University of Lisbon
Instituto Superior de Agronomia

Biod. & Cons.
2nd Module –
Man and Biodiversity

4th-5th lectures

30th March – 12th April 2021

José Lima Santos

jlsantos@isa.ulisboa.pt

Part 1

Introduction to Man & Biodiversity

- A sixth episode of mass extinction?

- Man as a cause of biodiversity loss

- Costs of biodiversity loss for Man

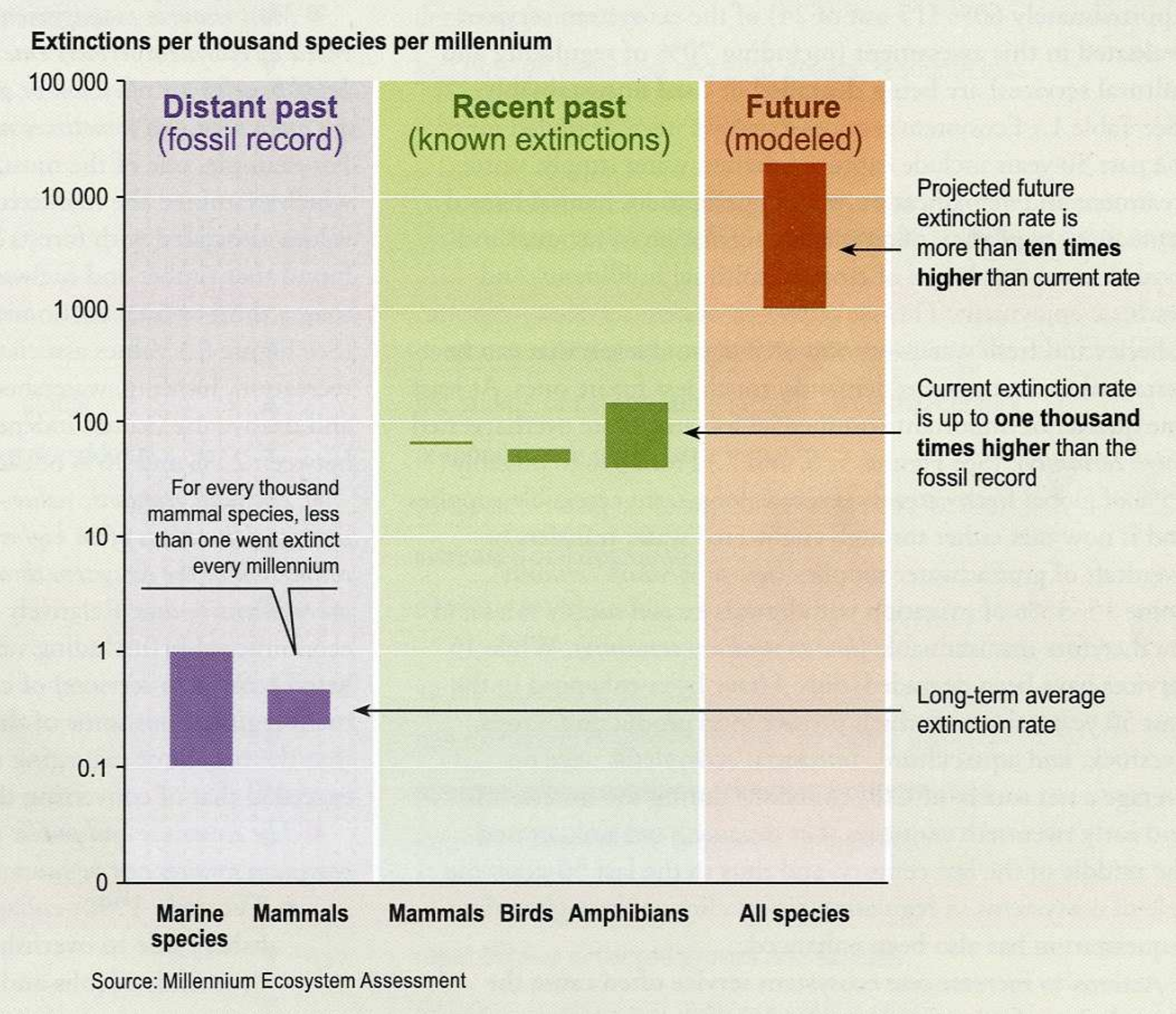
- Direct drivers of biodiversity loss

- Indirect (underlying) drivers of biodiversity loss

- Market failure / policy failure

- Internalizing external costs and benefits: the role of economic incentives in biodiversity conservation

- A sixth episode of mass extinction?



A sixth episode of mass extinction?
(Araújo, 2010)

Time scale:

- Global mass extinctions: in days
- Speciation: > 1-2 million years

Background, ordinary extinctions (95% of all extinctions), causes:

- climate change
- resource exhaustion
- competition
- diseases
- other changes requiring too much adaptive capacity and flexibility

A sixth episode of mass extinction?
(Araújo, 2010)

Mass extinctions (5% of all extinctions), extraordinary phenomena, which:

- are global (they occur all over the world, not only in some regions)
- they affect a large share of existing species (often > 50%)
- diverse species become extinct (not only particular branches of the Tree of Life)
- They occur in the short geological time (differently from ordinary background extinctions)

- A sixth episode of mass extinction?

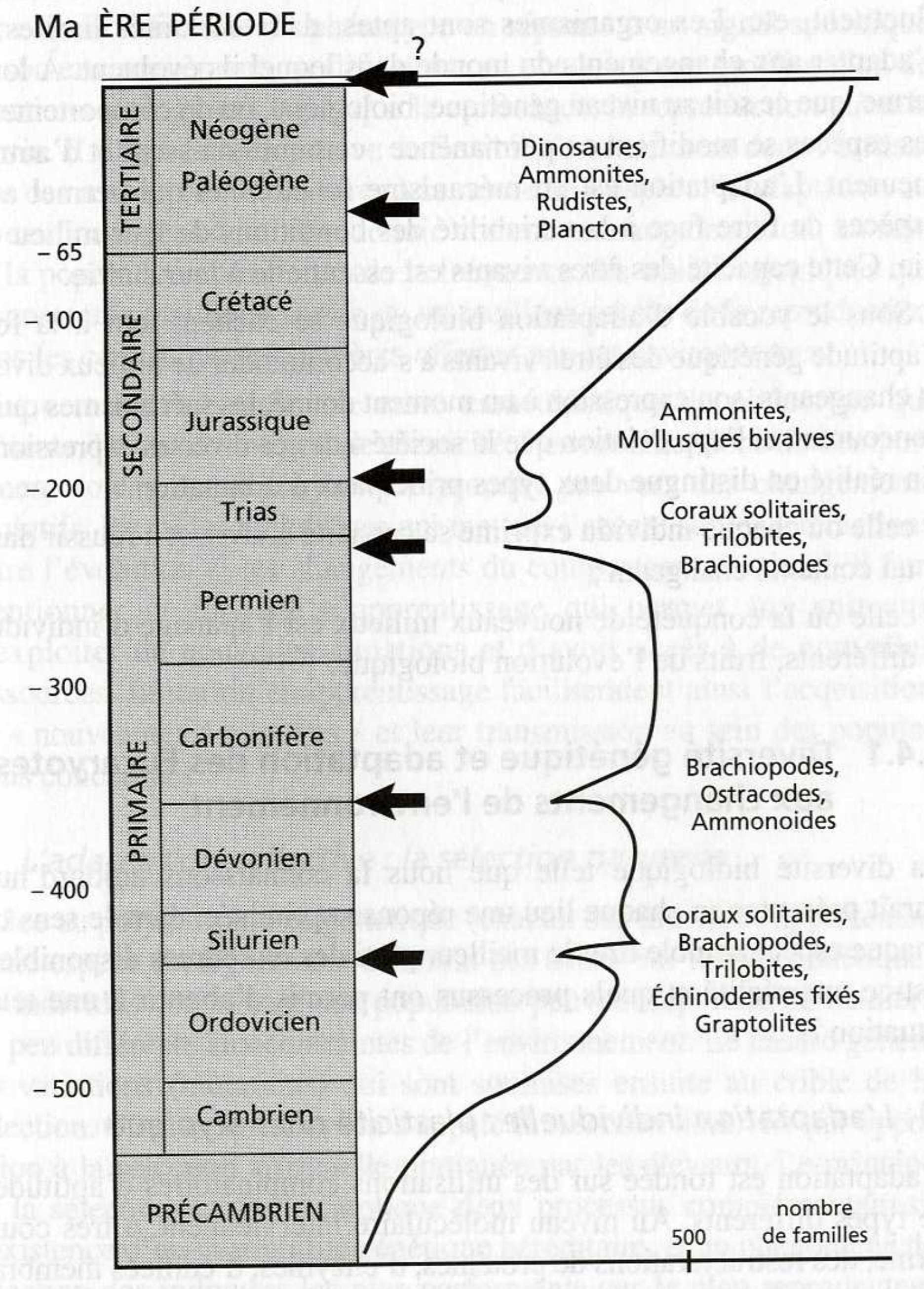


Figure 3.1 Les différentes périodes géologiques, les principales extinctions de masse et les principales étapes de la diversification du monde vivant.

Recent extinctions (Quaternary period):

- Phase 1 – transition of the hot and wet climates of the Pliocene epoch towards the colder and drier climates of the Pleistocene: in Southern Europe, Laurissilva is replaced by sclerophyll forests and shrubs (climate change);
- Phase 2 – transition of the Pleistocene to the Holocene – extinction of terrestrial megafauna (human expansion and biological invasions associated to this expansion are the major extinction factors);
- Phase 3 – large-scale changes of habitats and ecosystems since the invention of agriculture (Neolithic revolution); currently the human species chanels for his own use more than 24% of the gross primary production of the Planet.
- Phase 4 – combination and synergies among the three previous extinction sources : **a sixth mass extinction episode?**

- A sixth episode of mass extinction?

