BASQUE CENTRE
FOR CLIMATE CHANGE
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Adaptation strategies for sea level rise impacts on ecosystem services

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Outline

- Ecosystem services: the Millennium Ecosystem Assessment
- The conceptual framework linking physical changes, provision of Ess and economic impacts
- Economic values of ESs and methods
- Case study Basque country: economic impact due loss of ESs caused by sea level rise year 2100
    - K-Egokitzen Project (Tecnalia, AZTI y NEIKER, BC3)

1. The Millennium Ecosystem Assessment

Ecosystem goods definitions

… the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life
(Daily 1997).

...the benefits human populations derive, directly or indirectly, from ecosystem functions
(Costanza et al 1997).

<u>...the benefits people obtain from ecosystems</u>
(MEA 2005).

…ecological components directly consumed or enjoyed to produce human well-being
(Boyd and Banzhaf 2007)

2. MEA classification of ESs

PROVISIONING SERVICES

(products obtained from ecosystem)

- Food
- Timber
- Woodfuel
- Fiber

…

REGULATING SERVICES

(Benefits obtained from regulation of ecosystem processes)

- Climate regulation
- Water purification
- Disease regulation
- Water regulation
- Pollination

…

CULTURAL SERVICES

(Non-material benefits obtained from ecosystems)

- Spiritual and religious
- Recreation and tourism
- Aesthetic
- Educational
- Cultural heritage

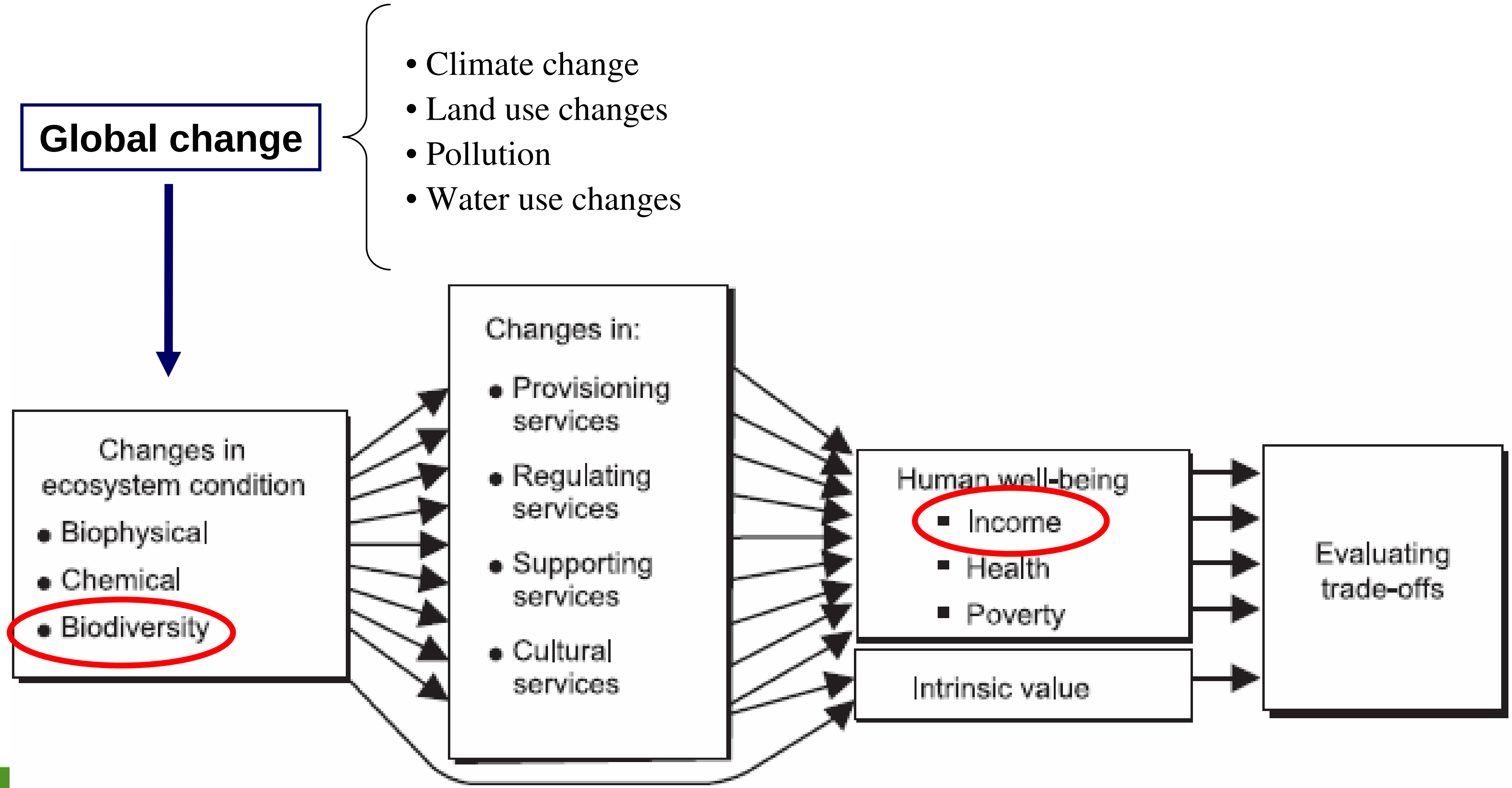
…

SUPPORTING SERVICES

(Services necessary for the production of all other ecosystem services)

