A hybrid approach to the valuation of climate change effects on ecosystem services: evidence from European forests

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12 September 2010 - 18 September 2010

Belpasso International Summer School:
The Economics of Ecosystem Services and Biodiversity Conservation

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Structure of the Presentation

1. Introduction
2. Methodological Road Map
3. A Hybrid Approach for Valuing the Forest EGS
4. Results & conclusions
5. The Follow-up of Current Research Work

Introduction

Objective:
To estimate the welfare losses w.r.t. the changes in forest ecosystem functioning, respective levels of provision of goods and services, caused driven by climate change.

The main questions:
1. How to quantify the climate change impacts in terms of a biophysical position of forests ecosystems goods and services?
2. how to translate those changes into monetary terms?

Study:
Forest Ecosystems of 34 selected European countries

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1. **Introduction**
2. Methodological Road Map
3. A Hybrid Approach for Valuing the Forest EGS
4. Results
5. The Follow-up of Current Research Work

Methodological Road Map

The-state-of-the-art assessment of the economic impacts of climate change

- The economic impacts of climate change is mostly focused on market-related impacts (Tol, 2005);
- Using a monetary metric to express non-market impacts, such as effects on ecosystems or human health is more difficult due to a lack of economic valuation in a climate change context (Pearce et al., 1996; Tol, 2005).

Therefore, there is the need for the development of a more comprehensive valuation framework.

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Methodological Road Map

1. Geo-Climate Mapping

Geographical groupings	Latitude classification
Mediterranean Europe	Latitude N35-45°
Central-Northern Europe	Latitude N45-55°
Northern Europe	Latitude N55-65°
Scandinavian Europe	Latitude N65-71°

Geographical groupings	Predominant forest biomes
Mediterranean Europe	Mediterranean Forests
Central-Northern Europe	Temperate Deciduous
Northern Europe	Temperate Deciduous
Scandinavian Europe	Boreal

2. Ecosystem Study

MA Approach

Ecosystem goods and services

- **Provisioning**
- **Regulating**
- Supporting
- **Cultural**

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IPCC Storylines - 2050			
A1FI	A2	B1	B2