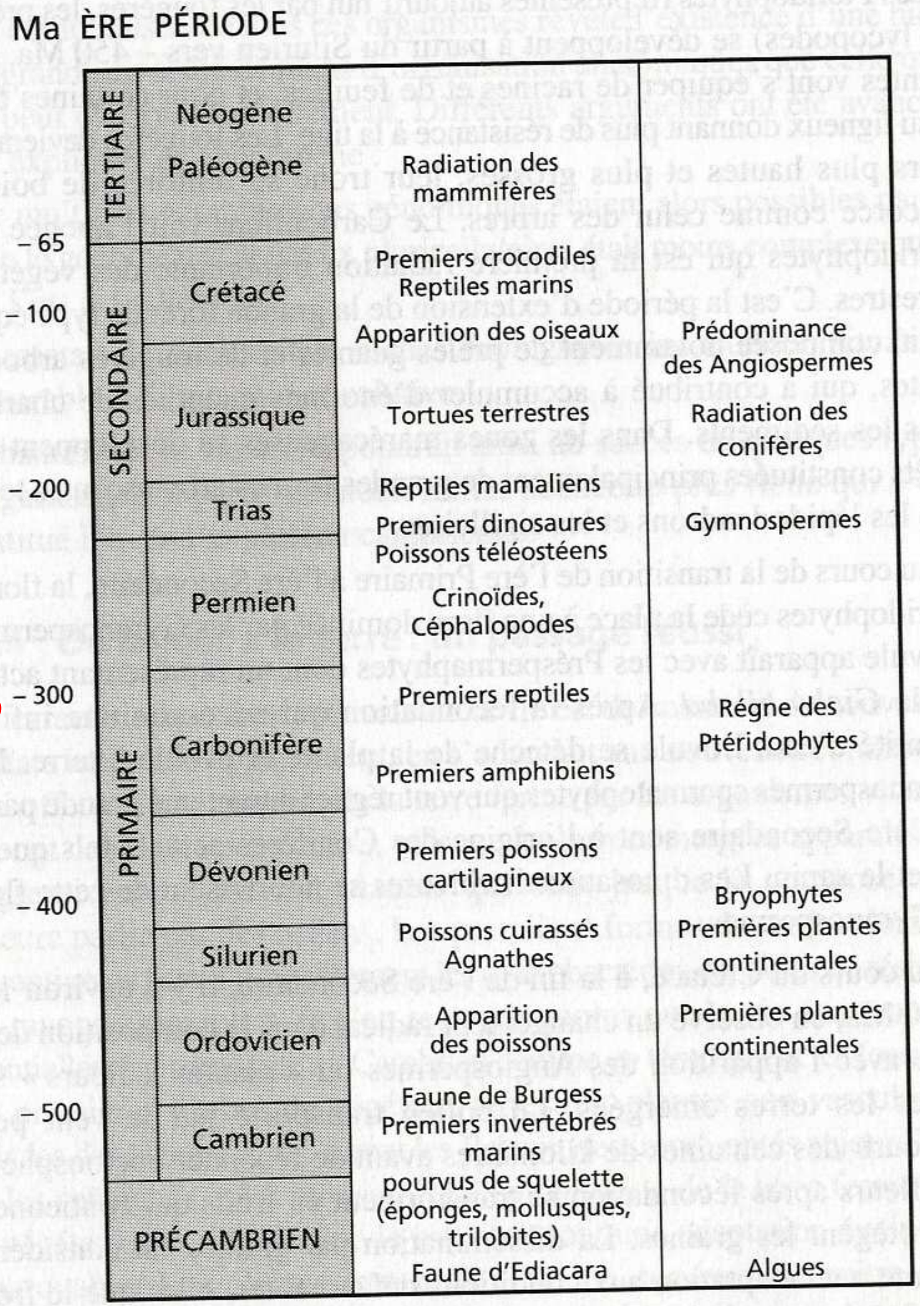


Figure 3.2 Périodes d'apparition des principaux groupes animaux et végétaux dans l'histoire de l'évolution.

- Man as a cause of biodiversity loss

Figure 2. Locations Reported by Various Studies as Undergoing High Rates of Land Cover Change in the Past Few Decades (C.SDM)

In the case of forest cover change, the studies refer to the period 1980–2000 and are based on national statistics, remote sensing, and to a limited degree expert opinion. In the case of land cover change resulting from degradation in drylands (desertification), the period is unspecified but inferred to be within the last half-century, and the major study was entirely based on expert opinion, with associated *low certainty*. Change in cultivated area is not shown. Note that areas showing little current change are often locations that have already undergone major historical change (see Figure 1).

