LIFE08 ENV/IT/436

PROJECT ACT

ADAPTING TO CLIMATE CHANGE IN TIME

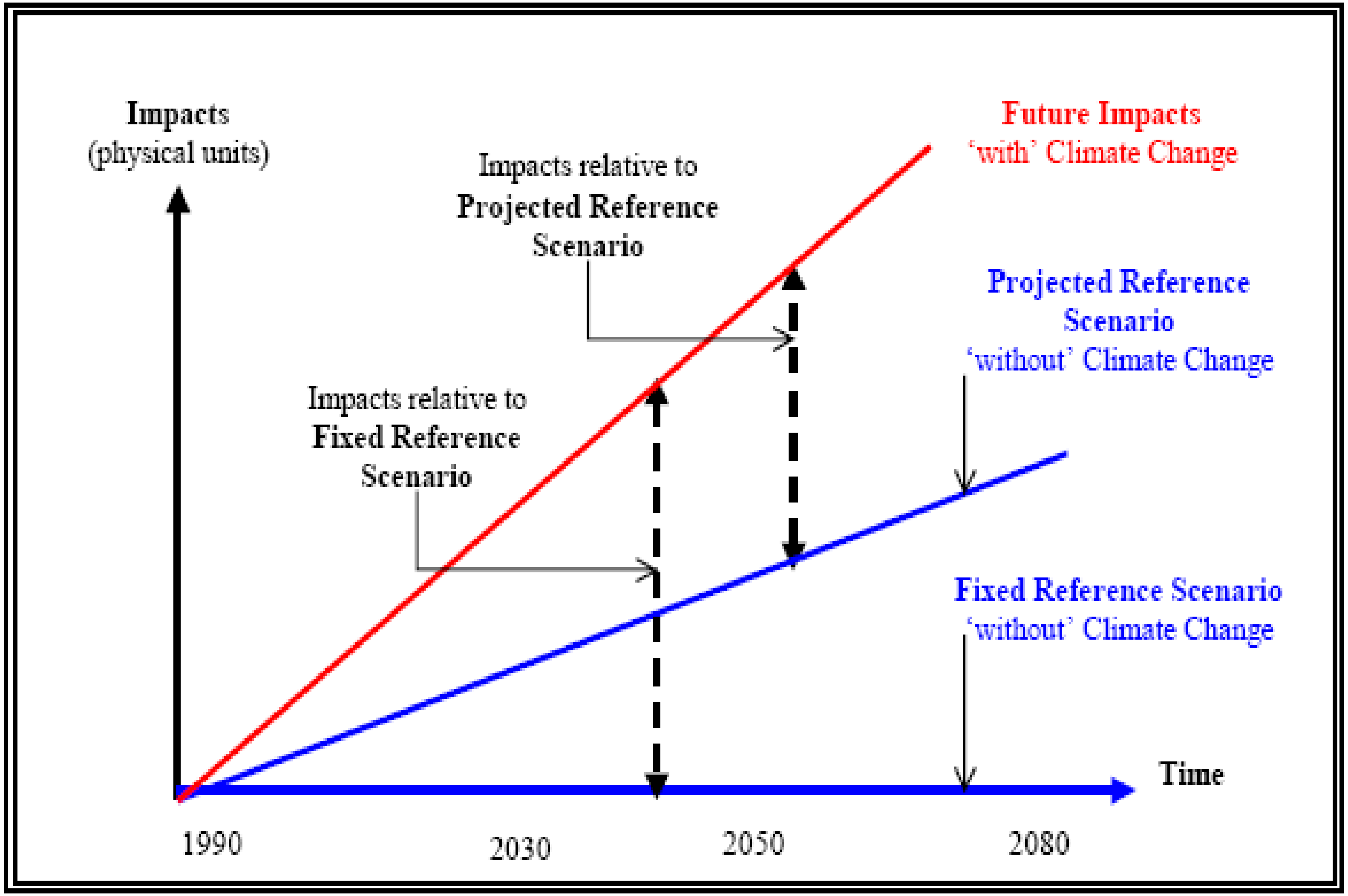
THE ECONOMICS OF CLIMATE CHANGE: METHODOLOGIES FOR COSTING THE IMPACTS

Rome July 2010