3. Quantitative Assessment

Forest area (ha)	Changed flows of EGS

4. Economic valuation

Value welfare impacts ($) due to CC at 2050

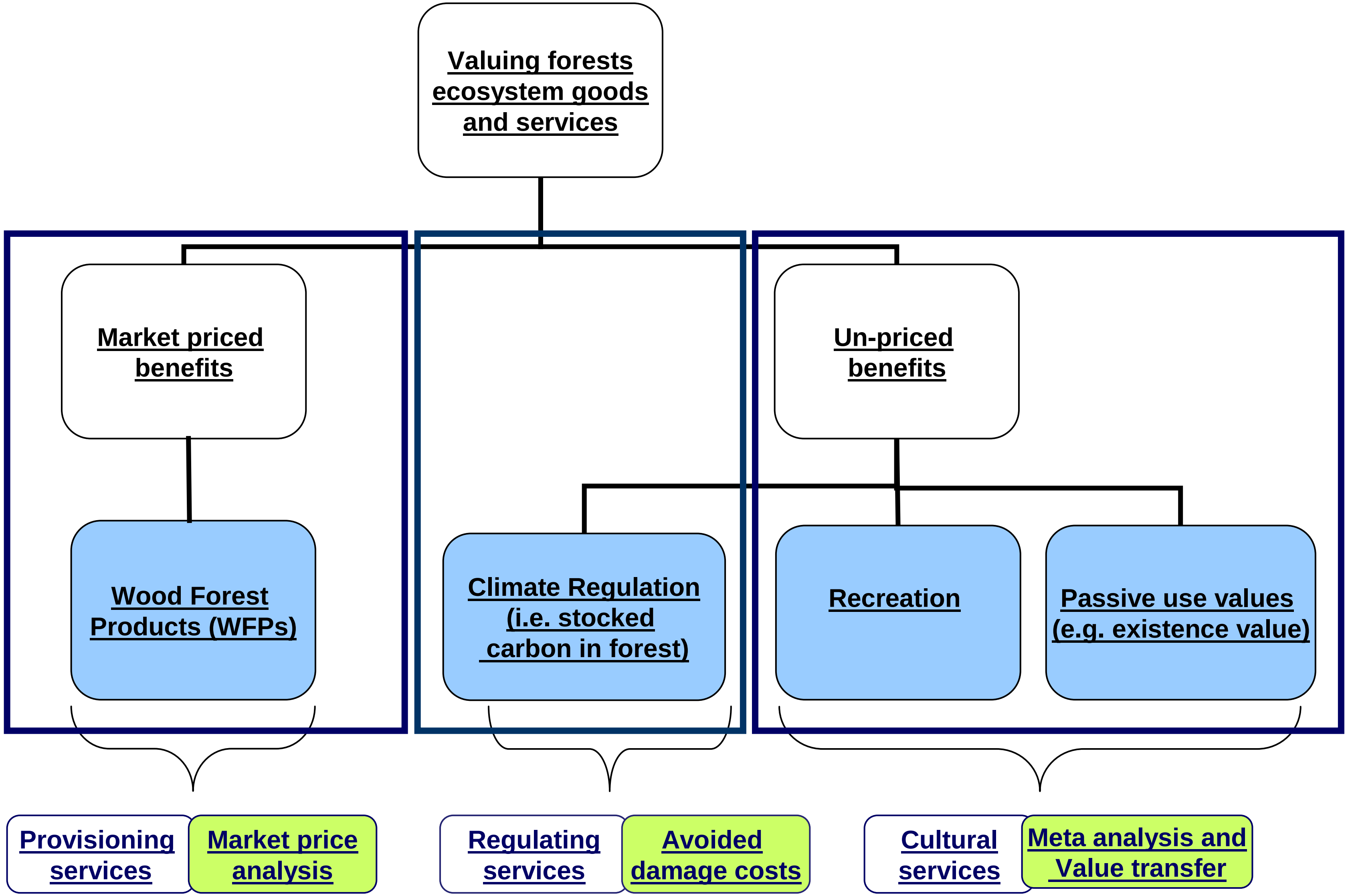
The Regrouping of the Countries

Geographical grouping of 34 European Countries

Geographical groupings	Latitude classification	Countries included
Mediterranean Europe	Latitude N35-45°	Greece, Italy, Portugal, Spain, Albania, Bosnia and Herzegovina, Bulgaria, Serbia and Montenegro, Turkey, TFRY Macedonia
Central-Northern Europe	Latitude N45-55°	Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia
Northern Europe	Latitude N55-65°	Denmark, United Kingdom, Estonia, Latvia, Lithuania
Scandinavian Europe	Latitude N65-71°	Finland, Iceland, Norway, Sweden

Note: these 34 European countries are chosen based on the classification reported by the *European Forest Sector Outlook Study 1960-2000-2020 main report*, covering two of the three sub-regions: i.e. Western Europe and Eastern Europe, whereas Russia Federal is excluded from our computation (See UNECE/FAO(2005) for information about the 3 sub-regions).

A hybrid approach of economic valuation

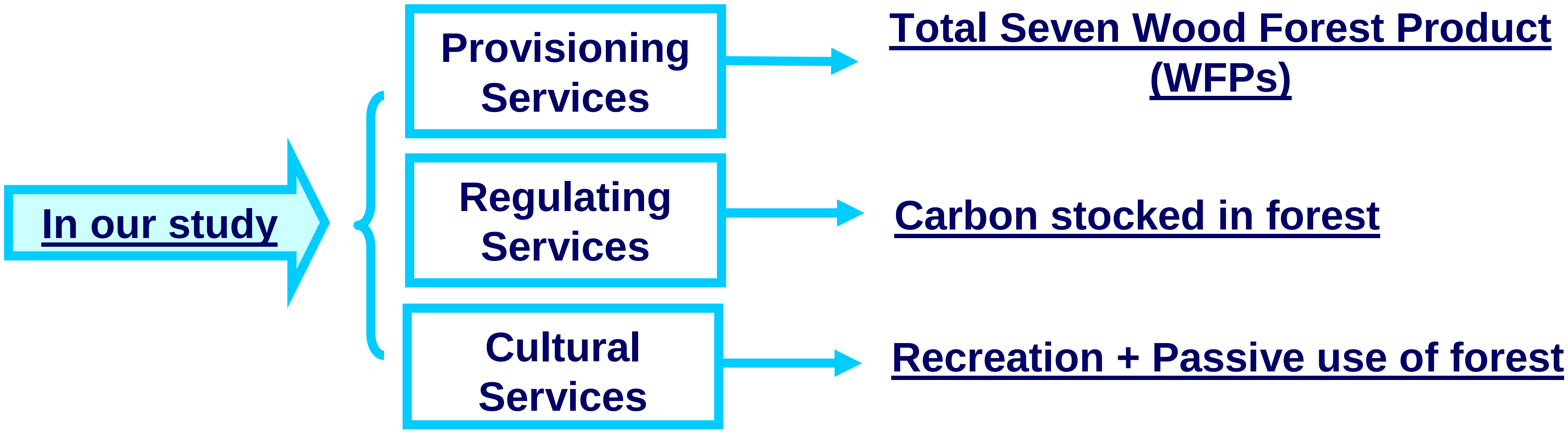


Mapping of ecosystem goods and services provided by European forests - MA approach

Table 2 A general classification of Ecosystem Goods and Services for European Forests

Provisioning Services-(1) Wood Forest Products (**WFPs**)						
Industrial Roundwood (Million m^3/yr)	Wood pulp (Million t/yr)	Recovered paper (Million t/yr)	Sawnwood (Million m^3/yr)	Wood-based panels (Million m^3/yr)	Paper and paper board (Million t/yr)	Wood fuel (Million m^3/yr)

N.B.: The WFPs are chosen based on the *European Forest Sector Outlook Study 1960-2000-2020 main report* (UNECE/FAO, 2005)



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Understanding of the IPCC Storylines

Economic

Global

Regional

Environmental

A1
(Rapid and successful economic development)

• Population (10^6): 376

• High savings and high rate of investments and innovation at national & international level

• Cumulative CO2 (pp

• Δ Temperature (ºC):

• Precipitation Europe

A2
(A differentiated world)

• Population (10^6): 419

• Eonomic growth is uneven in the world

• Income per capita: largely increased

m): 709

2.8

pe(%): 0.5

B
(Global sustainal

•Population (10^6): 376

• High investment in resource efficiency

• Distribution Efficiency: Hgih

• Cumulative CO2 (ppm): 518

• Δ Temperature (ºC): 3.1

• Δ Precipitation Europe(%): 4.8

nal sustainable
ment)

8

• Human welfare, equality, and environmental protection

• Cumulative CO2 (ppm): 567

• Δ Temperature (ºC): 2.1

• Δ Precipitation Europe(%): 2.7

Note that for the purpose of creating emissions scenarios as a result of this development, the IPCC assumes that no intentional action is taken in response to global warming.

