDSN))	Review: Part 4 of Sachs et al. 2020. *The Sustainable Development Goals and COVID-19. Sustainable Development Report 2020*. Cambridge: Cambridge University Press, p.63-73 (in Week 1 folder) Shepherd, K., Hubbard, D., Fenton, N., Claxton, K., Luedeling, E., & de Leeuw, J. 2015. Policy: Development goals should enable decision-making. *Nature News*, 523(7559), 152. Lutz, W., et al. 2021. Years of good life is a well-being indicator designed to serve research on sustainability . *PNAS*. 118 (12) e1907351118. (pp. 2-5) https://doi.org/10.1073/pnas.1907351118 Watch Population-Environment Research Network (PERN) webinar on Years of Good Life at https://www.youtube.com/watch?v=Fon1lpRNGrI *Optional* Scan some of the postings to the PERN cyberseminar at https://groups.google.com/a/ciesin.columbia.edu/g/pernseminars		
11/28	Week 11: Pollution data and monitoring, novel data streams (Guest Lectures by Richard Fuller, Executive Director, Pure Earth, and Beizhan Yan, LDEO)	Fuller, R., Landrigan, P. J., Balakrishnan, K., Bathan, G., Bose-O'Reilly, S., Brauer, M., ... & Yan, C. (2022). Pollution and health: a progress update. *The Lancet Planetary Health*. https://doi.org/10.1016/S2542-5196(22)00090-0 Hsu, A., et al.. 2013. Toward the next generation of air quality monitoring indicators. *Atmospheric Environment*. 80: 561–570. http://dx.doi.org/10.1016/j.atmosenv.2013.07.036. *Optional* de Sherbinin, A., M. Levy, et al. 2014. Using Satellite Data to Develop Environmental Indicators. *Environmental Research Letters*, 9 084013. (12 pages)		
12/5	Week 12: Debates and critiques of sustainability indicators (panel with Tom Parris, ISciences LLC, and Bilal Butt, University of Michigan)	Dahl, A. L. (2018). Contributions to the evolving theory and practice of indicators of sustainability. In *Routledge handbook of sustainability indicators* (pp. 42-58). Routledge. Bell, S., & Morse, S. (2018). Sustainability indicators past and present: what next?. *Sustainability*, 10(5), 1688.		

		Skim: Butt, B. (2018). Environmental indicators and governance. *Current Opinion in Environmental Sustainability*, 32, 84-89.		
12/12	Week 13: Final presentations		Final paper due Final project presentations	