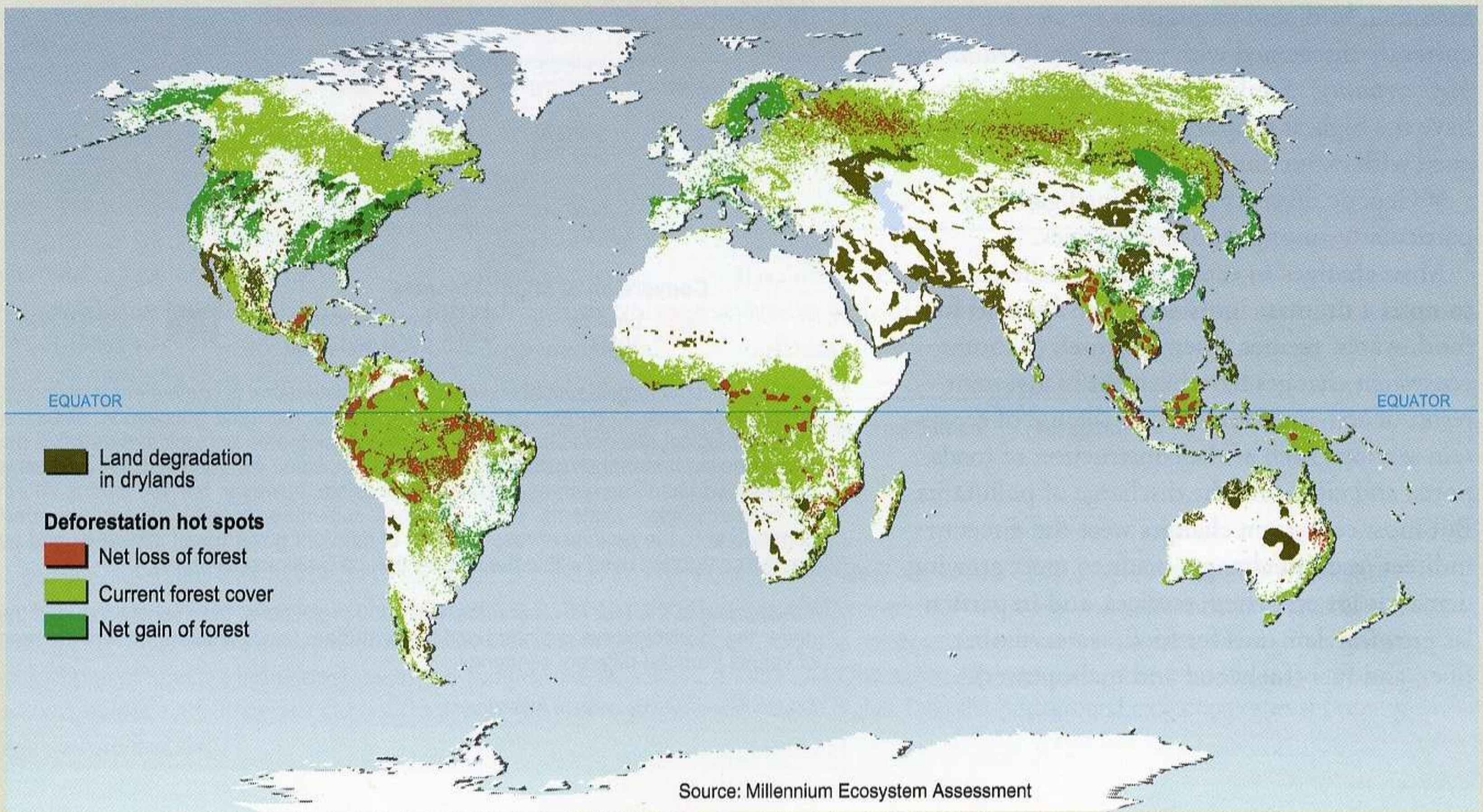
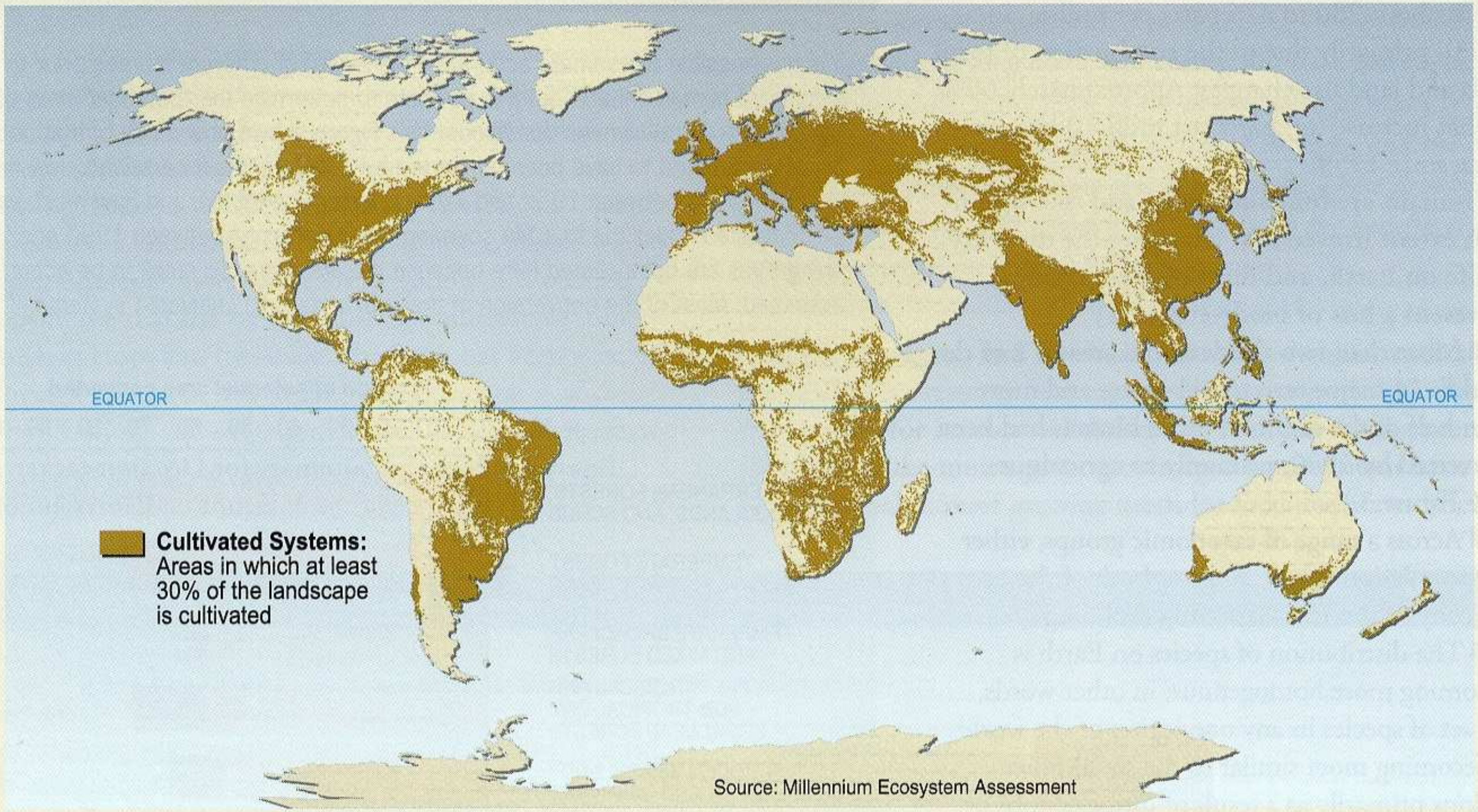
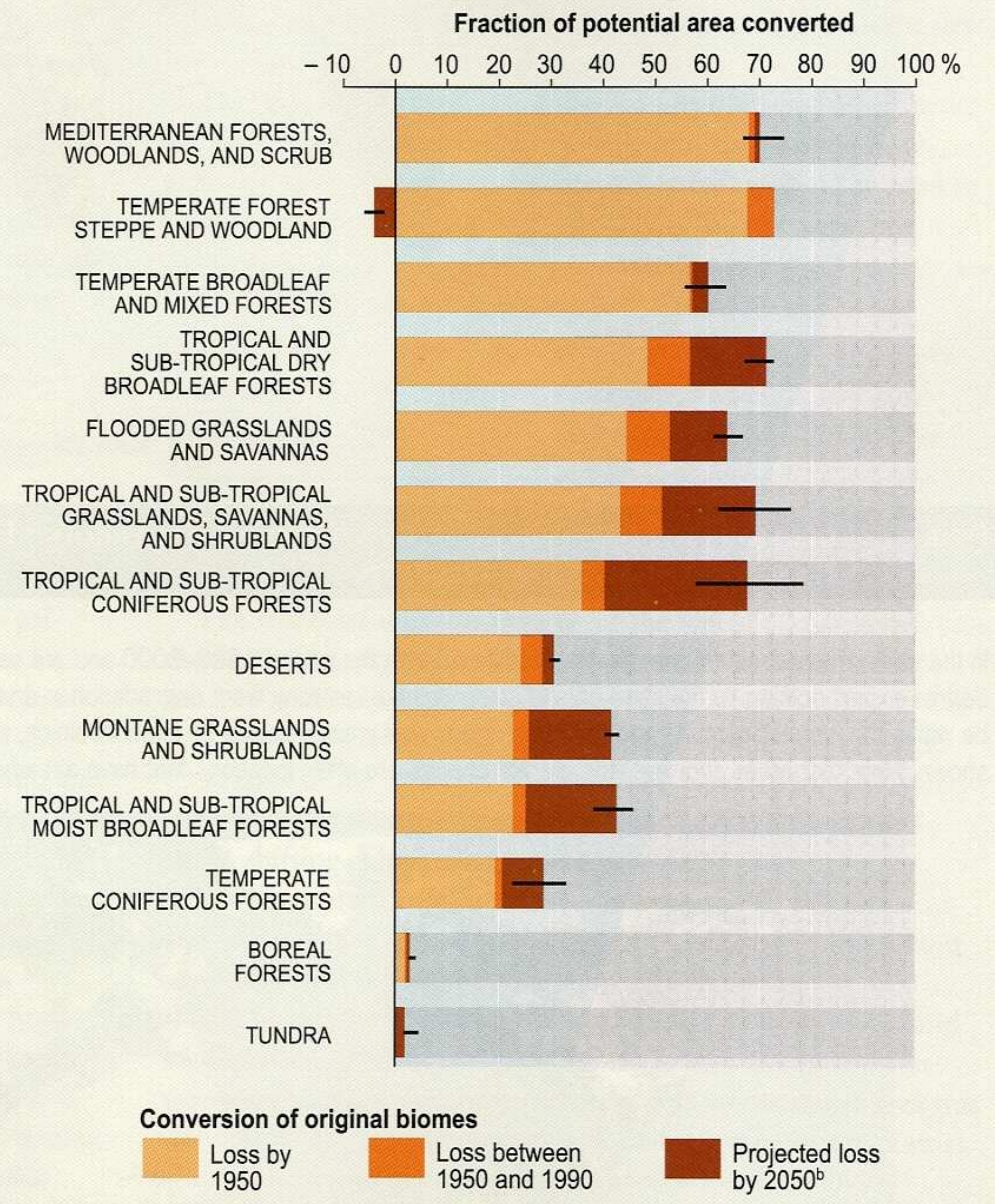


Figure 1. EXTENT OF CULTIVATED SYSTEMS, 2000. Cultivated systems cover 24% of the terrestrial surface.





Fraction of potential area converted
– 10
0
10
20
30
40
50
60
70
80
90
100 %
MEDITERRANEAN FORESTS, WOODLANDS, AND SCRUB
TEMPERATE FOREST STEPPE AND WOODLAND
TEMPERATE BROADLEAF AND MIXED FORESTS
TROPICAL AND SUB-TROPICAL DRY BROADLEAF FORESTS
FLOODED GRASSLANDS AND SAVANNAS
TROPICAL AND SUB-TROPICAL GRASSLANDS, SAVANNAS, AND SHRUBLANDS
TROPICAL AND SUB-TROPICAL CONIFEROUS FORESTS
DESERTS
MONTANE GRASSLANDS AND SHRUBLANDS
TROPICAL AND SUB-TROPICAL MOIST BROADLEAF FORESTS
TEMPERATE CONIFEROUS FORESTS
BOREAL FORESTS
TUNDRA
Conversion of original biomes
Loss by 1950
Loss between 1950 and 1990
Projected loss by 2050[b]

Direct drivers of biodiversity loss

The main direct drivers of biodiversity loss (Myers, 1997 and Millennium Ecosystem Assessment, 2005) are:

- natural habitat loss because of land use changes, in particular farmland expansion;

- modification and fragmentation of remaining habitat patches;

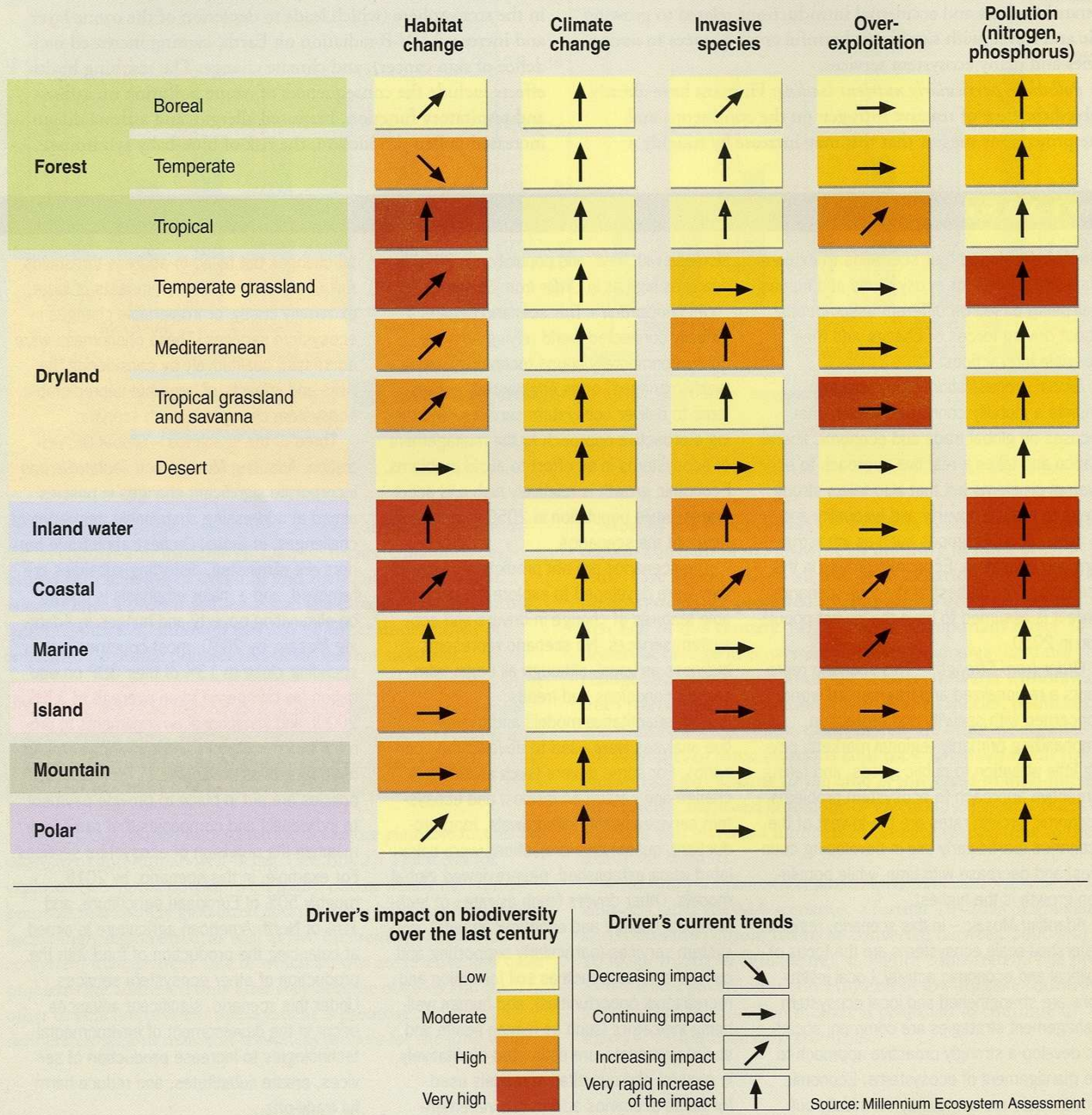
- excessive extraction of biological resources (fisheries, forests, grazed grasslands);