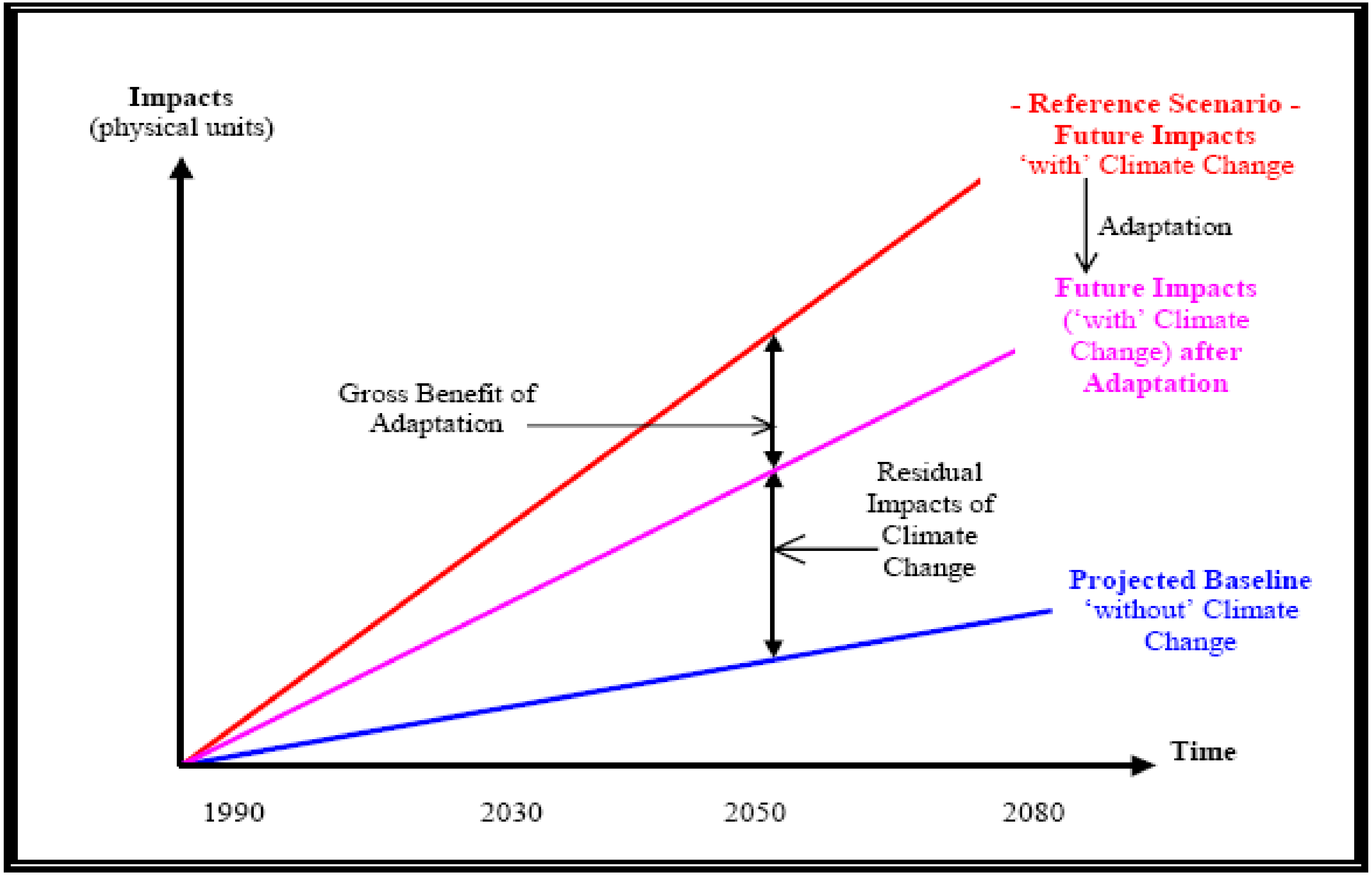
ISPRA Institute for Environmental Protection and Research

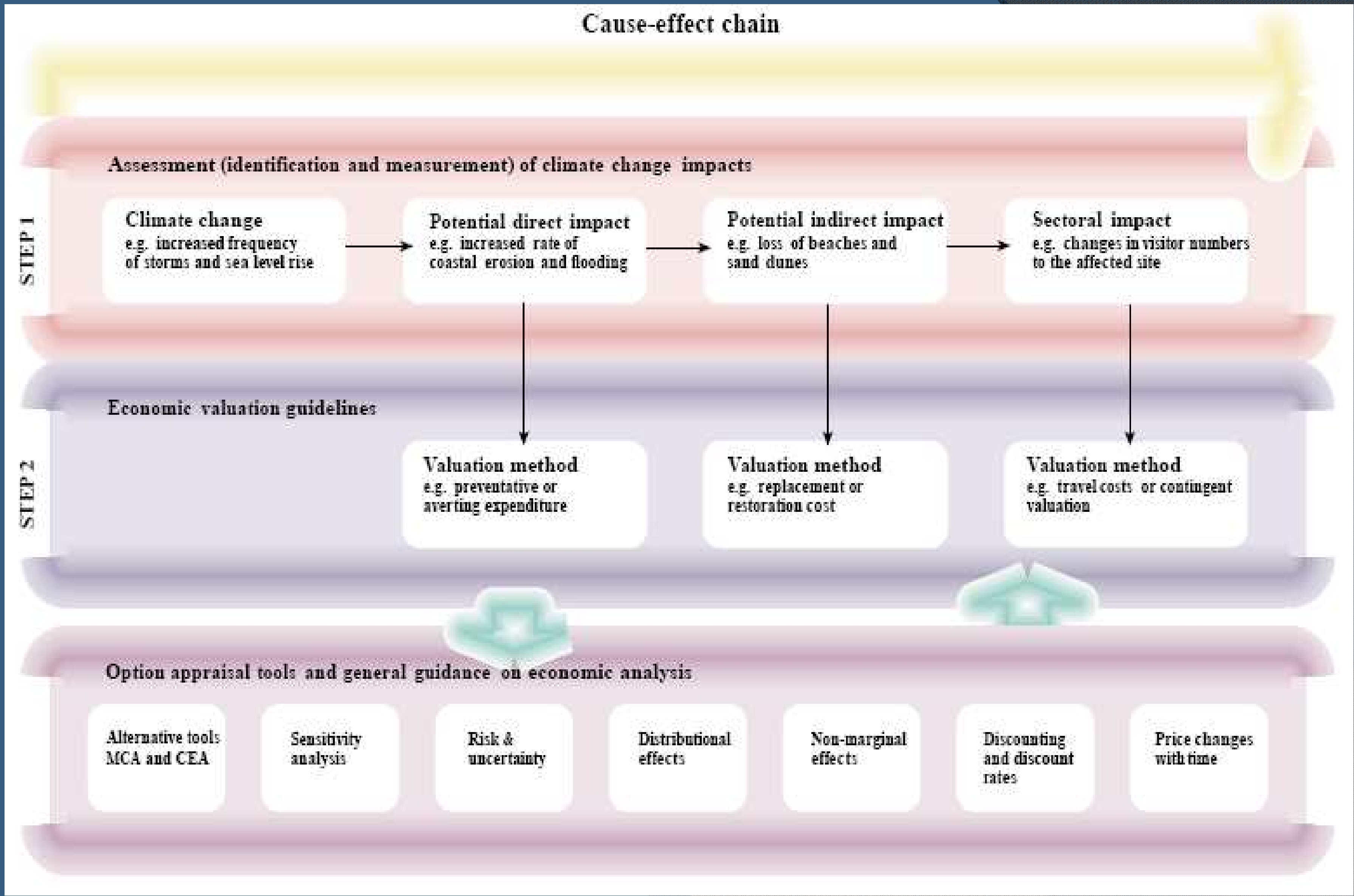
ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