- Soil formation
- Nutrient cycling
- Primary production

3. The conceptual framework MEA



Source: MEA (2005), adapted

Habitat ⇨ Ecosystem services ⇨ Welfare

HABITAT LOSS

- Loss of species and biodiversity
- Loss of hectares

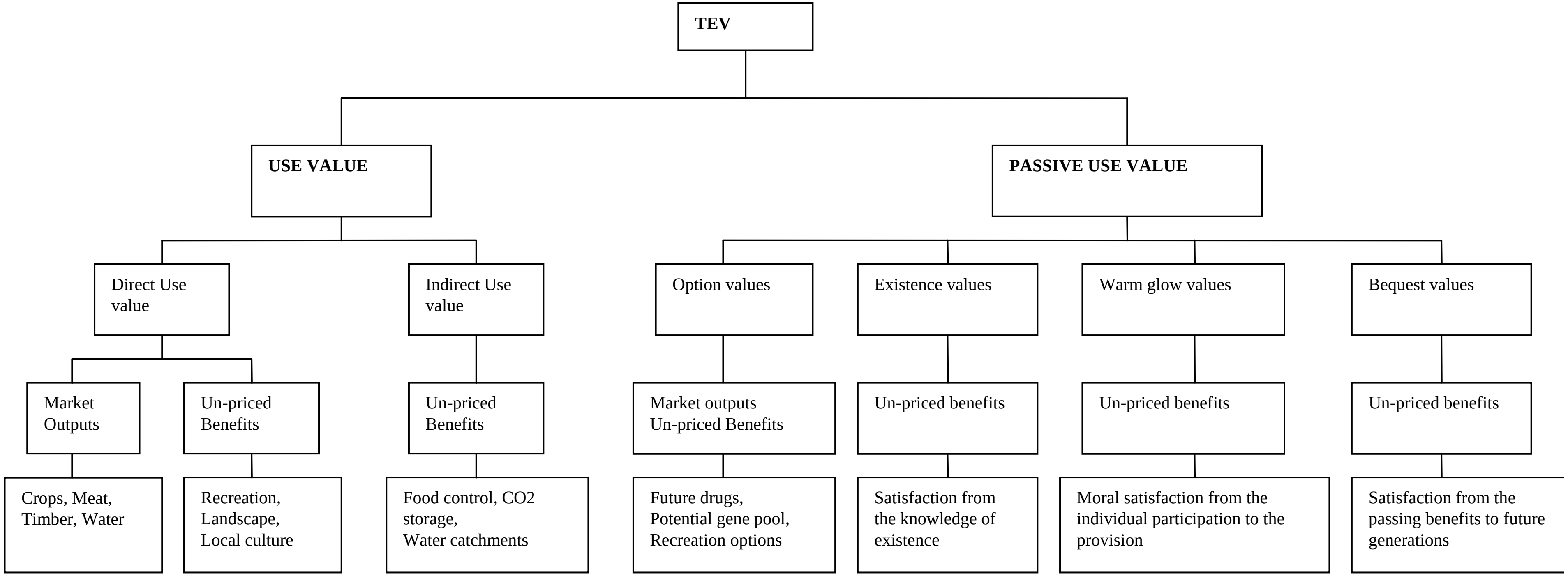
Loss of ESs

- Change in the quality of the services
- Loss of services (e.g. recreational)