- difusion of exotic invasive species;

- pollution, including nutrient accumulation in ecosystems

-**climate change (surely more important into the next future)**

(remember some slides already discussed in previous classes)



Source: Millennium Ecosystem Assessment

Indirect/ underlying drivers of biodiversity loss:

- human demography;

- economic growth and rising per-capita consumption;

- tecnological change;

- changing consumption patterns (diets, mobility, energy, recreation);

- market failure (external costs and benefits; environmental public goods);

- policy failure.

Box 3: Unravelling the Arithmetic of Growth

The Ehrlich equation states that environmental (I) is a product of population (P) times affluence or income level (A) times the technological intensity (T) of economic output.

$$I = P \times A \times T$$

For carbon dioxide emissions from fuel combustion, for example, the total emissions are given by the product of population (P) times income (measured as dollars of GDP/person) times the carbon intensity of economic activity (measured as $gCO_2/\$$):

$$C = P \times \$/person \times gCO_2/\$$$

8,27 x 11,69 in

Using this arithmetic for the year 2007, when the global population was about 6.6 billion, the average income level in constant 2000 dollars (at market prices) was $5,900, and the carbon intensity was 760 gCO_2/$, we find that the total carbon dioxide emissions C were:

6.6 x 5.9 x 0.77 = 30 billion tonnes of CO_2.

In 1990, when the population was only 5.3 billion and the average income was $4,700 but carbon intensity was 860 gCO_2/$, total carbon dioxide emissions C were given by:

5.3 x 4.7 x 0.87 = 21.7 billion tonnes of CO_2.

These numbers are confirmed against those reported in the Energy Information Administration's *International Energy Annual*. The cumulative growth in emissions between 1990 (the Kyoto base year) and 2007 was 39% (30/21.7 = 1.39) with an average growth rate in emissions (r_i) of almost 2% ($r_i = (1.39)^{1/17} - 1 = 1.96\%$).

to an almost 40% increase in emissions (Box 3).[21] The same rule of thumb allows us a quick check on the feasibility of decoupling carbon emissions from growth in the future. The IPCC's Fourth Assessment report suggests that achieving a 450

emissions are 80% *higher* than they are today. Not quite what the IPCC had in mind.

To achieve an average year-on-year reduction in emissions of 4.9% with 0.7% population growth

Market and policy failures

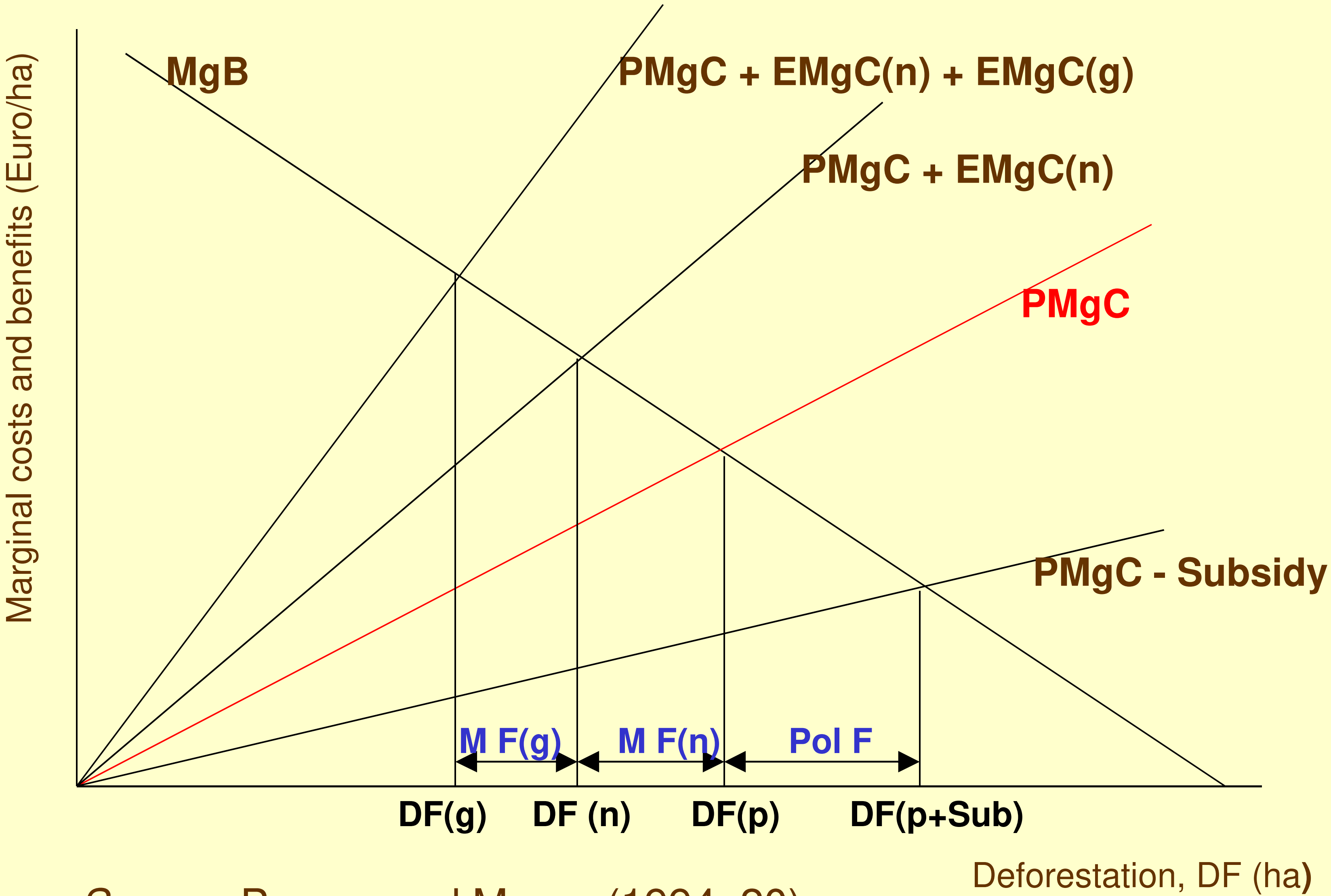
There are economic causes underlying many human behaviours responsible for direct drivers of biodiversity loss: market failure and policy failure.

Addressing underlying causes means to go to the root of the biodiversity loss problem instead of dealing with symptoms (direct drivers) alone. This will require us to change economic incentives driving human behaviours.

The core argument is grounded on the externality concept, which goes back to Arthur Pigou's (1920) book "The Economics of Welfare".

We follow here a graphical approach proposed by Pearce and Moran (1994) for the case of conversion of rain forest to crop and grazing land.

This is a relevant example: natural habitat loss by farmland expension is the main direct driver of biodiversity loss at the global level; in addition, the discussion applies with minor adaptations to other direct drivers.



Source: Pearce and Moran (1994: 20) with adaptations

Market failure/ policy failure

Private decision of the land owner

The owner of land rights will decide to deforestate an area DF(p) that maximizes his profit.

This happens when his Private Marginal Benefit PMgB (sales of wood and agricultural output from the last deforested hectare) is equal to the Private Marginal Cost PMgC (machinery, labour and energy spent in removing the forest and agriculturally using the last desforested hectare).

Destroying more area of forest habitat, he would be reducing his profit; destroying less forest area, he would be losing profit opportunities.

If the owner receives a subsidy Subs for each deforested hectare, this subsidy will cover part of the PMgC (that is: PMgC will decline to PMgC-Sub) and the private optimum of deforested area rises to DF(p+Sub).

Market failure/ policy failure

Optimal decision from the national standpoint

Adopting a national perspective, we need to add to the PMgC of deforestation the external marginal cost (EMgC(n)), that is: the cost incurred by others within the country as a consequence of the last deforested hectare (more floods downstream, declining profits in nature tourism).

Thus, from the national standpoint, the optimal deforestation level is DF (n) -- lower than the private optimum for the owner.

Optimal decision from the national standpoint

Adopting a global perspective, we need to add to the national marginal cost of deforestation the external marginal cost EMgC(g), that is: the cost incurred by others outside the country as a result of the last deforested hectare (higher GHG emissions, loss of option values related to possible future uses of genes or medicines).

From the global standpoint, the optimal deforestation level is DF(g)-- lower than the nacional and much lower than the private optimum.