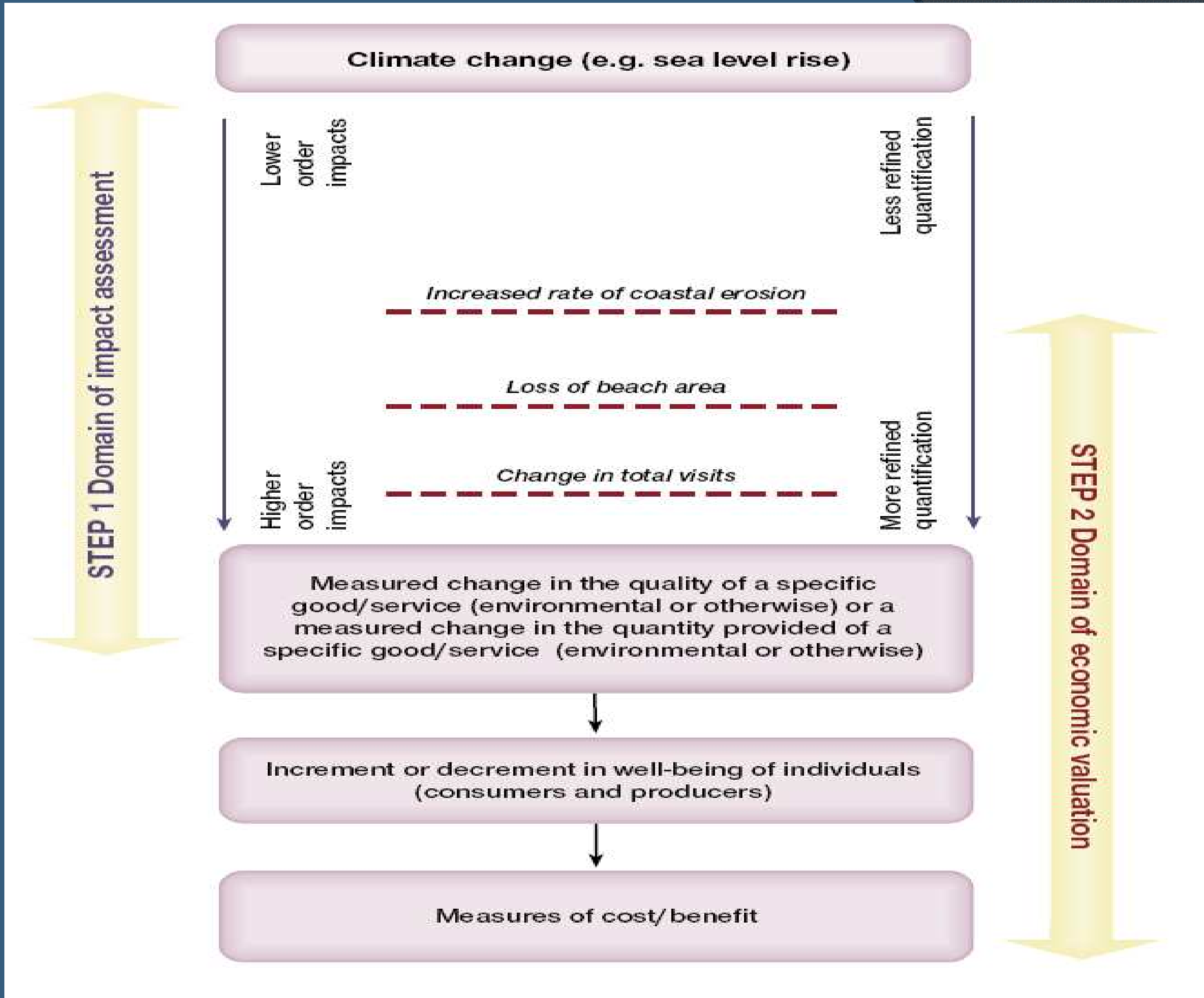
CLIMATE CHANGE RISK ASSESSMENT



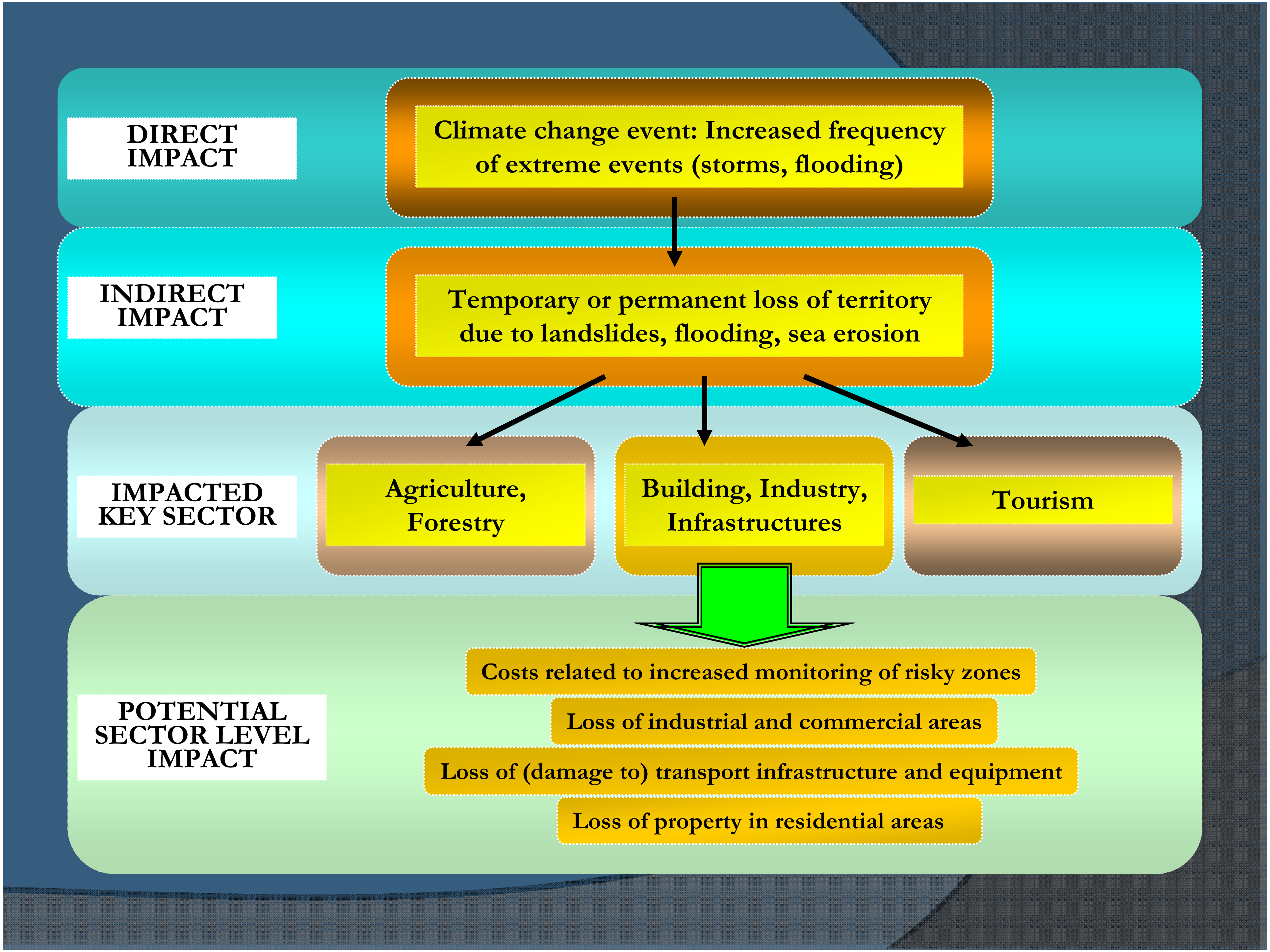
THE BENEFIT OF ADAPTATION

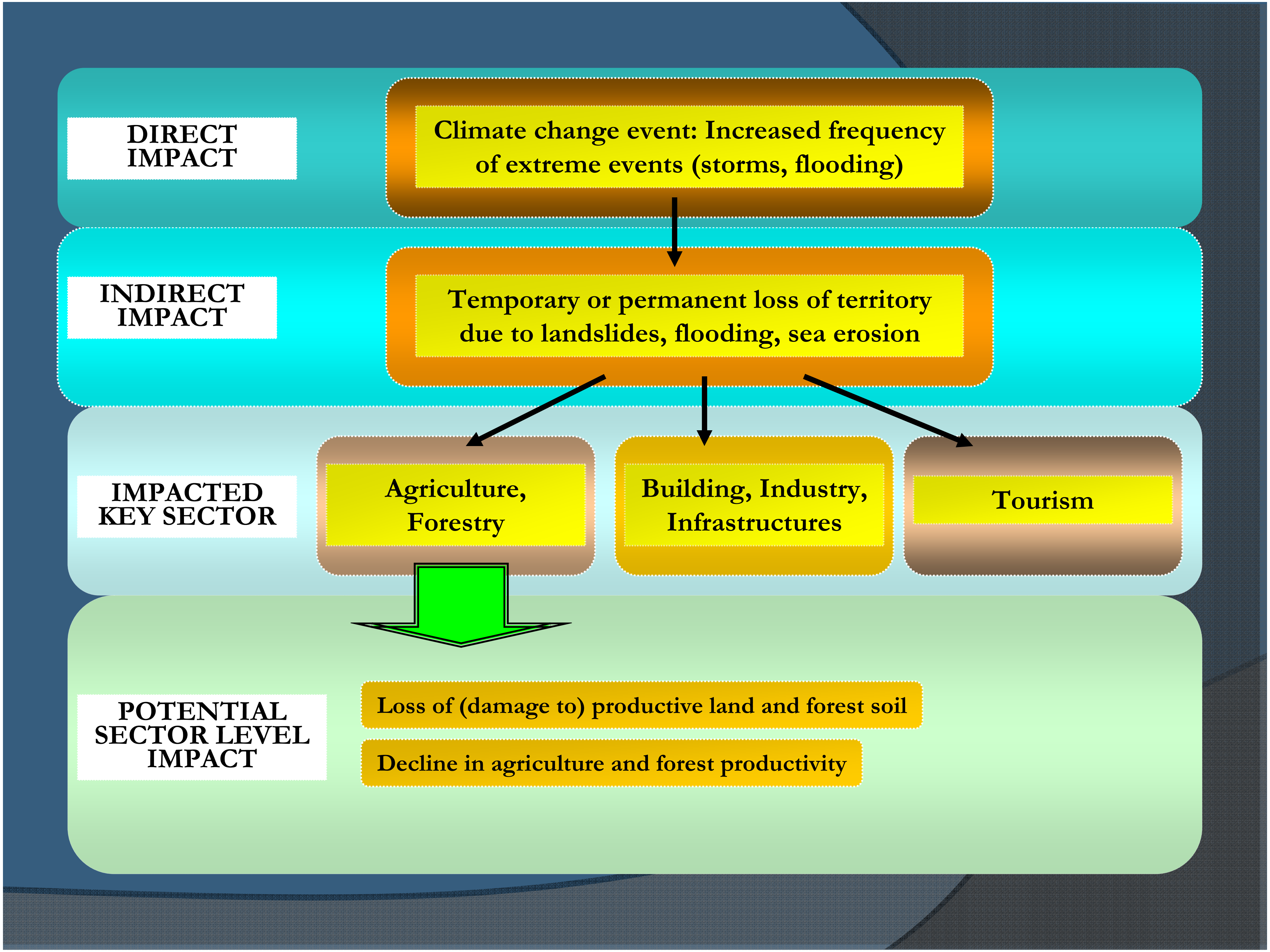



Cause-effect chain
STEP 1
Assessment (identification and measurement) of climate change impacts
Climate change
e.g. increased frequency of storms and sea level rise
Potential direct impact
e.g. increased rate of coastal erosion and flooding
Potential indirect impact
e.g. loss of beaches and sand dunes
Sectoral impact
e.g. changes in visitor numbers to the affected site
STEP 2
Economic valuation guidelines
Valuation method
e.g. preventative or averting expenditure
Valuation method
e.g. replacement or restoration cost
Valuation method
e.g. travel costs or contingent valuation
Option appraisal tools and general guidance on economic analysis
Alternative tools MCA and CEA
Sensitivity analysis
Risk & uncertainty
Distributional effects
Non-marginal effects
Discounting and discount rates
Price changes with time



Climate change (e.g. sea level rise)
STEP 1 Domain of impact assessment
Lower order impacts
Less refined quantification
Increased rate of coastal erosion
Loss of beach area
Change in total visits
Higher order impacts
More refined quantification
STEP 2 Domain of economic valuation
Measured change in the quality of a specific good/service (environmental or otherwise) or a measured change in the quantity provided of a specific good/service (environmental or otherwise)
Increment or decrement in well-being of individuals (consumers and producers)
Measures of cost/benefit