WELFARE LOSS

- Market impacts
- Non-market impacts
- Restoration costs

4) Economic valuation: total economic values of EGSs and potential methods



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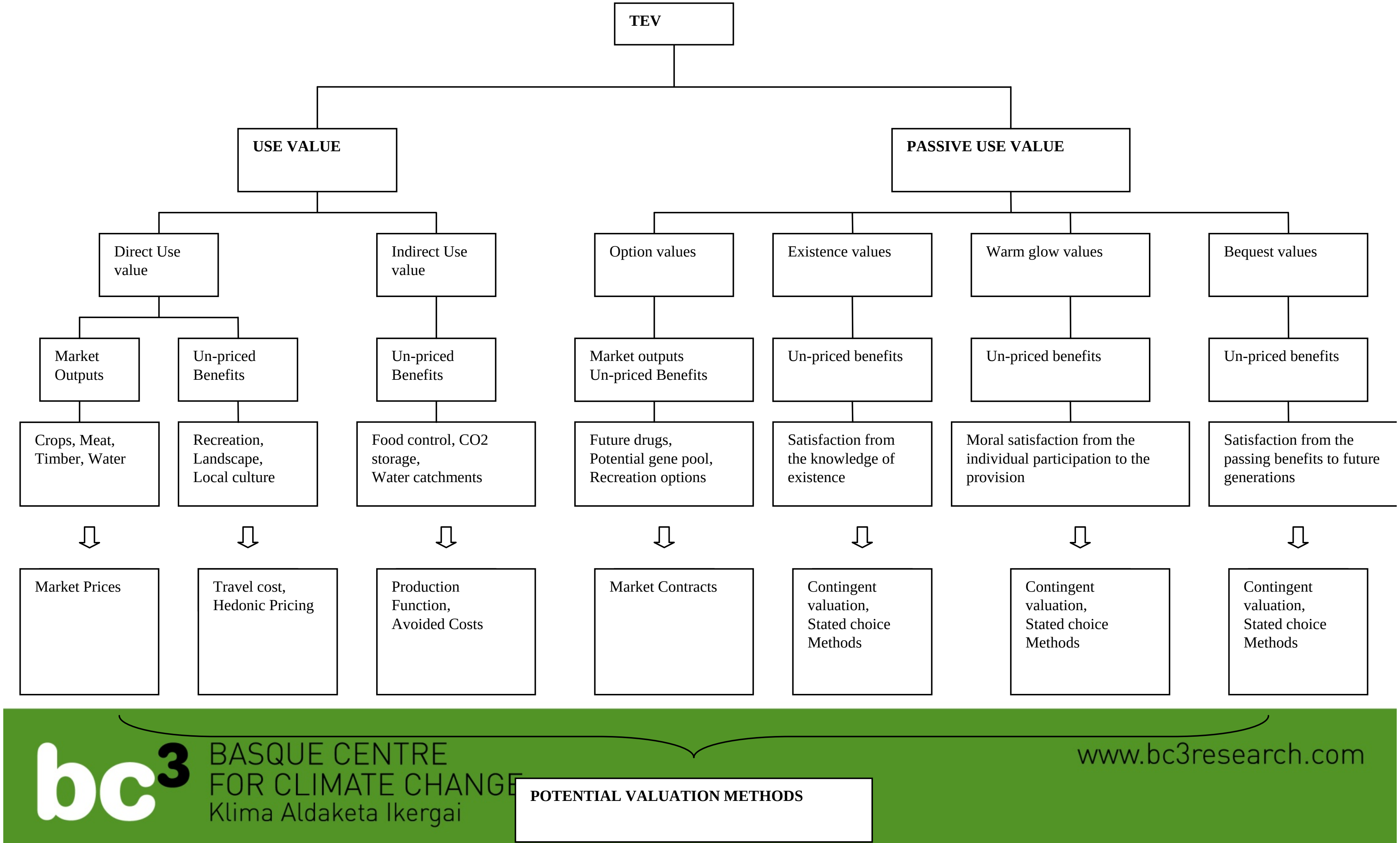


