

SUMA K4380 Financing Natural Infrastructure 3 Credits

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Office Hours: Will vary by week, but generally will occur after class and/or another time during the week to be scheduled by appointment. Please schedule an appointment in advance.
Response Policy: We will respond to student emails within 24-36 hours.

Course Overview

Population growth, climate change, increasing consumption, and rapid urbanization are putting unprecedented pressure on our infrastructure and the natural systems on which we rely. According to the World Economic Forum, more than \$60 trillion in infrastructure investments are needed between now and 2030 to support future growth. Our traditional response to these challenges—publicly-funded grey infrastructure—cannot be sustained. On top of that, the McKinsey Global Growth Institute has estimated that our current rate of environmental degradation is unsustainable for the long-term functioning of the global economy. Faced with these enormous needs, as well as aging infrastructure and limited public funding, governments and the private sector are rethinking how they design, finance and deploy infrastructure.

“Natural infrastructure”—the use of natural or engineered ecosystems and natural areas to provide services that could be provided through “grey infrastructure”—has received increasing attention as an alternative to traditional engineering solutions to protect water supplies, reduce flood risks, manage stormwater, and provide clean air. In addition, conservation is seen as a means of providing sustainable food supplies in response to increasing demand. While “greening” infrastructure is one aspect of the solution, a critical need is finding new ways to finance the construction and operation of our infrastructure in general.

This course will explore the potential for natural infrastructure to address—in place of or in conjunction with grey infrastructure—many of the challenges that we face and the financing tools that could be utilized to accelerate and take to scale its adoption. The course will draw heavily from “real-world” examples in cities, corporations, financial institutions, and national and subnational governments that have utilized natural infrastructure and/or innovative financing mechanisms to meet their needs. Through a mix of lectures, case studies, problem sets, and guest lectures, students will gain the skills needed to quantify the value of ecosystem services and understand how private investment and financial mechanisms could accelerate the use of natural infrastructure.

This course satisfies the Area 1: Integrative, Area 2: Economics and Area 5: General and Financial Management curriculum area requirements of the MS in Sustainability Management program. This course is also approved for the Certifications in Sustainability Analytics and Sustainable Finance.

Learning Objectives

What do we want students to know and or value at the end of the course?	Through the readings, lectures, in-class discussions, assignments and guest speakers, students will gain an understanding of how natural infrastructure can address sustainability challenges and how to identify and quantify the value of ecosystem services. Students will gain the skills to evaluate the potential for natural infrastructure to address critical challenges and the financing and policy tools that could be utilized to fund and incentivize natural infrastructure solutions. Students will examine the enabling policy and market conditions needed to make natural infrastructure work, with an emphasis on the role of finance and private capital. At the end of the course, students will understand how private investment could accelerate the use of natural infrastructure and how to develop metrics and outcomes to measure the effectiveness of natural infrastructure once it is deployed.
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<p>What will students be able to do at the end of the course?</p>	<p>Upon completing this course, students should be able to:</p> <ul style="list-style-type: none"> • effectively define natural infrastructure • analyze the ways in which natural infrastructure can address economic, social, and environmental challenges for public and private sector actors • assign a value ecosystem services • apply an analytic framework for approaching environmental issues and market activities • analyze the impacts of economic activity and human settlement patterns on the environment to assess the feasibility of natural infrastructure solutions • appraise the key technical, political, economic, and organizational challenges and propose and evaluate potential solutions to financing natural infrastructure at scale • apply the principles of financial economic analysis to the implementation of natural infrastructure solutions
<p>What “big” questions/issues are dealt with in the course?</p>	<ul style="list-style-type: none"> • What is natural infrastructure and how do you value ecosystem services? • How can natural infrastructure address economic, social, and environmental challenges for public and private sector actors? • What are the key technical, political, economic, and organizational challenges and potential solutions to financing natural infrastructure at scale to address local and global environmental issues? • What mechanisms can be used to access markets and private capital to address sustainability issues?
<p>How do these “big” questions/issues inform our teaching and assessment approach?</p>	<p>Through readings, case studies, problem sets, and in-class debates and discussions, the class will provide a set of fundamental skills that students may apply in professional settings, with an emphasis on developing an analytic framework for approaching environmental issues and market activities. The professors will draw on their professional experiences and guest lectures to ground all topics and discussions in “real world” examples that go well-beyond academic studies to actual case studies and applications.</p>
<p>What are the targeted student outputs (evidence of progress) toward course outcomes?</p>	<p>In this course, students will complete 2 case-study write-ups, a problem set, and a final group presentation and paper. The assignments are designed to replicate the analytical (both quantitative and qualitative) work expected of them working on issues related natural infrastructure financing in the public and private sector.</p>
<p>How do we measure/collect this evidence? What metrics are in play for this course?</p>	<p>Student outputs will be evaluated in such a way as to replicate a professional setting, with an emphasis on clear, convincing arguments based on quantitative and financial analysis.</p>

Readings

A textbook will not be required for this course, although some articles and case studies may require purchase from online resources such as Harvard Business School Case Studies. All readings are listed in the Course Schedule section of this syllabus and will be posted to Courseworks.

