SUBJECTS OF INSTRUCTION

Courses offered by the School of Forestry & Environmental Studies are described below. The letters “a” and “b” following the course numbers indicate fall- and spring-term courses, respectively. The letter “E” following a course number indicates an online course. Courses with bracketed titles will not be offered during the 2018–2019 academic year.

Project courses involve individually assigned advanced field or laboratory work, or literature review, on topics of special interest to the student; credits and hours for these projects are determined for each student in consultation with the instructor.

Courses throughout the University are generally open to students enrolled in the School of Forestry & Environmental Studies, subject to limitations on class size and requirements for prerequisites.

Note For updated course listings, please see the School of Forestry & Environmental Studies website, http://environment.yale.edu/courses.

LIST OF COURSES BY TOPIC

Basic Knowledge

<table>
<thead>
<tr>
<th>Course</th>
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<tbody>
<tr>
<td>F&amp;ES 511</td>
<td>Ecological Patterns and Processes</td>
</tr>
<tr>
<td>F&amp;ES 512</td>
<td>Microeconomics for Environmental Management</td>
</tr>
<tr>
<td>F&amp;ES 521</td>
<td>Physical Science Foundations for Environmental Managers</td>
</tr>
<tr>
<td>F&amp;ES 522</td>
<td>Problem Solving in the Global Era: How Social Sciences Contribute to Forward Looking Environment Management</td>
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Professional Skills Courses

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<tbody>
<tr>
<td>F&amp;ES 577</td>
<td>PSC: Environmental Communicator</td>
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<tr>
<td>F&amp;ES 578</td>
<td>PSC: Financial Concepts for Environmental Managers</td>
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Perspectives

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<tbody>
<tr>
<td>F&amp;ES 601</td>
<td>Perspectives: The Anthropocene</td>
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Capstone

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<tbody>
<tr>
<td>F&amp;ES 953</td>
<td>Business and the Environment Consulting Clinic</td>
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<tr>
<td>F&amp;ES 954</td>
<td>Management Plans for Protected Areas</td>
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<tr>
<td>F&amp;ES 955</td>
<td>Seminar in Research Analysis and Communication in Forest Ecology</td>
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<tr>
<td>F&amp;ES 964</td>
<td>Large-Scale Conservation: Integrating Science, Management, and Policy</td>
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<td>F&amp;ES 965</td>
<td>Advanced Readings: Social Science of Conservation and Development</td>
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<td>F&amp;ES 970</td>
<td>Environmental Protection Clinic: Policy and Advocacy</td>
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<td>F&amp;ES 971</td>
<td>Land Use Clinic</td>
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<tr>
<td>F&amp;ES 973</td>
<td>Capstone in Industrial Ecology</td>
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<td>F&amp;ES 983</td>
<td>Water Resource Science and Management</td>
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Ecology

COMMUNITY AND ECOSYSTEM ECOLOGY

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<tbody>
<tr>
<td>F&amp;ES 530</td>
<td>Ecosystems and Landscapes</td>
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<tr>
<td>F&amp;ES 681</td>
<td>Ethnobotany</td>
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<tr>
<td>F&amp;ES 717</td>
<td>Tropical Field Ecology</td>
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<td>F&amp;ES 723</td>
<td>Wetlands Ecology, Conservation, and Management</td>
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<td>F&amp;ES 731</td>
<td>Tropical Field Botany</td>
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<td>F&amp;ES 741</td>
<td>Biological Oceanography</td>
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<td>F&amp;ES 741</td>
<td>Ecosystem Measurements for Conservation and Restoration</td>
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<tr>
<td>F&amp;ES 752</td>
<td>Ecology and Conservation of Tropical Forests</td>
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<tr>
<td>F&amp;ES 768</td>
<td>Pests, Pathogens, and Parasites in Natural and Managed Systems</td>
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## Subjects of Instruction

### Environmental Education and Communication

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<tbody>
<tr>
<td>F&amp;ES 595</td>
<td>Yale Environment Review</td>
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<tr>
<td>F&amp;ES 613</td>
<td>Writing as a Public Scholar</td>
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<tr>
<td>F&amp;ES 625</td>
<td>Writing Workshop</td>
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<td>F&amp;ES 742</td>
<td>Fundamentals of Working with People</td>
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<td>F&amp;ES 743</td>
<td>Strategic Environmental Communication</td>
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<td>F&amp;ES 747</td>
<td>Global Communication Skills</td>
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<td>F&amp;ES 750</td>
<td>Writing the World</td>
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<td>F&amp;ES 822</td>
<td>Strategic Communication: Delivering Effective Presentations</td>
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<td>F&amp;ES 862</td>
<td>The Science of Science Communication</td>
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<tr>
<td>F&amp;ES 900</td>
<td>Doctoral Student Seminar and Responsible Conduct of Research</td>
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<tr>
<td>F&amp;ES 910</td>
<td>Survival Skills for Finishing Doctoral Students</td>
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### Forestry

#### Forest Biology

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<tr>
<td>F&amp;ES 652</td>
<td>Wood: Structure and Function</td>
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<tr>
<td>F&amp;ES 654</td>
<td>Structure, Function, and Development of Trees</td>
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<tr>
<td>F&amp;ES 656</td>
<td>Tree Physiology and Ecophysiology</td>
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<tr>
<td>F&amp;ES 671</td>
<td>Temperate Woody Plant Taxonomy and Dendrology</td>
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<tr>
<td>F&amp;ES 674</td>
<td>Seminar in Forest Ecosystem Health and Climate Adaptation</td>
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<tr>
<td>F&amp;ES 679</td>
<td>Plant Ecophysiology</td>
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<td>F&amp;ES 679L</td>
<td>Lab: Plant Ecophysiology</td>
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#### Forest Management

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<tr>
<td>F&amp;ES 658</td>
<td>Global Resources and the Environment</td>
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<tr>
<td>F&amp;ES 659</td>
<td>The Practice of Silviculture: Principles in Applied Forest Ecology</td>
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<tr>
<td>F&amp;ES 660</td>
<td>Forest Stand Dynamics</td>
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<tr>
<td>F&amp;ES 668</td>
<td>Field Trips in Forest Resource Management and Silviculture</td>
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<tr>
<td>F&amp;ES 669</td>
<td>Forest Management Operations for Professional Foresters</td>
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<td>F&amp;ES 670</td>
<td>Southern Forest and Forestry Field Trip</td>
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<td>F&amp;ES 680</td>
<td>Forest and Ecosystem Finance</td>
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<tr>
<td>F&amp;ES 692</td>
<td>Science and Practice of Temperate Agroforestry</td>
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### Physical Sciences

#### Atmospheric Sciences

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<tbody>
<tr>
<td>F&amp;ES 630</td>
<td>The Physical Science of Climate Change</td>
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<tr>
<td>F&amp;ES 700</td>
<td>Alpine, Arctic, and Boreal Ecosystems Seminar</td>
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<tr>
<td>F&amp;ES 704</td>
<td>Workshop on Remote Sensing and Photogrammetry with Drones</td>
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<td>F&amp;ES 773</td>
<td>Air Pollution Control</td>
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#### Environmental Chemistry

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<tr>
<td>F&amp;ES 706</td>
<td>Organic Pollutants in the Environment</td>
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<td>F&amp;ES 707</td>
<td>Aquatic Chemistry</td>
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<td>F&amp;ES 708</td>
<td>Introduction to Environmental Chemistry</td>
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<td>Air Pollution Control</td>
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#### Soil Science

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<tr>
<td>F&amp;ES 686</td>
<td>Advanced Issues in Soil Science</td>
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<td>F&amp;ES 709</td>
<td>Soil Science</td>
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#### Water Resources

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<tr>
<td>F&amp;ES 644</td>
<td>Watershed Science</td>
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<tr>
<td>F&amp;ES 667</td>
<td>Seminar: Fresh Water Topics</td>
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<tr>
<td>F&amp;ES 710</td>
<td>Coastal Governance</td>
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<tr>
<td>F&amp;ES 712</td>
<td>Water Resource Management</td>
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<td>F&amp;ES 714</td>
<td>Environmental Hydrology</td>
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<td>F&amp;ES 724</td>
<td>Watershed Cycles and Processes</td>
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<td>F&amp;ES 732</td>
<td>Hydrology and Riverine Geomorphology</td>
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<td>F&amp;ES 777</td>
<td>Water Quality Control</td>
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**Quantitative and Research Methods**

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<tr>
<td>F&amp;ES 510</td>
<td>Introduction to Statistics and Data Analysis in the Environmental Sciences</td>
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<td>F&amp;ES 510E</td>
<td>Introduction to Statistics and Data Analysis in the Environmental Sciences</td>
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<tr>
<td>F&amp;ES 550</td>
<td>Natural Science Research Methods</td>
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<td>F&amp;ES 551</td>
<td>Qualitative Social Science Research</td>
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<td>F&amp;ES 552</td>
<td>Master’s Student Research Conference</td>
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<td>F&amp;ES 611</td>
<td>Data Science for Social Research: An Introduction</td>
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<tr>
<td>F&amp;ES 638</td>
<td>Carbon Footprints – Modeling and Analysis</td>
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<td>F&amp;ES 720</td>
<td>Introduction to R</td>
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<tr>
<td>F&amp;ES 726</td>
<td>Observing Earth from Space</td>
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<td>F&amp;ES 751</td>
<td>Sampling Methodology and Practice</td>
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<td>F&amp;ES 753</td>
<td>Regression Modeling of Ecological and Environmental Data</td>
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<td>F&amp;ES 754</td>
<td>Geospatial Software Design</td>
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<td>Modeling Geographic Space</td>
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<td>Modeling Geographic Objects</td>
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<td>F&amp;ES 758</td>
<td>Multivariate Data Analysis in the Environmental Sciences</td>
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<td>F&amp;ES 762</td>
<td>Applied Math for Environmental Studies</td>
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<td>F&amp;ES 781</td>
<td>Applied Spatial Statistics</td>
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<td>F&amp;ES 902</td>
<td>Environmental Anthropology Research Lab</td>
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**Social Sciences**

**ECONOMICS**

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<tr>
<td>F&amp;ES 701</td>
<td>Climate Change Economics</td>
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<td>F&amp;ES 702</td>
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<td>F&amp;ES 730</td>
<td>Economics of Sustainability</td>
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<td>F&amp;ES 804</td>
<td>Economics of Natural Resources</td>
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<td>F&amp;ES 805</td>
<td>Seminar on Environmental and Natural Resource Economics</td>
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<td>F&amp;ES 834</td>
<td>Environmental Economics and Policy</td>
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<tr>
<td>F&amp;ES 905</td>
<td>Doctoral Seminar in Environmental and Energy Economics</td>
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**ENERGY AND THE ENVIRONMENT**

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<tr>
<td>F&amp;ES 583</td>
<td>American Energy History</td>
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<tr>
<td>F&amp;ES 635</td>
<td>Renewable Energy Project Finance</td>
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<td>F&amp;ES 716</td>
<td>Renewable Energy</td>
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<tr>
<td>F&amp;ES 800</td>
<td>Energy Economics and Policy Analysis</td>
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<td>F&amp;ES 812</td>
<td>Energy’s Impact on Freshwater Resources</td>
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<td>F&amp;ES 814</td>
<td>Energy Systems Analysis</td>
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<tr>
<td>F&amp;ES 816</td>
<td>Electric Utilities: An Industry in Transition</td>
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**ENVIRONMENTAL POLICY**

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<tbody>
<tr>
<td>F&amp;ES 573</td>
<td>Urban Ecology for Local and Regional Decision-Making</td>
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<td>F&amp;ES 590</td>
<td>The Climate Change Negotiations: A Practical Approach</td>
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<td>F&amp;ES 616</td>
<td>Business and Environmental Solutions: 7 by 7</td>
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<td>F&amp;ES 620</td>
<td>Integrative Assessment</td>
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<td>F&amp;ES 627</td>
<td>Environmental Law</td>
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<td>F&amp;ES 631</td>
<td>Solving Super Wicked Problems: Environmental Policy Analysis for a Low-Carbon World</td>
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<td>F&amp;ES 636</td>
<td>Sustainable Finance</td>
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<td>F&amp;ES 761</td>
<td>Negotiating International Agreements: The Case of Climate Change</td>
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<td>F&amp;ES 790</td>
<td>Sea Level Rise, Storms, and Coastal Defense</td>
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<td>F&amp;ES 798E</td>
<td>China's Energy and Environmental Sustainability Challenge</td>
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<td>F&amp;ES 799</td>
<td>Sustainable Development Goals and Implementation</td>
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<td>F&amp;ES 807</td>
<td>Corporate Environmental Management and Strategy</td>
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<td>F&amp;ES 811</td>
<td>Metrics, Tools, and Indicators in Corporate Responsibility</td>
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<td>Urban, Suburban, and Regional Planning Practice</td>
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<td>Strategies for Land Conservation</td>
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<td>Land Use Law and Environmental Planning</td>
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<td>Regulation of Energy Extraction</td>
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<td>Environmental Law and Policy</td>
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<td>Foundations of Natural Resource Policy and Management</td>
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<td>Comparative Environmental Law in Global Legal Systems</td>
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<td>Climate Change Policy and Perspectives</td>
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<td>F&amp;ES 850</td>
<td>International Organizations and Conferences</td>
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<td>Climate Change Mitigation in Urban Areas</td>
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<td>Natural Resources Law</td>
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<td>Climate Change and Animal Law</td>
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**SOCIAL AND POLITICAL ECOSYSTEM**

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<tr>
<td>F&amp;ES 520</td>
<td>Society and Environment: Introduction to Theory and Method</td>
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<tr>
<td>F&amp;ES 614</td>
<td>Environmental Justice, Nature, and Reflective Practice Seminar</td>
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<td>F&amp;ES 643</td>
<td>Managing Environment w/ People in Mind: Understanding Contribution of the Social Sci and Humanities</td>
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<td>F&amp;ES 760</td>
<td>Conservation in Practice: An International Perspective</td>
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<td>F&amp;ES 764</td>
<td>Environment, Culture, Morality, and Politics</td>
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<td>F&amp;ES 767</td>
<td>Tools for Conservation Project Design and Management</td>
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<td>F&amp;ES 772</td>
<td>Social Justice in the Global Food System</td>
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<td>F&amp;ES 774</td>
<td>Agriculture: Origins, Evolution, Crises</td>
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<td>F&amp;ES 780E</td>
<td>Journey of the Universe</td>
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<td>F&amp;ES 793</td>
<td>Climate Change, Societal Collapse, and Resilience</td>
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<td>F&amp;ES 836</td>
<td>Agrarian Societies: Culture, Society, History, and Development</td>
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<td>Social Science of Conservation and Development</td>
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<td>F&amp;ES 846</td>
<td>Perspectives on Environmental Injustices</td>
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<td>Environmental History and Values</td>
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<td>F&amp;ES 869</td>
<td>Disaster, Degradation, Dystopia: Social Science Approaches to Environmental Perturbation and Change</td>
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<td>Global Environmental History</td>
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<td>Indigenous Traditions and the Environment</td>
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<td>Anthropology of the Global Economy for Conservation and Development</td>
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<td>F&amp;ES 878</td>
<td>Climate and Society: Past to Present</td>
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<td>F&amp;ES 892</td>
<td>Introduction to Planning and Development</td>
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**HEALTH AND ENVIRONMENT**

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<tr>
<td>F&amp;ES 646</td>
<td>Foundations of Agriculture and Environment</td>
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<tr>
<td>F&amp;ES 727</td>
<td>Food: Science, Law, and Policy</td>
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<tr>
<td>F&amp;ES 803</td>
<td>Principles of Risk Assessment</td>
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<tr>
<td>F&amp;ES 806</td>
<td>Public Health Toxicology</td>
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Subjects of Instruction

F&ES 807  Environmental and Occupational Exposure Science
F&ES 808  The Environment and Human Health

INDUSTRIAL ECOSYSTEM, ENVIRONMENTAL PLANNING, AND TECHNOLOGY

F&ES 607  Advanced Methods: Industrial Ecology
F&ES 612  Readings in Waste and Materials Management: Fundamentals and Frontiers
F&ES 771  Fundamentals of Green Engineering and Green Chemistry
F&ES 782  Globalization Space: International Infrastructure and Extrastatecraft
F&ES 838  Environmental Product Life-Cycle Assessment
F&ES 884  Industrial Ecology
F&ES 885  Green Engineering and Sustainable Design
F&ES 888  Ecological Urban Design
F&ES 894  Green Building: Issues and Perspectives

ONLINE AND FLIPPED COURSES

In addition to offering courses in the traditional classroom setting, the School of Forestry & Environmental Studies in recent years has made a growing commitment to providing quality education through online learning. As part of this initiative, the School introduced a series of courses that “flip” the typical classroom model. These courses allow students to watch lectures online while still providing an opportunity for weekly personal interactions with F&ES faculty. The digital format helps the instructors incorporate multimedia resources that are difficult to use in the classroom and enables more time for discussion, questions, and/or group work during student-instructor interactions. During the 2018–2019 academic year, the School will offer several courses that use the flipped model. We are also actively developing flipped courses and integrating technology into the classrooms. Therefore, classes not listed here may include some flipped features. Courses offered in 2018–2019 include the following:

F&ES 510E  Introduction to Statistics and Data Analysis in the Environmental Sciences
F&ES 530  Ecosystems and Landscapes
F&ES 619  The Practice of Silviculture: Principles in Applied Forest Ecology
F&ES 720  Introduction to R
F&ES 762  Applied Math for Environmental Studies
F&ES 789E  Journey of the Universe
F&ES 798E  China's Energy and Environmental Sustainability Challenge
F&ES 835E  Seminar on Land Use Planning
F&ES 875E  Urban Resilience: Complexity, Collaborative Structures, and Leadership Challenges

COURSE DESCRIPTIONS

At F&ES, new courses are often added after this bulletin is printed. Our website at http://environment.yale.edu will have an updated list, as well as a list of environmental courses available in other departments at Yale. See also Yale Course Search at https://courses.yale.edu.

