Valuing Biodiversity from an Economic Perspective

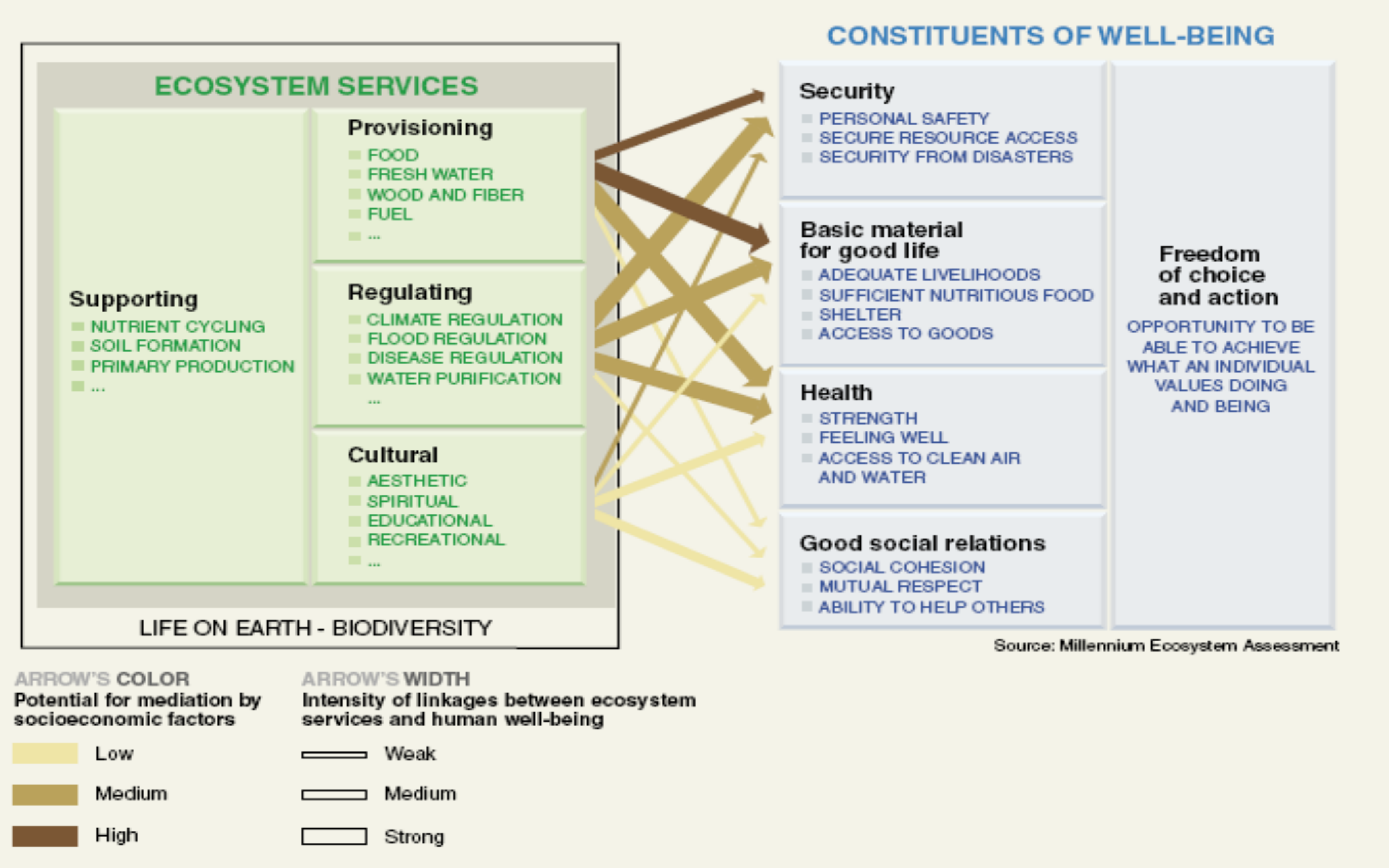
Anastasios Xepapadeas
Athens University of Economics and Business
and Beijer Fellow

UNESCO IYB
Biodiversity Science Policy Conference
Paris, January 2010

A Few Basic Facts

- Human activities have increased species extinction rates by as much as 1,000 times relative to background rates that were typical over Earth's history (MEA 2005).
- 10 – 50% of well-studied higher taxonomic groups (mammals, birds, amphibians, conifers, and cycads) currently face extinction (MEA 2005).
- 20 – 30% of species assessed are likely to be threatened with extinction from climate-change impacts possibly within this century as the increase in global average temperature above pre-industrial levels exceeds 2° – 3°C (IPCC 2007).