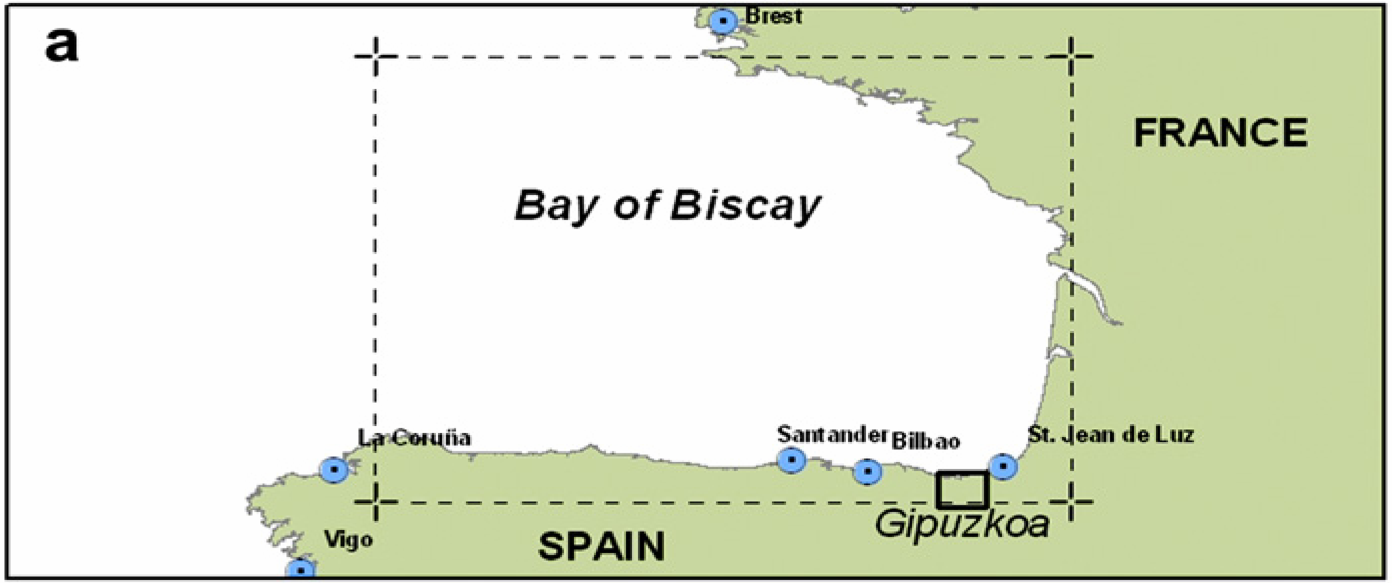
5. The case study

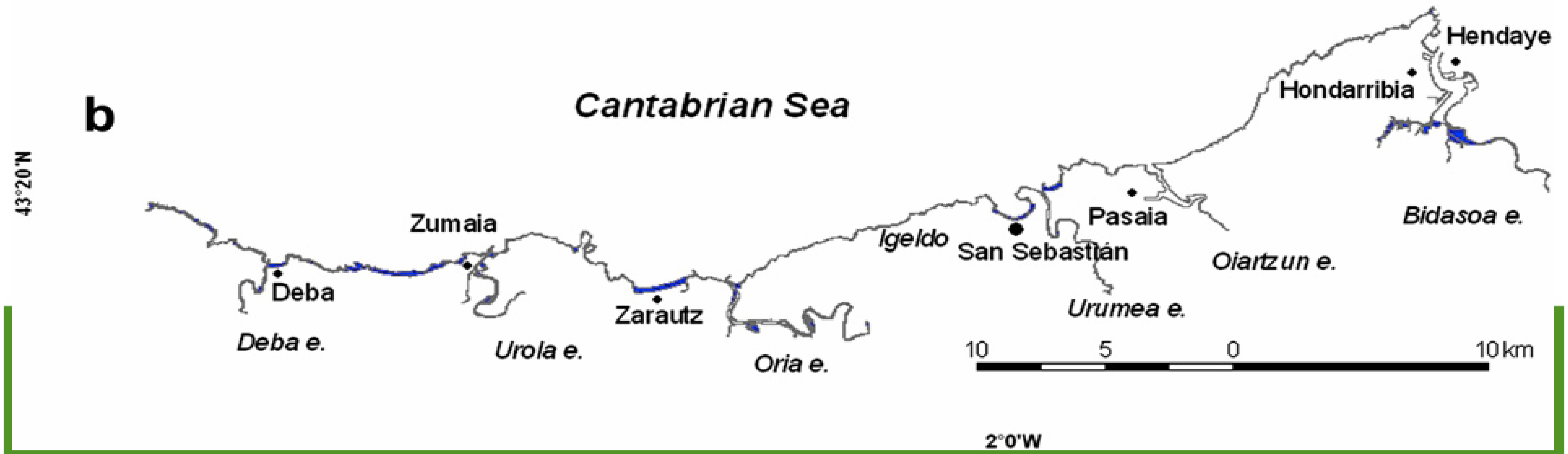
- Mapping coastal habitats
- Projection of areas at risk of flooding in 2100
- Classification and valuation of ESs per habitat
- Assessment of total economic loss

The study area

- Coast of Gipuzkoa, located within the Bay of Biscay, 198 km long at low tide
- Coast very steep, dominated by rocky substrata with vertical cliffs and intercalated by small estuaries with sandy beaches at the mouth of the rivers (Borja et al, 2004)
- Basque coast represents only 12% of the total surface of the Basque country
- It supports nevertheless 60% of the overall population and 33% of industrial activities (Cearreta et al, 2004)

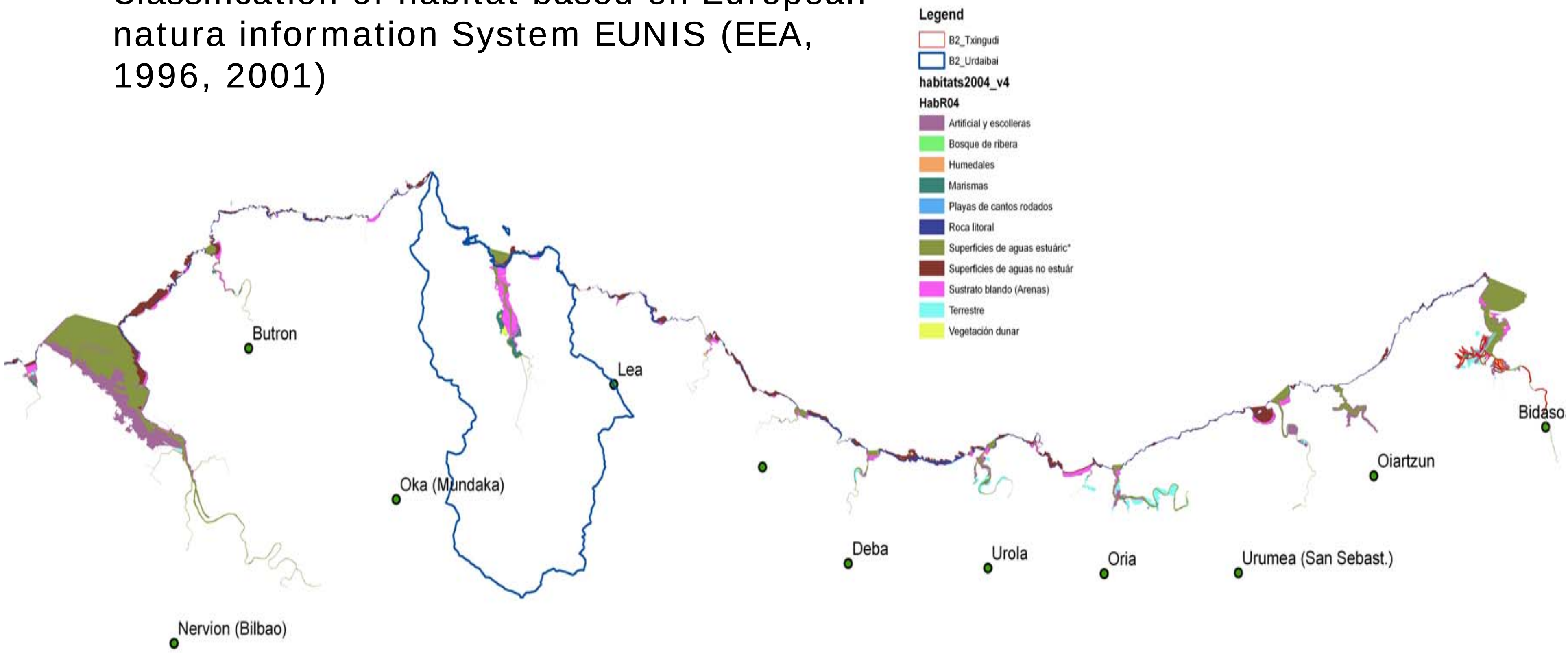
Study area: Gipuzkoa within the Bay of Biscay