Market failure/ policy failure

Concluding, the market fails in internalizing in the owner's decision the whole marginal cost that results from deforestation, namely its external cost for other national residents EMgC(n) and the global external cost EMgC(g).

In this way, acting as a rational decision-maker, the owner decides to deforest an area DF(p), which is larger than the national optimum DF(n) and much larger than the global optimum DF(g).

There are, thus, a nacional market failure MF(n) and a global market failure MF(g), which both lead to excessive deforestation. These market failures call for both global (multilateral) and national (governmental) public intervention aimed at correcting both market failures.

If the owner is led -- by a subsidy (Sub) to deforestation -- to desforestate even more, there is also a policy failure Pol F, that means excessive deforestation going beyond that which was already caused by market failure.

Market failure/ policy failure

This diagnostic – the identification of the economic causes underlying excessive deforestation as market and policy failures – clearly points to a solution that goes to the root of the deforestation problem:

realigning economic incentives so that forest owners are led to the global deforestation optimum while pursuing his own private interest.

This requires:

- **removing deforestation-inducing policies – such as output subsidiation of produce from deforested areas or public investments (e.g. new roads inside the forest) that reduce the private cost of producing or transporting outputs out from the forest into markets;**

- **creating new policies internalizing EMgC(n) and EMgC(g) into the private deforestation cost of owners, through e.g. a tax on each deforested hectare (or subsity on each hectare of conserved forest) that are equal to EMgC(n) and EMgC(g) at the global optimum (pigovian tax on deforestation).**

Biodiversity conservation policies – at which levels to conserve?

- **Multilateral conventions – e.g. Convention on Biological Diversity, CBD; or the Convention on International Trade of Endangered Species, CITES;**

- **EU Community policies (UE) – directives Birds and Habitats, which create the Natura 2000 network of protected areas;**

- **National conservation policy – Nacional network of protected areas, RNAP; legislation on hunting or freshwater fishing pesca; agri-environmental measures under the Portuguese Rural Development programme.**

Objectives for conservation policy – what to conserve?

Biodiversity is a complex, multidimensional entity. Thus, it is important to specify what is the level of biodiversity at which the policy goals are to be defined. This is important as, for example, target species to be conserved are differently selected if we want to conserve:

- **Genetic resources – focusing on genes;**
- **Global species diversity – focusing on globally rare species where they still have good conservation prospects (hotspots);**
- **The species diversity of a local ecosystem (or particular keystone species) to keep ecosystem stability, resilience and local/regional ecosystem services.**

Part 2

Linking ecosystem management and human well-being

- Biodiversity, ecosystems and ecosystem services

- Typology of ecosystem services

- Structure and process, intermediate services, final services and benefits

- Integrating the value of ecosystem services in the GDP: Green DGP and Ecosystem services index

- Ecosystem services: what is it?

Ecosystem management (e.g. protecting river buffers)

↓

State of the ecosystem (e.g. Biodiverse, complex, high and wide riparian woodland)

↓

Ecosystem service (e.g. Water quality improvement through pollutant filtering by the vegetation)

↓

Human well-being (e.g. Reduced water treatment costs, or reduced allergy symptoms)

Concluding, water quality improvement through pollutant filtering is an ecosystem service and not an economic service because:

– it flows from the ecosystem to human beneficiaries

– the level of the service depends on the state of the ecosystem.

In typical economic services, an economic agent (the producer of the service) uses man-made inputs (e.g. labour, a taxy and gasoil), which have a cost, to provide a (transportation) service to other economic agents (clients, the consumers of the service).

Obviously, the state of the ecosystem and the level of the ecosystem service often depend on past management of that ecosystem, and thus on the use of inputs (machines, labour, energy, fertilizers, capital ...), which also have a cost.

Examples of other ecosystem services (ES):

- **Carbon sequestration / climate-change mitigation;**
- **Habitat and biodiversity conservation;**
- **Soil erosion control, groundwater quality, flow regulation and flood prevention;**
- **Fire-risk prevention;**
- **Pest & disease regulation by biotic controls;**
- **Landscape, recreation and the quality of living space**

Resilient ecosystems are crucial for the sustainable delivery of all these ES.

- Ecosystem services: why are we loosing them?

- Any ecosystem service (e.g.: carbon sequestration /climate-change mitigation) depends on the state of the ecosystem (above and below ground biomass, soil carbon content, plant growth, vulnerability to fires...);
- On the other hand, the state of the ecosystem depends on past ecosystem management;
- There are no markets for many ecosystem services ...
- ... but there are markets for some other outputs (food, fiber, wood...) that we extract from ecosystems.

- And this is the origin of the problem!!!

- **Ecosystem managers made their management decisions looking for their effects on outputs that have a market price – because these are the ones generating their income;**
- **As a side-effect, these decisions also "produce" a particular state of the ecosystem and thus particular levels of ecosystem services (carbon sequestration, biodiversity, landscape, ...).**
- **Ecosystem service levels are, therefore, a side-effect of management decisions made with other goals (namely profit maximization) in mind...**
- **... this is why existing levels of ecosystem services are often far from those that would be more apropriate to fulfil relevant human needs such as security, health or recreation.**
- **The market fails in creating effective incentives that reward ecosystem managers for adequate management, that is: adequate ecosystem-service (and thus human well-being) levels.**

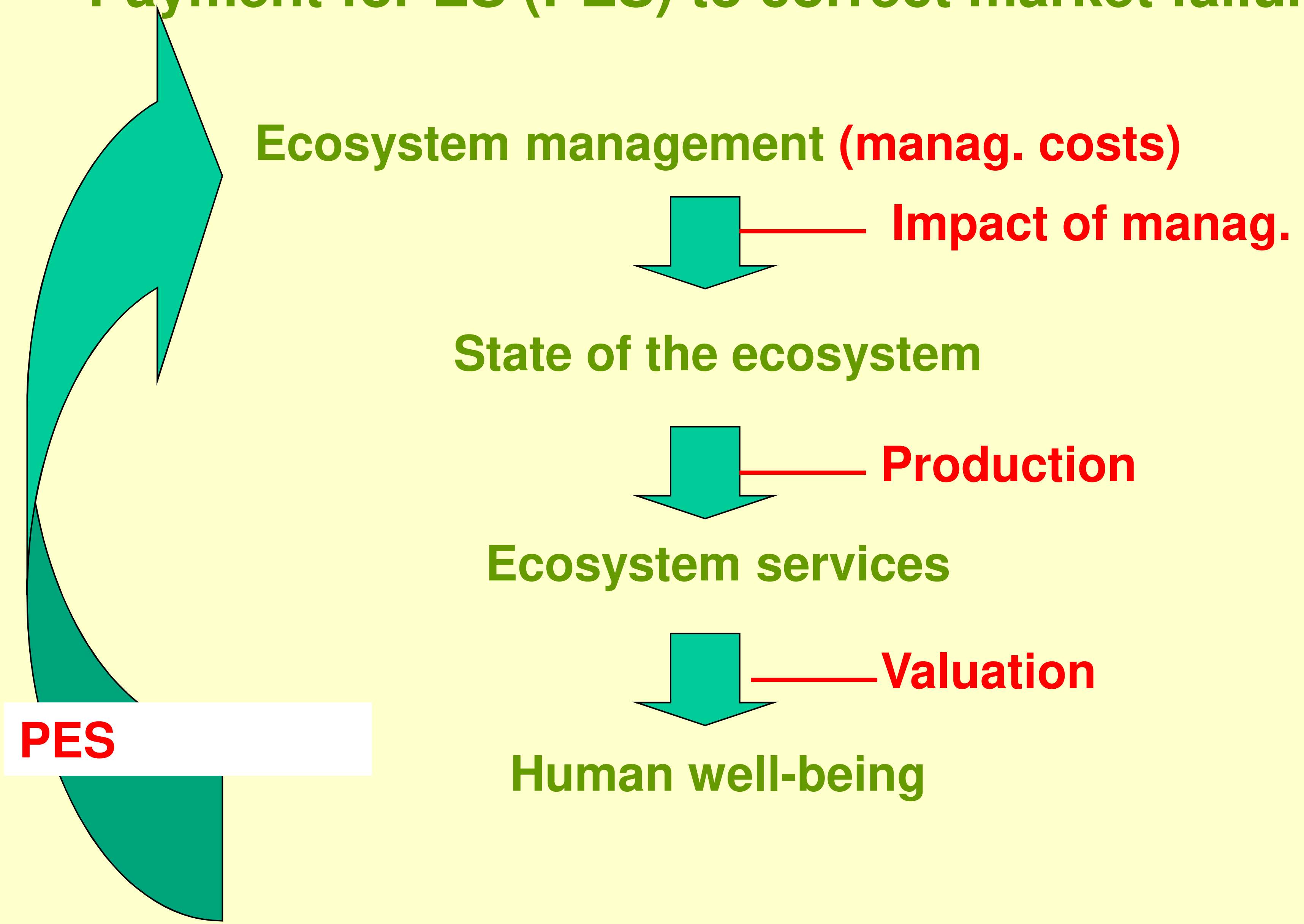
- **Economists call this a *market failure*.**
- **If this is the cause of ecosystem-services decline, then we need to look for solutions that:**