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3. **A Hybrid Approach for Valuing the Forest EGS**
4. Results
5. The Follow-up of Current Research Work

Elaborated valuation procedure

1. **Biophysical projections based on the two existing models**
   - **ATEAM model (Advanced Terrestrial Ecosystem Analysis and Modeling)**
   - **IMAGE 2.2 (Integrated Assessment Model on commodity demands at the European scale)**
2. **Projecting the changes of**
   - **<u>Land Use</u> (i.e. forest area) and**
   - **<u>Land Productivity</u> (i.e. WFPs and carbon stocks in the forests)**
3. **Partial equilibrium economic analysis**
4. **Value estimation of the forest EGS in 2050 across different IPCC scenarios**

Forest area 2005-2050

		Forest area 1000 ha	A1	A2	B1	B2
35-45	Mediterranean Europe					
	Greece	2770	2.730,28	2.811,04	4.481,43	4.285,35
	Italy	9273	7.545,23	7.461,22	10.556,52	10.751,94
	Portugal	2577	2.609,46	2.614,85	3.913,03	3.947,91
	Spain	13679	11.876,34	11.794,68	17.134,92	17.375,47
	Albania	794	680,67	682,67	1.016,15	1.014,77
	Bosnia and Herzegovina	2.185	2.311,77	2.259,10	2.268,75	2.387,19
	Bulgaria	3.625	3.480,21	3.400,92	3.415,45	3.593,75
	Serbia and Montenegro	2.694	2.117,85	2.180,50	3.476,20	3.324,10
	Turkey	10.175	8.712,61	8.615,60	12.189,80	12.415,45
	Yugoslav	906	947,72	926,13	930,09	978,64
Sub total		**47.771**	**42.064**	**41.821**	**58.452**	**59.096**
45-55	Central - Northern					
	Austria	5065	3.949,89	3.859,90	3.876,38	4.078,75
	Belgium	557	639,44	663,01	848,13	1.023,82
	France	16624	13.200,14	14.041,05	17.560,10	19.174,57
	Germany	10970	9.839,06	9.865,01	12.430,82	13.739,85
	Ireland	405	480,98	412,28	694,58	714,15
	Luxembourg	86	80,77	78,82	103,85	94,49
	Netherlands	188	276,81	770,43	609,20	756,52
	Switzerland	1945	1.178,32	1.135,74	1.254,38	1.259,18
	Croatia	2135	2.001,42	2.397,54	2.796,87	3.056,57
	Czech Republic	2648	2.487,58	2.979,93	3.476,26	3.799,05
	Hungary	1976	1.703,47	2.040,63	2.380,51	2.601,55
	Poland	9192	8.400,08	10.062,64	11.738,66	12.828,64
	Romania	6370	6.026,00	7.218,68	8.421,01	9.202,94
	Slovakia	1929	2.010,51	1.964,70	1.973,10	2.076,10
	Slovenia	1264	1.123,67	1.346,07	1.570,27	1.716,07
Sub total		**61.354**	**53.398**	**58.836**	**69.734**	**76.122**
55-65	Northern					
	Denmark	355	436,49	849,01	544,31	1.052,10
	United Kingdom	2224	2.770,05	2.518,69	3.264,53	4.081,37
	Estonia	2284	2.208,21	3.106,64	2.675,07	4.247,51
	Latvia	2941	2.833,00	3.985,64	3.431,95	5.449,30
	Lithuania	2099	1.985,65	2.793,54	2.405,46	3.819,42
Sub total		**9.903**	**10.233**	**13.254**	**12.321**	**18.650**
65-71	Scandinavian					
	Finland	16521	24.481,37	24.179,38	22.187,86	22.942,82
	Norway	5186	11.403,39	11.049,31	9.049,11	10.141,35
	Sweden	21521	28.871,79	28.228,97	32.916,06	28.872,84
Sub total		**43.228**	**64.757**	**63.458**	**64.153**	**61.957**
	Europe	162.256	170.453	177.368	204.661	215.825

Advanced Terrestrial Ecosystem Analysis and Modelling - ATEAM model

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IMAGE 2.2 Integrated Assessment Model on commodity demands at the European scale (IMAGE team, 2001)

Provisioning Services – Wood-based panels

	Wood-based panels (M m3/yr)2005	A1 2050 Wood-based panels (M m3/yr)	A1 2050 Wood-based panels (M m3/yr)	A1 2050 Wood-based panels (M m3/yr)	A1 2050 Wood-based panels (M m3/yr)
Greece	0,87	0,32	0,33	0,52	0,50
Italy	5,61	2,82	2,79	3,63	4,01
Portugal	1,31	1,03	1,08	1,33	1,34
Spain	4,84	3,26	3,24	4,23	4,76
Albania	0,04	0,02	0,04	0,04	0,04
Bosnia and Herzegovina	0,00	0,00	0,00	0,00	0,00
Bulgaria	0,35	0,22	0,35	0,35	0,39
Serbia and Montenegro	0,07	0,05	0,08	0,07	0,08
Turkey	4,77	3,16	5,16	5,12	5,75
Yugoslav	0,00	0,00	0,00	0,00	0,00
	17,86	**10,87**	**13,06**	**15,29**	**16,88**
Austria	3,45	5,81	5,60	4,01	5,33
Belgium	2,80	2,32	2,40	2,53	3,10
France	6,40	4,99	5,36	5,77	6,31
Germany	16,98	13,28	13,25	13,15	15,54
Ireland	0,88	0,48	0,40	0,48	0,61
Luxembourg	0,45	0,42	0,41	0,53	0,49
Netherlands	0,01	0,00	0,02	0,01	0,01
Switzerland	0,97	1,72	1,65	1,70	1,50
Croatia	0,13	0,10	0,17	0,10	0,16
Czech Republic	1,49	1,20	1,95	1,20	1,81
Hungary	0,67	0,53	0,85	0,53	0,79
Poland	6,74	5,37	8,73	5,38	8,07
Romania	1,01	0,82	1,33	0,82	1,23
Slovakia	0,61	0,49	0,79	0,49	0,73
Slovenia	0,41	0,33	0,53	0,33	0,49
	42,99	**37,52**	**42,91**	**36,71**	**45,67**
Denmark	0,35	0,31	0,63	0,24	0,42
United Kingdom	3,40	2,74	3,18	2,76	3,65
Estonia	0,41	0,30	0,57	0,33	0,49
Latvia	0,43	0,32	0,59	0,41	0,43
Lithuania	0,40	0,29	0,54	0,38	0,40
	4,98	**3,96**	**5,50**	**4,12**	**5,39**
Finland	1,99	1,95	1,88	1,59	1,74
Norway	0,58	0,36	0,29	0,26	0,30
Sweden	0,75	0,78	0,76	0,77	0,71
	3,31	**3,09**	**2,92**	**2,62**	**2,75**
Total Europe	69,14	55,44	64,38	58,73	70,70