Basic Knowledge

F&ES 511a, Ecological Patterns and Processes  Oswald Schmitz
This six-week course (Aug. 29–Oct. 5) gives students a fundamental mechanistic understanding about the way abiotic (e.g., climate) and biotic (e.g., resources, competitors, predators) factors determine pattern in the distribution and abundance of species. Students learn how individuals within a species cope with changing environmental conditions by altering their behavior, making physiological adjustments, and changing the allocation of resources among survival, growth, and reproduction. Students learn how populations of species coexist within communities and how species interactions within communities can drive ecosystem functioning. Students also learn how ecologists use scientific insight to deal with emerging environmental problems such as protecting biodiversity, understanding the consequences of habitat loss on species diversity, and forecasting the effects of global climate change on species population viability and geographic distribution. 1½ Course cr

F&ES 512a, Microeconomics for Environmental Management  Matthew Kotchen
This six-week course provides an introduction to microeconomic analysis and its application to environmental policy. Students study how markets work to allocate scarce resources. This includes consideration of how individuals and firms make decisions, and how policy analysts seek to quantify the benefits and costs of consumption and production. We consider the conditions under which markets are beneficial to society and when they fail. We see that market failure arises frequently in the context of environmental and natural resource management. The last part of the course focuses on the design of environmental and natural resource policies to address such market failures. The course is designed to cover basic knowledge of economics analysis and prepare students for F&ES 834 and other more advanced offerings. 1½ Course cr
F&ES 521a, Physical Science Foundations for Environmental Managers  Shimon Anisfeld
This six-week course (Oct. 15–Dec. 7) provides students with the physical science basics that they need in order to understand and manage environmental problems. The course draws on the following disciplines: climatology, environmental chemistry, geology, hydrology, meteorology, oceanography, and soil science. Focus is on understanding both the underlying concepts and how they apply to real-world environmental challenges. Useful both as a freestanding course and as a gateway to a wide spectrum of intermediate and advanced courses.  1½ Course cr

F&ES 522a, Problem Solving in the Global Era: How Social Sciences Contribute to Forward Looking Env Management  Benjamin Cashore and Amity Doolittle
This six-week course (Oct. 15–Dec. 7) is designed to identify key contributions of the social sciences for environmental managers. Targeted to nonspecialists as well as those considering the society and nature stream, the course emphasizes two key themes: the way in which scientific knowledge about environmental problems influences problem definitions, social movements, and policy responses; and the role of social sciences in fostering forward-looking environmental management. It draws on Clapp and Dauvergne’s “four environmental worldviews” framework, which integrates knowledge from political science, sociology, anthropology, human geography, and development studies; as well as international relations and public policy.  1½ Course cr

Professional Skills Courses

F&ES 577a, PSC: Financial Concepts for Environmental Managers  Maureen Burke
This course exposes students to the financial concepts used by companies to make and evaluate business decisions. The class covers key financial statements of for-profit businesses; building financial projections for a business, project, or investment; financial markets: what they are and how they operate; investors: the tools they use to evaluate potential investments; and common valuation techniques: uses and limitations.  1 Course cr

F&ES 578a, PSC: Environmental Communicator  William Vance
This course prepares students for the communication tasks they will face as environmental professionals, researchers, or employees. In their careers, most professionals spend more than half their work time communicating with others, both inside and outside their organization. To advance in their careers and contribute to the progress of an environmental cause, students need a refined ability to communicate their ideas with clarity and credibility. This course focuses on building a constellation of skills that students can apply to their work. They learn how to use communication to influence others, advocate their ideas, and collaborate with colleagues on project teams. Course topics include strategy in communication, diplomatic language, public speaking, writing styles, listening to people, and framing environmental issues for the public. The course meets for a weekly two-hour lecture and demonstration, and students attend a one-hour small-group practice session that allows them to reinforce new communicative behaviors in simulated job tasks, such as project meetings, budget requests, and public hearings. Meeting dates to be determined. Enrollment limited to forty-five.  1 Course cr

Perspectives

F&ES 601a, Perspectives: The Anthropocene  Julie Zimmerman and Paul Anastas
The course is intended to offer a common experience and exposure to the variety of perspectives represented by F&ES faculty and staff on the challenges and opportunities of environmental management. The theme for the inaugural offering is “The Anthropocene.” Humans are now drivers of environmental change on a scale that is unique in Earth’s history. Human-driven biological, chemical, and physical changes to the Earth’s system are so great, rapid, and distinct that they may characterize an entirely new epoch – the Anthropocene.  3 Course cr

Capstone

F&ES 953a or b, Business and the Environment Consulting Clinic  Maureen Burke
Students work as a team on a specific project for an external company. The course provides students with an opportunity to apply their knowledge of business and environmental issues to real-life situations. It also provides a unique opportunity for students to manage a real-life client consulting engagement. Examples of projects include (1) researching and recommending best practices in supply chain sourcing; (2) assessing water risk in a company’s operations; and (3) recommending improvements around energy usage, waste disposal, etc. The intent is to provide a “capstone” experience, calling for the application of skills and tools learned from previous courses. Class sessions consist of a mix of in-class lectures, team meetings with the instructor, and guest lecturers. Lectures address topics such as project management and business strategy. Guest speakers discuss various environmental and sustainability topics such as sustainability reporting, and environmental certifications and labeling. Enrollment limited to twenty-four. Prerequisites for F&ES students applying to the clinic are at least one of the following courses (or equivalent experience): F&ES 578, F&ES 616, F&ES 636, F&ES 680, F&ES 807, F&ES 811, F&ES 821, or F&ES 874.  3 Course cr

F&ES 954a, Management Plans for Protected Areas  Mark Ashton
A seminar that comprises the documentation of land use history and zoning, mapping and interpretation, and the collection and analysis of socioeconomic, biological, and physical information for the construction of management plans. Plans are constructed for private smallholders within the Quiet Corner Initiative partnership managed by the Yale School Forests. In the past, plans have been completed for the Nature Conservancy; Massachusetts Trustees of Reservations; town land trusts; city parks and woodlands of New Haven, New
F&ES 952a or b, Seminar in Research Analysis and Communication in Forest Ecology  
Mark Ashton  
Students work through the peer-review publication process on data sets and projects in applied forest ecology. Discussions involve rationale and hypothesis testing for a project, data analysis techniques, reporting and interpretation of results. It is expected that manuscripts developed in the course are worthy of publication and that oral presentations are of a caliber for subject area conferences and meetings. Three hours lecture. Enrollment limited to twelve. Prerequisite: F&ES 659 or permission of the instructor. 3 Course cr

F&ES 964, Large-Scale Conservation: Integrating Science, Management, and Policy  
Environmental sustainability and human dignity are important societal goals, but figuring out how to achieve them on large scales—geographic, temporal, and in terms of complexity—has proven to be extremely challenging. Abundant trend data show that many species, ecosystems, and other environmental and human systems are being overused, stressed, or degraded, thus undercutting the likelihood that we can reach sustainability and human rights for all. In addition, our institutions for science, management, and policy are not designed to address sustainability challenges on these scales. Over the past few decades numerous management and policy initiatives have been put forward to address large-scale resource use, including single and multiple use, parks and protected areas, ecosystem management, bioregional planning, integrated conservation and development, transboundary approaches, and adaptive governance. This course (a mixed seminar and practicum) explicitly uses an integrative (i.e., interdisciplinary) framework to examine the conceptual and contextual basis for these efforts; compares and contrasts their scientific, management, and policy components; explores themes of leadership, problem solving, decision-making, governance, change, and learning; and surveys cases from three arenas (terrestrial, aquatic, and marine). The course takes a problem-oriented, contextual, and multi-method approach that offers students conceptual, practical, and professional benefits. It includes readings, lectures, discussions, workshops, exercises, oral presentations, guest speakers, individual and small-group assignments, and possibly a field trip and group project. In past years the course took a field trip to the Connecticut River system to evaluate region-wide conservation efforts, the Greater Yellowstone Ecosystem, the Grand Canyon Ecosystem. It also organized an international workshop focused on the Yellowstone to Yukon initiative and assisted a major U.S. NGO plan for transboundary projects along the U.S.–Canadian border. Extensive student participation is required throughout. Enrollment limited to eighteen. 3 Course cr

F&ES 965b, Advanced Readings: Social Science of Conservation and Development  
Carol Carpenter  
This course is an advanced seminar on the social science theory of conservation and development, designed as an M.E.M. capstone course and to give M.E.Sc. and doctoral students a wider theoretical context for analyzing and writing up their research. The course traces the conceptual history of the social science theory of conservation and development, focusing on theories of power, governmentality, subject creation, and the economy. It examines relations between these theories, alternative theories, and how this history influences the field. The course covers the works of Michel Foucault most relevant to the field, important social scientists who have used Foucault’s ideas (e.g., Timothy Mitchell, Tania Li, Donald Moore, David Mosse, Anand Pandian), alternative theories of power (e.g., James Scott, Bruno Latour, Timothy Mitchell), applications of Foucault’s ideas to development (James Ferguson, Arturo Escobar), applications of Foucault’s ideas to the environment (especially Arun Agrawal, Bruce Braun, Eric Darier), theories of the economic subject (Peter Miller and Ted O’Leary, Anna Tsing, Katherine Rankin), Foucault on the economy and neoliberalism, the power of the economy in Tania Li, theories of resistance and counter-conduct (Foucault, Carl Death, James Scott), and Foucault and space. Students are expected to use the course to develop, and present in class, their own research and writing. Three hours lecture/seminar. Enrollment limited to twelve. Prerequisite: F&ES 859, F&ES 877, or F&ES 882. 3 Course cr

F&ES 970a or b, Environmental Protection Clinic: Policy and Advocacy  
Douglas Kysar  
The Clinic’s mission is to train students in environmental advocacy through skills-based seminars, interdisciplinary project work, and collaboration with the Natural Resources Defense Council and other significant environmental organizations. Students are assigned to teams of two-to-four members drawn from both the law school and the School of Forestry & Environmental Science. Teams work on a project developed in collaboration with client organizations, with most projects having both legal and policy components. In addition to covering substantive areas of environmental law, Clinic seminars help students master the tools of effective environmental advocacy, including the abilities to research law and science, write and cite persuasively, navigate environmental organizations, and manage projects cooperatively. Enrollment limited to eighteen. For all questions, please email Conor.reynolds@yale.edu. Note: Attendance at the first-class meeting is mandatory for admitted students and for those on the waiting list who wish to remain in consideration for admission if a place becomes available. Admitted students must confirm their participation in advance of the first class by a date designated by the instructors. A no-drop policy applies. Students in the School of Forestry & Environmental Studies (and students from any other school besides Yale Law School) must complete the Clinic’s Bidding Form by 4:30 p.m. on December 16. The Bidding Form is available: https://www.surveymonkey.com/r/YCNV8XN 3 Course cr

F&ES 971a, Land Use Clinic  
Jessica Bachr  
This clinic explores a variety of specific community land use topics of current concern and relevance to the field, to the curriculum, and to society. Potential project topics include renewable energy, natural resources, rural-based land uses, the intersection of water and land management, agriculture, climate adaptation, and sustainable urban planning. Students work with the instructor to develop papers, research memorandums, presentations, and publications on a selected topic for a client. The average project requires 10–12 hours of work outside of class per week. The instructor and guest speakers lecture on specific skills and topics related to student projects during a weekly class meeting. Students select from a project list or meet with the instructor to design a relevant project at the beginning of the term. Attendance at the first class is mandatory to learn about project options. A part of the course is a one-week field trip during spring
break. Enrollment limited to twelve, with priority given to F&ES students. Due to high demand, the course requires a short application. Students are selected during the fall term. 3 Course cr

F&ES 073b, Capstone in Industrial Ecology  Reid Lifset
The industrial ecology specialization examines the relationships among production, consumption, sustainability, design, and industrial ecology in diverse settings, from products to firms to cities to international trade flows. This capstone course offers opportunities to student teams to work with sponsor organizations to apply industrial ecology-related methods, including life-cycle assessment, to practical problems facing the organization. In addition, students working independently join the class to learn more about project preparation and to share insight with other students interested in industrial ecology insights and applications. 3 Course cr

F&ES 083b, Water Resource Science and Management   Gaboury Benoit
This course is designed as the preferred option to fulfill the requirement of a capstone course within the M.E.M. specialization in Water Resource Science and Management. Students work under the instructor’s direction, with advice from other water faculty, to develop management plans or other guidance documents supported by new or existing applied research. Students are trained in research methods so that they have useful background knowledge that will be essential in their future management careers. Topics emphasize real-world, interdisciplinary problems with possible immediate application. 3 Course cr

Ecology

COMMUNITY AND ECOSYSTEM ECOLOGY

F&ES 530a, Ecosystems and Landscapes  Mark Bradford
This course is an introduction to ecosystems and landscape ecology. Topics covered include element cycling, food web interactions, species-area relationships, whole system metabolism, models of biodiversity, etc. The course emphasizes how to integrate knowledge to understand ecological patterns and processes at multiple scales in order to study, manage, and conserve species and ecosystems. 3 Course cr

[ F&ES 681, Ethnobotany ]

Ethnobotany is the scientific study of mutual relationships among peoples, plants, and the environment. This course presents ethnobotany as a broad interdisciplinary field at the interface of anthropology and botany and discusses its methodology, ranging from plant inventories to multivariate analysis of plant knowledge. The course focuses on classic themes of interest to ethnobotany, such as the importance of plants for local livelihoods (including nutrition and medicine) and the ethnobotanical importance of selected plant families, but it also explores topics of current ethnobotanical investigation, such as urban ethnobotany, intellectual property rights, development cooperation, biocultural diversity, and conservation. The course topics have been selected to provide an all-round overview of how ethnobotany research has evolved over the past decades and to represent a well-rounded mix of theory and practice, with the aim to prepare an aspiring junior ethnobotanist for field research. 3 Course cr

F&ES 717b, Tropical Field Ecology  Liza Comita and Simon Queenborough
This course is designed to give students firsthand knowledge of tropical biology and the issues surrounding conservation of biodiversity in a developing nation, through a combination of seminar-style discussions and a mandatory field trip over winter break. The emphasis is on active learning and developing independent research projects carried out during the field trip. Using a case-study approach, topics covered include patterns of biodiversity, tropical forest dynamics, reforestation, species interactions and coevolution, climate change impacts, ecosystem services, and human land use. Students also gain experience with study design, data collection methods, and statistical analysis. This year’s field trip is to Panama, a country famous for its high biological, cultural, and economic diversity. We visit a variety of forest ecosystems and hear from local and international scientists about current research in the field. Students undertake two short research projects and also learn basic identification and natural history of tropical plant, bird, and insect species. Students should expect to spend a major part of each day outside in the natural tropical environment under adverse conditions. Enrollment limited to fifteen, with priority given to students who have taken F&ES 752. 3 Course cr

F&ES 723a, Wetlands Ecology, Conservation, and Management   L. Kealoha Freidenburg
Wetlands are ubiquitous. Collectively they cover 370,000 square miles in the United States and globally encompass more than five million square miles. Most points on a map are less than one kilometer from the nearest wetland. Yet wetlands are nearly invisible to most people. In this course we explore wetlands in all of their dimensions, including the critical services they provide to other systems, the rich biodiversity they harbor, and the links by which they connect to other systems. Additionally, wetlands are linchpin environments for scientific policy and regulation. The overarching aim of the course is to connect what we know about wetlands from a scientific perspective to the ways in which wetlands matter for people. 3 Course cr

F&ES 723b, Tropical Field Botany  Fabian Michelangeli and Lawrence Kelly
This course teaches students how to identify the most important tropical plant families, with an emphasis on woody taxa. Students learn key characteristics for identification. We concentrate on families that have high economic, ecological, or ethnobotanical importance. We also discuss distribution, habitat, and ecology. The course has a strong practical component, and instructors emphasize vegetative characters to identify families and higher-level taxa. The course includes a two-week field trip to Costa Rica over spring break. Enrollment limited to twelve. 3 Course cr

[ F&ES 734, Biological Oceanography ]

This course explores a range of oceanic ecosystems and how these environments function as coupled physical/biological systems. Solar energy drives the structuring of the oceans in the vertical dimension, and the formation of both deep and surface currents. These currents
are the means by which heat and material are redistributed and are the determinants of where nutrients are available for support of primary production. The currents and other physical processes also determine the distribution and abundance of organisms from phytoplankton to fish and whales. Anthropogenic impacts on oceans are also explored, such as the effects of fishing and climate change. This natural science course provides a foundation for those interested in the ecology of marine systems and in the management of coastal zones. Enrollment limited to fifteen. Recommended prerequisite: college-level biology or ecology course. 3 Course cr

F&ES 741b, Ecosystem Measurements for Conservation and Restoration  Marlyse Duguid
This course is intended to expose students to a variety of field and laboratory methods used in conservation science. During the first half of the term, students gain experience in a broad range of field and lab methods and analysis with applied conservation relevance (e.g., carbon stocks, biodiversity). The second half of the term is a practicum where students design, conduct, analyze, and present data as a rapid assessment of a local property of interest to local conservation organization(s). 3 Course cr

F&ES 722a, Ecology and Conservation of Tropical Forests  Liza Comita
Tropical forests contain extraordinarily high biological diversity and provide critical ecosystem services, yet are being rapidly destroyed and degraded by human activities. This course focuses on the structure, function, and diversity of intact and degraded tropical forests, with an emphasis on the ecological processes that shape these unique and diverse ecosystems. We also discuss the major threats to tropical forests, as well as examples of tropical forest recovery following disturbance. The course involves a mix of lectures and student-led discussions. Students who successfully complete this course are given priority for F&ES 717. 3 Course cr