Resources

Relevant Website Resources

- Ecosystem Marketplace – <http://www.ecosystemmarketplace.com/>
- Environmental Finance Magazine - <https://www.environmental-finance.com>
- Natural Capital Project - <http://www.naturalcapitalproject.org/>
- Urban Water Blueprint - <http://water.nature.org/waterblueprint/////index.html#/intro=true>
- Aqueduct, World Resource Institute - <http://www.wri.org/our-work/project/aqueduct>
- NatCap Coastal Hazard Web Portal - http://www.naturalcapitalproject.org/decisions/CoastalHazard_WebPortal.html
- City Resilience Framework - <http://www.rockefellerfoundation.org/uploads/files/0bb537c0-d872-467f-9470-b20f57c32488.pdf>
- Water Risk Monetizer - <http://waterriskmonetizer.com/>

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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/>.

SCE Academic Resources

The Office of Student Life and Alumni Relations (SLAR) provides students with academic counseling and support services such as online tutoring and career coaching: <http://ce.columbia.edu/student-life-and-alumni-relations/academic-resources> .

Course Requirements (Assignments)

- Case studies (15% each)

Students will individually complete two case write-ups, which are expected to be 2-3 pages and will be discussed in class on the date they are due. Students may choose (but are not required) to answer the questions posed in the case, but should offer an analytical response to one of more of the issues discussed in the case. A good overview of the case method and how to prepare for a case is available at http://www.ksgcase.harvard.edu/images/other/1136_0.pdf

- Problem set (20%)

Students will be provided with a problem set and relevant information/sources to quantify the economic, social and environmental value of a natural infrastructure solution and to evaluate the potential feasibility of a private financing mechanism to fund it. Students should individually complete the problem sets.

- Final project (30%)

A final group project will entail a group presentation and report that proposes a specific natural infrastructure solution and financing mechanism for a mutually agreed upon problem and set of actors (e.g., city, corporation). Presentations, which should be approximately 20-25 minutes, will be given during the second half of the semester with an accompanying paper no longer than 8-10 pages due at the final class. Teams are expected to go beyond a simple briefing to offer an analytical assessment of the issue being covered. External research and interviews are expected and the professors will work with the teams to provide contacts and introductions to relevant practitioners and experts. Additional information of the presentation topics and format will be provided.

At the conclusion of each presentation, the class will have a 30 minute discussion of the proposed solution and financing mechanism(s), pose questions to the presenters, and offer additional ideas.

Evaluation/Grading

- Case studies (15% each)

Each case study write-up will be evaluated on a scale of 100-0. Students will be evaluated on their quantitative analysis of the scenario presented in the case study as well as their assessment of the effectiveness of the financial indicators used in each case study scenario.

- Problem set (20%)

The problem set will be evaluated on a scale of 100-0. Students will be evaluated on their quantitative analysis of the presented problems.

- Final project (30%)

The final group project paper will be graded on a scale of 100-0. Each group member will receive the same grade. The paper will be evaluated based on the quality of the analytical assessment of the issue being covered. The paper should be well researched and include references to the course's assigned readings as well as interviews of professionals in the sector. The paper should use clear, concise, and professional language.

The final group presentation will be graded on a scale of 100-0. Each group member will receive the same grade. The presentation will be evaluated on both the clarity of the verbal presentation as well as the professionalism of the accompanying visuals.

- Class participation (20%)

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Class participation will be evaluated on a scale of 100-0. All students are expected to contribute to the classroom discussion throughout the course, including the in-class presentations and discussions with guest speakers. While classes will generally feature lectures on the specified topics each week, active discussion is encouraged to bring in students’ experiences and knowledge. Students should probe concepts introduced in the class and in readings and look for innovative solutions to challenges identified in the materials.

On-time attendance at each class meeting is expected. Partial attendance, i.e. lateness or early departure, if not excused in advance, will impact the “Participation” component of the course grade. If you need to miss a class for any reason, please email the instructors in advance.