DIRECT IMPACT
Climate change event: Increased frequency of extreme events (storms, flooding)
INDIRECT IMPACT
Temporary or permanent loss of territory due to landslides, flooding, sea erosion
IMPACTED KEY SECTOR
Agriculture, Forestry
Building, Industry, Infrastructures
Tourism
POTENTIAL SECTOR LEVEL IMPACT
Costs related to increased monitoring of risky zones
Loss of industrial and commercial areas
Loss of (damage to) transport infrastructure and equipment
Loss of property in residential areas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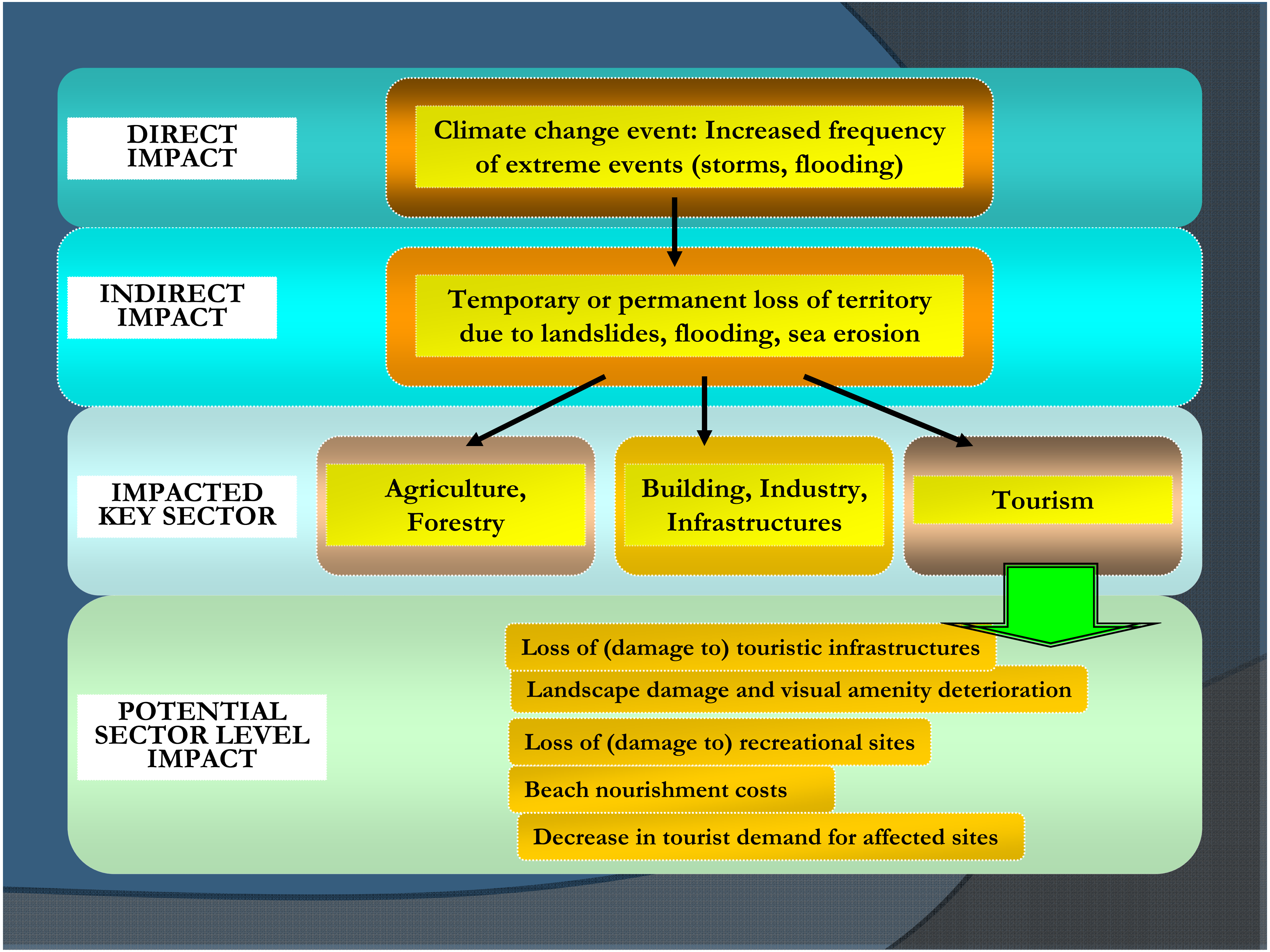
INDIRECT IMPACT
Temporary or permanent loss of territory due to landslides, flooding, sea erosion
IMPACTED KEY SECTOR
Agriculture, Forestry