[ F&ES 768, Pests, Pathogens, and Parasites in Natural and Managed Systems ]
Pests, pathogens, and parasites play an underappreciated but incredibly important role in the ecology of both natural and managed systems. This course combines lectures with in-class discussions of scientific literature to explore the influence of pests, pathogens, and parasites on the ecosystems around us. We ask and answer a number of questions, including: Can pathogens explain why tropical forests are so diverse? How is parasitic mind control related to nutrient-cycling? Does biodiversity loss cause an uptick in human disease? How do invasive insect herbivores impact carbon emissions from forests? Both basic scientific fundamentals and applied interdisciplinary case studies are covered. Students leave with an understanding of core ecological principles through the lens of pests, pathogens, and parasites, and ultimately an appreciation for how these organisms fit into a broader ecological context in a rapidly changing world. 3 Course cr

ENVIRONMENTAL EDUCATION AND COMMUNICATION

F&ES 595a or b, Yale Environment Review  Matthew Kotchen
*The Yale Environment Review* is a student-run online publication that aims to bridge the gap between the environmental science community and the interested public. Its aim is to shed light on cutting-edge environmental research through summaries, analyses and interviews. For the Spring 2019 semester, the YER team will be introducing new content to further engage both the YER audience and the student writers in environmental science communication. Student writers can choose one of two writing options for the semester. First, they can write two pieces, choosing from a Focus article based on a recent peer-reviewed academic article and/or a Spotlight that highlights the work of a leader or researcher in the environmental field. Second, writers can choose to write one Feature piece that builds a story around multiple recent peer-reviewed academic articles on one topic. Through a rigorous editing process and participation in five classes throughout the semester, students will be coached to write for a fast-growing environmental publication. *Joining the Yale Environment Review will help students sharpen their writing skills, familiarize themselves with science communication, and publish their work.* 1 Course cr

F&ES 613b, Writing as a Public Scholar  Stephanie Hanes Wilson
Environmental scholars and practitioners increasingly recognize the need, and often have the desire, to communicate their passions and expertise to a wide lay audience. The seminar starts from the premise that to do this effectively requires a mastery of written storytelling, particularly in today’s saturated and fractured media landscape. Students read popular works by classic and contemporary scholars, such as Rachel Carson and Richard Prum; practitioners in the sciences, such as Atul Gawande and Peter Wohlleben; and journalists such as Elizabeth Kolbert and John McPhee; as well as a growing number of authors, such as Bill McKibben, whose work crosses these categories. Students analyze some pieces multiple times, developing an increasingly nuanced understanding of storytelling technique. 3 Course cr

F&ES 625b, Writing Workshop  Roger Cohn
This is a practical course aimed at helping students improve their writing. The goal is not to try to shape students into professional writers, but rather to develop their writing skills and make them better able to communicate their work and ideas through writing that is clear, accessible, and free of jargon. Students are required to write short pieces each week and have the option of writing one longer article. The class is organized as a workshop, with students reading and commenting on each other’s work. The instructor is available for weekly meetings with students to discuss their writing. There are regular readings of articles or short book selections, but the focus is on developing the students’ own writing. Students are evaluated on the completion of all assignments on time; the quality of their work; the progress their writing shows over the course of the term; and participation in discussions. 3 Course cr

F&ES 742b, Fundamentals of Working with People  Bradford Gentry and Stuart DeCew
Using environmental science to help inform and change human actions is a key challenge for environmental managers. Doing so requires that professionals be able to work across different scales, including: (1) understanding their own values and ways of working, as well as those of others; (2) forming, working in, and leading teams reflecting a diversity of experiences and skills; (3) influencing the actions of the organizations within which they are working; and (4) building and managing collaborative networks with others in other organizations affecting the resource systems about which they care. The purpose of this course is to introduce students to the scholarship
being done (mostly within management fields) on how best to make these connections, as well as the ways individuals are putting those lessons learned into action. The course also introduces students to the professors, individual courses, workshops, and other offerings across Yale that offer deeper dives into specific approaches to working more effectively with people. 3 Course cr

**F&ES 743b, Strategic Environmental Communication** Anthony Leiserowitz
Increasing economic prosperity and improving the lives of an estimated ten billion people, while maintaining and restoring the life-support systems of the planet, is the ultimate challenge of the twenty-first century, often labeled “sustainability.” Governments, businesses, and civil society will each play critical roles in this historic transition and must operate and succeed in ever-more complex and often contested social, cultural, political, and natural environments. Strategic communication is a powerful means of advancing an organization’s mission, especially when informed by insights into human behavior and social systems. By the end of this course, students are able to develop communication strategies and apply insights from the social and behavioral sciences to improve the effectiveness of their communication campaigns. Enrollment limited to twelve. Nonstandard meeting times. 3 Course cr

**F&ES 747a, Global Communication Skills** William Vance
This course helps students to sharpen their language and strategy in professional communication. Course topics include accent reduction, language accuracy, writing styles, presentation skills, meeting leadership, barriers to communication, and types of persuasion in multicultural contexts. We first address aspects of intelligibility, exploring how improved word choices and speech clarity affect audience understanding. We then look at the problem of comprehension and discuss strategies for increasing the student’s ability to listen accurately and read efficiently. We also examine common difficulties and cultural differences in the arrangement of information, use of evidence, and academic argumentation. Several sessions are devoted to specific skills, such as negotiating agreements and writing research reports. The course meets for lecture (two hours), and students attend a weekly small-group practicum (one hour). The practicum allows students to reinforce new communicative behaviors in oral and written assignments, while receiving feedback from peers and the instructor. As students polish their skills, they improve their ability to express ideas and to interact in both academic and professional contexts. Enrollment limited to fifteen. 3 Course cr

**F&ES 750a, Writing the World** Verlyn Klinkenborg
This is a practical writing course meant to develop the student’s skills as a writer. But its real subject is perception and the writer’s authority—the relationship between what you notice in the world around you and what, culturally speaking, you are allowed to notice. What you write during the term is driven entirely by your own interest and attention. How you write is the question at hand. We explore the overlapping habitats of language—present and past—and the natural environment. And, to a lesser extent, we explore the character of persuasion in environmental themes. Every member of the class writes every week, and we all read what everyone writes every week. It makes no difference whether you are a would-be journalist, scientist, environmental advocate, or policy maker. The goal is to rework your writing and sharpen your perceptions, both sensory and intellectual. Enrollment limited to fifteen. 3 Course cr

**F&ES 822a or b, Strategic Communication: Delivering Effective Presentations** Taly Reich
The focus of this half-term course is to increase students’ competencies in oral communication and presentation. Developing and executing effective communication strategies is essential in a variety of business settings. Business leaders are often expected to present their message with confidence and clarity to employees, clients, partners, investors, and the public. This highly interactive, practical course helps students develop confidence in public speaking through weekly presentations and assignments, lectures and discussions, guest speakers, simulated activities, and filmed feedback. Students are given the opportunity to present both individually and as part of a team. We explore the essentials of communication strategy and persuasion: audience analysis, message construction, communicator credibility, and delivery. Students at all levels of mastery of public speaking will benefit from this course. Limited enrollment. F&ES students must submit a statement of interest to the instructor. Students are required to attend the first class session in order to remain enrolled in or bid for the course. 1½ Course cr

**F&ES 862b, The Science of Science Communication** Dan Kahan
The simple dissemination of valid scientific knowledge does not guarantee it will be recognized by non-experts to whom it is of consequence. The science of science communication is an emerging, multidisciplinary field that investigates the processes that enable ordinary citizens to form beliefs consistent with the best available scientific evidence, the conditions that impede the formation of such beliefs, and the strategies that can be employed to avoid or ameliorate such conditions. This seminar surveys and makes a modest attempt to systematize the growing body of work in this area. Special attention is paid to identifying the distinctive communication dynamics of the diverse contexts in which non-experts engage scientific information, including electoral politics, governmental policy making, and personal health decision-making. Paper required. Permission of the instructor required. 2 Course cr

**F&ES 900a, Doctoral Student Seminar and Responsible Conduct of Research** Karen Seto
This course provides an introduction to doctoral study at the School of Forestry & Environmental Studies. Students attend the F&ES Wednesday seminar each week and then meet with the seminar speakers after their presentations. Weekly assigned readings support these discussions, which are used as a foundation to explore diverse approaches to formulating and addressing research questions. Students also work with their advisers to design an assignment to be completed during the term. Students may choose to write and submit a fellowship application (e.g., NSF, NASA, EPA), carry out a literature review, or develop a collaborative research project. Students present their embryonic research ideas in class and use feedback from the group to further develop their ideas. The course also introduces the topic of research misconduct with examples of specific cases. Concepts and resources for responsible conduct of research are discussed in the areas of data acquisition and management, authorship and publication, peer review, conflicts of interest, mentoring, collaborative research, and animal and human subjects research. Required of all doctoral students in their first term. 1 Course cr
**F&ES 910b, Survival Skills for Finishing Doctoral Students**  
William Lauenroth and Ingrid Burke  
This course is aimed at preparing advanced doctoral students for successful and rewarding careers in ecology and environmental science. Students learn about academic and non-academic careers from readings of and presentations by scientists in those positions. Students identify important steps toward planning and launching their career paths, and skills for being effective in these positions; and they develop their own career plan, curriculum vitae, teaching and research plans, and critiques of professional web pages. Finally, the course exposes students to resources and opportunities for continuing to apply and polish their skills. Pass/Fail.  
1 Course cr

**Forestry**

**FOREST BIOLOGY**

**F&ES 652b, Wood: Structure and Function**  
Craig Brodersen  
This course focuses on the extraordinary diversity of wood anatomy at the cellular level, and on the practice of dendrochronology that allows students to take advantage of predictable, inter-annual variability in tree growth to reconstruct environmental history. The primary focus of the course is on common northeastern trees and other commercially important timber species. A primary goal is to participate in the development of a master tree-ring chronology for the School Forests. Prerequisites: basic statistics and a background in tree physiology and anatomy are strongly recommended.  
3 Course cr

**F&ES 654a, Structure, Function, and Development of Trees**  
Graeme Berlyn  
This course focuses on two aspects of plant life: (1) basic processes that drive plant development, such as seed formation, germination, seedling establishment, maturation, and senescence; and (2) basic structure and function of plants (such as root systems, leaf formation and development, height, and diameter growth). Differences between different groups of seed plants are analyzed from structural, functional, ecological, and evolutionary standpoints. Special attention is given to woody plants and their importance in the biosphere and human life. Coverage includes tropical, temperate, and boreal trees. Plant biology is discussed in the context of physiological and structural adaptations in terms of strength, storage, and water and solute transport.  
3 Course cr

**F&ES 656b, Tree Physiology and Ecophysiology**  
Graeme Berlyn  
Mineral nutrition and cycling, mycorrhizas, symbiosis, nitrogen fixation, light processing, photosynthesis, respiration, water relations including transpiration, and ecophysiology are covered. The interaction of photosynthesis with water relations, mineral nutrition, temperature, and environmental stress is discussed. Effects of climate changes on forests, past and present, and other current topics are also considered. Term paper required.  
3 Course cr

**F&ES 671a, Temperate Woody Plant Taxonomy and Dendrology**  
Marlyse Duguid  
Dendrology literally translates as “the study of trees” and integrates morphology, phenology, ecology, biogeography, and the natural history of tree species. In this course students learn how to identify more than 120 individual species of woody plants using common morphological and ecological traits used for field identification. Dendrology is by nature context-specific, so this course has a focus on North American forest species, primarily of eastern North America. In addition, we use phylogenetic systematics as the structure for understanding taxonomy and the evolutionary history and relationships between species. Enrollment limited to thirteen.  
3 Course cr

**F&ES 674, Seminar in Forest Ecosystem Health and Climate Adaptation**

This course is an introduction to the biotic and abiotic agents affecting the health of forest ecosystems and forest sustainability, including insects, pathogens, parasites, climate change, and other large-scale disturbances, and includes the consideration of linkages between forest health and human health. Using a case-study approach, several different forest types are examined in detail, with students interacting with research and management professionals who visit the class in person or via remote conferencing. Students learn concepts and methods of assessing forest health, as well as some of the challenges in describing and defining forest health. The course emphasizes the ecological roles played by disturbance agents (both biotic and abiotic), discusses how they affect the health and sustainability of forest ecosystems, and identifies when and how management can be used to improve forest health and/or forest sustainability to manage or mitigate disturbance agents such as invasive pathogens and insects. The course provides students with the necessary background to determine how different stressors may negatively impact management objectives, to identify the probable stress agents, and to decide what, if any, actions should be initiated to protect forest health and sustainability. The course includes several field trips and workshops on the weekends.  
3 Course cr

**F&ES 679a, Plant Ecophysiology**  
Craig Brodersen  
This course focuses on the physiological ecology of plants and their interaction with the biotic and abiotic environment, understood through the lens of first principles. We use a quantitative approach to demonstrate the linkages between photosynthesis, growth, and carbon allocation at the tissue and whole plant level, which can then be scaled up to forests and ecosystems. We also focus on specific physiological and anatomical adaptations plants use to survive in the many varied habitats on Earth. The laboratory component of this course (F&ES 679L) involves the theory, programming, and deployment of micrometeorological equipment to monitor environmental conditions in the field; as well as methods for measuring photosynthesis and growth in the greenhouse and field. Enrollment limited to sixteen.  
3 Course cr

**F&ES 679La, Lab: Plant Ecophysiology**  
Craig Brodersen  
Lab for F&ES 679.  
1 Course cr
FOREST MANAGEMENT
F&ES 658a / GLBL 573a, Global Resources and the Environment  Chadwick Oliver
Students first learn the global distribution of resources—the amounts, importance, and causes of distribution, and potential changes to soils, water, biodiversity, human societies, energy sources, climates, agriculture, forests and forest products, minerals, and disturbances. They also learn how to analyze and interpret data on global resource distributions. Second, they gain an understanding of the value of multiple-country trading of resources. Third, they gain an understanding of the many mechanisms that facilitate such exchanges, including policies and treaties; business, markets, trading partners, and economics; “good will”; social “taboos”; force; news media; philanthropy; skillful negotiations; cultural/social affiliation; technologies; shared infrastructures; and others. Four teaching methods are used: lectures on the different resources and policy mechanisms; analytical exercises for understanding how to use and interpret international data—and its limitations; a class negotiation exercise for learning the uses of international trade; and guest lectures by faculty and meetings with practitioners for learning the facilitation mechanisms. Three hours lecture; possible field trips.  3 Course cr

The scientific principles and techniques of controlling, protecting, and restoring the regeneration, composition, and growth of natural forest vegetation and its plantation and agroforestry analogs worldwide. Analysis of biological and socioeconomic problems affecting specific forest stands and design of silvicultural systems to solve these problems. Applications are discussed for management of wildlife habitat, bioenergy and carbon sequestration, water resources, urban environments, timber and nontimber products, and landscape design. Four to six hours lecture. One hour tutorial. Seven days fieldwork. Recommended: some knowledge of soils, ecology, plant physiology, human behavior, and resource economics.  4 Course cr

F&ES 660a, Forest Stand Dynamics  Chadwick Oliver
This course introduces the study of forest stand dynamics—how forest structures and compositions change over time with growth and disturbances. Understanding the dynamic nature of forest stands is important for creating and maintaining a variety of critical ecosystem services sustainably and synergistically, including sustainable supplies of wood products, biodiversity and wildlife habitats, water, fire protection, and others. Through readings, lectures, discussions, and field trips we explore forest development processes and pathways, concentrating on the driving mechanisms and emergent properties including natural and human disturbances. We make use of New England forests as living laboratories while discussing how similar forest patterns and processes are played out throughout the temperate, tropical, and boreal worlds. The course also includes content on the history and politics of forest ecology and conservation. It uses a book written by the instructor (Forest Stand Dynamics, 1996) and made available electronically. This class is a core component of the M.F. degree but is explicitly designed to be accessible to anyone interested in an in-depth exploration of forest ecosystems.  3 Course cr

F&ES 660b, Field Trips in Forest Resource Management and Silviculture  Mark Ashton
Seven- to twelve-day field trips to study the silviculture and forest management of particular forest regions. In previous years, classes have visited Slovenia, Germany, Austria, the United Kingdom, British Columbia, and, in the United States, the southern Coastal Plain and Piedmont, and the Allegheny, Appalachian, Adirondack, and Green mountains. Enrollment limited to sixteen.  1 Course cr

F&ES 669a, Forest Management Operations for Professional Foresters  Michael Ferrucci
The operational aspects of managing forestland are taught, including topics essential to the professional practice of forest management. Operational aspects of regeneration, intermediate tending, and harvesting (planning, layout, implementation, and postoperation evaluation), best management practices, regulatory and wetlands considerations, and socioeconomic dimensions of field operations are included. The ethical and professional responsibilities of forest managers who are responsible for land-altering activities are also considered. The course includes field time to help students utilize their existing knowledge about forests to rapidly assess stands and land parcels with respect to the planning and implementation of on-the-ground treatments. Classes feature local field trips to view forest operations and to develop and refine field skills. Students who take this class for credit have priority for selection for F&ES 670 for an additional credit. This trip is scheduled for the first week of March break and involves an intensive view of southern forest management and culture, including silviculture, harvesting, processing, and other management operations. Prerequisite: any silviculture course.  2 Course cr

F&ES 670b, Southern Forest and Forestry Field Trip  Michael Ferrucci
This course augments our forestry curriculum by providing a forum for viewing and discussing forestry and forest management with practitioners. The trip provides M.F. candidates and other interested students with an opportunity to experience the diversity of southeastern forested ecosystems and ownership objectives ranging from intensively managed pine plantations to restoration and protection of endangered habitats. Students discuss forest management issues—including forest health, fragmentation, policy, law, and business perspectives—with landowners and managers from large industries, nonindustrial private landowners, TIMOs, federal and state land managers, NGOs, and forestry consultants. We also tour sawmills, paper mills, and other kinds of forest products processing facilities, active logging operations, and, weather permitting, participate on prescribed fires. Not least, we experience the unique cultures, food, and hospitality of the southeastern United States. The course can be taken for 1 credit by any student at F&ES or combined with the 2-credit Forest Management Operations (F&ES 669) for 3 credits.  1 Course cr