Course Policies

Participation and Attendance

You are expected to do all assigned readings, attend all class sessions, and engage with others in class discussions. If you need to miss a class for any reason, please discuss the absence with me in advance.

Late work

Papers and projects are due by the beginning of class on the date that they are due. All assignments must be handed in on time. Any late submissions, unless pre-approved by the professors, will receive an automatic reduction of one letter grade.

Course Schedule

Date	Topics and Activities	Readings	Assignments
6/1	Overview	<p><u>Supplemental Readings:</u></p> <ul style="list-style-type: none"> McKinsey Global Institute, “Infrastructure Productivity: How to Save \$1 Trillion a Year”, January 2013. Available at http://www.mckinsey.com/insights/engineering_construction/infrastructure_productivity (71 pages) World Economic Forum, “The Green Investment Report: The ways and means to unlock private finance for green growth.” World Economic Forum, Geneva, Switzerland, 2013. Available at http://www3.weforum.org/docs/WEF_GreenInvestment_Report_2013.pdf (26 pages) 	
6/8	Making Markets	<p><u>Required Readings:</u></p> <ul style="list-style-type: none"> Debeare, Peter, “Framework to Think About Pollution.” University of Virginia, Charlottesville, VA, 2011. Available at https://cb.hbsp.harvard.edu/cbmp/content/UV5687-PDF-ENG (7 pages) Boyd, James, et. al., “Trading Cases: Is trading credits in created markets a better way to reduce pollution and protect natural resources?” Environmental Science & Technology, June 1, 2003. Available at http://teebforbusiness.earthmind.net/files/Trading_Cases-Is_Trading_Credits_in_Created_Markets_a_Better_Way_to_Reduce_Pollution.pdf (8 pages) The Aspen Institute, “Nature as Foundation of Economy: Investing in Natural Infrastructure for Conservation Supporting Human Development”, 2011, Available at http://www.aspeninstitute.org/sites/default/files/content/docs/pubs/Nature%20as%20Foundation%20of%20Economy%20%5BFINAL%5D.pdf (29 pages) World Economic Forum, “From the Margins to the Mainstream: Assessment of the Impact Investment Sector and Opportunities to Engage Mainstream Investors”, September 2013. Available at http://www3.weforum.org/docs/WEF_II_FromMarginsMainstream_Report_2013.pdf (31 pages) 	
6/15	Financing Tools	<p><u>Required Readings:</u></p> <ul style="list-style-type: none"> NatureVest and EKO Asset Management, “Investing in Conservation: A landscape assessment of an emerging market.” NatureVest, New York, NY, 2014. Available at https://www.jpmorgan.com/cm/BlobServer/InvestingInConservation_Nov2014.pdf?blobkey=id&blobwhere=1320654947295&blobheader=application/pdf&blobheadername1=Cache-Control&blobheadervalue1=private&blobcol=urldata&blobtable=MungoBlobs (read pages 9 – 24, skim the rest) E.T. Jackson and Associates Ltd., “Accelerating Impact Achievements: Challenges and What’s Next in Building the Impact Investing Industry.” Rockefeller Foundation, NY, NY, 2012. Available at http://www.rockefellerfoundation.org/uploads/images/fda23ba9-ab7e-4c83-9218-24fdd79289cc.pdf (51 pages) 	

