COLUMBIA UNIVERSITY
School of Professional Studies

Master of Science in Sustainability Science

Environmental Sustainability Indicators: Construction and Use

SUSCPS5210 (3 credits)
Fall 2024
Thursday, 6:10 – 8:00 p.m.

Instructors: Alex de Sherbinin, Director and Senior Research Scientist, CIESIN
Zach Wendling, Research Director, Yale Center for Environmental Law & Policy

Office Hours: By appointment
Response Policy: Weekdays only, within 12 hours

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 toward 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, the SDG Index, green accounting, and carbon indices. 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 instructors' 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 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. As a class exercise, the students 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 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 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 choices for 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 course schedule.

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 to 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 toward 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 an 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 instructors 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.

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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
Class Participation	15
Class Exercises	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 points 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 one of the instructors 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 instructors will be graded down 1/3 of a grade for every day it is late (e.g., from a B+ to a B).

Proper Attribution

Students in this course must be familiar with how to properly attribute ideas and quotations through citations and references. All written assignments will be submitted to Turnitin, an online database that scans documents for plagiarized content. Through Canvas, you will be able to see a report on each of your written assignments 15–60 minutes after submitting them. Students are responsible for understanding how to interpret these reports. If your report indicates that – through haste or confusion – you've inadvertently

committed plagiarism, you may fix the problem and resubmit your assignment. So long as the resubmission is before the deadline, only the latest submission will be graded. If, for any reason, you require additional time to resolve issues identified in the Turnitin report, contact the instructors as soon as possible, as you may be granted an extension.

Submission

All written assignments must be submitted through 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.

2024 Course Schedule/Course Calendar

Week 1 – September 5 – 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. https://doi.org/10.1016/j.ecolind.2011.04.033

Parris, T.M. and Kates, R.W. 2003. Characterizing and measuring sustainable development. *Annual Review of environment and resources*, *28*(1), pp.559–586. https://doi.org/10.1146/annurev.energy.28.050302.105551

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. https://doi.org/10.1016/j.envsci.2006.10.004

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)

Week 2 – September 12 – Environmental justice and social vulnerability indicators

Guest lecturers: Ben Preston, White House Office of Science and Technology Policy (OSTP and Eric Tate, Princeton University

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 15*(3), 149–159. https://doi.org/10.1089/env.2021.0059

(An updated version of the SEPHER data are available at 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

Week 3 – September 19 – 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. (Read 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. (Read Sections 3 and 4 only) https://doi.org/10.1016/j.ecolind.2011.01.007

UNDP (United Nations Development Programme). 2024. *Human Development Report 2023-24: Breaking the gridlock: Reimagining cooperation in a polarized world.* New York. https://hdr.undp.org/content/human-development-report-2023-24 (Read pp. 3–9, skim pp. 13–24)

UNDP. 2024. *Human Development Report 2023-24 Technical Notes.* New York. https://hdr.undp.org/sites/default/files/2023-24_HDR/hdr2023-24_technical_notes.pdf (Read Technical Notes 1 and 6)

Sachs, J.D., Lafortune, G., Fuller, G. (2024). *The SDGs and the UN Summit of the Future. Sustainable Development Report 2024.* Paris: SDSN, Dublin: Dublin University Press. DOI: 10.25546/108572 https://dashboards.sdgindex.org/chapters/part-2-the-sdg-index-and-dashboards). (Skim Part 2: The SDG Index and Dashboards)

In class: Explore data from the HDI:

- Arithmetic vs. Geometric means
- Equal vs. Unequal weights

Week 4 – September 26 – 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. https://doi.org/10.1016/j.ecolind.2006.11.012

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 pp. 188–203)

Due: Presentation on chosen indicator / index for Assignment 1

In class: Develop framework and indicator list for an Index designed by students

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Week 5 – October 3 – Data selection, exploratory analysis and imputation

Guest lecture: Tanja Srebotnjak, director of the Zilkha Center at Williams College, on imputation methods

Nardo et al. 2008. OECD Handbook. (Read pp. 44–62.)

Wendling et al. 2020. *2020 EPI.* New Haven: Yale University. https://bit.ly/3qVpoIY (Read Chapter 15 on methodology, pp. 168–176).

Srebotnjak, T., G. et al. 2012. "A global Water Quality Index and hot-deck imputation of missing data" *Ecological Indicators 17*: 108–119, http://dx.doi.org/10.1016/j.ecolind.2011.04.023. (Skim)

Wendling et al. 2020. *2020 EPI Technical Appendix.* New Haven: Yale University. https://sedac.ciesin.columbia.edu/downloads/data/epi/epi-environmental-performance-index-2020/2020-epi-technical-appendix.pdf (Skim 3–4 indicators in §§ 2 & 3).

In class: Conduct EDA for the Index

Week 6 – October 10 – Multivariate analysis

Guest lecture: Tanja Srebotnjak, director of the Zilkha Center at Williams College, on multivariate analysis

Nardo et al. 2008. OECD Handbook. (Read 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

Ramos, T.B. 2019. Sustainability assessment: Exploring the frontiers and paradigms of indicator approaches. *Sustainability 11*(3), 824 (Skim pp. 1–9). https://doi.org/10.3390/su11030824

Due: Abstract for final paper

In class: Conduct MVA and normalization for the Index

Week 7 – October 17 – Normalization, weighting, and aggregation

Nardo et al. 2008. OECD Handbook. (Read 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, & 6) https://doi.org/10.1016/j.ecolind.2017.03.056

Optional:

> Böhringer, C., & Jochem, P. E. 2007. Measuring the immeasurable—A survey of sustainability indices. *Ecological Economics, 63*(1), 1–8. https://doi.org/10.1016/j.ecolecon.2007.03.008

Due: Mid-term paper

In class: Weighting & Aggregation for the Index

Week 8 – October 24 – 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 https://doi.org/10.1007/s11069-012-0152-2

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.*

Due: Final paper abstract with indicators and data sources table

In class: Uncertainty and sensitivity analysis for Index; Data visualization handout

Week 9 – October 31 – Indicators in practice: Policy influence and use of indicators in real-world contexts

de Sherbinin, A., et al. 2013. Indicators in Practice. New Haven: Yale Center for Environmental Law and Policy. (Read main report and two 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).

Millennium Challenge Corporation, country score cards: https://www.mcc.gov/who-we-select/scorecards (Skim)

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. https://doi.org/10.1016/j.cosust.2015.05.009

Week 10 – November 7 – The Sustainable Development Goals (SDGs) and measures of wellbeing

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. https://doi.org/10.1038/523152a

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

Week 11 – November 14 – Pollution data and monitoring, novel data streams

Guest Lecturers: 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*(8): 084013. (12 pages) DOI 10.1088/1748-9326/9/8/084013

Week 12 – November 21 – Debates and critiques of sustainability indicators

Panelists: 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. https://doi.org/10.3390/su10051688

Butt, B. (2018). Environmental indicators and governance. *Current Opinion in Environmental Sustainability*, *32*: 84–89. https://doi.org/10.1016/j.cosust.2018.05.006 (Skim)

Week 13 – December 5 – Final presentation

Due: Final paper

In class: Project Presentations