1) Mapping coastal habitats

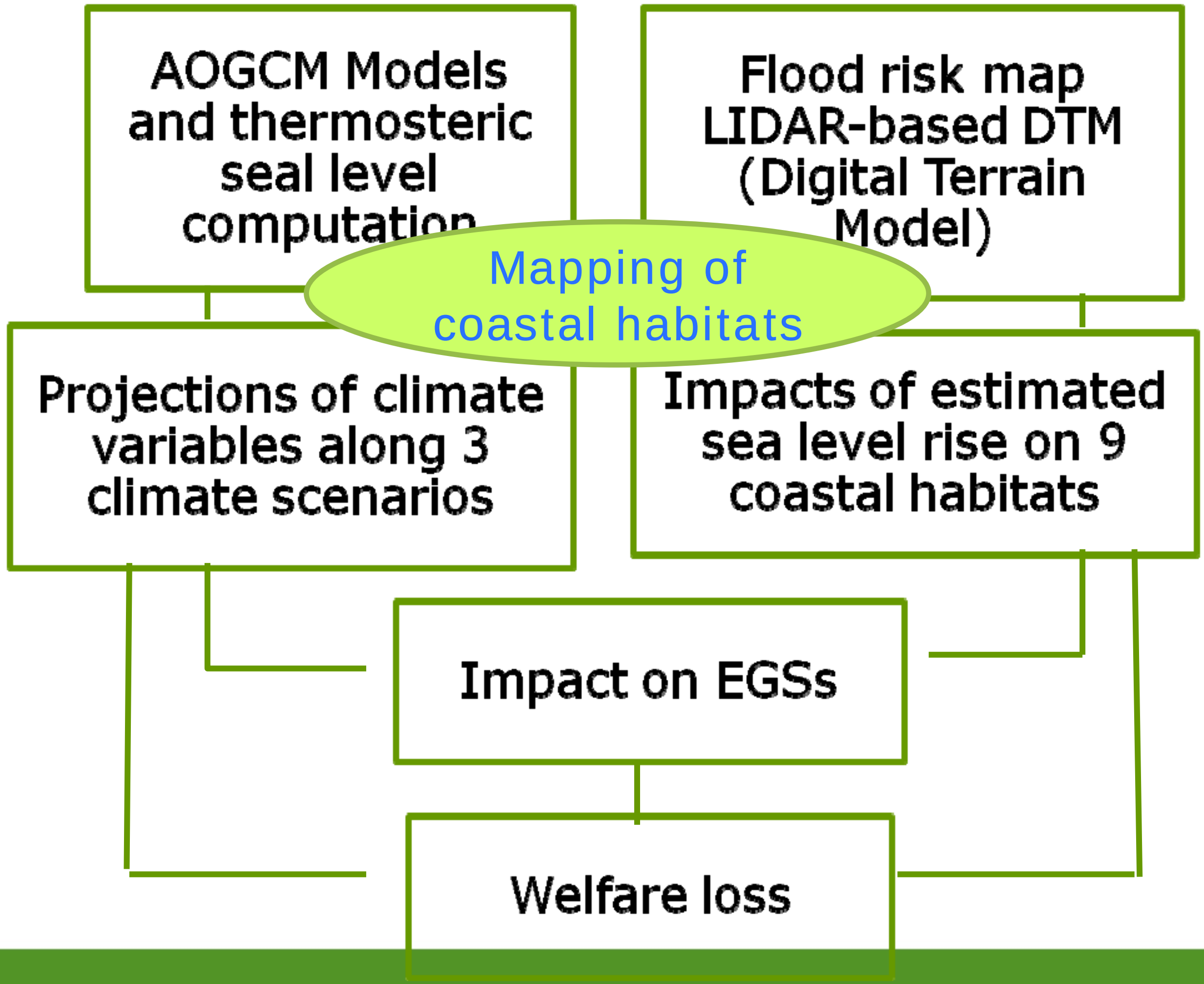
- Data and estimates of the Marine Research unit based in the region (Chust et al, 2008, 2009, 2010),Borja et al (2004)
- Airborne laser scanning Light Detection and Ranging LIDAR, providing high-resolution images for Digital Terrain Models DTM (Chust et al, 2008)
- Classification of habitat based on European natura information System EUNIS (EEA, 1996, 2001)



