

# Introduction to Natural Resource Economics

Lecture Notes on Natural Resource Economics (AEC- 608)

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# 1 Introduction

Economic development depends fundamentally on the rational use of natural capital. When economic development is not aligned with environmental conservation, it can lead to resource depletion, ecosystem degradation, and a decline in human well-being. Natural Resource Economics (NRE) provides the analytical tools and frameworks to address these challenges.

## 2 Definitions

### 2.1 Economics

Economics is the science that studies human behaviour as a relationship between ends and scarce means which have alternative uses. Here, **means** refer to the limited resources available, and **ends** are the various objectives or desires that individuals and societies pursue. Economics is fundamentally about making choices under conditions of scarcity.

### 2.2 Natural Resource Economics (NRE)

Natural Resource Economics is the study of the supply, demand, and allocation of the Earth's natural resources. It focuses on the efficient and sustainable use of both renewable and non-renewable resources, considering the dynamic interactions between economic and natural systems.

### 2.3 Environmental Economics

Environmental Economics deals with the efficient allocation and use of environmental goods and services, many of which are not traded in conventional markets. It addresses market failures such as externalities and public goods, and designs policies (e.g., taxes, permits) to correct these inefficiencies.

### 2.4 Ecological Economics

Ecological Economics is an interdisciplinary field that integrates ecological and economic principles. It emphasizes the embeddedness of the economy within the ecosystem, focusing on sustainability, equity, and the long-term health of both human and natural systems.

### 3 Why a Separate Field for NRE?

Natural Resource Economics has emerged as a distinct field due to the unique characteristics of natural resources:

- **Irreplaceability:** Many natural resources, especially non-renewables, cannot be re-generated within human timescales.
- **Lack of Substitutes:** For several ecosystem services and critical resources, there are no perfect substitutes (e.g., clean air, fertile soil, biodiversity).
- **Intertemporal and Spatial Effects:** The extraction or conservation of resources has impacts that extend across generations and geographic boundaries.
- **Externalities:** Many uses generate externalities—costs or benefits not borne by the users themselves.
- **Market Failures:** Due to externalities, public goods, and unclear property rights, markets often fail to allocate resources efficiently.

## 4 Important Milestones in Natural Resource Economics

Year	Milestone/Model/Concept	Main Contribution
1849	Faustmann Formula	Introduced the concept of the present value of forest land, foundational for the economics of optimal rotation in forestry.
1914	Gray Model (L.C. Gray)	Early analysis of exhaustible resources, highlighting optimal extraction and resource scarcity.
1920	Pigovian Tax (A.C. Pigou)	Proposed taxes to internalize negative externalities, foundational for environmental policy.
1931	Hotelling Model (Harold Hotelling)	Formalized the economics of exhaustible resources; Hotelling's Rule describes the optimal extraction path for non-renewable resources.
1947	Travel Cost Method (Hotelling's Letter)	Suggested the travel cost method for valuing recreational benefits of natural parks, foundational for non-market valuation.
1954	Gordon-Schaefer Fisheries Model	Developed economic models for renewable resources, especially fisheries; introduced maximum sustainable yield and economic optimum.
1960	Coase Theorem (Ronald Coase)	Demonstrated that, under certain conditions, private bargaining can lead to efficient outcomes in the presence of externalities.
1962	<i>Silent Spring</i> (Rachel Carson)	Raised global awareness of environmental impacts of pesticides, catalyzing the modern environmental movement.
1968	Garett Hardin - commons	Tragedy of commons paper introduced why resources under common property resource are over-exploited.
1972	Stockholm Conference	First major international conference on the environment, resulting in the Stockholm Declaration and Action Plan for global environmental management.
1974	Hartwick Rule (John Hartwick)	Provided a rule for investing resource rents to maintain constant consumption, foundational for sustainability economics.
1977	Safe Minimum Standard (Ciriacy-Wantrup)	Introduced the concept of a safe minimum standard for resource conservation under uncertainty.
1980s	Contingent Valuation Method	Developed as a key stated preference method for valuing non-market environmental goods and services.
1987	Brundtland commission	First systematic analysis and definition of Sustainability.
2009	Elinor Ostrom- commons	Wins the Noble prize for the analysis which highlighted that with good governance commons need not be a tragedy.

## 5 Summary

Natural Resource Economics is a vital field that addresses the unique challenges posed by natural resources, including their irreplaceability, lack of substitutes, intergenerational impacts, and market failures. The field has evolved through key theoretical and policy milestones, shaping both academic thought and practical approaches to managing the planet's finite resources.

## 6 Glossary of Key Terms

**Bequest Value** Value placed on preserving resources for the benefit of future generations.

**Biological Growth Function** Mathematical description of how a resource stock changes over time, often modeled as logistic growth:  $G(X) = rX(1 - \frac{X}{K})$ .

**Carrying Capacity ( $K$ )** The maximum population or stock size an environment can sustain.

**Common-Property Resource** A resource accessible to multiple users without exclusive rights.

**Current Annual Increment (CAI)** Incremental change in forest volume year by year;  $CAI = \frac{dQ}{dt}$ .

**Direct Use Value** Value derived from direct consumption or enjoyment of environmental goods (e.g., timber, recreation).