F&ES 680a, Forest and Ecosystem Finance  Dominick Grant and Deborah Spalding
Understanding the tools used in financial analysis is an important component of successful forestland investment and forest management decision-making. Moreover, as new ecosystem services markets develop, these skills become even more critical in determining those management strategies that are both ecologically sound and financially viable. This course provides students with a basic suite of financial tools used in the acquisition and management of forestland/timber as well as in the management of ecosystem services. It
includes an overview of traditional financial analysis metrics used in land acquisition, timber management, and risk management. It also applies these metrics in ecosystem services markets, allowing students to assess the financial impacts of various management choices. Concepts are reinforced through spreadsheet-based exercises and case studies. Prerequisite: F&ES 578 or permission of the instructor. 3 Course cr

F&ES 692a, Science and Practice of Temperate Agroforestry  Joseph Orefice
This course explores the science and practices of temperate agroforestry, covering current knowledge of agroforestry science and shedding light on the myths and assumptions that have yet to be tested regarding the integration of trees in agricultural systems. The course begins with an overview of modern agriculture to help us better understand why agroforestry systems have potential to improve the sustainability of farming systems. We also cover the social science regarding agroforestry and why it has not been widely adopted. Silvopasture and forest farming systems are the primary focus, but windbreaks, alley cropping, and riparian forest buffers are also covered. The field of agroforestry has struggled with the promotion of hypothetical practices; this course introduces students to real-world production agroforestry systems and helps them better contribute to financially viable and environmentally sound agricultural operations. 3 Course cr

Physical Sciences

ATMOSPHERIC SCIENCES

F&ES 630b, The Physical Science of Climate Change  Peter Raymond and Xuhui Lee
This course covers the science behind Earth’s climate system. The first part of the course entails understanding the components of Earth’s climate, including the chemical and physical atmosphere and the role of land, ice, and the oceans in regulating global climate. The second half takes a closer look at how Earth’s climate system impacts global sustainable boundaries, including its impact on ecosystems, water resources, the built environment, human health, and the global food system. During the first half of the course students are expected to complete weekly homework assignments that reinforce class concepts and perform a guided analysis using a climate model. The second half of the course involves project work on the impact of climate on a system (e.g., ecosystem, government, etc.). 3 Course cr

F&ES 700b, Alpine, Arctic, and Boreal Ecosystems Seminar  Graeme Berlyn
Biogeoclimatic analysis of these systems worldwide with special attention to biogeography, biometeorology, physiology, histology, morphology, autecology, and silviculture of high-elevation and high-latitude forests through lectures, guest lectures and discussions, student seminars, and field experience. 3 Course cr

F&ES 704a, Workshop on Remote Sensing and Photogrammetry with Drones  Xuhui Lee
A workshop that explores the current state and future outlook of remote sensing with unmanned aerial vehicles (UAVs or drones) for environmental monitoring. UAV-based remote sensing is a rapidly developing field in environmental science and technology. Versatile and inexpensive, it has the potential to offer solutions in a wide range of applications, such as forestry inventory, precision agriculture, flood hazard assessment, pollution monitoring, and land surveys. The class meets once a week for three hours. The workshop is divided into three parts: (1) reviewing the state of the technology on UAV types, sensor configurations, and data acquisition methods; (2) exploring GIS and remote-sensing software tools for analyzing super-high-resolution spectral data acquired by fixed-wing drones; (3) cross-validating drone products against Lidar data and satellite imagery. Students may also have the opportunity to participate in drone flight missions. Data analysis, presentation, literature critique, field trips. Prerequisite: F&ES 726 or equivalent experience. 3 Course cr

F&ES 773a, Air Pollution Control  Drew Gentner
An overview of air quality problems worldwide with a focus on emissions, chemistry, transport, and other processes that govern dynamic behavior in the atmosphere. Quantitative assessment of the determining factors of air pollution (e.g., transportation and other combustion-related sources, chemical transformations), climate change, photochemical “smog,” pollutant measurement techniques, and air quality management strategies. 3 Course cr

ENVIRONMENTAL CHEMISTRY

[ F&ES 706, Organic Pollutants in the Environment ]
An overview of the pollution problems posed by toxic organic chemicals, including petroleum, pesticides, PCBs, dioxins, chlorinated solvents, and emerging contaminants. Processes governing the environmental fate of organic pollutants, e.g., evaporation, bioconcentration, sorption, biodegradation. Technologies for prevention and remediation of organic pollution. Previous experience with organic chemistry is not required. 3 Course cr

F&ES 707a / ENAS 640a, Aquatic Chemistry  Gaboury Benoit
A detailed examination of the principles governing chemical reactions in water. Emphasis is on developing the ability to predict the aqueous chemistry of natural and perturbed systems based on a knowledge of their biogeochemical setting. Focus is on inorganic chemistry, and topics include elementary thermodynamics, acid-base equilibria, alkalinity, speciation, solubility, mineral stability, redox chemistry, and surface complexation reactions. Illustrative examples are taken from the aquatic chemistry of estuaries, lakes, rivers, wetlands, soils, aquifers, and the atmosphere. A standard software package used to predict chemical equilibria may also be presented. 3 Course cr

F&ES 708b, Introduction to Environmental Chemistry  Gaboury Benoit
A descriptive overview of baseline biogeochemistry and the nature and behavior of pollutants in the environment. The course is designed to aid future environmental professionals who sometimes may find it necessary to make decisions based on knowledge of environmental
chemistry. It is geared to the nonspecialist who needs to establish familiarity with various classes of pollutants and the chemical, biological, and physical processes that control their sources, behavior, toxicity, and fate. Topics include the fundamental kinds of chemical reactions in the environment, critical analysis of chemical data, sampling techniques, analytical methods, natural biogeochemical controls on environmental chemistry, water treatment, and green infrastructure, as well as detailed examination of such contaminants as acid precipitation, nutrients, urban runoff, and sewage. Three hours lecture. One class project, problem sets, midterm, final exam. A small number of field trips. Prerequisite: college-level general chemistry. 3 Course cr

F&ES 772a, Air Pollution Control  Drew Gentner
An overview of air quality problems worldwide with a focus on emissions, chemistry, transport, and other processes that govern dynamic behavior in the atmosphere. Quantitative assessment of the determining factors of air pollution (e.g., transportation and other combustion-related sources, chemical transformations), climate change, photochemical “smog,” pollutant measurement techniques, and air quality management strategies. 3 Course cr

SOIL SCIENCE
[ F&ES 686, Advanced Issues in Soil Science ]
To be offered in the academic year 2019–2020. 2 Course cr

F&ES 709a, Soil Science  Mark Bradford
Lectures, labs, and discussions of soil science, with emphasis on soil ecology. Topics cover the structure and functioning of soils, and how this relates to soil fertility and ecosystem health in a changing environment. Prerequisite: F&ES 521 or permission of the instructor. 3 Course cr

WATER RESOURCES
[ F&ES 644, Watershed Science ]
Watershed science is a powerful scientific approach that utilizes the watershed unit and the integrative nature of water to solve problems. This course in watershed science is designed to cover fundamental knowledge, tools, and case studies that have emerged through research over the past fifty years. Included are units on watershed classification, hydrology, chemistry, models, management, and case studies. The goal is to provide students with a knowledge and tool base that allows them to be system thinkers with respect to modern-day environmental problems. 3 Course cr

F&ES 667b, Seminar: Fresh Water Topics  James Saiers
This seminar is intended to convene F&ES students doing research on, or simply with a keen interest in, the array of issues pertaining to freshwater sustainability. It’s for one credit, meets once a week, and only for an hour. The overall goal is to get students talking, thinking together, and learning from one another about those aspects of freshwater availability, protection, quality, and supply that excite them the most. There are two kinds of class sessions. A paper session involves discussion of a water-related article that is selected by a student and read by everyone else. A research session is similarly interactive, but focuses on one student’s research and involves a 15–30 minute presentation of the research followed by a class discussion. Although there’s no expectation that the student research will be a “finished piece,” the research session provides the class an opportunity to learn about a pressing water-related problem and an approach for addressing it, and, equally as important, enables presenters to gain feedback, new perspectives, and advice in overcoming obstacles encountered in their research. The paper sessions can be led by anyone; research sessions are most likely to be appropriate for second-year master’s students or Ph.D. students. 1 Course cr

F&ES 710b, Coastal Governance  Richard Burroughs
Effective governance combines a basic understanding of natural systems with human values to create new coastal institutions. Single-use regulations of the past (energy, wastewater, ports, marsh conservation) are being replaced by more holistic thinking (spatial management and/or ecosystem-based management). To understand the state of this transition, policy analysis frameworks are applied to sector-based and ecosystem-based management initiatives. Term projects allow student teams to consider the merit of various alternatives that they create to address contemporary problems, which have included sea-level rise, hurricane damage, fisheries, and management in developing countries. Three hours seminar; term project. Enrollment limited to eighteen. F&ES 515 and F&ES 525 or equivalent knowledge recommended. 3 Course cr

F&ES 712a, Water Resource Management  Shimon Anisfeld
An exploration of water resource management at scales ranging from local to global. The course looks at multiple dimensions of the water crisis, including both human and ecosystem impacts; quantity and quality issues; and engineering, legal, economic, and behavioral solutions. Theory is illustrated through a variety of case studies. Topics covered include global water resources; flooding; water scarcity; residential, agricultural, and industrial water use; water and health; impacts of climate change and land use change; stormwater management; dams and other technologies for water management; human impacts on aquatic ecosystems; water and energy; water economics; water rights; water conflict and cooperation. 3 Course cr

F&ES 714b, Environmental Hydrology  James Saiers
Exploration of the roles of natural processes and anthropogenic activities in regulating the quantity, distribution, and chemical composition of the Earth’s freshwater. Students gain exposure to theoretical and applied elements of surface and subsurface hydrology. The theory covered in the course focuses on hydrologic phenomena of societal and environmental importance, including stream-flow generation, wetland-water cycling, groundwater-flow dynamics, contaminant migration in surface and groundwater, and water use and redistribution by plants. Application of theory is accomplished through student use of hydrologic simulation models, which are
expressions of theory and essential tools of water-resource management and assessment. Intended as a first course in scientific hydrology; appropriate for M.E.M., M.E.Sc., and Ph.D. students, as well as for advanced undergraduates. Because hydrology is a quantitative science, treatment of the course subject matter involves mathematics. The course is designed for students who typically do not have previous course work in mathematics beyond one semester of college-level calculus. Students who have not completed a college-level calculus course can succeed in F&ES 714 provided that they are comfortable with arithmetic operations and algebra and are willing to learn a few, very basic principles of introductory calculus. Although students use hydrologic simulation models, the course does not involve any computer programming and requires no special computer skills. 3 Course cr

F&ES 724a, Watershed Cycles and Processes  James Saiers and Peter Raymond
Everyone lives in a watershed, an area of land that funnels rainfall and snowmelt to a stream, river, lake, or section of coastline. F&ES 724 explores watershed processes that affect, or are affected by, the stocks, flows, and quality of freshwater. It also surveys challenges faced by watershed managers, while emphasizing the science that informs their choices. By drawing from the fields of hydrology, ecology, and chemistry, the course begins by examining the flows of water, nutrients, carbon, and pollutants through watersheds. This basic knowledge underpins watershed management decisions that, for example, are intended to safeguard drinking-water quality, ensure sustainable freshwater consumption, and preserve ecosystem services that depend on healthy riparian corridors. Following treatment of watershed functions, F&ES 724 shifts focus toward impacts of landscape alteration and other anthropogenic stresses on freshwater cycles, water quality, and the ecology of sensitive watershed ecosystems. The course culminates by covering measurements, models, and other tools used in watershed assessment and with case studies of science-based watershed planning and adaptive management. 3 Course cr

[ F&ES 732, Hydrology and Riverine Geomorphology ]
This course is designed to build a general understanding of the physical processes that control river channel formation, including climatology, erosion, and sedimentation, and their implications with respect to fluvial (river) geomorphology. The course examines the classic themes in precipitation, stream flow, statistical hydrology, river hydraulics, sediment transport and storage, riverine habitat and riparian vegetation, fluvial geomorphology, and stream rehabilitation. This course is designed to provide students with a mix of classroom theory, dataset management, and field experience. In addition, it provides students a global perspective on the interrelationship between the hydrologic processes and natural resources management. 3 Course cr

F&ES 777a, Water Quality Control  Jaehong Kim
Study of the preparation of water for domestic and other uses and the treatment of wastewater for recycling or discharge to the environment. Topics include processes for removal of organics and inorganics, regulation of dissolved oxygen, and techniques such as ion exchange, electrodialysis, reverse osmosis, activated carbon adsorption, and biological methods. 3 Course cr

Quantitative and Research Methods

F&ES 510a, Introduction to Statistics and Data Analysis in the Environmental Sciences  Jonathan Reuning-Scherer
An introduction to statistics and data analysis with emphasis on practical applications in the environmental sciences. Includes graphical analysis, common probability distributions, hypothesis testing, confidence intervals, and linear regression. The second part of the course introduces the topics of multiple regression and ANOVA that are typically not covered in an introductory class such as AP statistics. There are weekly problem sets using MINITAB, SPSS, or R, as well as a final project. This course is a prerequisite for other statistics courses offered through F&ES, and it presents statistical methods used in many Yale courses in both the natural and social sciences. Three hours lecture. 3 Course cr

F&ES 510Ea, Introduction to Statistics and Data Analysis in the Environmental Sciences  Jonathan Reuning-Scherer
An introduction to probability and statistics with emphasis on applications in forestry and environmental sciences. Includes methods of graphical analysis, introduction of common probability distributions, and hypothesis testing. The final third of the course introduces the topics of regression and analysis of variance that are covered more thoroughly in F&ES 753. There are weekly problem sets using MINITAB software, as well as a final project. This course is a prerequisite for all other statistics courses offered through F&ES, and it presents statistical methods used in many of the School's courses in both the natural and social sciences. This course is taught in a flipped classroom approach. Enrollment limited to thirty. 3 Course cr

F&ES 550a, Natural Science Research Methods  William Lauenroth
The course prepares students to design and execute an intensive research project. It covers elementary principles and philosophy of science; research planning, including preparation, criticism, and oral presentation of study plans; communicating research findings; limitations of research techniques; the structure of research organizations; and professional scientific ethics. 3 Course cr

F&ES 551a, Qualitative Social Science Research  Sara Smiley Smith
This course is designed to provide a broad introduction to issues of qualitative research methods and design. The course is intended for both doctoral students who are in the beginning stage of their dissertation research, as well as master's students developing research proposals for their thesis projects. The course covers the basic techniques of designing qualitative research and for collecting, interpreting, and analyzing qualitative data. We explore three interrelated dimensions of research: theoretical foundations of science and research, specific methods available to researchers for data collection and analysis, and the application and practice of research methods. The final product for this course is a research proposal. 3 Course cr

F&ES 552a or b, Master's Student Research Conference  Staff
One of the most important aspects of scientific research involves the communication of research findings to the wider scientific community. Therefore, second-year M.E.Sc. and M.F.S. students are required to present the results of their faculty-supervised research
as participants in the Master’s Student Research Conference, a daylong event held near the end of the spring term. Student contributors participate by delivering a fifteen-minute oral presentation to the F&ES faculty and student body or by presenting a research poster in a session open to the F&ES community. Students receive a score of satisfactory completion for this effort. 0 Course cr

F&ES 611a, Data Science for Social Research: An Introduction  Justin Farrell
This seminar provides an introduction to a rapidly growing and promising area of social scientific research that has accompanied the explosion of data in our digital age, as nearly every aspect of life is now connected (e.g., mobile phones, smart devices, social media) and digitized (book archives, government records, websites, communication). Students are introduced to various techniques and software for collecting, cleaning, and analyzing data at large scales, especially text data (e.g., machine learning, topic modeling, location extraction, semantic networks). Strong emphasis is placed on integrating these methods into actual research, in hopes of moving new or ongoing student papers toward publication. The course is in a seminar format, with a focus on reading and discussing cutting-edge research, as well as interacting with invited guests from industry (e.g., Google) and academia. An overarching goal of the course is to incubate and launch new interdisciplinary collaborative projects at Yale that integrate data science techniques to solve important problems. 3 Course cr

F&ES 638b, Carbon Footprints—Modeling and Analysis  Edgar Hertwich
Carbon footprinting is an important tool in climate policy making. Carbon footprints describe the greenhouse gas emissions associated with an activity, company, household, or nation and are based on a life-cycle perspective, assigning emissions of greenhouse gases to the end user. Carbon footprints are also discussed in connection with responsibility for reducing greenhouse gas emissions. This course offers an introduction to the assessment of carbon footprints using input-output techniques and life-cycle assessment, and it examines scientific, policy, and management issues associated with carbon footprinting. It also offers an introduction to the analysis and interpretation of carbon footprint results. The course is split into two parts. In the first, students learn the techniques of carbon footprint modeling and analysis using generic tools such as Python or MatLab through both lectures and exercises. The second part of the course is dedicated to assessing and understanding carbon footprints of areas of final demand (e.g., food), specific product groups (e.g., cars), or organizations (e.g., F&ES, YNHH). Grading is based on problem sets, a midterm exam, and a final project. Enrollment limited to twenty-five. Prerequisite: students must be comfortable with linear algebra and prepared to acquire basic programming and modeling skills. Prior knowledge of life-cycle assessment and industrial ecology is desirable and may be gained through taking F&ES 884 or F&ES 838. 3 Course cr

