

University of Minnesota  
Department of Applied Economics

**Natural Resource Economics  
APEC 8601  
Fall Semester 2006**

Professor Steve Polasky

Offices: Classroom Office Bldg. 337E Ecology 503

Phone: 625-9213 624-3663

email: [polasky@umn.edu](mailto:polasky@umn.edu)

**Course Content and Objectives:**

This course has two main objectives:

- To acquaint you with the major issues and seminal literature in natural resource economics. We will cover issues related to the use of renewable and non-renewable resources over time, biodiversity conservation, climate change and sustainability. We will analyze the issue of efficient use of resources over time, whether market equilibrium achieves an efficient outcome, common property resources, spatial modeling, imperfect competition, multiple equilibria, uncertainty, irreversibilities, discounting, and sustainability.
- To increase your ability to do economic research. We will do a set of activities to increase your ability to think critically and formulate specific researchable questions, as well as improving your modeling and analytical skills.

**Course Requirements:**

|                                   |     |
|-----------------------------------|-----|
| Weekly questions/class discussion | 10% |
| Problem sets                      | 20% |
| Short research papers             | 20% |
| Midterm 1                         | 25% |
| Midterm 2                         | 25% |

We will read and discuss major articles that have helped define the field of resource economics and recent articles on the frontier. Reading the literature is important for gaining literacy and understanding the evolution of ideas and analytical techniques. Class time will be largely devoted to lecture and discussion of this material.

Each week you will hand in a question or insight arising from lecture, class discussion, class readings, other readings, or recent events. A couple of sentences will typically be sufficient for each question or insight. At the start of each class session we will spend a few minutes discussing selected issues raised by submitted questions or insights, or from outside events. We will use this time to think critically about the issue, formulate specific researchable questions, and potential modeling strategies.

There will be periodic problem sets. The best way to learn natural resource economics (or any branch of economics) is to solve problems. The problem sets will be mostly analytical but will also include some numerical problems. The latter type may involve the use of *Excel* or *Matlab* on the computer. I encourage you to work together on problem sets but each of you must hand in your own assignment.

There will be three short research papers. The first two papers will involve writing a short paper, on the order of 3 to 5 pages (double-spaced), that formally describes and motivates the research question, defines the analytic model and the analysis for an assigned problem that is akin to something on a problem set. The final paper will be similar except that the problem analyzed will be up to you to define.

There will be two tests on the material, one at midterm and one at the end of the semester. The two tests will be equally weighted except in the case where a student does much better on the second test in which case the second test will get greater weight.

### **Texts:**

There are two books that we will reference fairly extensively in the course (only one of which I have asked you to purchase):

Clark, Colin. 1990. *Mathematical Bioeconomics: The Optimal Management of Renewable Resources* (2<sup>nd</sup> Ed.). John Wiley.

Conrad, Jon and Colin Clark. 1987. *Natural Resource Economics: Notes and Problems*. Cambridge University Press.

Clark (1990) contains useful discussion of renewable resource models (but is really expensive so I'm not asking you to buy it). Conrad and Clark (1987) contain a summary of important concepts and a set of exercises that will allow you to apply the concepts to resource problems. I will assign some exercises from this book on problems set. Clark (1990) will be on reserve in Waite Library. Most of the readings for the course are journal articles. These articles will be available in Waite Library.

There are several other useful books that are good reference books that you may wish to purchase or have access to:

#### 1. Natural Resource Economics

- a. Dasgupta and Heal. 1979. *Economic Theory and Exhaustible Resources*.
- b. Hanley, Shogren and White. 1997. *Environmental Economics in Theory and Practice*
- c. Hartwick and Olewiler. 1998. *The Economics of Natural Resource Use* (2<sup>nd</sup> Ed)
- d. Kneese and Sweeney (Eds.) 1985. *The Handbook of Natural Resources and*

*Energy Economics*, Vol. I, II and III

- e. Maler and Vincent. 2005. *The Handbook of Environmental Economics*, Vol. I,II and III.

## 2. Dynamic Optimization

- a. Chiang. 2000. *Elements of Dynamic Optimization*
- b. Dixit and Pindyck. 1994. *Investment under Uncertainty*
- c. Dockner, Jorgensen and Long. 2001. *Differential Games in Economics and Management Science*
- d. Kamien and Schwartz. 1991. *Dynamic Optimization* (2<sup>nd</sup> Ed.)
- e. Leonard and Long. 1992. *Optimal Control Theory and Static Optimization in Economics*.
- f. Seierstad and Sydsaeter. 1987. *Optimal Control Theory with Economic Applications*
- g. Stokey and Lucas. 1989. *Recursive Methods in Economic Dynamics*

Note: I am assuming that people enrolled in this class have been exposed to techniques of dynamic optimization (optimal control theory and dynamic programming). If you do not have an adequate background in dynamic optimization we will arrange a way for you to catch up on this material (or you may wish to take this class after having ApEc 8991, Dynamic Optimization).