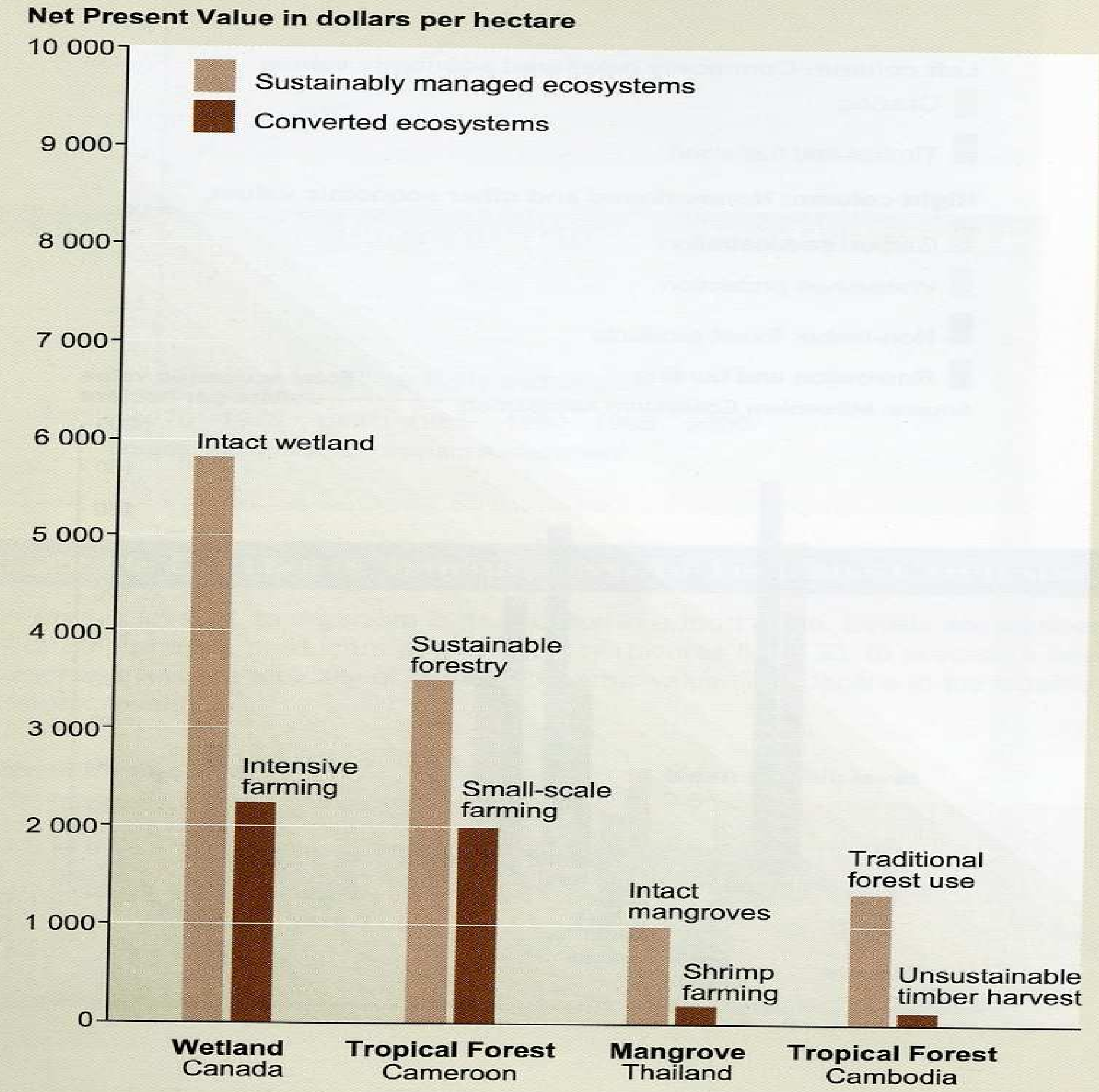
  create incentives that reward ecosystem-managers effort to manage ecosystems in ways that lead to better levels of ecosystem services

e.g. Payments for ES

Market failure usually requires *policy intervention* to correct that (incentive) failure

- Payment for ES (PES) to correct market failure

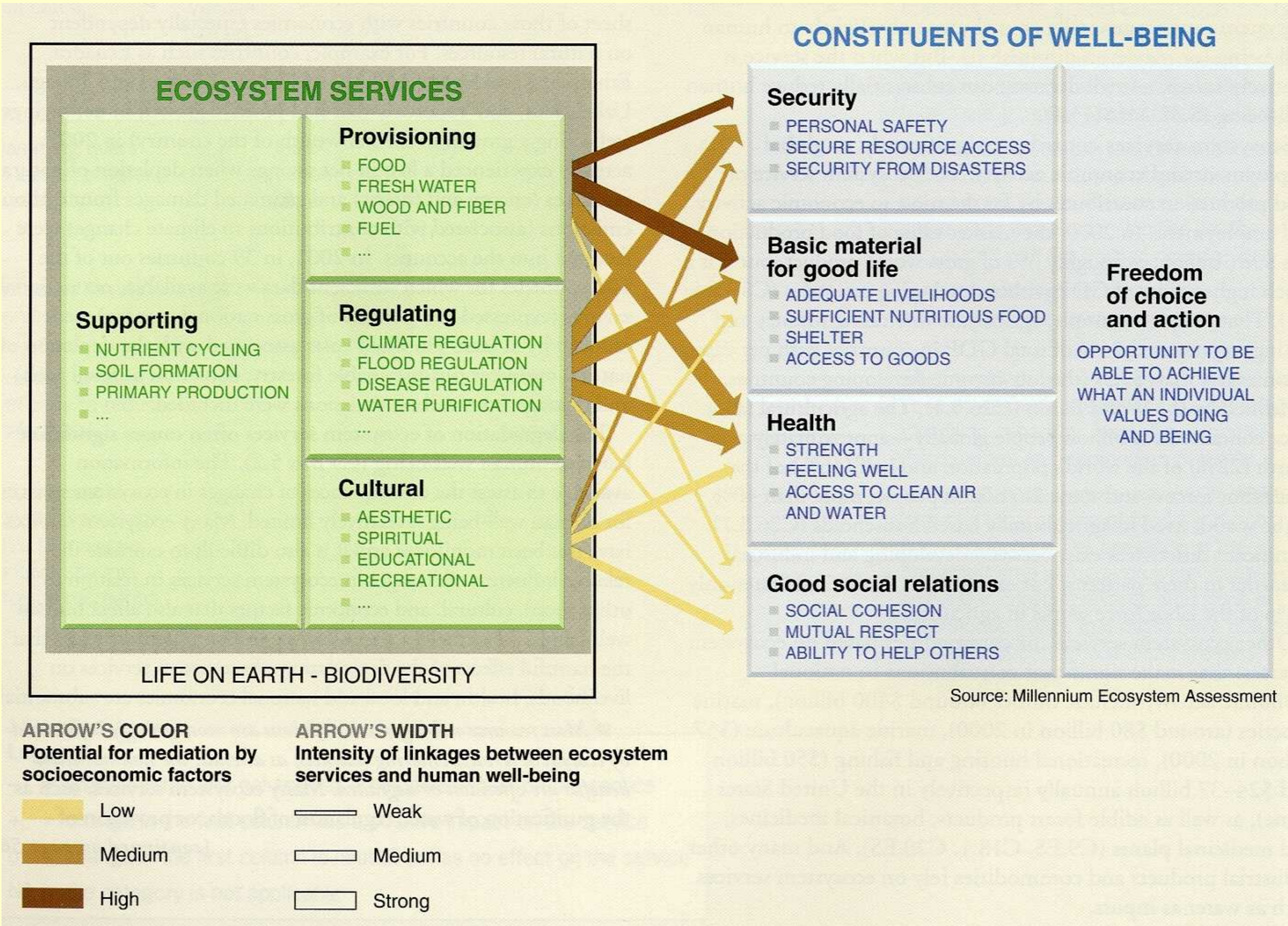




Source: Millennium Ecosystem Assessment

Typology of ecosystem services
(MEA - Millenium ecosystem assessment)

- Provisioning services
- Regulating services
- Cultural services
- Supporting services



Source: Millennium Ecosystem Assessment

Table 1. GLOBAL STATUS OF PROVISIONING, REGULATING, AND CULTURAL ECOSYSTEM SERVICES EVALUATED IN THE MA

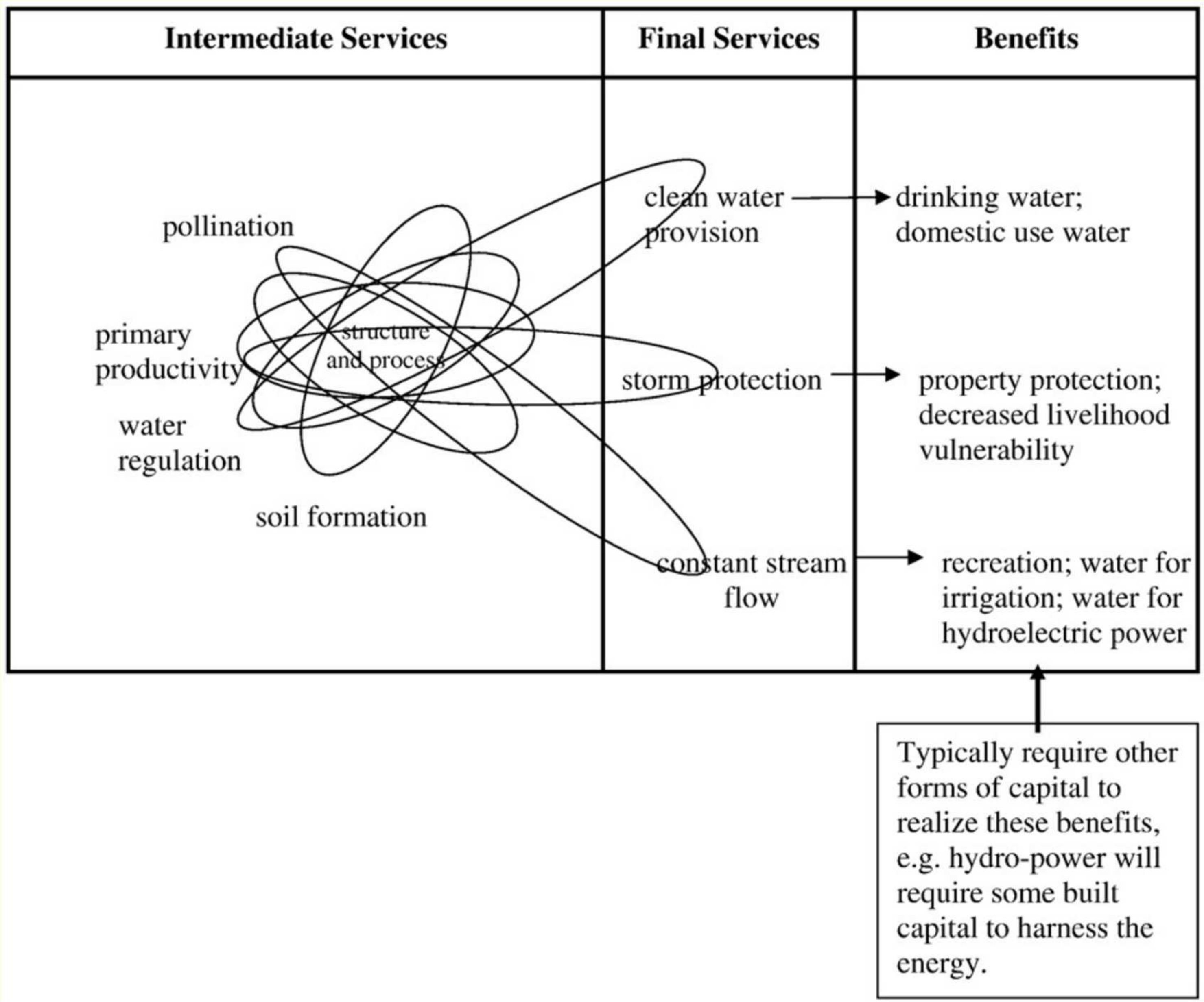
Status indicates whether the condition of the service globally has been enhanced (if the productive capacity of the service has been increased, for example) or degraded in the recent past. Definitions of "enhanced" and "degraded" are provided in the note below. A fourth category, supporting services, is not included here as they are not used directly by people.