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		<ul style="list-style-type: none"> Bell, C.; Nadel, S., and Hayes, S., “On Bill Financing for Energy Efficiency Improvements; A Review of Current Program Challenges, Opportunities and Best Practices”, December 2011. Available at http://www.aceee.org/sites/default/files/publications/researchreports/e118.pdf (28 pages) Holland, C. and Daniello, N. “Investing for Impact: Environmental Impact Bonds and Green Infrastructure.” Available at http://sites.duke.edu/casei3/files/2013/03/CASEi3_EIB_Report_FINAL-links.pdf (24 pages) <p><u>Supplemental Reading:</u></p> <ul style="list-style-type: none"> Max, D.T., “Green is Good.” The New Yorker, New York, NY, May 12, 2014. Available at http://www.newyorker.com/magazine/2014/05/12/green-is-good (27 pages) 	
6/22	Water: Water Supplies	<p>*** CASE STUDY: “Water Funds: Financing Nature’s Ability to Protect Water Supplies.: Available for purchase at https://cb.hbsp.harvard.edu/cbmp/content/OIT104-PDF-ENG (13 pages) ***</p> <p><u>Required Readings:</u></p> <ul style="list-style-type: none"> McDonald, R.I and D. Shemie, “Urban Water Blueprint: Mapping conservation solutions to the global water challenge.” 2014, The Nature Conservancy, Washington, D.C. Available at http://water.nature.org/waterblueprint/////about.html (65 pages) Bennett, G., and N. Carroll, “Gaining Depth: State of Watershed Investment 2014.” Forest Trends, Washington, D.C. Executive Summary only. Available at http://www.forest-trends.org/documents/files/SOWI2014.pdf (14 pages) Peter Debaere, Peter, Brian D. Richter, et al., “Water markets as a response to scarcity.” Water Policy. Vol. 16. No 4, pp. 625–649, IWA Publishing, 2014. Available at http://www.jessicagephart.com/uploads/2/2/5/8/22586384/debaere_et_al_2014_water_policy.pdf (23 pages) Boccaletti, Giulio, “Could water markets encourage collaboration and reduce conflict?” The Guardian, September 6, 2013. Available at http://www.theguardian.com/sustainable-business/water-markets-encourage-collaboration-reduce-conflict (2 pages) Fargher, Will, “Responding to scarcity: Lessons from Australian water markets in supporting agricultural productivity during drought.” Organisation for Economic Co-operation and Development, Paris, 2011. Available at http://www.oecd.org/tad/sustainable-agriculture/49192129.pdf (19 pages) <p><u>Supplemental Readings:</u></p> <ul style="list-style-type: none"> King, Dennis and Peter Kuch, “Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles.” Environmental Law Reporter, 2003. Available at http://www.envtn.org/uploads/ELR_trading_article.PDF (12 pages) Nguyen, Nga et. al., “How well do water quality trading markets work with asymmetric information, uncertainty and transaction costs?” Global Water Forum, UNESCO, November 24, 2013. Available at http://www.globalwaterforum.org/2013/11/24/how-well-do-water-quality-trading-markets-work-with-asymmetric-information-uncertainty-and-transaction-costs/ (1 page) Van Houtven, George, et. al., “Nutrient Credit Trading for the Chesapeake Bay: An Economic Study.” Chesapeake Bay Commission, May 2012. 5-30 only. Available at http://www.chesbay.us/Publications/nutrient-trading-2012.pdf (25 pages) 	Case Study Write-Up 1 Due
6/29	Water: Stormwater Management	<p><u>Required Readings:</u></p> <ul style="list-style-type: none"> The City of New York, “PlaNYC: Sustainable Stormwater Management Plan”, 2008. pp 6-50. Available at http://s-media.nyc.gov/agencies/planyc2030/pdf/nyc_sustainable_stormwater_management_plan_final.pdf (44 pages) Natural Resources Defense Council, “Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows”, 2011. pp 1-31; Available at http://www.nrdc.org/water/pollution/rooftopsII/files/rooftopstoriversII.pdf (31 pages) NRDC, EKO, and The Nature Conservancy, “Creating Clean Water Cash Flows: Developing Private Markets for Green Stormwater Infrastructure in Philadelphia”, January 2013, pp 4-72. Available at http://www.nrdc.org/water/stormwater/files/green-infrastructure-pa-report.pdf (68 pages) 	
7/6	Water: Coastal Resilience	<p><u>Required Readings:</u></p> <ul style="list-style-type: none"> Freed, Adam and Erin Percifull, Charlotte Kaiser, Jonathan Goldstick, Matthew Wilson, and Emily Maxwell. “Integrating Natural Infrastructure into Urban Coastal Resilience: Howard Beach, 	Problem Set Due