Coastal habitats in the Gipuzkoa area

HABITAT	Description
Sandy beaches and muds	Sandy beaches and artificial sandy shores. Unvegetated or partially vegetated by marine plants (Zostera noltii, Spartina) and algae (Gracilaria, Ulva, Fucus). Coastal beaches and beaches sheltered within inner estuaries.
Shingle beaches	Accumulation of shingles and peebles; without or with very scarce benthos (lichen), occurring in supralittoral and upper intertidal zone.
Vegetated dunes	• Secondary dunes or white dunes, mobile or semi-fixed (flora: Ammophila arenaria, Eryngium maritimum, Euphorbia paralias, Calystegia soldanella, Medicago marina); • Tertiary dunes or fixed (flora: Helichrysum stoechas), • Artificial sediment accumulations colonized by vegetation.
Sea cliffs and supralittoral rock	Unvegetated seacliffs and rocky shore in the supralitoral (splash zone). The supralittoral rocky zone may be covered by Xanthoria parietina lichen in the upper supralittoral, and by the black lichen Verrucaria maura (black belt) in the lower supralittoral. On the lower levels, specimens of melarphe neritoides, Patella rustica and seasonal belts of clorophyte Blindingia minima.
Wetlands	Two main areas and vegetation communities: 1)Suffers from weak tidal influence, flooded only during high spring tides. Mono-specific formation dominated by Phragmites australis. 2)Flooded only during high spring tides characterised by mature soils. Dominance of Juncus maritimus which appears together with Elymus pycnanthus. Allocthonous shrub (Baccharis halimifolia) also occur which spreads along the high vegetation zone with Limonium vulgare, Sarcocornia fruticosa and Triglochin maritimum.
Saltmarshes	Placed in the inner part of the estuary of low hydrodinamism. Two main communities: 1)Middle vegetation zone, flooded twice a day, dominated by vascular halophilic plants such as Halimione portulacoides, Salicornia sp. and Suaeda maritima. 2)Upper levels of the mid-intertidial, with sparse perennial grasses Spartina maritima growing in the muddy sediments in lush patches or with Fucus ceranoides and ulva sp.
Terrestrial habitats	Riparian woodland associated to rivers placed around wetlands in soils rich in alluvial deposits. Dominance of Alnus glutinosa, Tamarix gallica, Frazinus excelsior and Salix sp.

2) Projection areas at risk



The model results

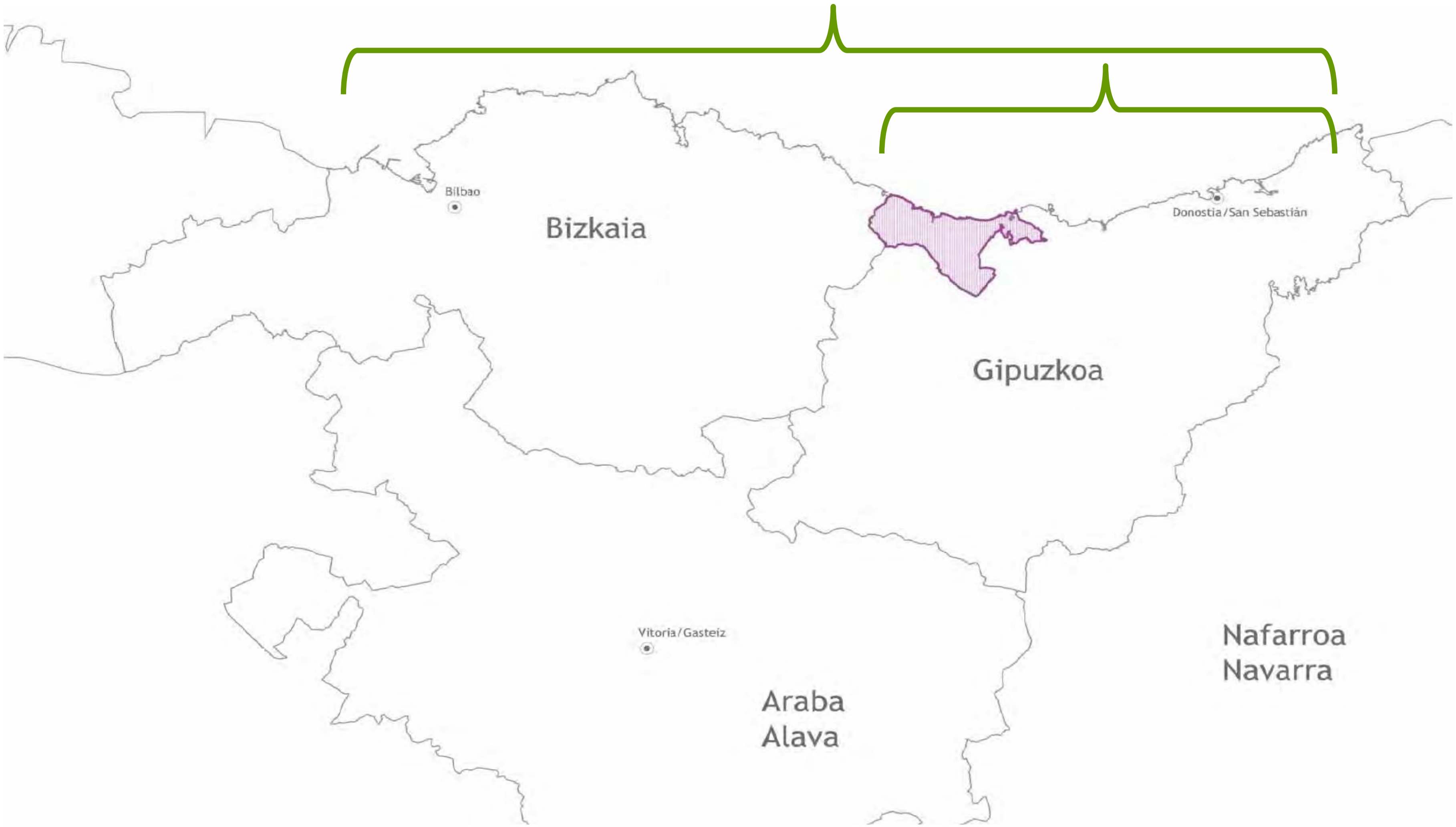
- Global climate change models predict a sea level rise between 0.18 m and 0.59 m by 2100, with high regional variability
- Several studies show a see level rise for the Bay of Biscay slightly higher than the global rates
- AOGCM models - Atmosphere-Ocean Coupled General Climate Models - used within the Bay of Biscay:
  - ✓ Projections for 2100: increase in seal level between 28.5 and 48.7 cm, as a result of regional thermal expansion and global ice-melting, under scenarios A1B and A2 of IPCC
  - The projected sea level rise was added to the high tide level of the coast to generate a flood risk map using high-resolution Digital Terrain Model (DTM)