Global Forest Resources Assessment 2005: Progress towards sustainable forest management, FAO Forestry Paper no.147

ATEAM
(A1, A2, B1, B2)

percentage change

Harvested timber is taken as an indicator for wood supply. The wood supply (the amount of stem wood removed from the forest) is related to forest production.

Stocked carbon

$$Stockedcarbon_{i,j} = \sum \left(ha_{i,j} \big|_k \times C(t/ha)_{i,j} \big|_k \right)$$

from ATEAM project and IMAGE 2.2 model

(A1, A2, B1, B2)

from ATEAM project (A1, A2, B1, B2)

Carbon storage in tree biomass and forest soils

Where:

i= country

j= IPCC scenarios

K= forest area

Specified Valuation approaches

- WFPs:
  - Productivity value of Forests in 2005 in country (*n*) is computed based on the market value of harvested forest products (*i*) and the extension of forest area (US$ per T/M3 per country)

$$ProductivityValue^{provisioning\ service}_{geo\text{-}climatic\ region} = \sum_{n=1}^{N}\sum_{i=1}^{7} ExportValue_{in} \Big/ \sum_{n=1}^{N} ForestArea_{n}$$

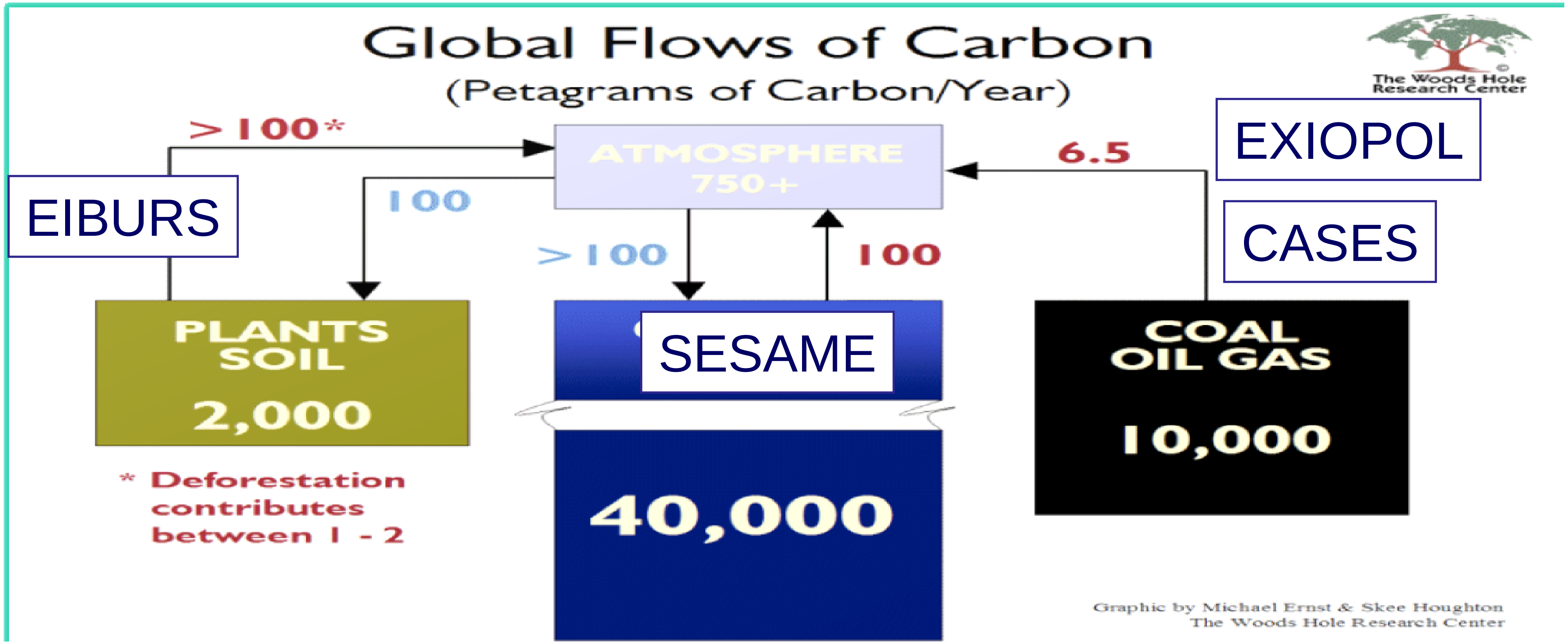
(Source of data: FAOSTAT)

  - Future value of this sector is projected based on the assumption that the price of WFPs will keep stable for the next 50 years (Clark, 2001)

Specified Valuation approaches (Cont.)