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		<p>Queens.” The Nature Conservancy, New York, NY, December, 2013, pp. 30-85. Available at http://www.nature.org/media/newyork/howard-beach-report-12-23-2013.pdf (55 pages)</p> <ul style="list-style-type: none"> • ICLEI, “Financing the Resilient City: A demand driven approach to development, disaster risk reduction and climate adaptation - An ICLEI White Paper.” ICLEI, 2011. Available at http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Frontend_user/Report-Financing_Resilient_City-Final.pdf (43 pages) • Arkema, Katie K., Greg Guannel, et al., “Coastal Habitats Shield People and Property from Sea-Level Rise and Storms.” Nature Climate Change Journal, July 14, 2013. Available at http://www1.prweb.com/prfiles/2013/07/14/10925480/kareiva%20report.pdf (22 pages) • da Silva, Jo, et. al, “A systems approach to meeting the challenges of urban climate change.” International Journal of Urban Sustainable Development, Vol. 1, 2012, pp. 1–21. Available at http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Resilient_Cities_2012/Digital_Congress_Proceedings/IJUSD_Article_-_da_Silva_Kernaghan_Luque_2012_A_systems_approach.pdf (20 pages) <p><u>Supplemental Reading:</u></p> <ul style="list-style-type: none"> • World Economic Forum, “A Vision for Managing Natural Disaster Risk: Proposals for Public/Private Stakeholder Solutions.” World Economic Forum, April 2011. Available at http://www3.weforum.org/docs/WEF_VisionManagingNaturalDisaster_Proposal_2011.pdf (99 pages) • Farrow, Scott, “Residual Risk Accounting: A Pilot Study of the Coastal Sector.” UMBC and the Woods Hole Oceanographic Institution, January 21, 2014. Skim only. Available at http://economics.umbc.edu/files/2014/09/wp_14_01.pdf (19 pages) 	
7/13	Air: Air Quality	<p><u>Required Readings:</u></p> <ul style="list-style-type: none"> • The Nature Conservancy, “Dow-TNC Collaboration Analysis Summary.” The Nature Conservancy, Washington, D.C., 2014. Available at http://www.dow.com/sustainability/pdf/air-quality-analysis.pdf (6 pages) • Quelch, John A., and Margaret L. Rodriguez. "Fresno's Social Impact Bond for Asthma." Harvard Business School Case 515-028, September 2014. Available at https://hbr.org/product/Fresno-Social-Impact-Bond/515028-PDF-ENG (7 pages) • Pugh, Thomas A. M., et. al, “Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons.” Environmental Science and Technology, 2012, Vol. 46, pp. 7692–7699. Available at http://greenroofs.org/resources/GreenInfrastructurePaper.pdf (6 pages) • Shackleton, Kyle, et. al, “The role of shrubs and perennials in the capture and mitigation of particulate air pollution in London.” Imperial College London. Available at https://www.tfl.gov.uk/cdn/static/cms/documents/role-gi-pmpollution.pdf (22 pages) • Wentworth, Jonathan, “Urban Green Infrastructure – Post Note.” Houses of Parliament, Parliamentary Office of Science and Technology, Post Note No. 448, November 2013. Available at http://www.parliament.uk/business/publications/research/briefing-papers/POST-PN-448/urban-green-infrastructure (4 pages) 	
7/20	Air: Carbon & Climate	<p>*** CASE STUDY: Harvard Business School, “AEP: Carbon Capture and Storage”, July 2013. Available for purchase at https://cb.hbsp.harvard.edu/cbmp/product/711036-PDF-ENG (26 pages) ***</p> <p><u>Required Readings:</u></p> <ul style="list-style-type: none"> • United States Agency for International Development, “Emerging Compliance Markets for REDD+: An Assessment of Supply and Demand”, March 2013. Available at http://theredddesk.org/sites/default/files/resources/pdf/Emerging%20compliance%20markets%20of%20REDD%2B%20An%20Assessment%20of%20Supply%20and%20Demand.pdf (54 pages) • McKinsey & Co, “Pathways to a Low-Carbon Economy; Version 2 of the Global Greenhouse Gas Abatement Cost Curve”, 2009, pp 1-50; 59-74; 116-134. Available at http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves (83 pages) • Allayannis, Y., Harvard Business Publishing, Background Note, “Carbon Credit Markets”, March 2011. Available at https://cb.hbsp.harvard.edu/cbmp/content/UV2543-PDF-ENG (17 pages) 	Case Study Write-Up 2 Due
7/27	Food & Fiber: Fisheries	<p><u>Required Readings:</u></p> <ul style="list-style-type: none"> • The World Bank and The International Bank for Reconstruction and Development, “The Sunken Billions: The Economic Justification for Fisheries Reform”, 2009. Available at http://siteresources.worldbank.org/EXTARD/Resources/336681-1224775570533/SunkenBillionsFinal.pdf (84 pages) 	

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		<ul style="list-style-type: none"> EKO Asset Management Partners, “Sustainable Fisheries Financing Strategies: Save the Oceans Feed the World”, March 2014. Available at http://ekoamp.com/wp-content/uploads/2014/03/sustainable-fisheries-report-8g.pdf (15 pages) 	
8/3	Food & Fiber: Ranching & Agriculture	<u>Required Readings:</u> <ul style="list-style-type: none"> To be finalized 	
8/10	Wrap-Up and Guest Lecture: NatureVest	<u>Required Readings:</u> <ul style="list-style-type: none"> NatureVest website - http://www.naturevestnc.org/ 	Final Group Project Papers Due, Final Group Presentations to be presented in class

School Policies

Copyright Policy

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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.

SCE holds each member of its community responsible for understanding and abiding by the SCE Academic Integrity and Community Standards posted at <http://ce.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>.