F&ES 720a, Introduction to R  Simon Queenborough
This seminar provides an overview and introduction to the statistical software R for the analysis and graphical presentation of natural and social science data. We follow a flipped style of teaching, with class time primarily used for worked examples and problems. Students also work together in small groups to analyze data from collaborators (or the student's own data) with a view to publication. The course provides the practical training in R for theoretical courses such as F&ES 510 and 753; they can be taken concurrently or sequentially, although some statistics background is preferred. 3 Course cr

F&ES 726b / ARCG 762b / G&G 562b, Observing Earth from Space  Xuhui Lee and Ronald Smith
A practical introduction to satellite image analysis of Earth's surface. Topics include the spectrum of electromagnetic radiation, satellite-borne radiometers, data transmission and storage, computer image analysis, the merging of satellite imagery with GIS and applications to weather and climate, oceanography, surficial geology, ecology and epidemiology, forestry, agriculture, archaeology, and watershed management. 3 Course cr

F&ES 751b, Sampling Methodology and Practice  Timothy Gregoire
This course is intended to provide a fundamental understanding of the principles of statistical sampling, alternative estimators of population parameters, and the design basis for inference in survey sampling. Natural, ecological, and environmental resource applications of sampling are used to exemplify numerous sampling strategies. Sample designs to be studied include simple random; systematic; unequal probability, with and without replacement; stratified sampling; sampling with fixed-radius plots; horizontal point sampling; and line intercept. The Horvitz-Thompson, ratio, regression, and other estimators are introduced and used repeatedly throughout the course. Three hours lecture. Weekly and biweekly problem sets requiring the use of a computer spreadsheet. 3 Course cr

F&ES 753a, Regression Modeling of Ecological and Environmental Data  Timothy Gregoire
This course in applied statistics assists scientific researchers in the analysis and interpretation of observational and field data. After considering the notion of a random variable, the statistical properties of linear transformations and linear combinations of random data are established. This serves as a foundation for the major topics of the course, which explore the estimation and fitting of linear and nonlinear regression models to observed data. Three hours lecture. Statistical computing with R, weekly problem exercises. Prerequisite: a course in introductory statistics. 3 Course cr

F&ES 754a, Geospatial Software Design  Charles Tomlin
This course introduces computer programming tools and techniques for the development and customization of geospatial data-processing capabilities. It relies heavily on use of the Python programming language in conjunction with ESRI’s ArcGIS and on JavaScript in conjunction with Google’s Earth Engine geographic information systems (GIS). Three hours lecture, problem sets. Prerequisite: previous experience in GIS. 3 Course cr

F&ES 755b, Modeling Geographic Space  Charles Tomlin
An introduction to the conventions and capabilities of image-based (raster) geographic information systems (GIS) for the analysis and synthesis of spatial patterns and processes. In contrast to F&ES 756, the course is oriented more toward the qualities of geographic space
To be offered in the academic year 2019–2020. Prerequisites: econometrics and relevant courses in economics.

The aim is to train students to deal with quantitative economic analysis and modeling. Students form teams of two and choose a study; gather the data and methods of that study from the authors or a journal; and then reproduce the published results. The teams study the theory and empirical analysis, gather the data and modeling to replicate the results, and determine how sensitive the results are to the assumptions and specifications. Three hours lecture, problem sets. No previous experience is required. 3 Course cr

F&ES 76a, Modeling Geographic Objects  Charles Tomlin
This course offers a broad and practical introduction to the nature and use of drawing-based (vector) geographic information systems (GIS) for the preparation, interpretation, and presentation of digital cartographic data. In contrast to F&ES 755, the course is oriented more toward discrete objects in geographical space (e.g., water bodies, land parcels, or structures) than the qualities of that space itself (e.g., proximity, density, or interspersion). Three hours lecture, problem sets. No previous experience is required. 3 Course cr

F&ES 755b, Climate Change Economics  Robert Mendelsohn
The course reviews several modern valuation studies that are central to the estimation of the economic damages from climate change. The aim is to train students to deal with quantitative economic analysis and modeling. Students form teams of two and choose a study; gather the data and methods of that study from the authors or a journal; and then reproduce the published results. The teams study the theory and empirical analysis, gather the data and modeling to replicate the results, and determine how sensitive the results are to the assumptions and specifications. Three hours lecture, problem sets. No previous experience is required. 3 Course cr

F&ES 758b / S&DS 563b, Multivariate Data Analysis in the Environmental Sciences  Jonathan Reuning-Scherer
An introduction to the analysis of multivariate data. Topics include multivariate analysis of variance (MANOVA), principal components analysis, cluster analysis (hierarchical clustering, k-means), canonical correlation, multidimensional scaling ordination methods, discriminate analysis, factor analysis, and structural equations modeling. Emphasis is placed on practical application of multivariate techniques to a variety of natural and social examples in the environmental sciences. Students are required to select a dataset early in the term for use throughout the term. There are regular assignments and a final project. Extensive use of computers is required—students may use any combination of R, SAS, SPSS, STATA, and MINITAB. Three hours lecture/discussion. Prerequisites: a prior course in introductory statistics and a good understanding of multiple linear regression. 3 Course cr

[ F&ES 762, Applied Math for Environmental Studies ]
The language of mathematics is an important leg in the stool of interdisciplinary research and analysis, and many graduate courses at F&ES involve mathematical content. However, many graduate students have not taken a math course in years, and their math skills are rusty. Furthermore, many graduate-level mathematical concepts may be entirely new. Experience suggests that many students either opt out of taking courses they are truly interested in or muddle through, struggle with the math, and miss important concepts. AMES is meant to help students refresh or acquire new math skills and succeed in content and “toolbox” graduate-level courses. AMES provides a structured opportunity to learn a range of mathematical concepts used in environmental studies. The course assumes that, at a minimum, students took college algebra and perhaps a semester of calculus (but might not really remember it). Concepts are presented heuristically in a “how to” and “why” approach with examples from environmental studies. The goal is for students to be conversant and have intuition about (i.e., to demystify) why logs, exponents, derivatives, integrals, linear algebra, probability, optimization, stability analysis, and differential equations show up throughout environmental studies. Students learn (review) how to use these techniques. Also covered is a bit of history of math and an introduction to computer programming. 3 Course cr

F&ES 781b, Applied Spatial Statistics  Timothy Gregoire
An introduction to spatial statistical techniques with computer applications. Topics include modeling spatially correlated data, quantifying spatial association and autocorrelation, interpolation methods, variograms, kriging, and spatial point patterns. Examples are drawn from ecology, sociology, public health, and subjects proposed by students. Four to five lab/homework assignments and a final project. The class makes extensive use of the R programming language as well as ArcGIS. Prerequisite: introductory course in statistics. An intermediate-level course in statistical modeling and handling spatial data is strongly preferred, but not required. 3 Course cr

F&ES 902a or b, Environmental Anthropology Research Lab  Michael Dove
A biweekly seminar for Dove doctoral advisees and students in the combined F&ES/Anthropology doctoral degree program. It consists of the presentation and discussion of dissertation prospects and proposals, dissertation chapters, and related publications; collaborative writing and publishing projects on subjects of common interest; and discussion of such topics as grantsmanship, data analysis, writing and publishing, and the job search. Pass/Fail. Two-hour seminar. 1 Course cr

Social Sciences

ECONOMICS

[ F&ES 701, Climate Change Economics ]
The course reviews several modern valuation studies that are central to the estimation of the economic damages from climate change. The aim is to train students to deal with quantitative economic analysis and modeling. Students form teams of two and choose a study; gather the data and methods of that study from the authors or a journal; and then reproduce the published results. The teams study the theory and empirical analysis, gather the data and modeling to replicate the results, and determine how sensitive the results are to the assumptions and specifications. The course meets every other week for the entire year to give students time to analyze their studies and present their results. Prerequisites: econometrics and relevant courses in economics. 3 Course cr

F&ES 702b, Climate Change Economics  Robert Mendelsohn
The course reviews several modern valuation studies that are central to the estimation of the economic damages from climate change. The aim is to train students to deal with quantitative economic analysis and modeling. Students form teams of two and choose a study; gather the data and methods of that study from the authors or a journal; and then reproduce the published results. The teams study the theory and empirical analysis, gather the data and modeling to replicate the results, and determine how sensitive the results are to the assumptions and specifications. Prerequisites: econometrics and relevant courses in economics. 3 Course cr

[ F&ES 730, Economics of Sustainability ]
To be offered in the academic year 2019–2020. 3 Course cr
Energy development on freshwater resources is increasing as the world's economies grow. Changing this trajectory will not be easy, but ecosystem stresses induced by freshwater demands of agriculture and other human needs. Energy development also influences freshwater refined fuels, and heat. Water appropriation for energy development alters stream flows and depletes aquifers, thereby exacerbating to grow biofuel feedstocks. More water is needed to convert these primary energy sources to usable forms of energy, such as electricity, management of renewable resources (forests, fisheries, etc.); land and biodiversity conservation; the relationship between development, trade, and the environment; strategic incentives for international environmental agreements; and environmental behavioral economics. Prerequisite: F&ES 512 or equivalent. 3 Course cr

ENERGY AND THE ENVIRONMENT

F&ES 583b, American Energy History  Paul Sabin
The history of energy in the United States from early hydropower and coal to present-day hydraulic fracturing, deepwater oil, wind, and solar. Topics include energy transitions and technological change; energy and democracy; environmental justice and public health; corporate power and monopoly control; electricity and popular culture; labor struggles; the global quest for oil; changing national energy policies; the climate crisis. 3 Course cr

F&ES 635b, Renewable Energy Project Finance  Daniel Gross
The course is intended to be a practicum, exposing students to real-world tools of the trade as well as the theory underlying them. In place of a textbook, students are provided with approximately 400 pages of actual project documents used for a U.S. wind energy project constructed relatively recently. Through weekly homework assignments, students develop the skills necessary to construct a detailed financial model, largely comparable to what would be used by an investment firm, project developer, or independent power producer. Modeling skills include sizing debt capacity, sensitivity analysis, stochastic forecasting, taxes, and the creation of financial statements. Lectures also provide an introduction to risk management, energy market dynamics, alternative contractual structures, financial structuring, and the core engineering and risks inherent in the most common renewable energy technologies. 3 Course cr

F&ES 716b, Renewable Energy  Xuhui Lee and Ronald Smith
Introduction to renewable energy, including physical principles, existing and emerging technologies, and interaction with the environment. Energy demand; transmission and storage; generation by hydroelectric, wind, solar, biofuel, and geothermal sources, as well as waves and tidal generation. Includes field trips to conventional, hydroelectric, and wind-power facilities in Connecticut. Prerequisites: high school physics, chemistry, and mathematics; college-level science, engineering, and mathematics recommended. 3 Course cr

F&ES 800a, Energy Economics and Policy Analysis  Kenneth Gillingham
This course examines energy policy issues that pertain to the environment, with a focus on providing tools for analyzing these issues. A primary objective is to apply economics to particular issues of energy markets, environmental impacts, investment in renewables, and other energy issues such as transportation and energy efficiency. We cover the economic and technical considerations behind a particular energy policy issue and then discuss a related article or case study. Prerequisites: F&ES 505 (or equivalent) and at least one course on energy. 3 Course cr

[ F&ES 812, Energy’s Impact on Freshwater Resources ]
Energy development depends on fresh water. Water is consumed to mine uranium, tar sands, and coal; to recover oil and natural gas; and to grow biofuel feedstocks. More water is needed to convert these primary energy sources to usable forms of energy, such as electricity, refined fuels, and heat. Water appropriation for energy development alters stream flows and depletes aquifers, thereby exacerbating ecosystem stresses induced by freshwater demands of agriculture and other human needs. Energy development also influences freshwater quality, usually in deleterious ways. Coal-mine drainage, leaky oil and gas wells, hydraulic fracturing, and uranium processing are among the culprits tied to energy development that have been implicated in contamination of surface and subsurface waters. The burden of energy development on freshwater resources is increasing as the world's economies grow. Changing this trajectory will not be easy, but
progress will be made by those scientists and decision makers who understand the potential responses and vulnerabilities of freshwater resources to major forms of energy development. This course is intended to help students gain this understanding through analysis of the academic and professional literature on the linkages between freshwater systems and energy resource extraction, processing, and conversion. Readings focus on natural gas, nuclear, coal, and biofuels, although other energy types could be considered subject to student interests. Class sessions primarily involve structured discussion, with responsibility for presentation and facilitation shared by the instructor and rotating student groups. 3 Course cr

F&ES 814b, Energy Systems Analysis Narasimha Rao
This lecture course offers a systems analysis approach to describe and explain the basics of energy systems, including all forms of energy (fossil and renewable), all sectors/activities of energy production/conversion, and all energy end uses, irrespective of the form of market transaction (commercial or noncommercial) or form of technology (traditional as well as novel advanced concepts) deployed. Students gain a comprehensive theoretical and empirical knowledge base from which to analyze energy-environmental issues as well as to participate effectively in policy debates. Special attention is given to introducing students to formal methods used to analyze energy systems or individual energy projects and also to discussing traditionally less-researched elements of energy systems (energy use in developing countries; energy densities and urban energy use; income, gender, and lifestyle differences in energy end-use patterns) in addition to currently dominant energy issues such as climate change. Active student participation is required, including completion of problem sets. Participation in extra-credit skill development exercises (presentations, fact-finding missions, etc.) is encouraged. Invited outside speakers complement topics covered in class. 3 Course cr

F&ES 816a, Electric Utilities: An Industry in Transition Lawrence Reilly
The U.S. electric utility industry is a $370 billion business with capital expenditures on the order of $100 billion per year to replace aging infrastructure, implement new technologies, and meet new regulatory requirements. A reliable electricity infrastructure is essential for the U.S. economy and the health and safety of its citizens. The electric industry also has a significant impact on the environment. In the United States, electric power generation is responsible for about 40 percent of human-caused emissions of carbon dioxide, the primary greenhouse gas. Electric utilities in the United States are at a crossroads. Technological innovations, improving economics, and regulatory incentives provide a transformational opportunity to implement demand-side resources and distributed energy technologies that will both lower emissions and improve service to customers. Such significant changes could, however, disrupt existing utility business models and therefore may not be fully supported by incumbent utilities. This course focuses on the issues, challenges, risks, and trade-offs associated with moving the U.S. utility industry toward a cleaner, more sustainable energy future. We explore how utilities are regulated and how economic factors and regulatory policies influence outcomes and opportunities to align customer, environmental, and utility shareholder interests to craft win-win-win solutions. 3 Course cr

ENVIRONMENTAL POLICY

F&ES 573a, Urban Ecology for Local and Regional Decision-Making J. Morgan Grove
Urban ecology is the interdisciplinary study of urban and urbanizing systems from local to global scales. While urban ecology shares many features with the biological science of ecology, it emphasizes linkages with social, economic, and physical sciences and the humanities. Geographically, the subject includes central and edge cities, suburbs of various ages and densities, and exurban settlements in which urban lifestyles and economic commitments are dominant. In application, urban ecology can be useful as a social-ecological science for making cities more sustainable, resilient, and equitable. Emerging “grand challenges” in urban ecology include the development of robust approaches and understanding of (1) integrated social-ecological systems in urban and urbanizing environments; (2) the assembly and function of novel ecological communities and ecosystems under novel environmental conditions; (3) drivers of human well-being in diverse urban areas; (4) pathways for developing healthy, sustainable, and disaster-resilient cities; and (5) co-production of actionable science for policy, planning, design, and management. 3 Course cr

F&ES 590a, The Climate Change Negotiations: A Practical Approach Susan Biniaz
This course introduces students to the history of the international climate change negotiations (from the UNFCCC to the Paris Agreement), discusses the ways in which negotiating differences are typically resolved, identifies the issues to be addressed at this year’s Conference of the Parties, and concludes with a mock negotiation. It meets on four evenings in the fall, in Oct.–Nov., each session lasting two hours. 1 Course cr

F&ES 616a, Business and Environmental Solutions: 7 by 7 Todd Cort
Seven wicked challenges in business and the environment, seven weeks to come up with a solution. You have studied business and the environment for years and are left with the feeling that there is a lot of talk out there and very few solutions. Here is your chance to try to address some of the stickiest, and yet tangible, challenges at the intersection of business and the environment. In this project-based course, we present student teams with seven constrained yet recalcitrant challenges at the intersection of business and the environment. In each challenge, we have a potential game-changing idea to address a major environmental problem, but little idea how to make that idea into a reality through business. Half-term course; follows SOM academic calendar. Also MGT 867. 1½ Course cr

[ F&ES 620, Integrative Assessment ]
This course illustrates how to integrate the insights and models of different disciplines to address key environmental management questions facing society. Examples are drawn from across pollution and natural resource issues so that students can become familiar with a diverse set of issues. The course illustrates the merits of learning about the natural sciences, engineering, and economics in order to practice environmental management. 3 Course cr
F&ES 627b, Environmental Law  Douglas Kysar
This course explores what environmental laws are, who they are for, and how they can be used. It addresses federal statutes, like the Clean Air Act and the Civil Rights Act, as well as common law, tribal law, and international law. It seeks to understand those who write environmental laws, those who wield them, and those who are subject to them. Grades are based on three written assignments and student participation; there is no examination option. Enrollment limited to joint law school students.  4 Course cr