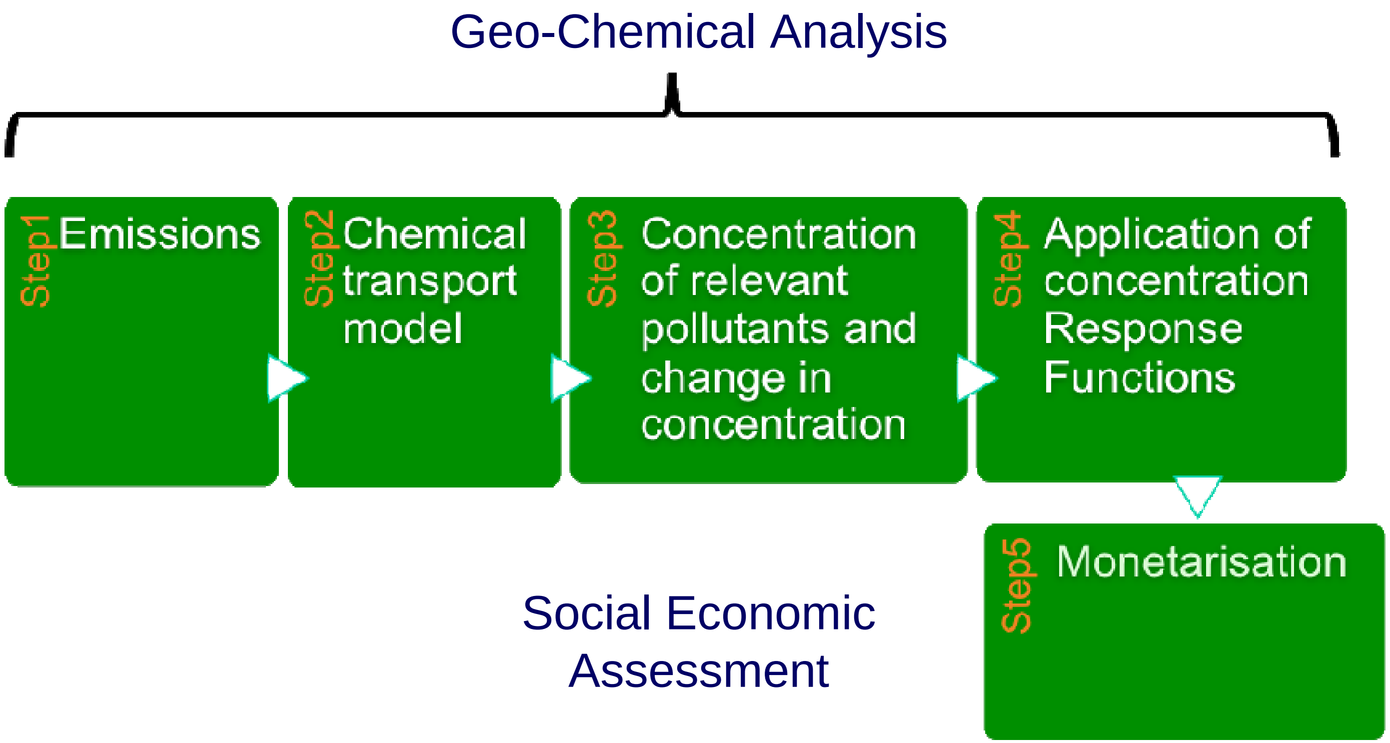
- CO_2 regulation:

The Earth's Carbon Reservoirs with Estimates of Carbon Flow In and Out per Year



Specified Valuation approaches (Cont.)

- CO_2 regulation, how to estimate



Source: EcoSense

Avoided damage costs of CO2 emissions

- Definition:

The damage cost of CO_2 emissions, and other GHG in terms of CO_2 equivalent, refers to the Social Cost of Carbon (SCC), which is an economic measurement of the damage caused by CO2 emissions, compared to a baseline context in which those emissions do not increase, or increase at a slower rate.

Setting the SCC in practice: CASES

- CASES project - Cost Assessment for Sustainable Energy Systems
- Objectives of the project:
  - To provide a comprehensive and dynamic assessment of the full costs of electricity generation
- To combine the dynamics of global economic growth with the dynamics of geophysical climate dynamics
  - To estimate the cost of GHG emission under different energy evolution paths in 2020 and 2050

- CASES adopted the value of social costs of carbon estimated by DEFRA (2005) for it is reflexive to the policy context in which the values are used.
- Moreover, the SCC estimates in CASES project are built on various available estimates produced by Integrated Assessment Models in recent years.

The range of value estimates for carbon

Estimated	2000	2030
Lower estimates	€4/tCO_2	€8/tCO_2
Central estimates	€23/tCO_2	€41/tCO_2
Upper estimates	€53/tCO_2	€110/tCO_2

Reference: *CASES*

Specified Valuation approaches (Cont.)

- Cultural Value
  - Selecting the CV studies for each Geo-Climatic Region
  - Worldwide Meta-analysis (Ojea *et al.*2008) and Regional Value Transfer
  - WTPs from the selected CV studies are corrected by forest area, PPP-GDP per capita, population under four IPCC scenarios

Specified Valuation approaches (Cont.)

Selected studies on recreational use for geographical value-transfer

Country	Reference study	Forest biome	Geo-climatic region
United Kingdom	Scarpa, R., S. M. Chilton, W. G. Hutchinson, J. Buongiorno (2000)	Temperate broadleaf and mixed forests	Northern Europe
The Netherlands	Scarpa, R., S. M. Chilton, W. G. Hutchinson, J. Buongiorno (2000)	Temperate broadleaf and mixed forests	Central-Northern Europe
Finland	Bostedt, G. and L. Mattsson (2005)	Boreal	Scandinavian Europe
Italy	Bellu, L. G. and Cistulli V. (1994)	Mediterranean and Temperate Broadleaf	Mediterranean Europe

Specified Valuation approaches (Cont.)