Service	Sub-category	Status	Notes
Provisioning Services			
Food	crops	▲	substantial production increase
	livestock	▲	substantial production increase
	capture fisheries	▼	declining production due to overharvest
	aquaculture	▲	substantial production increase
	wild foods	▼	declining production
Fiber	timber	+/–	forest loss in some regions, growth in others
	cotton, hemp, silk	+/–	declining production of some fibers, growth in others
	wood fuel	▼	declining production
Genetic resources		▼	lost through extinction and crop genetic resource loss
Biochemicals, natural medicines, pharmaceuticals		▼	lost through extinction, overharvest
Fresh water		▼	unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy

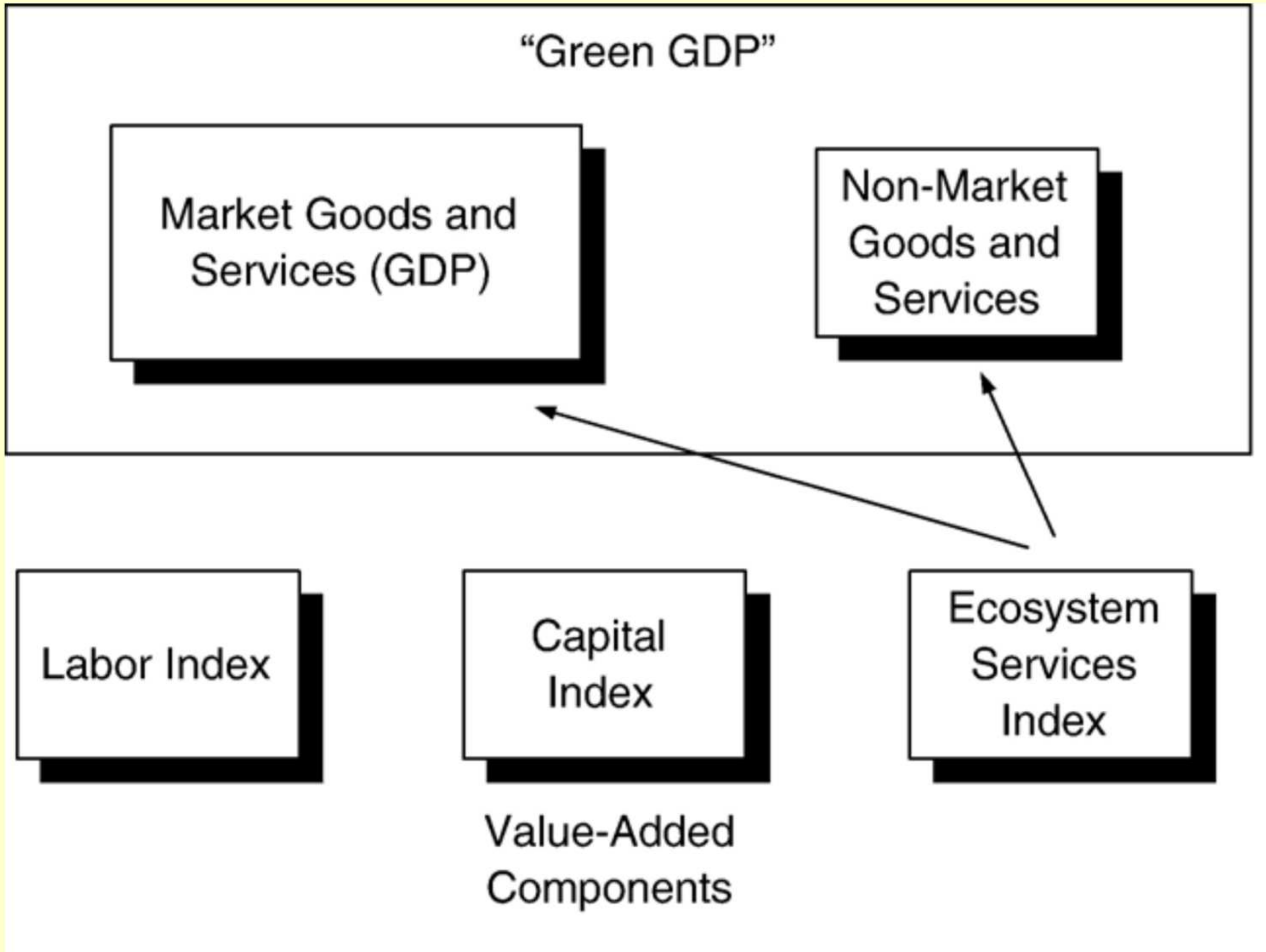
Regulating Services			
Air quality regulation		▼	decline in ability of atmosphere to cleanse itself
Climate regulation	global	▲	net source of carbon sequestration since mid-century
	regional and local	▼	preponderance of negative impacts
Water regulation		+/–	varies depending on ecosystem change and location
Erosion regulation		▼	increased soil degradation
Water purification and waste treatment		▼	declining water quality
Disease regulation		+/–	varies depending on ecosystem change
Pest regulation		▼	natural control degraded through pesticide use
Pollination		▼[a]	apparent global decline in abundance of pollinators
Natural hazard regulation		▼	loss of natural buffers (wetlands, mangroves)
Cultural Services			
Spiritual and religious values		▼	rapid decline in sacred groves and species
Aesthetic values		▼	decline in quantity and quality of natural lands
Recreation and ecotourism		+/–	more areas accessible but many degraded

Note: For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g., spread of agriculture) or increased production per unit area. We judge the production to be degraded if the current use exceeds sustainable levels. For regulating and supporting services, enhancement refers to a change in the service that leads to greater benefits for people (e.g., the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of regulating and supporting services means a reduction in the benefits obtained from the service, either through a change in the service (e.g., mangrove loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g., excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, enhancement refers to a change in the ecosystem features that increase the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem.

Structure & process, intermediate services, final services and benefits (Fisher, 2009)



ES, Green GDP and ES Index (Boyd e Banzhaf, 2007)



What is a final service depends on what is the benefit we are interested in

BENEFIT	Final Services	Intermediate Components
Recreational angling	The water body The bass population The riparian forest	The water body's quality
Drinking water	The water body's quality	Wetlands, natural riparian land cover

Part 3

Biodiversity and human well-being

(Cont.)