F&ES 636a, Sustainable Finance  Todd Cort
For a variety of reasons, today’s businesses and investors are dealing with the risks and opportunities of environmental, social, and governance (ESG) issues. Climate change, water scarcity, community conflicts, resource depletion, supply chain breakdowns, worker well-being, and economic inequality pose material challenges that make sustainability and ESG an imperative for successful corporations and investors. This course couples established and emerging theory on how finance can be used to address sustainability challenges with the practice of sustainable investing. We examine current ESG investment and corporate strategies, trends, future scenarios, players, and frameworks and integrate that theory with practical investment performance analysis, metrics, and studies of data, screens, asset classes, and diversification. The course mixes multiple formats of learning and interaction including lectures, class discussions, workshops, interactions with industry leaders, and student-led research. Students of all disciplines interested in the fields of investment and environmental/social policy are encouraged to attend the mandatory first class meeting. This course is designed to be accessible to those with varying levels of knowledge of financial markets and economics backgrounds. Though there are high expectations for the quality of final stock pitches, mentoring and resources are readily available from the instructors.  3 Course cr

F&ES 761b, Negotiating International Agreements: The Case of Climate Change  Susan Biniaz
This seminar is a practical introduction to the negotiation of international agreements, with a focus on climate change. Students learn about the cross-cutting features of international environmental agreements and, through the climate change lens, explore the process of negotiating agreements, the development of national positions, advocating positions internationally, and the many ways in which differences among negotiating countries are resolved. The course also examines the history and substance of the climate change regime, including, inter alia, the 1992 UN Framework Convention on Climate Change, the 1997 Kyoto Protocol, the 2009 Copenhagen Accord, and the 2015 Paris Agreement. Climate change issues in other international fora are also discussed, e.g., the International Civil Aviation Organization’s market-based mechanism to address CO2 emissions from international aviation. Grades are based on a series of short non-research papers, as well as class participation and a mock negotiation. Enrollment limited to twenty-two.  2 Course cr

F&ES 790a, Sea Level Rise, Storms, and Coastal Defense  Robert Mendelsohn
The purpose of this course is to develop detailed coastal defense plans for Connecticut towns. Starting from available data about coastal tides, the class develops an empirical estimate of the probability of flooding along the Connecticut coast. Pairs of students then choose a town to study. Each pair identifies which properties are at risk of flooding over the next one hundred years and then calculates the expected damage from flooding for the next thirty years given current risks for each segment of the coast. Students evaluate what defense strategy (nothing, hardened structures, or retreat) minimizes the sum of defense costs plus expected damage. A separate analysis is undertaken to predict wetlands and beaches. The analysis then takes into account sea-level rise over time. The objective is to identify a scientifically supported strategy for each town.  3 Course cr

F&ES 798Eb, China's Energy and Environmental Sustainability Challenge  Angel Hsu
Developing solutions for global energy and climate challenges necessitates an understanding of China. This course examines China’s economic rise in the context of its energy and environment, as they relate both within China and abroad. Issues of security, the long-term sustainability of current resource consumption and growth, and the need for innovative technology and policy are all challenges China’s energy system faces. At the same time, as the world’s largest consumer of energy and emitter of greenhouse gases, China has the ability to singlehandedly shape the course of the global climate system. The environmental consequences of China’s energy consumption and growth are also critical considerations, particularly as China’s air and water pollution have become transboundary in nature. This is the first joint course offered with students at Yale-NUS College in Singapore.  3 Course cr

F&ES 799b, Sustainable Development Goals and Implementation  Gordon Geballe
This course has students (working alone or in a small group) design a specific implementation plan for a specific country for a specific item that is part of the Sustainable Development Goals adopted by the UN in September 2015. Students study the new post-2015 sustainable development goals and their implementation in the real world. The course focuses primarily on understanding and developing the ability to effectively apply a variety of tools and means of implementation, relying primarily on guest lecturers. The aim is for each student or group of students to combine a geographic area/region (for example, a country of key interest), a sustainable development goal, and a tool for implementation to design an effective implementation strategy to present to those at the ministerial and decision-making level.  3 Course cr

F&ES 807a, Corporate Environmental Management and Strategy  Marian Chertow
This survey course serves as a gateway to the Business and Environment specialization by focusing on understanding the business and policy logic for making environment and sustainability core elements of corporate management and strategy. Students are asked to: (1) analyze how and when environmental, energy, and other sustainability issues can be translated into competitive advantage; and (2) explore the extent to which corporate and environmental performance can be achieved simultaneously. The course combines lectures, case
studies, and class discussions that investigate management theory, tools, and frameworks shaping the business-environment interface and evolving requirements for business success.  

**F&ES 811b, Metrics, Tools, and Indicators in Corporate Responsibility**  
Todd Cort  
This is an applied course on the standards, guidelines, and tools for designing, implementing, auditing, and communicating a corporate environmental and social responsibility (CR) program. The purpose of the course is to introduce students to the knowledge and tools needed to enter a career in CR and sustainability. The course is designed for students who currently hold or will hold positions in organizations where they are or will be responsible for creating, implementing, measuring, and/or managing internal CR and sustainability programs, or responsible for assisting a corporation in this area.  

3 Course cr

**F&ES 817a, Urban, Suburban, and Regional Planning Practice**  
David Kooris  
Our cities, towns, and regions represent the cumulative impact of planning policies implemented at multiple scales over the past century. This course explores the dynamic trends facing the United States and its communities and the evolution in planning practice that is occurring at the local and regional scale to address them. It looks at both suburban and urban approaches. The recent deep recession, climate change, and a lack of social cohesion call for a new triple bottom-line approach to decision-making for our future. Existing policies and governance structures are not always well suited for the new challenges and opportunities that we face. Local, state, and the national government are, to varying degrees, crafting new solutions to the challenges of urban and suburban America.  

3 Course cr

**F&ES 810b, Strategies for Land Conservation**  
Bradford Gentry  
This is a professional seminar on private land conservation strategies and techniques, with particular emphasis on the legal, financial, and management tools used in the United States. The seminar is built around presentations by guest speakers from land conservation organizations. Speakers are assigned topics across the land conservation spectrum, from identification of target sites, through the acquisition process, to ongoing stewardship of the land after the deal is done. The tools used to protect land are discussed, including the basics of real estate law, conservation finance, and project/organizational management. Students are required to undertake a clinical project with a local land conservation organization. Enrollment limited to twenty-five; preference to second-year students if limit reached.  

3 Course cr

**F&ES 820b, Land Use Law and Environmental Planning**  
Marjorie Shansky  
This course explores the regulation by local governments of land uses in urban, rural, and suburban areas and the effect of development on the natural environment. The course helps students understand, in a practical way, how the environment can be protected through effective regulation at the local level. It introduces students to federal, state, regional, and local laws and programs that affect watershed protection and to the laws that delegate to local governments primary responsibility for decision-making in the land use field. Theories of federalism, regionalism, states’ rights, and localism are studied, as are the cases that provide a foundation in regulatory takings and the legitimate scope of land use regulation. The history of the delegation of planning and land use authority to local governments is traced, leading to an examination of local land use practices particularly as they relate to controlling development in and around watersheds as well as regulatory response to sea-level rise and climate change. Students engage in empirical research working to identify, catalog, and evaluate innovative local laws that successfully protect environmental functions and natural resources, and the manner in which towns, particularly on the coast, incorporate climate change into their planning and regulations. Nearby watersheds are used as a context for the students’ understanding of the strengths and weaknesses of local planning and regulation. Attention is paid, in detail, to how the development of the land adversely affects natural resources and how these impacts can be mitigated through local planning and subsequent adoption of environmental regulations and regulations designed to promote sustainable development in a climate-changing world. The course includes examination of the state and local response to climate change, sea-level rise, growth management, alternatives to Euclidean zoning, low-impact development, brownfields redevelopment, energy conservation, and innovative land use strategies.  

3 Course cr

**F&ES 823a, Regulation of Energy Extraction**  
E Donald Elliott  
This comparative risk course explores the troubled intersection between energy and environmental policies. We consider a diverse range of regulatory approaches to minimize adverse environmental effects of various forms of energy development. These include emerging issues regarding hydraulic fracturing (“fracking”) in the United States and European Union; regulation of off-shore drilling and lessons from the Deepwater Horizon oil spill; liability for natural resources and other damages from oil spills under the Oil Pollution Act of 1990 (OPA90); the Fukushima, Three Mile Island, and Chernobyl nuclear accidents; applicability of the National Environmental Policy Act (NEPA) to oil and coal leases on federal lands; the Endangered Species Act; visual pollution and other issues relating to wind farms; coal mine disasters; mountaintop mining and the Mine Safety Act; and tailings piles and the Surface Mining Control and Reclamation Act of 1977 (SMCRA). The class concludes by considering how concerns about climate change may affect the future of energy development. No prerequisites. Self-scheduled examination or paper option.  

3 Course cr

**F&ES 824a, Environmental Law and Policy**  
E Donald Elliott  
This course provides an introduction to the major concepts of environmental law with a focus on U.S. statutes, regulations, and treaties for managing waste, air and water pollution, toxic substances, public lands, and global environmental resources. Alternative policy approaches to addressing environmental problems, such as market-based incentives, “nudges,” information disclosure requirements, and voluntary programs, are also considered. Overarching legal and policy concepts, such as federalism, administrative procedure, separation of powers, environmental justice, judicial review, and statutory interpretation, are explored.  

3 Course cr
F&ES 826a, Foundations of Natural Resource Policy and Management  Susan Clark
This course offers an explicit interdisciplinary (integrative) framework that is genuinely effective in practical problem solving. This unique skill set overcomes the routine ways of thinking and solving conservation problems common to many NGOs and government organizations by explicitly developing more rigorous and effective critical-thinking, observation, and management skills. By simultaneously addressing rational, political, and practical aspects of real-world problem solving, the course helps students gain skills, understand, and offer solutions to the policy problems of managing natural resources. The approach we use requires several things of students (or any problem solvers): that they be contextual in terms of social and decision-making processes; that they use multiple methods and epistemologies from any field that helps in understanding problems; that they strive to be both procedurally and substantively rational in their work; and, finally, that they be clear about their own standpoint relative to the problems at hand. The approach used in this course draws on the oldest and most comprehensive part of the modern policy analytic movement—the policy sciences (interdisciplinary method)—which is growing in its applications worldwide today. The course includes a mix of critical thinking, philosophical issues, history, as well as issues that students bring in. Among the topics covered are human rights, scientific management, decision-making, community-based approaches, governance, common interest, sustainability, professionalism, and allied thought and literature. In their course work students apply the basic concepts and tools to a problem of their choice, circulating drafts of their papers to other seminar participants and lecturing on and leading discussions of their topics in class sessions. Papers of sufficient quality may be collected in a volume for publication. Active participation, reading, discussion, lectures, guests, and projects make up the course. Enrollment limited to sixteen; application required. 3 Course cr

F&ES 826b, Comparative Environmental Law in Global Legal Systems  Nicholas Robinson and Lin Heng Lye
This course examines environmental law in the various legal systems of the world—from the common and civil law traditions to socialist law, customary law, and Islamic law. In particular, environmental law and case studies from a number of countries are examined, including Australia, Canada, China, Europe, New Zealand, the United States, Singapore, and the states of Southeast Asia. The objective is to understand the scope and evolution of national environmental law through the patterns of legislative, administrative, and judicial decision-making in the various legal regimes. The systems of central/unitary governments are contrasted with those of federal systems. As corporations engage in the same manufacturing activities around the world, it is important that corporate managers and their legal advisers understand how these activities are regulated in the different legal systems. Additionally, as Earth's natural systems are integrated throughout the biosphere, the effectiveness of one nation's environmental laws is complemented or undermined by the efficacy of another nation's comparable laws. Students are examined by a written paper that is a comparative study of some aspect of environmental law, involving at least two jurisdictions. 3 Course cr

F&ES 826c, Global Environmental Governance  Benjamin Cashore
The development of international environmental policy and the functioning of global environmental governance. Critical evaluation of theoretical claims in the literature and the reasoning of policy makers. Introduction of analytical and theoretical tools used to assess environmental problems. Case studies emphasize climate, forestry, and fisheries. 3 Course cr

F&ES 835a, Seminar on Land Use Planning  Jessica Bacher
Land use control exercised by state and local governments determines where development occurs on the American landscape, the preservation of natural resources, the emission of greenhouse gases, the conservation of energy, and the shape and livability of cities and towns. The exercise of legal authority to plan and regulate the development and conservation of privately owned land plays a key role in meeting the needs of the nation’s growing population for housing and nonresidential development and in ensuring that critical environmental functions are protected from the adverse impacts of land development. This course explores the multifaceted discipline of land use and urban planning and their associated ecological implications. Numerous land use strategies are discussed, such as consensus building, resiliency planning, and proper renewable energy siting, that provide practical tools for professionals to use to create sustainable buildings, neighborhoods, and communities. The focus of this seminar is to expose students to the basics of land use and urban planning in the United States and to serve as an introduction for the F&ES curricular concentration in land use. Guest speakers are professionals involved in sustainable development, land conservation, smart growth, and climate-change management. Classes include discussions on the trajectory for professional careers. 1 Course cr

F&ES 835Eb, Seminar on Land Use Planning  Jessica Bacher
This is an online course. Land use control exercised by state and local governments determines where development occurs on the American landscape, the preservation of natural resources, the emission of greenhouse gases, the conservation of energy, and the shape and livability of cities and towns. The exercise of legal authority to plan and regulate the development and conservation of privately owned land plays a key role in meeting the needs of the nation’s growing population for housing and nonresidential development and in ensuring that critical environmental functions are protected from the adverse impacts of land development. This course explores the multifaceted discipline of land use and urban planning and their associated ecological implications. Numerous land use strategies are discussed, such as consensus building, resiliency planning, and proper renewable energy siting, that provide practical tools for professionals to use to create sustainable buildings, neighborhoods, and communities. The focus of this seminar is to expose students to the basics of land use and urban planning in the United States and to serve as an introduction for the F&ES curricular concentration in land use. Guest speakers are professionals involved in sustainable development, land conservation, smart growth, and climate-change management. Classes include discussions on the trajectory for professional careers. 1 Course cr

F&ES 840a / GLBL 745a, Climate Change Policy and Perspectives  Daniel Esty
This course examines the scientific, economic, legal, political, institutional, and historic underpinnings of climate change and the related policy challenge of developing the energy system needed to support a prosperous and sustainable modern society. Particular attention
is given to analyzing the existing framework of treaties, law, regulations, and policy—and the incentives they have created—which have done little over the past several decades to change the world’s trajectory with regard to the build-up of greenhouse gas emissions in the atmosphere. What would a twenty-first-century policy framework that is designed to deliver a sustainable energy future and a successful response to climate change look like? How would such a framework address issues of equity? How might incentives be structured to engage the business community and deliver the innovation needed in many domains? While designed as a lecture course, class sessions are highly interactive. 3 Course cr

**F&ES 850a, International Organizations and Conferences**  Gordon Geballe
IOC will focus on UNFCCC COP 24 taking place in Poland in December 2018. This course and Sue Biniaz’s F&ES 590 The Climate Change Negotiations: a practical approach are coordinated and both are required if you want to apply for F&ES funding and Yale badges. Focus of both courses is to be prepared to get the most out of you trip. Taking Dan Esty’s F&ES 840 Climate Change Policy and Perspectives is strongly recommended. 1 Course cr

[ **F&ES 855, Climate Change Mitigation in Urban Areas** ]
This course provides an in-depth assessment of the relationships between urbanization and climate change, and the central ways in which urban areas, cities, and other human settlements can mitigate climate change. The course explores two major themes: (1) the ways in which cities and urban areas contribute to greenhouse gas emissions and climate change; and (2) the ways in which urban areas can mitigate greenhouse gas emissions and climate change. Class topics parallel the IPCC 5th Assessment Report, Chapter 12, Human Settlements, Infrastructure, and Spatial Planning, and include spatial form and energy use, land use planning for climate mitigation, urban metabolism, and local climate action plans. The class format is reading-, writing-, and discussion-intensive. Students are taught how to synthesize scientific literature, write policy memos, and develop effective oral presentations on the science of climate change mitigation in urban areas. Enrollment limited to sixteen. 3 Course cr

[ **F&ES 859, Natural Resources Law** ]
Managing natural resources is complicated and contentious. Today’s economy relies on oil and gas, but tapping those resources can scar landscapes and spoil tourism. Dredging a coastal marsh might free barge traffic, but might also sink bird habitat and erode natural flood barriers. Everyone loves a sunlit forest, but we need wood too. Trade-offs like these are everywhere. This course examines the ways that law allocates and manages many of our most important natural resources, including public lands, biodiversity, wetlands, and offshore oil. Readings take us to a variety of landscapes, from the Mojave Desert to the Rocky Mountains to Cajun swamps to Walden Pond. We examine constitutional dilemmas and the pivotal role played by administrative law. While the focus is on federal law (the National Environmental Policy Act, the National Forest Management Act, the Endangered Species Act, and more), the course also considers some aspects of state law, including doctrines of public trust. Throughout, we keep an eye on historical, ethical, and economic considerations too—and, of course, climate change. Classes include a few lectures, lots of discussion, and a few structured simulations. Self-scheduled examination. 3 Course cr

**F&ES 866a, Climate Change and Animal Law**  Douglas Kysar
This course examines the relationship between climate change, humans, and animals. With few exceptions, researchers and policy advocates looking at the impact of climate change on animals tend to focus on species loss and biodiversity at a macro level. But climate change is also having profound impacts on the individual lives and well-being of billions of animals. Large-scale human use of animals for food is also a significant and often overlooked cause of climate change emissions. The course seeks to develop a deeper understanding of the impacts of climate change on animals; the power dynamic between privileged human actors and the disenfranchised victims of climate change; and the intersection of animal welfare, environmentalism, food policy, and climate change. The course is organized partly as a traditional seminar and partly as a collective research endeavor to gather and analyze information on this significant and neglected topic. As part of the course experience, students work in small groups to conduct research and write a report on an underdeveloped topic concerning animals and climate change. The various sub-reports are edited into a single white paper that will be distributed to the animal welfare, environmental, food policy, and climate change advocacy communities. Paper required. Enrollment limited. Permission of the instructor required. 2 Course cr