. Selected studies on passive use for geographical value-transfer

Country	Reference study	Forest biome	Geo-climatic region
United Kingdom	Garrod, G.D. and Willis, K. G. (1997) Hanley, N., Willis, K, Powe, N, Anderson, M. (2002) ERM Report to UK Forestry Commission (1996)	Temperate	Northern and central-northern Europe
Finland	Kniivila, M., Ovaskainen, V. and Saastamoinen, O. (2002) Siikamaki, Juha (2007)	Boreal	Scandinavian Europe
Spain	Mogas, J., Riera, P. and Bennett, J. (2006)	Mediterranean	Mediterranean Europe

Specified Valuation approaches (Cont.)

$$V_i = f(S_i, I_i)$$

V_i = the marginal value for recreation or passive use in country *i* measured as WTP/hectare/year

S_i = size of the forest area designated to recreation or conservation in country *i* [hectares]

I_i = income level in country *i* [PPPGDP]

$$\log V_i = \alpha + \beta \log S_i + \gamma \log I_i$$

β = marginal effect of the forest size designated to recreation or conservation

γ = marginal effect of the income level of the country where the site is located

Value transfer

Scaling up recreational and passive use values, at the different geo-climatic regions

$$V_{EU,l} = V_{i,l}\left(\frac{S_{i,l}}{S_{EU,l}}\right)^{\beta}$$

From original case studies i

Intertemporal IPCC transfer

$$V_{i,T_1} = V_{i,T_0}\left(\frac{H_{i,T_1}}{H_{i,T_0}}\right)\left(\frac{S_{i,T_0}}{S_{i,T_1}}\right)^{\beta}\left(\frac{PPPGDP_{i,T_1}}{PPPGDP_{i,T_0}}\right)^{\gamma}$$

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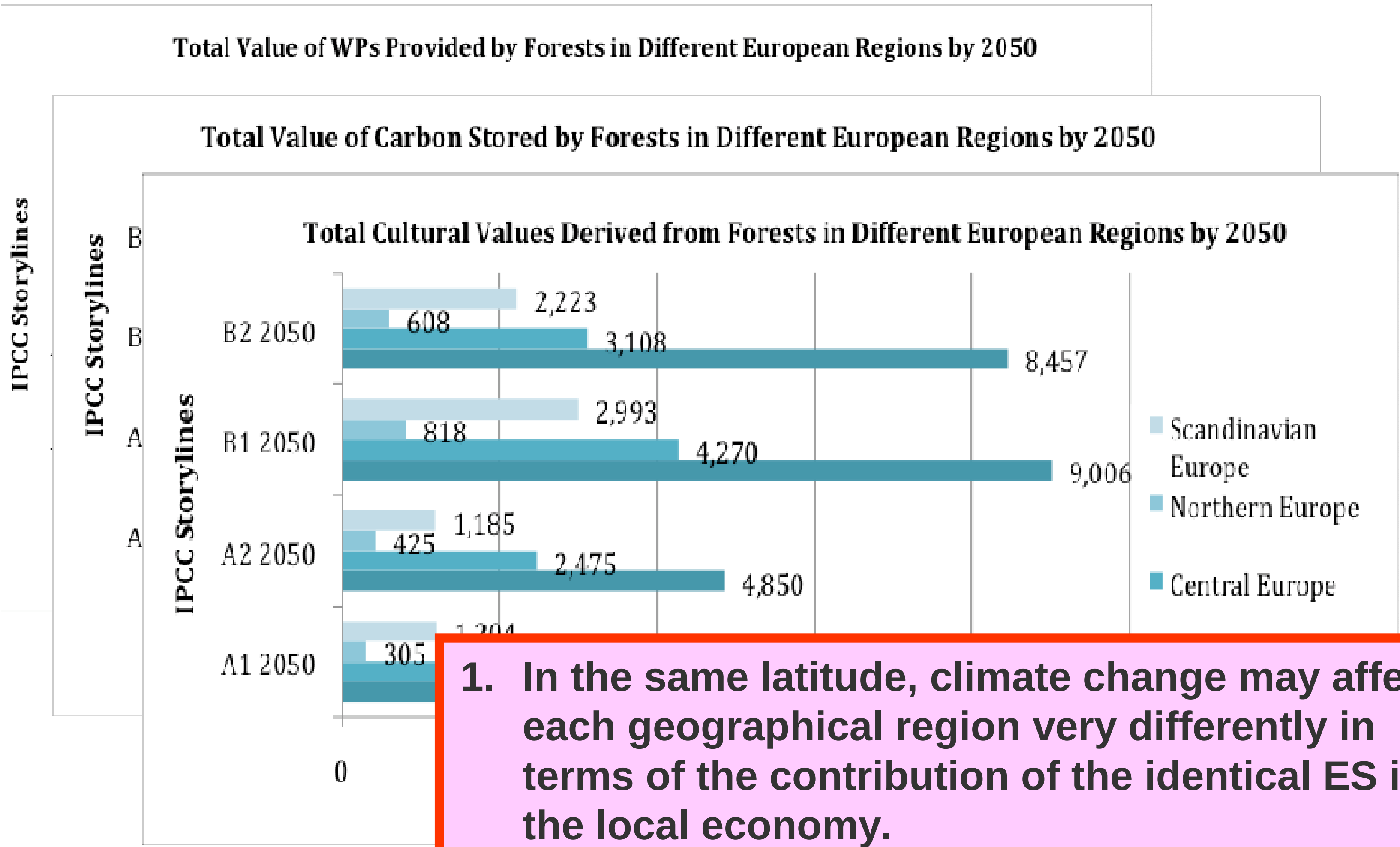
An Overview of the projected TEV in 2050



1. **In the same latitude, climate change may affect each geographical region very differently in terms of the contribution of the identical ES in the local economy.**
2. **For each type of forest ES, climate change impact also varies across latitudes.**

Reporting on the Valuation Results

- In our analysis, IPCC A2 storyline has been selected as benchmark as it shows a very differentiated world compared to other storylines: e.g. highest pop, fast per capita economic growth, high CO2 concentration, etc.
- By comparing all other three IPCC storylines, i.e. A1, B1 and B2 with the A2 storyline, we are able to measure the costs of changing in global climate for future scenarios.
- Our computation results show that climate change is complex and the answer about the nature and magnitude of its impacts is multifaceted.