## Reading List:

### I. The Big Picture: Resources and Sustainability

Arrow, K., et al. 1995. Economic Growth, Carrying Capacity, and the Environment, *Science* 268: 520-521.

### II. Renewable Resources:

#### A. Basic Growth Theory

Conrad and Clark, chapter 1.

Hanley, Shogren and White, chapter 7.

Blanchard, O. and S. Fischer. 1989. *Lectures on Macroeconomics*, chapter 2.

Malinvaud, E. 1953. Capital Accumulation and Efficient Allocation of Resources, *Econometrica* 21: 233-268.

Gould, J.P. 1968. Adjustment Costs and the Theory of the Firm, *Review of Economic Studies* 35: 47-55.

#### B. Bioeconomic Models: Optimal Harvesting (Fishery Models)

Clark, chapters 1-4, 7.

Conrad and Clark, chapter 2.

Hanley, Shogren and White, chapter 10.

Hartwick and Olewiler, chapter 11.

Wilen, J. 1985. Bioeconomics of Renewable Resource Use, in Kneese and Sweeney (Eds.), *Handbook of Natural Resource Economics* Vol. 1.

Scott, A. 1955. The Fishery: The Objective of Sole Ownership, *Journal of Political Economy* 63: 116-124.

Clark, C. and G. Munro. 1975. The Economics of Fishing and Modern Capital Theory: A Simplified Approach. *Journal of Environmental and Resource Economics* 2: 92-106.

Clark, C. 1973. Profit Maximization and the Extinction of Animal Species, *Journal of Political Economy* 81: 950-961.

Spence, M. and D. Starrett. 1975. Most Rapid Approach Paths in Accumulation Problems. *International Economic Review* 16(2): 388-403.

Clark, C., F. Clarke, and G. Munro. 1979. The Optimal Exploitation of Renewable Resource Stocks: Some Problems of Irreversible Investment, *Econometrica* 47: 25-47.

Conrad, J. 1989. Bioeconomics and the Bowhead Whale, *Journal of Political Economy* 97: 974-987.

### C. Open Access and Regulation

- Smith, V. 1968. Economics of Production from Natural Resources, *American Economic Review* 58: 409-431.
- Bjorndal, T. and J. Conrad. 1987. The Dynamics of an Open Access Fishery. *Canadian Journal of Economics* 20: 74-85.
- Homans, F. and J. Wilen. 1997. A Model of Regulated Open Access Resource Use, *Journal of Environmental Economics and Management* 32: 1-21.
- Brander, J. and M.S. Taylor. 1998. The Simple Economics of Easter Island: A Ricardo-Malthus Model of Renewable Resource Use, *American Economic Review* 88: 119-138.
- Kremer, M. and C. Morcom. 2000. Elephants, *American Economic Review* 90: 212-234.

### D. Common Property Resources: Game Theoretic Models

- Clark, chapter 8.
- Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*.
- Tirole, J. 1988. Noncooperative Game Theory: A User's Manual, in *The Theory of Industrial Organization*.
- Dockner, Jorgensen and Long. 2001. Differential Games in Resources and Environmental Economics, in *Differential Games in Economics and Management Science*.
- Gordon, H.S. 1954. The Economic Theory of a Common Property Resource: The Fishery, *Journal of Political Economy* 62: 124-142.
- Levhari, D and L. Mirman 1980. The Great Fish War: An Example Using a Dynamic Cournot-Nash Solution, *Bell Journal of Economics* 11: 322-334.
- Reinganum, J. and N. Stokey. 1985. Oligopoly Extraction of a Common Property Natural Resource: The Importance of the Period of Commitment in Dynamic Games, *International Economic Review* 26: 161-173.
- Mason, C. and S. Polasky. 1994. Entry Deterrence in the Commons, *International Economic Review* 35: 507-525.
- Dutta, P. 1995. Collusion, Discounting and Dynamic Games, *Journal of Economic Theory* 66: 289-306.
- Polasky, S., N. Tarui, G. Ellis and C. Mason. 2006. Cooperation in the Commons. *Economic Theory*.