Ecosystems Services and Human Well-being (MEA)



Ecosystems Services and Natural Capital

- Ecosystems are collections of all living organisms in a particular area together with the physical and chemical environment they live in. The stocks of these organisms should be regarded as capital stocks as should the stocks of water, minerals etc available to organisms.
- Ecosystems Services are generated by these stocks of natural capital.

Ecosystems as Dynamical Systems

- Ecosystems can be described in principle as nonlinear dynamical systems of these stocks:

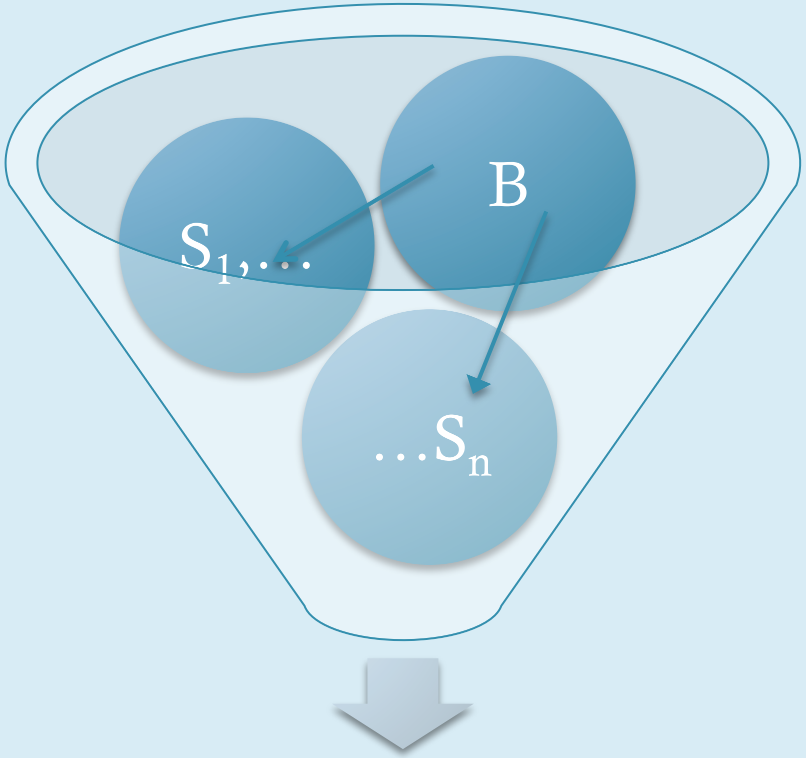
$$\frac{dS_1}{dt} = F_1(S_1, \ldots, S_n, B)$$

$$\ldots$$

$$\frac{dS_{n+1}}{dt} = F_{n+1}(S_1, \ldots, S_n, B)$$

- Biodiversity *B* can be regarded as a stock of natural capital, measured by an appropriate metric **(species richness, Shannon or Simpson index)**.

Stocks of Natural Capital and Ecosystems Services



Supporting, Provisioning, Regulating, Cultural Ecosystem Services

Relation between Biodiversity and Ecosystems Services

- Biodiversity is essential for the proper functioning of an ecosystem so it retains its ability to provide a flow of Supporting, Provisioning, Regulating and Cultural Services.
- The particular contribution to each category and to items within each category is an open research area which will determine an economic value for biodiversity.
- Estimation of contribution could be better accomplished on an ecosystem specific basis.

Biodiversity Impact on Ecosystems Characteristics

- Biodiversity provides or enhances a number of important ecosystems characteristics which are related to the flow of ecosystems services regarded as desirable.

- These characteristics include: productivity, resilience, insurance and knowledge.

Biodiversity and Ecosystems Characteristics

1. **Productivity:** More diverse plant systems are more productive than less diverse ones. Functional diversity is a principal factor explaining plant productivity (D. Tilman). Productivity relates mainly to ***Provisioning Services.***
2. **Resilience:** Diverse system are more resilient to exogenous disturbances. Diversity promotes stability. Monocultures tend to make ecosystems unstable. Resilience relates to ***All Services.***

Biodiversity and Ecosystems Characteristics

3. **Insurance:** Genetic diversity provides insurance against catastrophic events or infections. Insurance relates mainly to ***Provisioning and Cultural Services.***

4. **Knowledge:** Biodiversity can be used as a source of knowledge to develop new products in the biotechnology industry or pharmaceuticals. Knowledge relates mainly to ***Provisioning Services.***

The Economic Dimension of Biodiversity

Biodiversity loss implies loss in ecosystems services

Loss in ecosystems services has a negative impact on human well-being

How do we value the impact on human well-being?