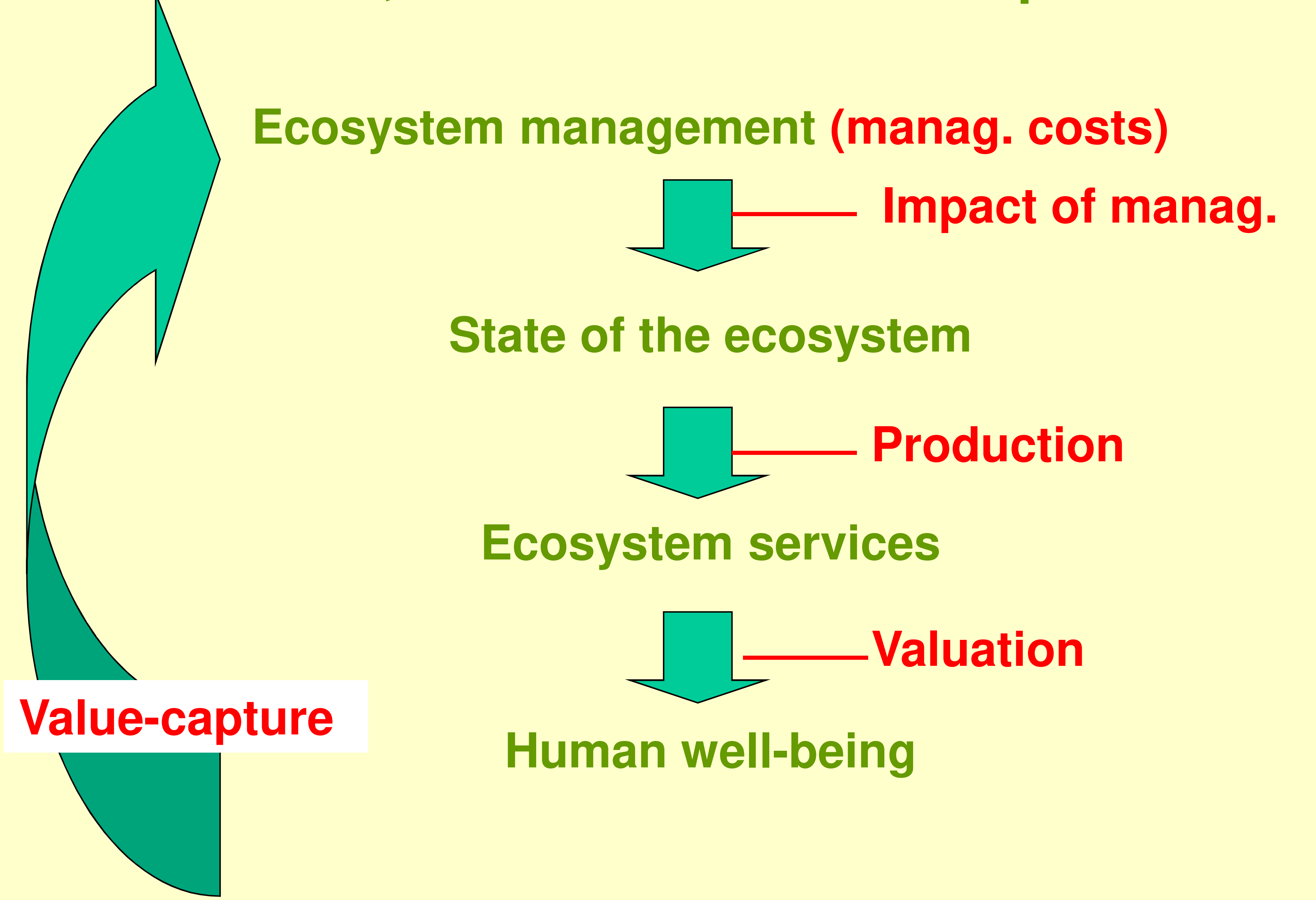
- production, valuation and value-capture of ecosystem services

- The Total Economic Value (TEV) of biodiversity and ecosystems

- Methods for economic valuation of biodiversity and ecosystem services

- Economic valuation of ecosystem services of Amazon rain forest

- Production, valuation and value-capture of ES



The economic value of biodiversity and ecosystem services

Biodiversity and ecosystem services have an economic value if they are simultaneiously useful and scarce.

If this is the case, an additional unit of biodiversity or ES has a positive effect on human well-being, that is: it has a marginal utility (or economic value).

The generalised decline of biodiversity implies that, more and more, a particular biodiversity component (gene, species ...) becomes scarce, and thus it acquires a marginal value, or mg utility.

In some cases, this scarcity (thus value) is global (e.g. a globally threatened gene or species).

In other cases, that scarcity (thus value) is only local or regional (e.g. a keystone species whose local extinction will lead to lower resilience of a local ecosystem).

Economic value – money metrics

Economic value refers to the impact of an ecosystem service (or, more precisely, of changes in that service) on human well-being.

Z_0 – existing level of the service (e.g.: more frequent flooding)
Z_1 – improved level of the service (e.g.: less frequent flooding)
Y – the individual's monetary income
U(Y, Z) – the individual's utility level

$U_0=U(Y, Z_0)$ – nível de bem-estar do indivíduo com cheias mais frequentes

$U_1=U(Y, Z_1)$ – nível de bem-estar do indivíduo com cheias menos frequentes

$\Delta U=U_1-U_0$ >0 – individual's welfare gain when flood frequency declines (which is the value of the ecosystem service)

Economic value – money metrics

Directly measuring welfare (or welfare changes) of individuals is difficult or impossible – which leads us to resort to money metrics of welfare variation, e.g.: the compensating variation VC:

$$U(Y, Z_0) = U(Y - VC, Z_1)$$

VC is a money metrics of the individual's welfare change ΔU that we would like to measure but that we cannot directly measure – that is: it is a measurement of the value of the service.

If $\Delta U>0$ (as in our example) then $VC>0$ and it represents the maximum individual's willingness-to-pay (WTP) for the service;

If $\Delta U<0$ (service loss) then $VC<0$ and it represents the minimum amount the individual would require as a compensation (WTA) for the loss of the service.

Total Econmic Value (TEV)

The utility of biodiversity or ecosystems – its contribution to human well-being – can assume different forms: it may depend on direct or indirect use, current or future use, extractive vs non-extractive uses; and there is sometimes utility without any use.

Pearce and Moran (1994) have developed a system to classify different components of the Total Economic Value (TEV) of biodiversity and ecoststems.

Relevant components of the TEV:

- Direct use, current or future use, comercial or not, extractive or not. Examples: crop harvests, wood, non-wood forest products, biomass and fishery yields (extractive uses), or recreation, bathing and touristic use of ecosystems (non-extractive uses);

- Indirect use. Depends on particular ecological functions of ecosystems, such as soil and water conservation, waste assimilation and nutrient cycling, carbon sequestration or regional climate regulation by forests.

TEV (Cont.)

The sustainability of these functions in time depends on stable and resilient ecosystems, what generally means diverse ecosystems.

Below particular diversity thresholds (which are mostly not-well understood), those functions will no more be sustainably provided.

Ecosystem stability depends on the complexity of its food web, which depends on the species diversity (populations of different species control each other through feedback mechanisms associated to food-web biotic interactions).

On the other hand, ecosystem resilience (that is: the maximal disturbance it can absorb while keeping its working conditions) depends on species that, though seeming irrelevant, act as "spare parts" (Holling 1995).

TEV (Cont.)

Other components of the TEV of biodiversity are:

- **Option value - our current willingness-to-pay to keep an option for future use. It is not the value of future use. It's an additional value beyond the expected value of future use. It is the value of reducing the risk about availabilty of the ecosystem for future use. It results from our aversion to risk when facing irreversibilities such as the loss of a tropical forest.**

Example: conserving that forest with current costs (income foregone) to keep the option of using genetic resources (possible existing genes in the forest) to produce medicines or genetically improve crops.

- Non-use values, such as the legacy value of a threatened species we pass to future generations; or the existence value of a particularly unique (non-replaceable) species for para some people.
Example: donations by people to particular conservation funds that use symbolic species, as the Panda, as a communication strategy.

TEV (Cont.)

The different components of the TEV of biodiversity and ecosystems are not independent from each other.

Example: a direct extractive use, such as a crop harvest, depends on a set of ecological functions (that is indirect use), such as:

- **the biological control of pests and diseases by predator or parasitoids that occur in the agro-ecosystem;**

- **the cycling of nutrients included in crop remains by bacteria and fungi.**

How to use the TEV?

- It is an accounting concept to measure <u>all</u> modes through which an ecosystem, such as a lake, forest or fishery, contributes to human well-being.

- Different management options for that ecosystem are then specified …

- … the TEV is estimated for each particular option…

- and we chose the management options that yields the maximum TEV, that is the one maximizing the ecosystem's contribution to human well-being.

- To be able to estimate the TEV, we are required, first, to identify all possible components of the TEV – that is: the different channels through which that ecosystem may contribute to human well-being.

VET components (summary table):

- U*se values*

- **Direct use (either commercial or not, present or future use)**
  - **Extractive use**
  - **Non-extractive use**
- **Indirect use (ecological and environmental functions)**

- Non-use (or *passive-use) values*

- **Option value**
- **Quasi-option value**
- **Legacy (bequest, heritage) value and other altruistic value components**
- **Existence value**

-TEV is an anthropocentric framework, because it is oriented towards human well-being,

- Outside this anthropocentric frame, we could consider the values of the ecosystem in itself (intrinsic values), which are based e.g. on the right of non-human species themselves to exist independently of any kind of utility they may have for humans.

- Even if these values may exist, intrinsic values will be mostly irrelevant for human decisions if they are not taken by humans as valuable; and this is sufficient for these values to become part of the TEV.

-Economic values imply a trade off between costs and benefits of the different management options for a particular ecosystem taking human well-being as a basis for value measurement.

Economic valuation techniques

Concept to be measured: compensating variation (WTP, WTA) which includes all components of the TEV

Criteria used to classify valuation techniques:

- techniques with or without an economic-teory foundation;

- Techniques based on agents' actual decisions in real contexts which reveal value (revealed preference techniques) *versus* techniques based on hypothetical decisions of individuals facing hypothetical decision contexts (stated preference techniques)

- Direct versus indirect techniques as regards the analytical strategy that is used to reveal value

Examples of econimic techniques used for ecosystem-service valuation

- Substitution costs;

- Dose-response funtions using unit values for damage;

- Techniques using effects on production;

- *Averting behaviour models*

- Continent valuation and choice modelling;

- Travel cost models;

- Hedonic price models

Classification of economic valuation techniques

1. **Techniques without an economic-theoretic foundation**

- Substitution costs;
- Dose-response funtions using unit values for damage;
- Techniques using effects on production;

2. Techniques with an economic-theoretical foundation (preference based techniques)

a) Revealed-preferences techniques, where choices actually made by individuals in actual contexts are used as data

- Travel-cost models
- *Random utility models*
- Hedonic-price models
- *Averting behaviour models*

b) Stated-preference techniques, where individuals are asked to make hypothetical choices to reply to hypothetical choice scenarios

- Contingent valuation
- Choice modelling

Revealed preference techniques are preferred in some contexts because of their explicit link with actual, observed market prices.
However, these techniques are **useful only in the context of estimating use values**. (CE, 2001: p.4)

While these techniques may be used to estimate use and/or non-use values for a resource, they are the ***only*** **techniques available for estimating non-use values**. (CE, 2001: p.5).

Além disso têm uma muito maior **flexibilidade** para gerar cenários para avaliar bens futuros novos (não presentes no passado).