**F&ES 875Ea, Urban Resilience: Complexity, Collaborative Structures, and Leadership Challenges**  Bradford Gentry
The world continues to urbanize. From 1913 to 2013, the proportion of the world’s population that lives in cities grew fivefold from 10 to 50 percent, and estimates suggest that 75 percent will live in cities in 2050. Though history reveals that urbanization has always been an accelerator of growth and development, it also poses profound challenges for corporations, communities, cities, and countries. A recent McKinsey report succinctly notes: “Cities are essential to global economic growth and productivity. They are where most of the world’s population live, work, and play, and they are important to everyone else, too. They are the world’s economic engine, consuming the majority of global power and resources, while generating 80 percent of GDP and 70 percent of greenhouse-gas emissions. Making cities great is the critical infrastructure challenge of this century.” This online course is a collaborative offering to students across the GNAM network schools. It brings together the 100 Resilient Cities (100RC) network, the Rockefeller Foundation, schools across the GNAM (with faculty from Yale, as well as the University of British Columbia, EGADE Business School, University of Ghana Business School, and the Indian Institute of Management Bangalore), and practitioners from business, government, and civil society to engage with the topic of urban resilience. For the purposes of this course, we draw on the view of urban resilience articulated by 100RC as the ability of individuals, communities, businesses, institutions, and systems within a city to survive, adapt, and thrive in response to the acute shocks and chronic stresses they may experience. The purposes of the course are to help students: (1) articulate resilience challenges and opportunities facing global cities; (2) describe the holistic and integrated nature of resiliency and its key drivers; and (3) work in virtual global teams to design collaborative approaches to addressing urban resilience challenges involving business, government, and
Sociology and Environment: Introduction to Theory and Method  
Michael Dove

Introductory course on the scope of social scientific contributions to environmental and natural resource issues. Section I, overview of the field and course. Section II, framing of environmental problems: placing problems in their wider political context, new approaches to uncertainty and failure, and the importance of how the conceptual boundaries to resource systems are drawn. Section III, methods: the dynamics of working within development projects, and the art of rapid appraisal and short-term consultancies. Section IV, local communities, resources, and (under)development: representing the poor, development discourse, and indigenous peoples and knowledge. There are two guest lectures by leading scholars in the field. No prerequisites. This is a core M.E.M. specialization course in F&ES, a core course in the combined F&ES/Anthropology doctoral degree program, and a prerequisite for F&ES 869/ANTH 572. Three hours lecture/seminar.  3 Course cr

Environmental Justice, Nature, and Reflective Practice Seminar  
Michael Mendez

Through an interdisciplinary approach to public health, and urban and environmental studies, we will examine the changing relationship between social systems, urbanization, biodiversity conservation, and environmental justice. Particular attention will be focused on how race, class, gender, immigration status, indigeneity, and sexuality intersects with the distribution of natural resources and the equitable development of cities. In the social sciences, the concept of intersectionality has been used to highlight how these social categories of culture and identity overlap, heightening the effects of discrimination, exclusion, social inequality, and systemic injustice in the lives of specific individuals. An intersectional approach to environmentalism emphasizes how certain people and groups suffer worse effects because of overlapping factors that are often measured separately. In the seminar, we define reflective practice as the ability to reflect on one’s professional experiences, actions, and positionality, so as to engage in a process of continuous learning. Students will focus on reflective practice exercises to engage in the practical and theoretical methods used in the field of environmental policy and planning to address the immediate and long-term sustainability challenges posed by global and local environmental change. Urban and sociological theories will be complemented by real-world environmental controversies that require group collaboration to produce in-class presentations, role-playing negotiation case simulations, and the completion of a final research paper.  3 Course cr

Managing Environment w/ People in Mind: Understanding Contribution of the Social sciences and Humanities  
Amity Doolittle and Benjamin Cashore

This class focuses on three key contributions of the myriad of social science and humanities disciplines for environmental managers: 1) how to understand, and assess, the way in which different types of environmental problems emerge as concerns among society and policy makers; 2) how different societies define appropriate resource use and how ‘bottom up’ social movements can trigger transformative change; and 3) the ways in which ‘top down’ state and non-state governance systems develop environmental policies. To do this, the class begins, and ends, with a historical emphasis that challenges the idea that norms or ethics surrounding natural resource management are static and universal. Instead, we seek to understand why norms change, and the lessons for environmental management. The class first turns to the humanities and social science disciplines, from political philosophy to religion and the environment, in order to unpack the ways in which norms emerge among humans that can’t be reduced to purely utility enhancing explanations. The class then turns to the disciplines of anthropology and sociology to better understand the role of cultural values and power dynamics in shaping how natural resources are valued, controlled, and protected. Finally, the class turns to political science, policy sciences, and institutional analysis to understand how, in the global era, environmental policies emerge and influence critical problems facing environmental managers. As each discipline makes an enormous contribution to these questions, the class draws on two different social scientists to organize the class, and then turns to experts in particular disciplines within F&ES and Yale.  3 Course cr

Conservation in Practice: An International Perspective  
Amy Vedder and Albert Weber

This seminar focuses on the practice of wildlife and wildlands conservation, examining key topics from the dual perspectives of academic literature and actual field experiences; bringing together interdisciplinary thinking; and drawing on examples from Africa, Asia, Latin America, and the United States. The thematic outline of the seminar is organized around three fundamental questions in nature conservation: What are we trying to save — and why? How is this being done — and how has it changed over time? What lessons are we learning — and what overarching issues remain problematic? Specific topics include how different players define and value wilderness; selection and prioritization of conservation targets; comparisons of various species and landscape conservation approaches; and governance and decision-making in conservation, including ties between conservation and development and community-based conservation. During the course of the term, six to eight guest conservation practitioners join the seminar, bringing tangible examples of current practice into the classroom via presentations and discussions. Student participation and leadership are key, as the seminar is discussion-based, centers on the sharing of ideas and experiences, demands challenging thinking, and is frequently led by students. Limited enrollment. Evaluation is based on participation, comments on assigned readings, and a final paper.  3 Course cr

Environment, Culture, Morality, and Politics  
Justin Farrell

This course equips students to think critically and imaginatively about the social aspects of natural landscapes and the communities who inhabit them. It draws on empirical cases from the United States to examine interrelated issues pertaining to culture, morality, religion, politics, power, elites, corporations, and social movements. Because of the deep complexity of these issues, and the fact that this is a reading- and writing-intensive course, it requires a significant time commitment from each student. Students in the course gain fluency
with cutting-edge empirical research on these issues; better recognize the social, moral, and political roots of all things; and finally, are able to apply philosophical theory to concrete environmental problems.  

F&ES 767b, Tools for Conservation Project Design and Management  Amy Vedder and Albert Weber
As wildlife and wildland conservation programs have multiplied and grown in size, conservation organizations have sought methods to improve strategic project planning, assessment of progress, cross-project comparison, learning of lessons, and transparency for donors. To address these challenges, major nonprofit organizations have collaboratively designed a set of decision-support tools for planning field projects and programs and for monitoring their progress, summarized in the “Open Standards for the Practice of Conservation” (http://cmp-openstandards.org). Use of these tools has allowed organizations to more clearly articulate strategies, define priority actions, critically assess success, manage adaptively, and derive lessons—all of which help to improve effectiveness and respond to donor interests. Students in this course explore a mutually reinforcing suite of these project tools: their underlying principles are introduced, students practice the techniques, and current case studies from field conservation are examined to explore tool utility. Students synthesize use of these design tools in a final project or program proposal focused on a single case study of their choice. The suite of decision-support tools covered includes conceptual models for project design, situational and stakeholder assessments, threats and opportunities analysis, conservation target identification (particularly landscape species selection), and monitoring frameworks. Students gain experience in design of projects and their monitoring, as well as familiarity with budgeting. Enrollment limited to twelve.  

F&ES 772a, Social Justice in the Global Food System  Kristin Reynolds
This course explores social justice dimensions of today’s globalized food system, considering sustainability in terms of sociopolitical as well as environmental dynamics. We examine how governmental and nongovernmental environmental strategies affect social equity in the food system at multiple scales. We discuss how issues such as land grabbing or food insecurity are connected to relative power on the global stage. We consider how phenomena such as structural violence and neoliberalization surface within the food system, and what this means for sustainability and justice. With an emphasis on connecting theory and practice, we examine and debate concepts including food sovereignty, agroecology, and the Right to Food that are used by governmental and/or civil society actors to advance positive change. Throughout the term we explore our own positions as university-based stakeholders in the food system. The course includes guest speakers; students are encouraged to integrate aspects of their own academic and/or professional projects into one or more course assignments.  

F&ES 774a, Agriculture: Origins, Evolution, Crises  Harvey Weiss
Analysis of the societal and environmental causes and effects of plant and animal domestication, the intensification of agroproduction, and the crises of agroproduction: population pressure, land degradation, societal collapses, technological innovation, transformed social relations of production, sustainability, and biodiversity. From the global field, the best-documented eastern and western hemisphere trajectories are selected for analysis.  

F&ES 793b, Climate Change, Societal Collapse, and Resilience  Harvey Weiss
Collapse documented in the archaeological and early historical records of the Old and New Worlds, including Mesopotamia, Mesoamerica, the Andes, and Europe. Analysis of politicoeconomic vulnerabilities, resiliencies, and adaptations in the face of abrupt climate change, anthropogenic environmental degradation, resource depletion, “barbarian” incursions, or class conflict.  

F&ES 826a / ANTH 541a / HIST 965 / PLSC 779a, Agrarian Societies: Culture, Society, History, and Development  Kalyanakrishnan Sivaramakrishnan, James Scott, and Elisabeth Wood
An interdisciplinary examination of agrarian societies, contemporary and historical, Western and non-Western. Major analytical perspectives from anthropology, economics, history, political science, and environmental studies are used to develop a meaning-centered and historically grounded account of the transformations of rural society. Team-taught.  

F&ES 839a, Social Science of Conservation and Development  Carol Carpenter
This course is designed to provide a fundamental understanding of the social aspects involved in implementing conservation and sustainable development projects. Social science makes two contributions to the practice of conservation and development. First, it provides ways of thinking about, researching, and working with social groupings—including rural households and communities, but also development and conservation institutions, states, and NGOs. This aspect includes relations between groups at all these levels, and especially the role of politics and power in these relations. Second, social science tackles the analysis of the knowledge systems that implicitly shape conservation and development policy and impinge on practice. The emphasis throughout is on how these things shape the practice of sustainable development and conservation. Case studies used in the course have been balanced as much as possible between Southeast Asia, South Asia, Africa, and Latin America; most are rural and Third World. The course includes readings from all noneconomic social sciences. The goal is to stimulate students to apply informed and critical thinking (which means not criticizing...
others, but questioning our own underlying assumptions) to whatever roles they may come to play in conservation and sustainable development, in order to move toward more environmentally and socially sustainable projects and policies. The course is also designed to help students shape future research by learning to ask questions that build on, but are unanswered by, the social science theory of conservation and development. No prerequisites. This is a requirement for the combined F&ES/Anthropology doctoral degree program and a prerequisite for some advanced F&ES courses. Open to advanced undergraduates. Three hours lecture/seminar. 3 Course cr

[ F&ES 846, Perspectives on Environmental Injustices ]
In this seminar we explore domestic and global environmental issues from a perspective that foregrounds questions of social justice. This course is based on three fundamental premises: (1) all individuals and communities, regardless of their social or economic conditions, have the right to a clean and healthy environment; (2) there is a connection between environmental exploitation, human exploitation, and social justice; and (3) many environmental and social injustices are rooted in larger structural issues in society that must be understood. With these premises as a starting point, we turn to more difficult questions such as, Why and through what political, social, and economic processes are some people denied this basic right to a clean and safe environment? What is the state of scientific evidence surrounding environmental injustice and what are the current scientific challenges in assessing environmental injustices in relationship to human health? What legal frameworks exist within the United States to address environmental injustice? 3 Course cr

F&ES 857b, Environmental History and Values John Grim and Mary Tucker
This course provides an overview of major figures, ideas, and institutions in American environmentalism. The course explores the development of environmental awareness in America as distinct historical strands with diverse ethical concerns. It begins with an examination of Native American perspectives on land and biodiversity and then focuses on writings by Thoreau and Emerson to explore early American voices in the discourse on “nature.” Readings from Pinchot, Muir, and Leopold have been selected to investigate the emergence of conservation and forest management. The beginnings of urban and park planning are considered in relation to these positions on the management of nature. Students survey the environmental movements from the 1960s onward in readings from the social sciences and humanities. The course explores the major debates in environmental ethics and the broader reach for global ethics. Writings celebrating biodiversity are examined along with the emergence of conservation biology as an example of engaged environmental scholarship. New efforts to widen the interdisciplinary approaches toward environmental issues are introduced in investigating world religions and ecology as well as cosmology and ecology. 3 Course cr

F&ES 860b / ANTH 572b, Disaster, Degradation, Dystopia: Social Science Approaches to Environmental Perturbation and Change Michael Dove
This is an advanced seminar on the long tradition of social science scholarship on environmental perturbation and natural disasters, the relevance of which has been heightened by the current global attention to climate change. The course is divided into three main sections. The first consists of central questions and debates in the field: social dimensions of natural disasters; the discursive dimensions of environmental degradation, focusing on deforestation; and the current debate about the relationship between resource wealth and political conflict, focusing on the “green war” thesis. The second focuses on anthropological and interdisciplinary approaches to climate change and related topics, encompassing canonical anthropological work on flood and drought; cyclones, El Niño, and interannual cycles; ethno-ecology; and risk. Additional lectures focus on interdisciplinary work. The final section consists of the classroom presentation of work by the students. Prerequisite: F&ES 520 or F&ES 839. 3 Course cr

F&ES 873a / NELC 605a, Global Environmental History Harvey Weiss
The dynamic relationship between environmental and social forces from the Pleistocene glaciations to the Anthropocene present: Pleistocene extinctions; transitions from hunting to gathering to agriculture; Old World origins of cities, states, and civilization; adaptations and collapses of Old and New World civilizations in the face of climate disasters; the destruction and reconstruction of the New World by the Old. In the foreground of each analysis are the issues of adaptation, resilience, and sustainability: what forced long-term societal changes? 3 Course cr

F&ES 876b, Indigenous Traditions and the Environment John Grim and Mary Tucker
Exploration of how particular indigenous peoples relate to local bioregions and biodiversity. Differences between and within indigenous societies, especially in cultural relationships to place. Ways in which values associated with physical places are articulated in symbols, myths, rituals, and other embodied practices. 3 Course cr

F&ES 877b, Anthropology of the Global Economy for Conservation and Development Carol Carpenter
This seminar explores topics in the anthropology of the global economy that are relevant to conservation and development policy and practice. Anthropologists are often assumed to focus on micro- or local-level research, and thus to have limited usefulness in the contemporary, global world of conservation and development policy. In fact, however, they have been examining global topics since at least the 1980s, and little current anthropological research is limited to the village level. More importantly, the anthropological perspective on the global economy is unique and important. This course examines the topics that make up this perspective, including using a single commodity to study the global economy, theorizing the transition to capitalism, the moral relation between economy and society, models for thinking about power in the global economy, articulations between rural households and the global economy, rural-urban relations in the global economy; the process of becoming a commodity, the commons debate, credit and debt, contracting and flexible accumulation, globalization and scale, and theorizing REDD. Readings for the course come from the subfields of environmental anthropology, economic anthropology, the anthropology of development, and the anthropology of conservation. This class is a prerequisite for F&ES 965. Though designed for master’s and doctoral students, it is open to advanced undergraduates. Three hours lecture/seminar. 3 Course cr
F&ES 878a, Climate and Society: Past to Present  Michael Dove
Seminar on the major traditions of thought—both historic and contemporary—regarding climate, climate change, and society, drawing on the social sciences and anthropology in particular. Section I, overview of the field and course. Section II, continuities from past to present: use of differences in climate to explain differences among people, differences between western and non-western intellectual traditions, and the ethnographic study of folk knowledge. Section III, impact on society of environmental change: environmental determinism in the nineteenth and twentieth centuries, attribution of historic cases of societal “collapse” to extreme climatic events, and the role of extreme events in the development of a society. Section IV, vulnerability and control: how societies cope with extreme climatic events, and how such events reflect, reveal, and reproduce socioeconomic fault lines. Section V, knowledge and its circulation: construction of knowledge of climate and its extremes, and contesting of knowledge between central and local authorities and between the global North and South. The main texts, The Anthropology of Climate Change and Climate Cultures, were written especially for this course. No prerequisites; graduate students may enroll with permission of the instructor. Two hours lecture/seminar. 3 Course cr

F&ES 892a, Introduction to Planning and Development  Alexander Garvin
This course demonstrates the ways in which financial and political feasibility determine the design of buildings and the character of the built environment. Students propose projects and then adjust them to the conflicting interests of the financial institutions, real estate developers, civic organizations, community groups, public officials, and the widest variety of participants in the planning process. Subjects covered include housing, commercial development, zoning, historic preservation, parks and public open space, suburban subdivisions, planned communities, and comprehensive plans. 3 Course cr

HEALTH AND ENVIRONMENT

F&ES 446, Foundations of Agriculture and Environment
Agricultural systems have a profound impact on the environment, but also depend on environmental processes—such as climate and nutrient cycling—for continued productivity. Because of this two-way relationship, there has been a growing integration of environmental and agricultural sciences over the past several decades with growing recognition that designing and implementing agricultural systems that minimize environmental harm and benefit people is necessary to sustainable development. 3 Course cr