Ecosystem Valuation *implies* **Biodiversity Valuation**

What is the value of an ecosystem?

- The value of an ecosystem is the value of the services it produces.
- It is defined as the discounted sum of the flow of the values of all services provided by the ecosystem.
- Formally:

$$Value_0 = \sum_{t=0}^{\infty} \frac{VS_t}{(1+r)^t}$$

Economic Values Associated with Ecosystem Services

Total Economic Value/ Types of Values				
Ecosystem Services	Direct Use Values (Production Consumptions)	Indirect Use Values (Resilience)	Option Values (Potential future values)	Non-use values (the intrinsic value of Nature)
Provisioning	*		*	
Regulating	*		*	*
Cultural		*	*	
Supporting	*	*	*	*

Valuation Methods

Valuation Method	Examples of types of Ecosystem Services
Travel Cost (Direct use)	Maintenance of beneficial species, Recreation
Averting behavior (Direct use)	Pollution control detoxification
Hedonic Pricing (Direct and indirect use)	Storm protection; flood mitigation; maintenance of air quality
Production Function (indirect use)	Maintenance of beneficial species; maintenance of arable land and agricultural productivity; prevention of damage from erosion and siltation; groundwater recharge; drainage and natural irrigation; storm protection; flood mitigation
Stated Preference Methods (Use and non-use)	Most services with missing markets
Expected damage method (Direct use)	Storm buffer service of mangroves

What is the price for a stock of natural capital?

- If there are (approximately efficient) markets for the services generated by the stock, then the market price is a good proxy, especially for direct use values.
- If markets are missing or if they are heavily distorted, we need **accounting or shadow prices.**
- An accounting price for a natural stock is defined as the change in the total value of ecosystem services caused by a marginal change in the stock associated with the specific service.