Nevertheless…,

we still can get some interesting insights from our results….

Reporting the valuation results - WFPs

Benchmark A2 Scenario		Mediterranean Europe (N35-45)	Central Europe (N45-55)	Northern Europe (N55-65)	Scandinavian Europe (N65-71)	Europe
Absolute value difference Million$, 2005)	A1vs.A2	-40	-6,306	-1,802	1,597	-6,551
	B1vs.A2	1,565	-6,115	-2,503	-2,171	-9,223
	B2vs.A2	2,283	1,186	-405	-1,999	1,065
Percentage change	A1vs.A2	-0.6%	-13.3%	-25.0%	4.7%	-6.9%
	B1vs.A2	24.3%	-12.9%	-34.7%	-6.4%	-9.7%
	B2vs.A2	35.4%	2.5%	-5.6%	-5.9%	1.1%

1. **A1 scenario with highest concentration of CO_2 and higher ºC will result in welfare loss to the whole Europe on average, except Scandinavian counties.**
2. **In B type scenarios, more sustainable and environmental sound policies may reduce the extraction of WFPs, which thus relates to a decrease in market values, like shown in B1 scenario.**
3. **However, one should realize that a local or national oriented sustainable development strategy (i.e. B2 scenario) may be more effective, in terms of improving the regional social welfare related to the production of WFPs.**

Reporting the valuation results – Stocked Carbon

Benchmark A2 Scenario		Mediterranean Europe (N35-45)	Central Europe (N45-55)	Northern Europe (N55-65)	Scandinavian Europe (N65-71)	Europe
Absolute value difference (Million$, 2005)	A1vs.A2	-8,614	-42,212	-5,874	212	-56,489
	B1vs.A2	20,785	31,303	5,317	13,705	71,109
	B2vs.A2	17,819	30,888	6,183	3,128	58,018
Percentage Change	A1vs.A2	-18.8%	-26.5%	-33.8%	0.6%	-22.1%
	B1vs.A2	45.4%	19.6%	30.6%	42.0%	27.9%
	B2vs.A2	38.9%	19.4%	35.6%	9.6%	22.7%

1. **Not surprisingly we can observe a loss in the benefits of carbon storks from forests in Europe in A1 scenario, due to its rapid progress of economic development, thus less concern about forest protection.**
2. **On the contrary, B type scenarios show on average welfare gains in most of the regions, due to the extension of protective forest area under more sustainable sound policies.**
3. **Another interesting finding is, that global cooperation on environmental protection (represented by B1 scenario) can lead to an overall welfare gain, compared to the regional environmental protection (represented by B2 scenario).**

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Reporting the valuation results – Cultural Value

Benchmark A2 Scenario		Mediterranean Europe (N35-45)	Central Europe (N45-55)	Northern Europe (N55-65)	Scandinavian Europe (N65-71)	Europe
Absolute value difference (Million$, 2005)	A1vs.A2	-862	-352	-121	18	-1,317
	B1vs.A2	4,156	1,795	393	1,808	8,152
	B2vs.A2	3,607	633	182	1,038	5,460
Change in %	A1vs.A2	-17.8%	-14.2%	-28.3%	1.5%	-14.7%
	B1vs.A2	85.7%	72.5%	92.3%	152.5%	91.2%
	B2vs.A2	74.4%	25.6%	42.9%	87.5%	61.1%

1. **A1 scenario is worse off comparing to A2 scenarios, indicating that rapid world economic growth, leads to negative impacts on cultural values of forest ecosystem, which contains local specific cultural heritage, such as the existence of rare and endangered species in the forests.**
2. **All B-type scenarios have positive impacts on welfare economy in terms of provisioning of cultural services, therefore moving from B-type scenarios A2 scenario will involve welfare costs.**

Conclusions

- The different IPCC storylines (climate, social and land use embedded implications) is reflected in the overall level of provision of provisioning, regulating and cultural services by the European forests
- The impacts do also reflect important redistributional welfare effects (who wins and who loses)
- The magnitudes signal the potential for adaptation, and/or mitigation measures, however further analysis is needed so as to evaluate the net welfare impacts.