### E. Age Dependent Growth and Timing of Harvest (Forestry Models)

- Clark, chapter 9.
- Hanley, Shogren and White, chapter 11.
- Hartwick and Olewiler, chapter 10.
- Samuelson, P. 1976. Economics of Forestry in an Evolving Society, *Economic Inquiry* 14: 466-492.
- Hartman, R. 1976. The Harvesting Decision when a Standing Forest has Value,

*Economic Inquiry* 14: 52-58.

Reed, W. 1986. Optimal Harvesting Models in Forestry Management - A Survey, *Natural Resource Modeling* 1: 55-79.

#### F. Spatially Explicit Models

Sanchirico, J. and J. Wilen. 1999. Bioeconomics of Spatial Exploitation in a Patchy Environment, *Journal of Environmental Economics and Management* 37: 129-150.

Sanchirico, J. and J. Wilen. 2005. Optimal Spatial Management of Renewable Resources: Matching Policy Scope to Ecosystem Scale, *Journal of Environmental Economics and Management* 50: 23-46.

Holland, D. and K.E. Schnier. 2006. Individual Habitat Quotas for Fisheries, *Journal of Environmental Economics and Management* 51: 72-92.

Costello, C. and S. Polasky. 2006. Optimal Harvesting of Stochastic Spatial Resources. Working Paper.

#### G. Renewable Resource Management with Uncertainty

Clark, chapter 11.

Conrad and Clark, chapter 5.

Mangel, M. 1985. *Decision and Control in Uncertain Resource Systems*.

Cropper, M. 1976. Regulating Activities with Catastrophic Environmental Effects, *Journal of Environmental Economics and Management* 3: 1-15.

Reed, W. 1979. Optimal Escapement Levels in Stochastic and Deterministic Harvesting Models, *Journal of Environmental Economics and Management* 6: 350-363.

Reed, W. 1984. The Effects of Fire on the Optimal Rotation of a Forest, *Journal of Environmental Economics and Management* 11: 180-190.

Clark, C. and G. Kirkwood. 1986. On Uncertain Renewable Resource Stocks: Optimal Harvest Policies and the Value of Stock Surveys, *Journal of Environmental Economics and Management* 13: 235-244.

Costello, C., S. Polasky and A. Solow. 2001. Renewable Resource Management with Environmental Prediction, *Canadian Journal of Economics* 34(1): 196-211.

Peterson, Brock and Carpenter. 2003. Uncertainty and the Management of Multistate Ecosystems: An Apparently Rational Route to Collapse. *Ecology* 84(6): 1403-1411.

#### H. Irreversibility, Uncertainty, and Option Value

Dixit and Pindyck, chapter 2 and chapter 4, pp. 93-103.

Conrad and Clark, chapter 5, sections 5.1 and 5.7.

Krutilla, J.V. and A.C. Fisher. 1975. *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources*.

Pindyck, R. 1991. Irreversibility, Uncertainty, and Investment, *Journal of Economic*

*Literature 1110-1148.*

- Dixit, A. 1992. Investment and Hysteresis, *Journal of Economic Perspectives*, 107-132.
- Krutilla, J. 1967. Conservation Reconsidered, *American Economic Review* 47: 777-786.
- Arrow, K. and A. Fisher. 1974. Environmental Preservation, Uncertainty, and Irreversibility, *Quarterly Journal of Economics* 88: 312-319.
- Freixas, X. and J.J. Laffont. 1984. The irreversibility Effect. In *Bayesian Models in Economic Theory*, K. Boyer and M. Kilstrom (eds). North Holland.
- Hanemann, W. M. 1989. Information and the Concept of Option Value, *Journal of Environmental Economics and Management* 16: 23-37.
- Olson, L. 1990. Environmental Preservation with Production, *Journal of Environmental Economics and Management* 18: 88-96.
- Kolstad, C. 1996. Learning and Stock Effects in Environmental Regulation: The Case of Greenhouse Gas Emissions, *Journal of Environmental Economics and Management* 31: 1-18.
- Fisher, A.C. 2000. Investment Under Uncertainty and Option Value in Environmental Economics, *Resource and Energy Economics* 22: 197-204.
- Gollier, C., B. Jullien and N. Treich. 2000. Scientific Progress and Irreversibility: An Economic Interpretation of the Precautionary Principle. *Journal of Public Economics* 75: 229-253.