Accounting Price for Phosphorous Stock in a Lake

V_1, B_1

V_1: value of oligotrophic lake ecosystem

S_1: stock of phosphorous

V_2, S_2

V_1: value of a eutrophic lake ecosystem

S_2: stock of phosphorous

$$p_S = \frac{V_2 - V_1}{S_2 - S_1}$$

Accounting price of phosphorous in the lake

Accounting Price for Forest Biodiversity

V_1, B_1

V_1: value of timber harvest from a forest when species richness is B_1

V_2, B_2

V_2: value of timber harvest from a forest when species richness is B_2

$$p_B = \frac{V_2 - V_1}{B_2 - B_1}$$

Accounting price of biodiversity in terms of timber value

A Framework for Valuing Changes in Biodiversity

Change in Biodiversity Metric

- Species richness
- Shannon Index
- Simpson Index

→

Impact on Ecosystem Characteristic

- Productivity
- Resilience
- Insurance
- Knowledge

→

Change in Ecosystem Services Flows

- Provisioning
- Regulating
- Cultural
- Supporting

A Framework for Valuing Changes in Biodiversity: Productivity

Provisioning Services

Direct use values

Market values *Possible corrections for Distortions*

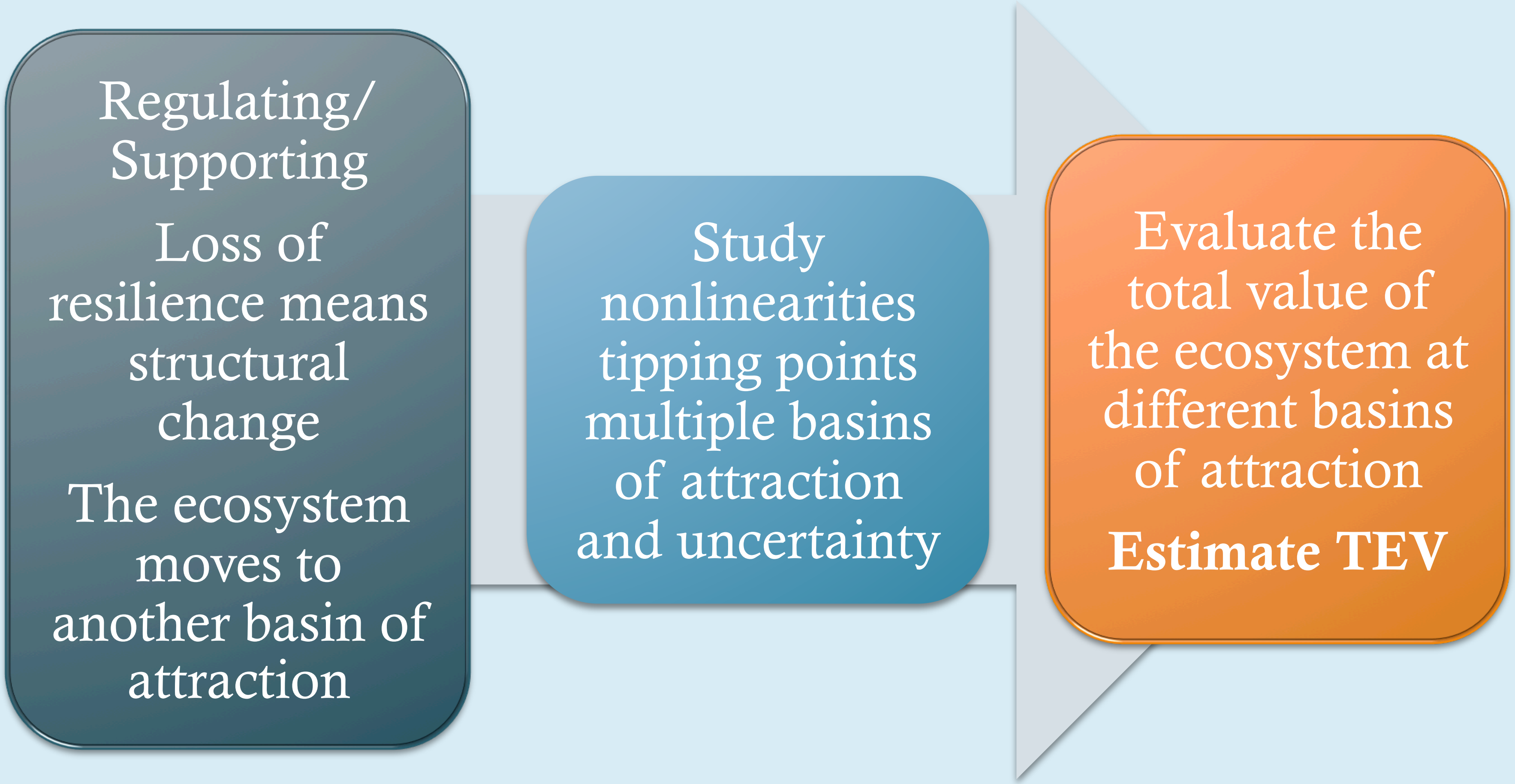
Missing Markets

Use valuation methods

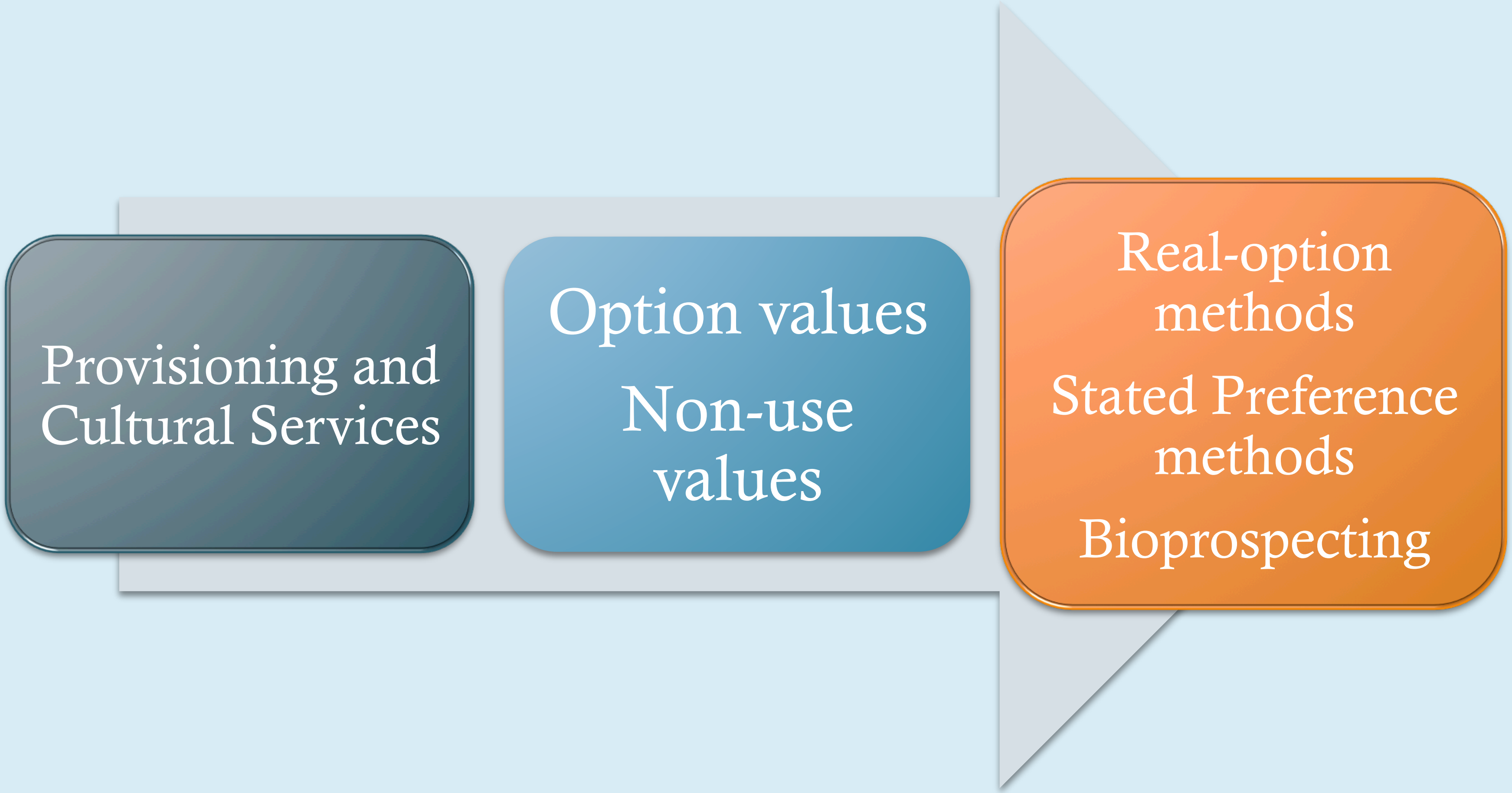
Production Function methods

Treat ecosystem services as inputs in the production of marketed goods and services

A Framework for Valuing Changes in Biodiversity: Resilience



A Framework for Valuing Changes in Biodiversity: Insurance and Knowledge



Summarizing Valuation Stages

Establish a relationship between changes in biodiversity impact on ecosystems characteristics and changes in ecosystem services

Ecosystem Specific-Service Specific: $S_i = f(B,\mathbf{z})$

Associate changes in Biodiversity metric with changes in Service metric

$\Delta B \rightarrow \Delta S_i$

Value changes in ecosystems services and derive accounting price for biodiversity

$$p_B = \frac{\Delta VS_i}{\Delta B}$$

Cost-Benefit rules

- If a certain project provides gains in terms of species richness of ΔB and the project costs C a cost benefit rule for accepting the project could be

$$p_B \Delta B - C > 0$$

Estimating the value of ecosystem services: some examples