Building, Industry, Infrastructures
Tourism
POTENTIAL SECTOR LEVEL IMPACT
Loss of (damage to) productive land and forest soil
Decline in agriculture and forest productivity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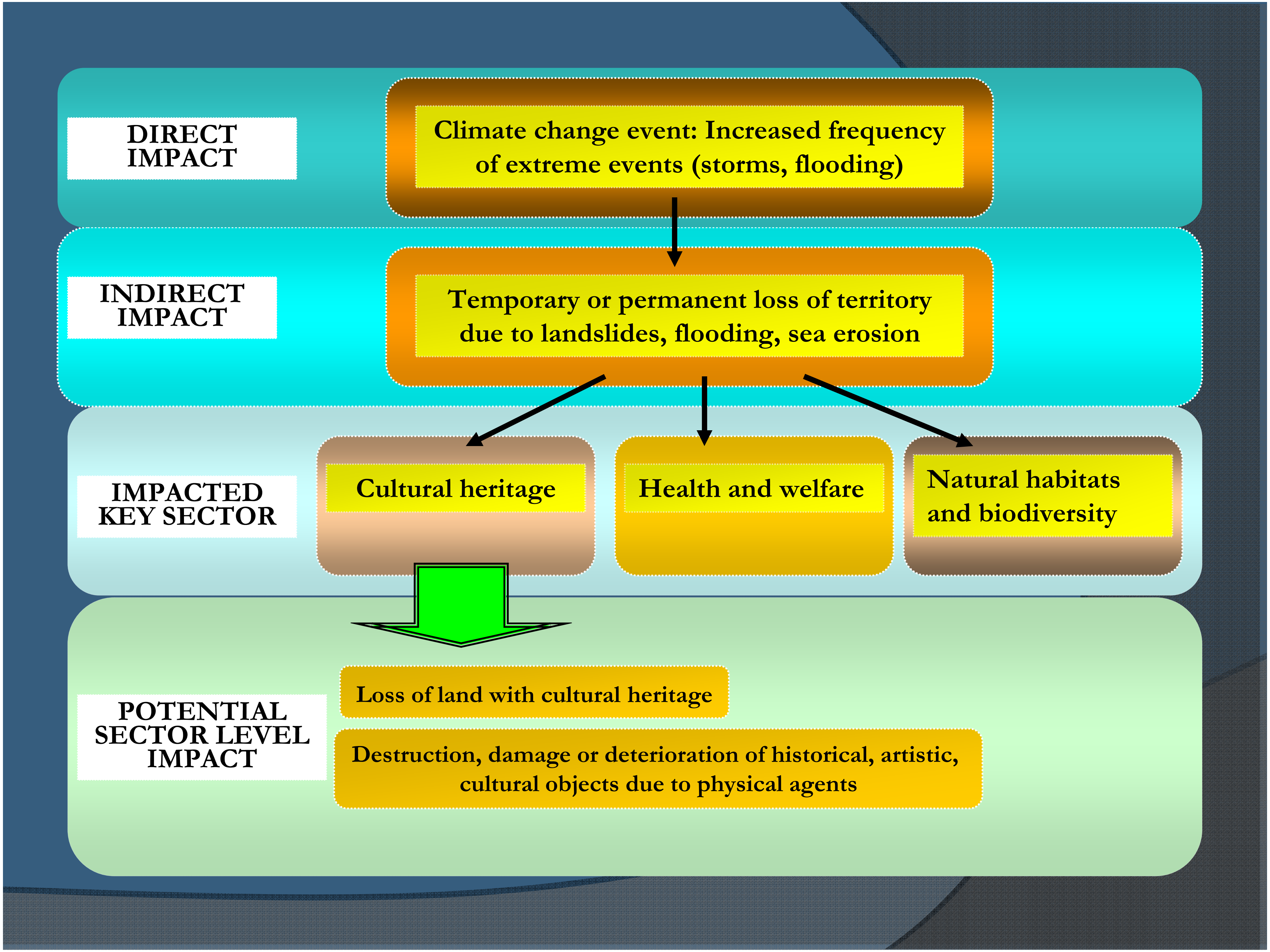
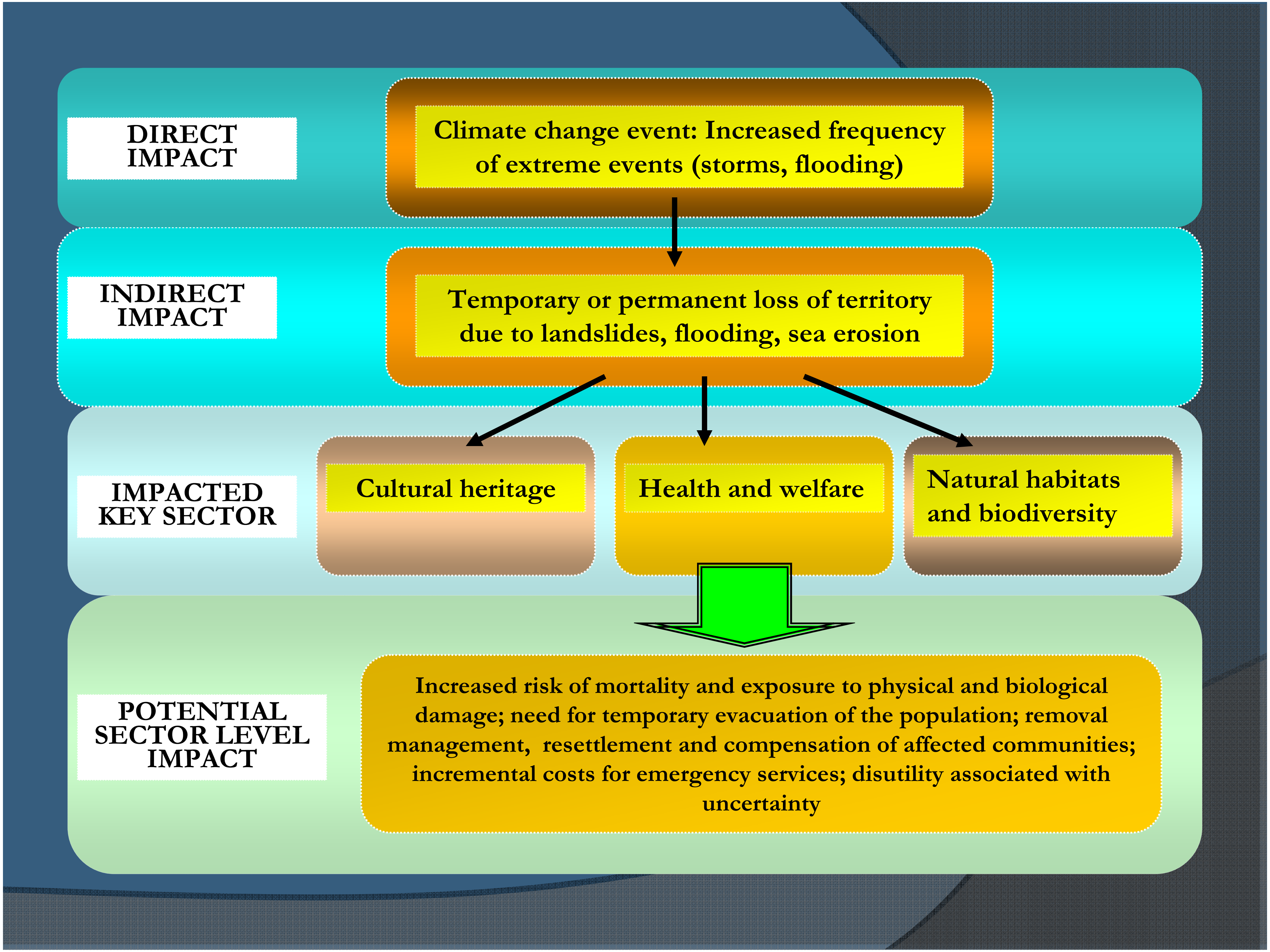
Temporary or permanent loss of territory due to landslides, flooding, sea erosion
IMPACTED KEY SECTOR
Agriculture, Forestry
Building, Industry, Infrastructures
Tourism
POTENTIAL SECTOR LEVEL IMPACT
Loss of (damage to) touristic infrastructures
Landscape damage and visual amenity deterioration
Loss of (damage to) recreational sites
Beach nourishment costs
Decrease in tourist demand for affected sites