### III. Non-Renewable Resources

#### A. The Basic Hotelling Model and Extensions

- Conrad and Clark, chapter 3.
- Dasgupta and Heal, chapter 6.
- Hanley, Shogren and White, chapter 9.
- Hartwick and Olewiler, chapter 8.
- Hartwick, J. 1989. *Non-Renewable Resources: Extraction Programs and Markets*.
- Hotelling, H. 1931. The Economics of Exhaustible Resources, *Journal of Political Economy* 39: 137-175.
- Gray, L. 1914. Rent Under the Assumptions of Exhaustibility, *Quarterly Journal of Economics* 28: 466-489.
- Solow, R. 1974. The Economics of Resources or the Resources of Economics, *American Economic Review* 64:1-14.
- Levhari, D. and N. Liviatan. 1977. Notes on Hotelling's Economics of Exhaustible Resources, *Canadian Journal of Economics* 10:177-192.
- Hartwick, J. 1978. Exploitation of Many Deposits of an Exhaustible Resource, *Econometrica* 46: 201-217.
- Eswaran, M., T. Lewis, and T. Heaps. 1983. On the Nonexistence of Market Equilibria in Exhaustible Resource with Decreasing Costs, *Journal of Political Economy* 91: 154-167.
- Farzin, H. 1984. The Effect of the Discount Rate on Depletion of Exhaustible

Resources, *Journal of Political Economy* 92: 841-851.

Gaudet, G., M. Moreau and S. Salant. 2001. Intertemporal Depletion of Resource Sites by Spatially Distributed Users, *American Economic Review* 91: 1149-1159.

## B. Empirical Tests

Slade, M. 1982. Trends in Natural-Resource Commodity Prices: An Analysis of the Time Domain, *Journal of Environmental Economics and Management* 9: 122-137.

Smith, V.K. 1980. The Evaluation of Natural Resource Adequacy: Elusive Quest or Frontier of Economic Analysis?" *Land Economics* 56: 257-298.

Farrow, S. 1985. Testing the Efficiency of Extraction from a Stock Resource, *Journal of Political Economy* 93: 452-487.

Miller, M. and C. Upton. 1985. A Test of the Hotelling Valuation Principle, *Journal of Political Economy* 93: 1-15.

Halvorsen, R. and T. Smith. 1991. A Test of the Theory of Exhaustible Resources, *Quarterly Journal of Economics*, 123-140.

Cuddington, J. and D. Moss. 2001. Technological Change, Depletion, and the U.S. Petroleum Industry, *American Economic Review* 91: 1135-1148

## C. Exploration and Uncertainty

Pindyck, R. 1978. The Optimal Exploration and Production of Nonrenewable Resources, *Journal of Political Economy* 86: 841-861.

Loury, G. 1978. The Optimal Exploitation of an Unknown Reserve, *Review of Economic Studies* 45: 621-636.

Arrow, K. and S. Chang. 1982. Optimal Pricing, Use and Exploration of Uncertain Natural Resource Stocks, *Journal of Environmental Economics and Management* 9: 1-10.

Swierzbinski, J. and R. Mendelsohn. 1989. Information and Exhaustible Resources: A Bayesian Analysis, *Journal of Environmental Economics and Management* 16: 193-208.

Polasky, S. 1992. The Private and Social Value of Information: Exploration for Exhaustible Resources, *Journal of Environmental Economics and Management* 23: 1-21.

## D. Imperfect Competition

Hartwick and Olewiler, chapter 9.

Karp, L. and D. Newbery. 1993. Intertemporal Consistency Issues in Depletable Resources, in Knesse and Sweeney (Ed.) *Handbook of Natural Resource and Energy Economics*, Vol. III.

Stiglitz, J. 1976. Monopoly and the Rate of Extraction of Exhaustible Resources, *American Economic Review* 66: 655-661.

Salant, S. 1976. Exhaustible Resource and Industrial Structure: A Nash-Cournot Approach to the World Oil Market, *Journal of Political Economy* 84: 1079-1093.

- Pindyck, R. 1978. Gains to Producers from the Cartelization of Exhaustible Resources, *Review of Economics and Statistics* 60: 238-251.
- Loury, G. 1986. A Theory of 'Oil'igopoly: Cournot Equilibrium in Exhaustible Resource Markets with Fixed Supplies, *International Economic Review* 27: 285-301.
- Polasky, S. 1992. Do Oil Producers Act as 'Oil'igopolists?" *Journal of Environmental Economics and Management* 23: 216-247.