- The value of ecosystem services varies across time and space.
- Reasonable estimates of the value of many provisioning services exist because markets are rather well developed.
- However few reliable estimates of the value of cultural regulating or supporting services exist.
- Markets don’t function well.

Market Failures in Ecosystem Services

- Missing markets because of:
  - Spatial separation that prevents negotiations. Upstream – downstream interactions
  - Temporal separation and missing future markets. Climate change, future generations cannot negotiate
  - Open access and the tragedy of the commons

Sample estimates

- **Water regulation / watershed protection** in the tropical forests in Mount Kenya: $273/ha/yr (Emerton, 1999).
- **Watershed protection** provided by intact coastal ecosystems, such as mangroves and other wetlands: $845/ha/yr in Malaysia and $1,022/ha/yr in Hawaii (Kaiser and Roumasset, 2002).
- Overall, the values of the multiple **watershed services** tend to range from $200 to 1,000/ha/yr (Mullan and Kontoleon, 2008).

Sample estimates

- **Pollination** service of tropical forests for coffee production in Costa Rica: $361/ha/yr (Ricketts et al., 2004), although the benefits only accrued to producers within 1 km of natural forests.
- Ecosystem services **biochemicals, natural medicines and pharmaceuticals**, found in tropical forests. The marginal values for bioprospecting have been estimated (Costello and Ward, 2006) at ranging from $14/ha (mean estimate) to $65/ha (upper 5% quantile estimate). These are below what would likely be required for large-scale private-sector conservation via bioprospecting.
- **Reef recreation***:* $184 per visit globally (Brander et al, 2007)

How can we approximate the value of biodiversity?

- If we estimate that a change in the biodiversity metric **species richness** (e.g. loss of **N** species in a coastal ecosystem) will reduce:
  - Watershed protection services by **y** hectares-equivalent with value $\mathbf{V_y}$
  - Provisioning services by $\mathbf{V_p}$
- Then the accounting price of biodiversity is $\frac{V_y + V_p}{N}$