DIRECT IMPACT
Climate change event: Increased frequency of extreme events (storms, flooding)
INDIRECT IMPACT
Temporary or permanent loss of territory due to landslides, flooding, sea erosion
IMPACTED KEY SECTOR
Cultural heritage
Health and welfare
Natural habitats and biodiversity
POTENTIAL SECTOR LEVEL IMPACT
Loss of land with cultural heritage
Destruction, damage or deterioration of historical, artistic, cultural objects due to physical agents


DIRECT IMPACT
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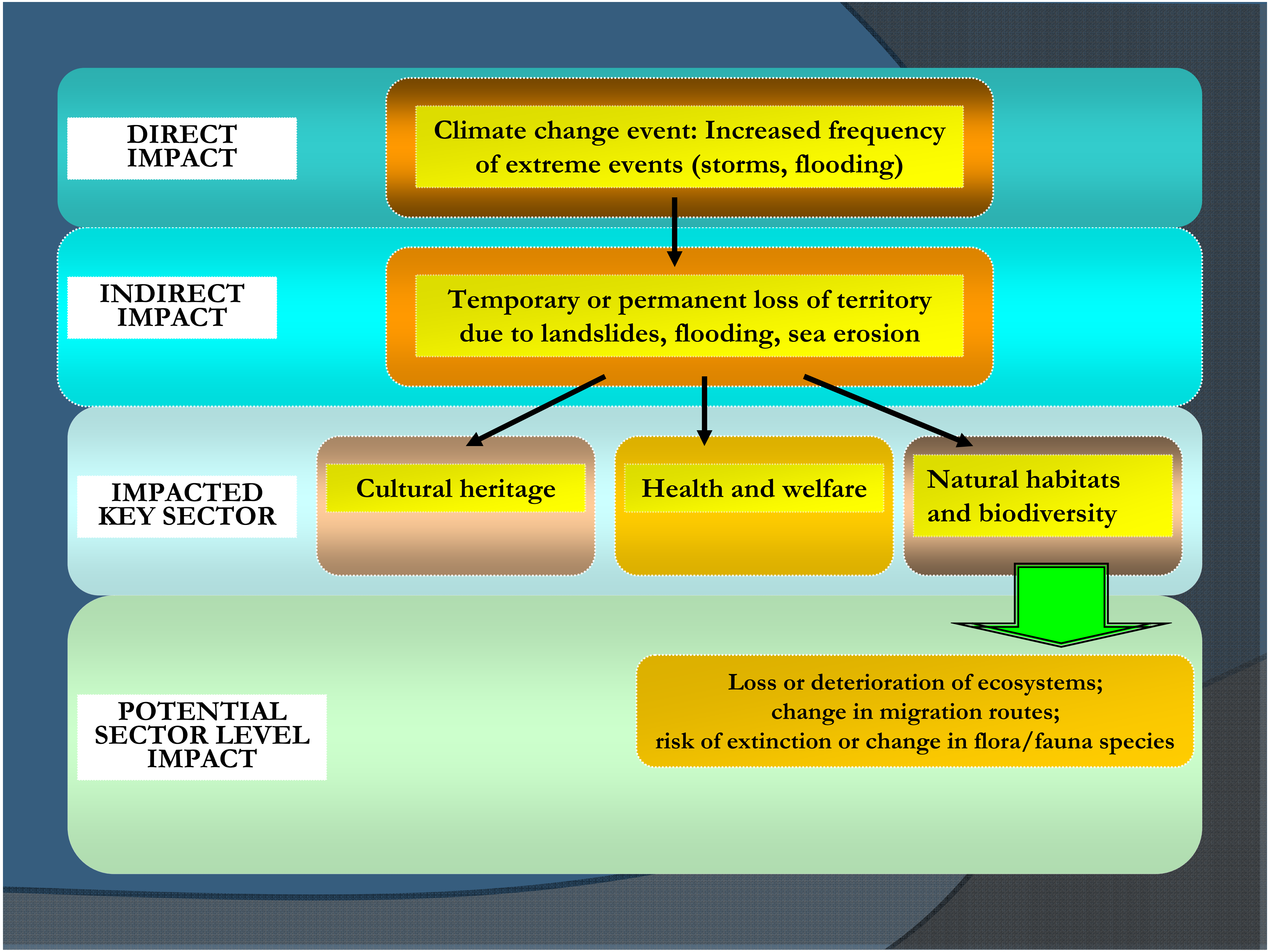
INDIRECT IMPACT
Temporary or permanent loss of territory due to landslides, flooding, sea erosion
IMPACTED KEY SECTOR
Cultural heritage
Health and welfare
Natural habitats and biodiversity
POTENTIAL SECTOR LEVEL IMPACT
Increased risk of mortality and exposure to physical and biological damage; need for temporary evacuation of the population; removal management, resettlement and compensation of affected communities; incremental costs for emergency services; disutility associated with uncertainty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Temporary or permanent loss of territory due to landslides, flooding, sea erosion
IMPACTED KEY SECTOR
Cultural heritage
Health and welfare
Natural habitats and biodiversity
POTENTIAL SECTOR LEVEL IMPACT
Loss or deterioration of ecosystems;
change in migration routes;
risk of extinction or change in flora/fauna species

SYSTEM BOUNDARIES

- ***general equilibrium analysis*** – required where the impacts of climate change on a market result in economic flow-on effects through the economy. General equilibrium analysis accounts for the inter-sectoral reallocation of resources (production factors and products) that could occur as a consequence of climate change. Essentially it simulates the supply and demand behaviour across the different markets in the whole economy. Thus, it is appropriate when the impacts of climate change are likely to affect simultaneously many sectors or markets and factor prices and incomes <u>on a large scale</u>

- ***partial equilibrium analysis:*** these techniques are most appropriately applied in the context of local or regional scale climate change impacts, disaggregated by sector or market; provide flexible and generally straightforward approaches to estimate the costs of climate change impacts on an industry or market, or for assessing the costs / benefits of alternative adaptation options. <u>Assumption:</u> any climate change impact will not have large, indirect (non-marginal) impacts, affecting the prices of a range of goods and services that flow through the macro-economy

Estimating the Economic Value of climate change impacts in partial equilibrium

The economic value of the climate change impact (€)

=