Projected flooded area in the Basque coast 2100 (up-scaling)

HABITAT	Total area ha (2004)	Flooded area ha (2100)	Flooded area (%)
Sandy and shingle beaches and muds	165.32	22.35	13.5%
Vegetated dunes	36.23	7.59	20.9%
Sea cliffs and supralittoral rock	254.75	13.15	5.1%
Wetlands and saltamarshes	178.4	11.63	6.5%
Terrestrial habitats	61.16	45.54	74.5%

Results from Chust et al, 2009

The Basque Coast



3) Identifying ESs at risk

HABITAT	Ecosystem services
Sandy beaches and muds	(1) sediment storage and transport; (2) wave dissipation and associated buffering against extreme events (storms); (3) dynamic response to sea-level rise (within limits); (4) breakdown of organic materials and pollutants; (5) water filtration and purification; (6) nutrient mineralisation and recycling; (7) groundwater discharge through beaches; (8) maintenance of biodiversity and genetic resources; (9) nursery areas for juvenile fishes; (10) nesting sites for shorebirds (11) prey resources for birds and terrestrial wildlife; (12) scenic vistas and recreational opportunities (bathing and sun-bathing, sports, etc.); (13) fishing bait and food organisms; (14) functional links between terrestrial and marine environments in the coastal zone; (15) Marine ressources: shellfish gathering.
Shingle beaches	(1) wave dissipation and associated buffering against extreme events (storms); (2) maintenance of biodiversity and genetic resources.
Vegetated dunes	(1) sediment storage and transport; (2) wave dissipation and associated buffering against extreme events (storms); (3) dynamic response to sea-level rise (within limits); (4) breakdown of organic materials and pollutants; (5) water filtration and purification; (6) nutrient mineralisation and recycling; (7) water storage in dune aquifers; (8) maintenance of biodiversity and genetic resources; (9) nesting sites for shorebirds; (10) scenic vistas and recreational opportunities; (11) functional links between terrestrial and marine environments in the coastal zone.
Sea cliffs and supralittoral rock	(1) wave dissipation and associated buffering against extreme events (storms): protection of coasts by erosion control; (2) water filtration and purification; (3) maintenance of biodiversity and genetic resources; (4) nesting sites for shorebirds; (5) scenic vistas (aesthetic) and recreational opportunities; (6) functional links between terrestrial and marine environments in the coastal zone; (7) maintenance of biodiversity and genetic resources; (8) Marine ressources: shellfish gathering.
Wetlands and saltmarshes	(1) sediment storage and transport; (2) wave dissipation and associated buffering against extreme events (storms): i.e. flood control; (3) dynamic response to sea-level rise (within limits); (4) breakdown of organic materials and pollutants; (5) water filtration and purification (i.e. water quality improvement); (6) nutrient mineralisation and recycling; (7) maintenance of biodiversity and genetic resources (passive use); nesting sites for shorebirds; (8) scenic vistas (aesthetic) and recreational opportunities; (9) fishing bait and food organisms; (10) functional links between terrestrial and marine environments in the coastal zone; and (11) Cultural (Educational: e.g. bird watching); (12) Marine ressources: shellfish gathering (in saltmarshes).
Terrestrial habitats	(1) buffering against extreme events (floods); (2) breakdown of organic materials and pollutants (Carbon control); (3) water filtration and purification; (4) nutrient mineralisation and recycling; (5) groundwater discharge through beaches; (6) maintenance of biodiversity and genetic resources; (7) nesting sites for river birds (8) scenic vistas and recreational opportunities.

4) Economic valuation

- Restoration costs (beach clean-up, regeneration of ecosystems...) assuming that allocated resources reflect preferences to preserve it

- Use and non-use values (WTP for recreational and passive-use, TEV through meta-analysis, value transfer)

- Avoidance costs and damaged costs

The present value of the asset

- Unit of measurement = economic value per ha of the asset lost
- Flow values are therefore converted into present values:

$$PV = \sum \frac{V_t}{(1+i)^t}$$

PV is the present value
V(t) is the flow value over time *t*
i is the discount rate (1-2%)

Carbon stocks valuation in terrestrial habitat

(1) Assessing the biomass carbon capacity in the Basque coast woodland areas (tC/ha)

(2) Computing economic values of carbon stocks per hectare (euro/ha)