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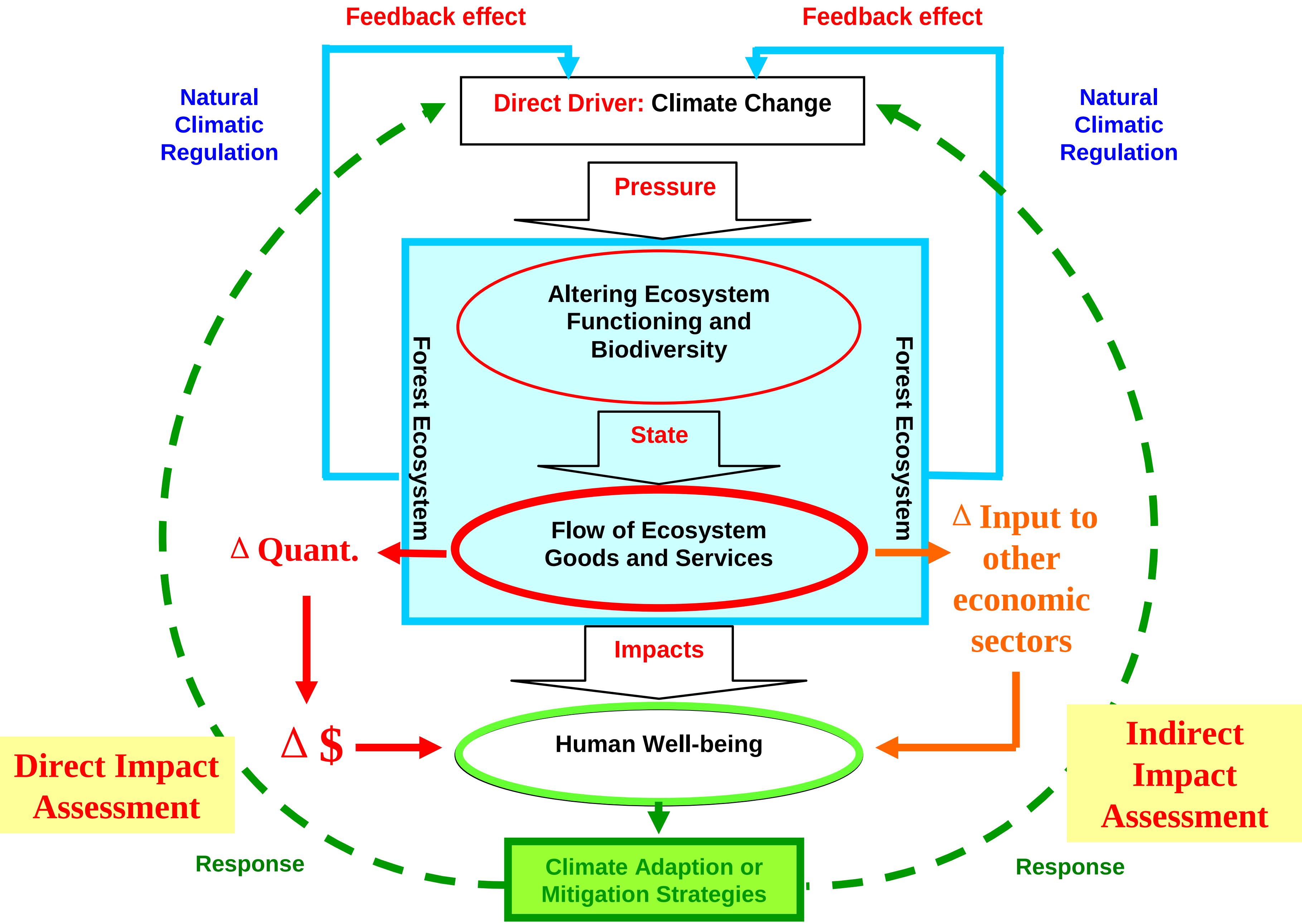
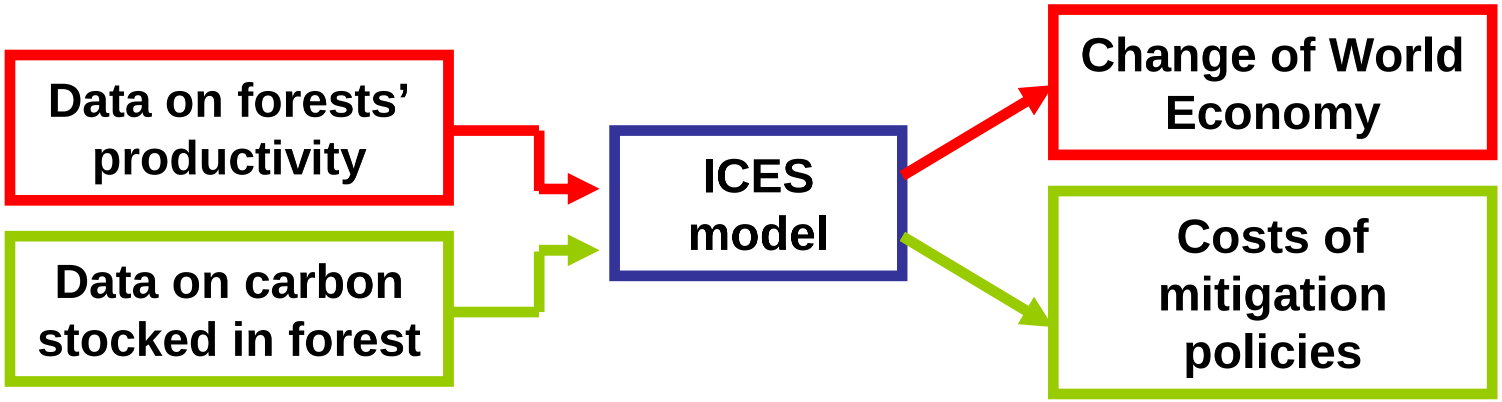

Feedback effect
Feedback effect
Natural Climatic Regulation
Direct Driver: Climate Change
Natural Climatic Regulation
Pressure
Altering Ecosystem Functioning and Biodiversity
Forest Ecosystem
State
Forest Ecosystem
Flow of Ecosystem Goods and Services
Δ Quant.
Δ Input to other economic sectors
Impacts
Δ $
Human Well-being
Direct Impact Assessment
Indirect Impact Assessment
Climate Adaption or Mitigation Strategies
Response
Response

Two Ongoing Experimental Exercises:

- The experimental exercise with ICES model (work in progress):



- Estimating the marginal effects of policy action for CC management through the change in biodiversity:

$$\frac{\partial Value\_EGS_{Scenario}}{\partial Biodiversity_{Scenario}} \cdot \frac{\partial Biodiversity_{Scenario}}{\partial CC_{Scenario}}$$

Thank you for your attention!

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Acknowledgement:

The research is financed by the European Investment Bank.