**Discount Rate** The rate used to convert future costs and benefits into present values.

**Ecological Economics** An interdisciplinary field integrating ecological and economic principles, emphasizing sustainability and the embeddedness of the economy within ecosystems.

**Economic Optimum (MEY)** The harvest and effort level that maximizes the present value of net economic benefits, typically at higher stock and lower effort than MSY.

**Economics** The science that studies human behaviour as a relationship between ends and scarce means which have alternative uses.

**Economic Rent** The excess return above the opportunity cost of resource use.

**Effort at MSY** The level of fishing effort that achieves MSY,  $E_{MSY} = \frac{r}{2q}$ .

**Environmental Economics** The branch of economics dealing with the allocation and use of environmental goods and services, addressing market failures like externalities and public goods.

**Environmental Value** The monetary worth of environmental goods and services as reflected in individual or societal preferences.

**Existence Value** Value from knowing a resource or species exists, even without direct use.

**Externality** A cost or benefit from an economic activity not reflected in market prices, affecting third parties.

**Faustmann Formula** A method for determining the optimal rotation period in forestry by maximizing the present value of an infinite series of rotations.

**Harvest Function**  $H = qEX$ , where  $q$  is catchability,  $E$  is effort, and  $X$  is biomass.

**Hartwick Rule** The principle that investing all rents from exhaustible resources in reproducible capital can sustain constant consumption.

**Indirect Use Value** Value from ecosystem functions that support economic activity (e.g., water purification, flood control).

**Institutional Change** The evolution of rules and norms governing resource use.

**Intergenerational Equity** Fairness in the distribution of resources and welfare across generations.

**Internalization** The process of incorporating external effects into decision-making through property or regulatory arrangements.

**Irreversibility** An action whose effects cannot be undone, such as species extinction.

**Logistic Growth Model**  $G(X) = rX(1 - \frac{X}{K})$ , where  $r$  is the intrinsic growth rate.

**Marginal User Cost** The opportunity cost of extracting a unit of resource today rather than in the future.

**Market Failure** A situation where markets fail to allocate resources efficiently, often due to externalities, public goods, or unclear property rights.

**Mean Annual Increment (MAI)** Average annual increase in forest volume up to a given time;  $MAI(t) = \frac{f(t)}{t}$ .

**Maximum Sustainable Yield (MSY)** The largest constant harvest that can be sustained indefinitely without depleting the resource, achieved at  $X = K/2$ .

**Natural Resource Economics (NRE)** The study of the supply, demand, and allocation of Earth's natural resources, focusing on efficient and sustainable use of both renewable and non-renewable resources.

**Non-Use Value** Value not associated with current or planned use, including existence, bequest, and option values.

**Open Access** A regime where no user can be excluded from resource use, often leading to overexploitation.

**Option Value** Value of preserving the option to use a resource in the future under uncertainty.

**Pareto Improvement** A change that makes at least one person better off without making anyone worse off.

**Pareto-Relevant Externality** An externality whose internalization would lead to a Pareto improvement.

**Pigovian Tax** A tax imposed to correct the negative externalities of a market activity.

**Precautionary Principle** The policy of erring on the side of caution when outcomes are uncertain and potentially irreversible.

**Private Cost** The cost incurred by an individual or firm directly involved in an economic activity.

**Production Function Approach** Method for measuring the contribution of environmental inputs to production.

**Property Rights** Socially or legally recognized rights to use, control, and transfer resources.

**Public Good** A good that is non-excludable and non-rivalrous, leading to free-riding and under-provision.

**Recovery Function** The process by which resource stocks regenerate or are discovered.

**Regulatory Capture** The process by which regulatory agencies are dominated by the industries they regulate.

**Renewable Resource** A resource that can replenish itself through natural growth or regeneration.

**Rent Dissipation** The loss of potential economic surplus (rent) due to excessive competition in open access resources.

**Resource Rent** The return to the owner of a resource in excess of the minimum necessary to keep it in use.

**Resource Scarcity** The limited availability of natural resources relative to demand.

**Risk Aversion** The preference for certain outcomes over uncertain ones.

**Shadow Price** An administratively determined price reflecting the true social value of resources.

**Social Discount Rate** The rate at which society discounts future benefits and costs in public project evaluation.

**Social Opportunity Cost (SOC)** The value of the next best alternative use of funds.

**Social Time Preference (STP)** The rate at which society is willing to trade off present for future consumption.

**Soil Expectation Value (SEV)** The present value of all future net returns from land managed in perpetual rotations.



**Substitutability** The ability to replace one input with another in production.

**Total Economic Value (TEV)** A framework that includes both use values (direct and indirect) and non-use values (existence, bequest, option).

**Transaction Costs** Costs of negotiating, monitoring, and enforcing agreements or property rights.

**Tragedy of the Commons** Overuse and depletion of a resource due to lack of property rights, as each user ignores the impact on others.

**Use Value** Value derived from the actual use of the environment, either directly or indirectly.

**Weak Sustainability** The view that natural and man-made capital are largely substitutable.