- 1Ton Carbon = 3.66 CO_2
- Price per ton of CO_2 based on Marginal Damage Cost and Marginal Avoidance Cost approaches (CASES project)

$$V = (tC / ha) * \$ / tC$$

V = carbon value per hectare
tC/ha = tons of carbon stocked per hectare,
\$/tC = estimated price per ton of carbon stocked

BIOMASS CARBON STOCK ESTIMATES (tCO2/ha)

Forest biome	NAM	EUR	JPK	ANZ	BRA	RUS	SOA	CHN	OAS	ECA	OLC	AFR
Boreal	136.77	136.77	136.77	136.77	0.00	136.77	217.40	94.32	217.40	139.01	124.44	0.00
Tropical	336.72	0.00	545.34	545.34	680.76	0.00	823.50	351.36	336.72	0.00	545.34	732.00
Warm mixed	336.72	336.72	366.00	490.44	614.88	336.72	658.80	285.48	285.48	0.00	490.44	614.88
Temperate mixed	186.66	217.40	173.30	186.66	0.00	139.01	614.88	94.32	0.00	217.40	217.40	0.00
Cool coniferous	136.77	136.77	136.77	0.00	0.00	136.77	217.40	94.32	0.00	139.01	0.00	0.00
Temperate deciduous	186.66	217.40	173.30	186.66	0.00	139.01	614.88	94.32	217.40	217.40	127.66	217.40

Note: (*) Directly reported from the original studies by forest type and geographical region. (**) Transferred from the original studies to similar world regions. Source: R.B. Myneni et al. (2001); H.K. Gibbs (2007).

Carbon stocks valuation

CASES “Cost Assessment of Sustainable Energy Systems”

Costs of CO2 [Euro 2005 per ton]	
Marginal damage costs (lower-bound)	Marginal avoidance costs (upper-bound)
4.76	19

Note: Source http://www.feem-project.net/cases

The meta-regression model

$$V = \alpha + \beta_{context} \log X_{context} + \beta_{site} X_{site} + u$$

V = site value per hectare per year (recreational or passive use) (log)
Xsite = site specific (hectares, vegetation type, runoff, etc)
Xcontext = context specific , includes income and population of the country
u = vector of residuals

Value-transfer

$$V_{Basque} = V_{Eu}^{*}\left(\frac{N_{Basque}}{N_{Eu}}\right)^{\delta}\left(\frac{S_{Basque}}{S_{Eu}}\right)^{\sigma}\left(\frac{PPPGDP_{Basque}}{PPPGDP_{Eu}}\right)^{\gamma}$$

V_{Basque} = estimated WTP value per hectare in the Basque Country

V_{Eu} = WTP value per hectare in the European *study sites*.

S = area designated to recreation or conservation.

N = number of households

Results: restoration costs (€2005)

Habitat	Coste de restauración	V/ha (1.000 €)	Pérdida total de bienestar (1.000 €)
Playas de arena y grava y zonas fangosas	Limpieza de playas	29,9	669,4
Dunas vegetadas	Regeneración de ecosistemas	14,4	109,4
Acantilados y rocas supralitorales	Limpieza de zonas rocosas y acantilados	30,9	406,9
Humedales y marismas	Regeneración de ecosistemas	60,7	705,9
Pérdida económica total			**1.892**
Pérdida por ha			**18,9**

Results: non-market valuation (use and non-use) (2% discount rate, €2005)

Habitat	Value category	V/ha (1.000 €)	Pérdida total de bienestar (1.000 €)
Playas de arena y grava y zonas fangosas	Valor recreacional Valor de uso pasivo	1.152-2.063 241-605	31.134-59.630
Acantilados y rocas supralitorales	Valor de uso pasivo	1.052-3.273	13.833-43.040
Humedales y marismas	Valor económico total	101	1.171
Hábitats terrestres (bosques de ribera)	Captura de Carbono Recreación en zonas boscosas Valor de uso pasivo	1,4-4,1 2,4-10,1 904-2.779	41.328-127.200
Pérdida económica total			**87.466-231.032**
Pérdida por ha			**872-2.304**

Results: non-market valuation (use and non-use) (1% discount rate, €2005)

Habitat	Value category	Pérdida total de bienestar (1.000 €)
Playas de arena y grava y zonas fangosas	Valor recreacional Valor de uso pasivo	71.979-132.776
Acantilados y rocas supralitorales	Valor de uso pasivo	34.794-108.262
Humedales y marismas	Valor económico total	2.841
Hábitats terrestres (bosques de ribera)	Captura de Carbono Recreación en zonas boscosas Valor de uso pasivo	104.255-320.925
Pérdida económica total		**213.869-564.804**
Pérdida por ha		**2.133-5.633**

Main conclusions (1)

- A substantial area of the Basque coast is predicted to flood by year 2100, and the associated EGSs will be negatively impacted, with a significant number of ha permanently lost
- Economic loss (use/non use values): **88-231€ million** (2005€) using 2% discount rate
- Loss per ha: **0.87–2.3€ million/ha** (2005€), comparable to average price per ha of industrial sites in the Basque country (1-3 million/ha)
- Restoration costs: **1.892€ million** resulting in **18,900/ha**
- Using 1% discount rate (more appropriate for time span 76-100 years), total loss: 214-565€ million, equivalent to 2-5.6€ million/ha, comparable to average price per ha of urban areas in the Basque country (2-5million/ha)