#### IV. Biodiversity

##### A. Biodiversity Measures and the Value of Biodiversity

- Polasky, S., C. Costello and A. Solow. 2005. The Economics of Biodiversity. In *The Handbook of Environmental Economics, Vol. 3*, J. Vincent and K.-G. Maler (eds.). Elsevier – North Holland.
- Weitzman, M. 1992. On Diversity, *Quarterly Journal of Economics* 107(2): 363-405.
- Solow, A. and S. Polasky. 1994. Measuring Biological Diversity, *Environmental and Ecological Statistics* 1(2): 95-107.
- Brock, W. and A. Xepapadaes. 2003. Valuing Biodiversity from an Economic Perspective: A Unified Economic, Ecological and Genetic Approach, *American Economic Review* 93(5): 1597-1614
- Tilman, D., S. Polasky and C. Lehman. 2005. Diversity, productivity and temporal stability in the economies of humans and nature. *Journal of Environmental Economics and Management* 49(3): 405-426.

##### B. Strategies to Conserve Biodiversity

- Montgomery, C., G. Brown and D. Adams. 1994. The Marginal Cost of Species Preservation: The Case of the Northern Spotted Owl, *Journal of Environmental Economics and Management* 26: 111-128.
- Ando, A., J. Camm, S. Polasky and A. Solow. 1998. Species Distributions, Land Values and Efficient Conservation, *Science* 279: 2126-2128.
- Weitzman, M.L. 1998. The Noah's Ark Problem. *Econometrica* 66: 1279-1298.
- Montgomery, C., R. Pollak, K. Freemark and D. White. 1999. Pricing Biodiversity, *Journal of Environmental Economics and Management* 38: 1-19.
- Polasky, S., C. Costello and C. McAusland. 2004. On Trade, Land-use, and Biodiversity. *Journal of Environmental Economics and Management* 48(2): 911-925.
- Polasky, S., E. Nelson, E. Lonsdorf, P. Fackler and A. Starfield. 2005. Conserving species in a working landscape: land use with biological and economic objectives. *Ecological Applications* 15(4): 1387-1401.

##### C. Land Use Modeling

- Stavins, R. and A. Jaffe. 1990. Unintended Impacts of Public Investments on Private

- Decisions: The Depletion of Wetlands, *American Economic Review* 80: 337-352.
- Deacon, R. 1995. Assessing the Relationship between Government Policy and Deforestation, *Journal of Environmental Economics and Management* 28: 1-18.
- Albers, H. 1996. Modeling Ecological Constraints on Tropical Forest Management: Spatial Interdependence, Uncertainty and Irreversibility, *Journal of Environmental Economics and Management* 30: 73-94.
- Lubowski, R.N., A.J. Plantinga and R.N. Stavins. 2006. Land Use Change and Carbon Sinks: Econometric Estimation of the Carbon Sequestration Supply Function, *Journal of Environmental Economics and Management* 51: 135-152.

## V. Climate Change

- Kolstad, C.D. and M. Toman. 2005. The Economics of Climate Change Policy. In *The Handbook of Environmental Economics, Vol. 3*, J. Vincent and K.-G. Maler (eds.). Elsevier – North Holland.
- Nordaus, W.D. and J. Boyer. 2000. *Warming the World: Economic Models of Global Warming*. MIT Press.
- Pizer, W. 1999. The Optimal Choice of Climate Change Policy in the Presence of Uncertainty, *Resource and Energy Economics* 21: 255-287.
- Goulder, L.H. and K. Mathai. 2000. Optimal CO<sub>2</sub> Abatement in the Presence of Induced Technological Change, *Journal of Environmental Economics and Management* 39: 1- 38.

## VI. Sustainability

- Hanley, Shogren and White, chapter 14.
- Hartwick and Olewiler, chapters 2, 12.
- Dasgupta and Heal, chapters 7-8.
- Heal, G. 1998. *Valuing the Future: Economic Theory and Sustainability*.
- Solow, R. 1991. Sustainability: An Economist's Perspective, J. Seward Johnson Lecture, Marine Policy Center, Woods Hole Oceanographic Institution.
- Solow, R. 1974. On the Intergenerational Allocation of Resources, *Review of Economic Studies* (Symposium): 29-45.
- Stiglitz, J. 1974. Growth with Exhaustible Natural Resources: Efficient and Optimal Growth Paths, *Review of Economic Studies* (Symposium): 123-137.
- Hartwick, J., 1977. Intergenerational Equity and the Investing of Rents from Exhaustible Resources, *American Economic Review* 66: 972-974.
- Arrow, K. et al. 2004. Are We Consuming Too Much? *Journal of Economic Perspectives* 18(3): 147-172.