F&ES 727a, Food: Science, Law, and Policy  John Wargo
This seminar explores significant challenges posed by the global food supply to environmental quality and human health. The primary obligation is a research paper, dissertation chapter, master’s project, or senior essay draft. We read critically 150–200 pages per week, and students should be prepared to discuss or present analyses. Challenges examined include fresh vs. processed foods, nutritional sufficiency and excess, radionuclides, pesticides, pharmaceuticals, fertilizers, animal feeds, plastics, flame retardants, flavors, fragrances, ingredient fraud, genetic modification, waste, energy input and yield, locality, processing technologies, packaging, and carbon emissions. Corporate case histories are considered in a number of sessions. Private innovations in the production and management of food are analyzed, including trends in certification and labeling initiatives. Most sessions examine one or several foods. Examples include cow’s milk, human milk, infant formula, grapes, wine, corn, bananas, tomatoes, salmon, cod, tuna, sodas, fruit juice, water, coffee, and olive oil. Enrollment limited to sixteen. 3 Course cr

F&ES 803b, Principles of Risk Assessment  Gary Ginsberg
This course introduces students to the nomenclature, concepts, and basic skills of quantitative risk assessment (QRA). The goal is to provide an understanding necessary to read and critically evaluate and perform QRA. Emphasis is on the intellectual and conceptual basis of risk assessment, particularly its dependence on toxicology, epidemiology, and exposure assessment. Quantitation of exposure and dose response provides practical skills and theoretical background, although not detailed in mathematical and model derivations. Specific cases consider the use of risk assessment for setting occupational exposure limits, establishing community exposure limits, and quantifying the hazards of environmental exposures to chemicals in air, drinking water, consumer products, and the built environment 3 Course cr

F&ES 806b, Public Health Toxicology  Staff
This course is designed to serve as a foundation for understanding public health toxicology in the twenty-first century. Although it includes the basic principles of toxicology such as dose response and mechanisms of toxicity and cellular defense, this course introduces new concepts of toxicology such as lifetime exposures, low-level exposure to mixtures, high-throughput screening and computational toxicology, and green chemistry in order to understand fundamental interactions between chemicals and biological systems and possible health outcomes. Through the use of case studies and up-to-date published research, the course provides insights into prevention of mortality and morbidity resulting from environmental exposure to toxic substances, the next-generation risk assessment and regulatory toxicology, and the causes underlying the variability in susceptibility of people to chemicals. 3 Course cr

F&ES 807b, Environmental and Occupational Exposure Science  Nicole Deziel
This course examines the fundamental and practical aspects of assessing exposures to environmental agents, broadly defined, in the residential, ambient, and workplace environments. The course provides the knowledge and skills to design and conduct exposure assessments, and has a particular focus on applications to environmental epidemiology and risk assessment. Indirect and direct methods of assessing exposures, such as questionnaires, environmental sampling, biological monitoring, and spatial modeling, are reviewed; and case studies and hands-on projects are presented. 3 Course cr

F&ES 808a, The Environment and Human Health  Michelle Bell
This course provides an overview of the critical relationships between the environment and human health. The class explores the interaction between health and different parts of the environmental system including water, indoor and outdoor air, environmental justice, and occupational health. Other topics include exposure assessment, case studies of environmental health disasters, links between
climate change and health, and integration of scientific evidence on environmental health. Students learn about current key topics in environmental health and how to critique and understand scientific studies. The course incorporates lectures and discussion. Enrollment limited to twenty-five. 3 Course cr

INDUSTRIAL ECOLOGY, ENVIRONMENTAL PLANNING, AND TECHNOLOGY

F&ES 607b, Advanced Methods: Industrial Ecology  Edgar Hertwich
Modeling the socioeconomic metabolism. Humans have transformed the Earth's surface to serve their production and consumption systems. While social sciences study the sphere of human decision-making and behavior rooted in culture, organization, and preferences, and earth scientists study the effect of human actions on nature, industrial ecology studies the acquisition and transformation of natural resources to products, their use and disposal, and the ensuing emissions in biophysical terms. This course provides an advanced treatment of input-output analysis and dynamic stock-flow models of materials in products and infrastructures. It also addresses hybrid approaches, such as the combination of life-cycle assessment and input-output methods or the application of such methods in conjunction with prospective models rooted in stock-flow dynamics. The course is primarily focused on modeling tools, combining blackboard-based lectures with computer-based exercises. Modeling is conducted in Python and MatLab. The overall goal of the course is to provide skills necessary to produce biophysical models of technical systems. Grading is based on problem sets and a final exam. Prerequisite: a firm grasp of industrial ecology and its methods. At a minimum, students should have taken F&ES 638. 3 Course cr

This reading seminar introduces and formalizes concepts related to waste and materials management seen from perspectives of operations, policy, sustainability, and business. Because there is no disposal-free society, learning about waste that remains waste is a key element of the class. Interest in using wastes as resources opens up other questions related to materials management, policy and regulation, and finance and economics. One goal is to examine fundamentals including generation, collection, processing (e.g., by recycling and composting), and landfilling. A second goal is to describe and discuss alternative futures for waste and materials using ideas drawn from industrial ecology and technology. The class meets once a week to discuss assigned readings as a grounding in fundamentals and launching point for analysis of opportunities for sustainable materials management. Enrollment limited to ten. 3 Course cr

F&ES 771b, Fundamentals of Green Engineering and Green Chemistry  Paul Anastas
There is a broad desire to ensure that consumer products, manufacturing processes, and material and energy systems are compatible with public health and environmental sustainability. This course provides fundamental knowledge of the frameworks, methods, tools, and techniques of designing for sustainability. Through an understanding of conceptual contracts and application to real-world case studies, students learn the impacts of design on health (including toxic and ecotoxic effects) and the ways to ensure that new products, processes, and systems can be constructed through the principles of green engineering and green chemistry. This course provides the foundation for more advanced investigations in sustainable design; there are no prerequisites. 3 Course cr

[F&ES 782, Globalization Space: International Infrastructure and Extrastatecraft]
The course researches global infrastructure space as a medium of polity. It considers networks of trade, energy, communication, transportation, spatial products, finance, management, and labor as well as new strains of political opportunity that reside within their spatial disposition. Case studies include free zones and automated ports around the world, satellite urbanism in South Asia, high-speed rail in Japan and the Middle East, agripoles in southern Spain, fiber-optic submarine cable and mobile telephony in East Africa, spatial products of tourism in the DPRK, and the standards and management platforms of ISO. 3 Course cr

F&ES 838b, Environmental Product Life-Cycle Assessment  Staff
Life-cycle assessment (LCA) is an analytical method that aims to quantify potential environmental impacts along the entire life cycle of a product, from extraction or harvest of natural, mineral, or fossil resources through production, distribution, and consumption, to final end-of-life disposal or reuse/recycling. LCA provides a quantitative evaluation of a wide range of environmental issues to avoid “burden shifting” between different life stages or different environmental concerns. Its primary applications include decision support in the context of design-for-environment programs and policy making as well as provision of a science-based basis for environmental claims used for marketing products in business-to-business (B2B) and business-to-consumer (B2C) settings. The course conveys the general principles and relevant definitions of the LCA methodology as defined in the ISO 14040 series of standards and exemplifies them through frequent reference to real-world case studies covering a wide array of industry sectors and product categories. The overall goal of the course is to provide the skills necessary to scope, manage, and scrutinize LCA studies in the business, consulting, or government sectors. Prerequisites: it is recommended that students complete F&ES 884 to provide a foundation for the LCA course. In addition, if constructing mass and energy balances, conducting numerical analyses, etc., are not familiar topics, it is recommended that students complete F&ES 762 or F&ES 814. 3 Course cr

F&ES 884a, Industrial Ecology  Barbara Reck and Thomas Graedel
Industrial ecology studies (1) the flows of materials and energy in industrial and consumer activities, (2) the effects of these flows on the environment, and (3) the influences of economic, political, regulatory, and social factors on the flow, use, and transformation of resources (White 1994). The goals of the course are to define and describe industrial ecology; to demonstrate the relationships among production, consumption, sustainability, and industrial ecology in diverse settings and at multiple scales; to show how industrial ecology serves as a framework for the consideration of environmental and sustainability-related aspects of science, technology, and policy; and to define and describe tools, applications, and implications of industrial ecology. 3 Course cr
F&ES 885b, Green Engineering and Sustainable Design  Dudley Andrew
This course provides a hands-on foundation in green engineering and the design and assessment of green products. Approaching sustainability from a design perspective requires a fundamental conceptual shift from the current paradigms of product toward a more sustainable system, based on efficient and effective use of benign materials and energy. Through course assignments, class exercises, and a term-long team project, students are challenged with the same issues facing production and consumption systems today. The course is organized around the “engineering design process” from opportunity definition; criteria definition; ideation; alternatives assessment; and solution selection, implementation, and monitoring. To begin, the mega-trends driving sustainability discussions are presented and the case for new greener product systems is made. The course emphasizes quantitative and rigorous analysis of green design in addition to the tools needed to develop these designs. The foundational principles of the course can be summarized in the five Is: (1) Innovation—we can’t solve problems at the same level of thinking used to create them, (2) Interdisciplinary—we can’t solve problems without looking at the nature of the system that created them, (3) Interdisciplinary—we can’t solve problems without looking at other aspects of the problem, (4) Integration—we can’t solve problems without connecting segments at a system level, and (5) International—we can’t solve problems without considering their context. The current approach to design, manufacturing, and end of life is discussed in the context of examples and case studies from various sectors, providing a basis for what and how to consider designing green products, processes, and systems.
Fundamental engineering design topics include pollution prevention and source reduction, separations and disassembly, virtual and rapid prototyping, life-cycle design, management, and assessment. Enrollment limited to thirty-two. Preference given to second-year M.E.M. students.  3 Course cr

F&ES 888a, Ecological Urban Design  Alexander Felson
This course lays the groundwork for students from the School of Architecture and the School of Forestry & Environmental Studies to collaboratively explore and define ecologically driven urban design. The goal is to work as an interdisciplinary group to cultivate a perspective on the developing field of urban ecology and approaches to implementing urban ecological design. The transformation of urban ecology from a role in studying a system to studying and shaping urban ecosystems is a primary focus for the course, which concentrates on the following questions: How do we define urban ecosystems? How do we combine science, design, and planning to shape and manage urban ecosystems? How do we implement effective and adaptable experimental and monitoring methods specific to urban sites and human subjects in order to conduct viable urban ecological research? The course uses the Earth Stewardship Initiative, a large land-planning project developed for the Ecological Society of America in Sacramento, Calif., to create a real-world project where interdisciplinary teams can work to combine ecological applications and design with the goal of shaping urban systems to improve the ecological, social, and infrastructural function of city components. Limited enrollment.  3 Course cr

F&ES 894a, Green Building: Issues and Perspectives  Peter Yost
Our built environment shapes the planet, our communities, and each of us. Green buildings seek to minimize environmental impacts, strengthen the fabric of our cities and towns, and make our work and our homes more productive and fulfilling. This course is an applied course, exploring both the technical and the social-business-political aspects of buildings. Topics range from building science (hygrothermal performance of building enclosures) to indoor environmental quality; from product certifications to resilience (robust buildings and communities in the face of disasters and extended service outages). The purpose of the course is to build a solid background in the processes and issues related to green buildings, equipping students with practical knowledge about the built environment. Extensive use is made of resources from BuildingGreen, Inc., one of the leading information companies supporting green building and green building professionals. The course takes a “joint-discovery” approach with substantial emphasis on research and group project work, some fieldwork, and online individual testing. There are too many topics within green building to cover in one term, so the course is broken down into two sections. The first six weeks focus on the following topics, led by the instructor and/or an expert guest lecturer: building science, materials, indoor environmental quality, rating programs and systems, resilience, systems integration. The second half of the course focuses on selected topics driven by students and their particular interest/academic focus. The class meets once a week, with the instructor available to students that same day. Enrollment limited to twenty-four.  3 Course cr

UNDERGRADUATE COURSES
Seminars are identified by an asterisk; enrollment is limited. The abbreviations SC and SO identify courses that fulfill Yale College distributional requirements in the sciences and social sciences, respectively.

Ecology

ECOSYSTEM ECOLOGY

* F&ES 221a / E&EB 230a / EVST 221a, Field Ecology  Linda Puth
A field-based introduction to ecological research, using experimental and descriptive approaches, comparative analysis, and modeling for field and small-group projects. Weekly field trips explore local lake, salt marsh, rocky intertidal, traprock ridge, and upland forest ecosystems. Includes one Saturday field trip and a three-day trip during the October recess. Concurrently with or after E&EB 220 or with permission of instructor. SC  1 Course cr

WILDLIFE ECOLOGY AND CONSERVATION BIOLOGY

F&ES 315a / E&EB 115a, Conservation Biology  Linda Puth
An introduction to ecological and evolutionary principles underpinning efforts to conserve Earth’s biodiversity. Efforts to halt the rapid increase in disappearance of both plants and animals. Discussion of sociological and economic issues. SC  1 Course cr
[ F&ES 365, Landscape Ecology ]
An introduction to the study of large-scale ecological patterns and processes. Topics include species viability, ecosystem management, and the design of nature reserves. Focus on when and how to integrate a spatial perspective into consideration of major ecological questions. After E&EB 220a. 1 Course cr

[ F&ES 370, Aquatic Ecology ]
An intensive introduction to the ecology of populations and communities in freshwater systems. Concepts, patterns, and organisms important in lakes and streams; techniques of information collection and analysis. Weekly field trips to gather data. Familiarity with ecological concepts and terminology is presumed. After E&EB 220. 1 Course cr

Physical Sciences

ENVIRONMENTAL CHEMISTRY
* F&ES 261a / EVST 261a, Minerals and Human Health Ruth Blake
Study of the interrelationships between Earth materials and processes and personal and public health. The transposition from the environment of the chemical elements essential for life. After one year of college-level chemistry or with permission of instructor; G&G 110 recommended. SC 1 Course cr

[ F&ES 344a / EVST 344a, Aquatic Chemistry Gaboury Benoit
A detailed examination of the principles governing chemical reactions in water. Emphasis on developing the ability to predict the aqueous chemistry of natural, engineered, and perturbed systems based on a knowledge of their biogeochemical setting. Calculation of quantitative solutions to chemical equilibria. Focus on inorganic chemistry. Topics include elementary thermodynamics, acid-base equilibria, alkalinity, speciation, solubility, mineral stability, redox chemistry, and surface complexation reactions. SC 1 Course cr

WATER RESOURCES
[ F&ES 367, Water Resources and Environmental Change ]
The effects of variations in the hydrologic cycle on the global distribution of freshwater. The role of environmental change in regulating freshwater supply and quality. The influences of agriculture, industry, mining, urbanization, climate change, and energy-production alternatives on freshwater resources in the United States and abroad. 1 Course cr

[ F&ES 440, Environmental Hydrology ]
An overview of the principles that govern the distribution and flows of water and waterborne constituents between the land, atmosphere, and oceans. 1 Course cr

Quantitative and Research Methods
* F&ES 290b / EVST 290b, Geographic Information Systems Charles Tomlin
A practical introduction to the nature and use of geographic information systems (GIS) in environmental science and management. Applied techniques for the acquisition, creation, storage, management, visualization, animation, transformation, analysis, and synthesis of cartographic data in digital form. 1 Course cr

[ F&ES 441, Methods in Geomicrobiology ]
A laboratory-based course providing interdisciplinary practical training in geomicrobiological methods including microbial enrichment and cultivation techniques; light, epifluorescence, and electron microscopy; and molecular methods (DNA extraction, PCR, T-RFLP, FISH). Prerequisite: college-level chemistry. 1 Course cr

Social Sciences

ENVIRONMENTAL POLICY
F&ES 245b / EVST 245b / PLSC 146b, Global Environmental Governance Benjamin Cashore
The development of international environmental policy and the functioning of global environmental governance. Critical evaluation of theoretical claims in the literature and the reasoning of policy makers. Introduction of analytical and theoretical tools used to assess environmental problems. Case studies emphasize climate, forestry, and fisheries. SO 1 Course cr

F&ES 255b / EVST 255b / PLSC 215b, Global Food Challenges: Environmental Politics and Law John Wargo
Exploration of the politics, policy, and law associated with attempts to manage environmental quality and natural resources. Themes of democracy, liberty, power, property, equality, causation, and risk. Case histories include air quality, water quality and quantity, pesticides and toxic substances, land use, agriculture and food, parks and protected areas, and energy. SO 1 Course cr
Subjects of Instruction

[F&ES 277, Environmental Science and Policy]

The synthesis of science, both for scientists and for policy makers. Usefulness of the two types of synthesis for developing scientific research and policy. Advancement of complementary practices between science and policy arenas. Concepts and data from ecological and biogeochemical disciplines are used to predict and manage the effects of environmental change on ecosystem services that underlie the provisioning of resources such as food and clean water. 1 Course cr

SOCIAL AND POLITICAL ECOLOGY

* F&ES 285b / EVST 285b, Political Ecology of Tropical Forest Conservation  Amity Doolittle

Study of the relationship between society and the environment focusing on tropical forest conservation. Global processes of environmental conservation, development, and conflicts over natural resource use and control; approaches to conserving trees and forest cover using strategies that support biodiversity and rural agricultural livelihoods; specific focus on tropical forest landscapes dominated by agriculture and cattle ranching practices using Panama and Colombia as a case studies. The course includes an optional field trip during Spring Break: March 17-March 23 in Panama at the ELTI’s focal training site. 1 Course cr

[F&ES 384, Environmental Anthropology]

The history and contemporary study of anthropology and the environment, with special attention to current debates regarding human environmental relations. Topics include: nature-culture dichotomy; ecology and social organization; methodological debates; politics of the environment; and knowing the environment. 1 Course cr

* F&ES 422a / ANTH 409a / ER&M 394a / EVST 422a, Climate and Society from Past to Present  Michael Dove

Discussion of the major traditions of thought—both historic and contemporary—regarding climate, climate change, and society; focusing on the politics of knowledge and belief vs disbelief; and drawing on the social sciences and anthropology in particular. 1 Course cr