The estimated impact of climate change (physical units)

X

The economic unit value of the impact (€ per unit)

Conventional market-based techniques

They are concerned with the impacts of climate change on goods/services traded in conventional markets. The two main types of conventional market-based technique covered in the guidelines are: (1) **changes in the inputs or outputs** of marketed goods or services (including the change in productivity and production cost techniques); and (2) **cost-based methods** (including the *replacement cost* and *avertive expenditure* techniques). These techniques use market price data to value climate change impacts. These techniques facilitate the use of primary data, since such data should be available to the user.

Non-marketed goods/services techniques

The two types of technique used to value non-market goods/services are known in the technical literature as **revealed preference** and **stated preference** techniques, respectively

PROCEDURE	SUMMARY TERMS
Determine whether:	
Impacts can be measured and quantified	
AND	
Prices can be determined from market data	
If this cannot be readily done:	
Use 'willingness to pay' for a benefit	'willingness to pay'
determined by	
Inferring a price from observing consumer behaviour	'revealed preference' or a subset of this called 'hedonic pricing'
If this does not provide values, determine whether:	
Willingness to pay can be estimated by asking people what they would be willing to pay for that particular benefit	'stated preference'
or whether	
In the case of a cost: identifying the amount of compensation consumers would demand in order to accept it	'willingness to accept'

Changes in Inputs/Outputs (1)

In many cases the environment has a direct effect on:

♦ the capability of an economic agent (e.g. a fishery) to produce (provide) a good (service)

♦ the costs that the agent incurs in producing (providing) that good (service)

$$Q = f\{R, S(E)\}$$

Q = the quantity of fish commercially harvested,

f = the function that relates environmental quality to the quantity of fish harvested,

R = the amount of resources devoted to catching fish, and

S (E) = the stock of fish in the water body, which itself depends on the quality of the water body's environment (E)

If ΔE ⟶ (↓ S)

♦ If Q unchanged, then more resources to catching fish (↑ R).,e.g.: equal harvest rates buying additional fishing equipment, fish longer hours, etc.

♦ If R unchanged, the quantity of fish harvested to decrease (↓ Q)

Two different measures of the cost of the climate change-induced deterioration in environmental quality:

(1)the cost of the additional resource inputs (change in production cost)

(2) value of lost output (change in productivity)

Changes in Inputs/Outputs (2)

♦ **CASE 1** - changes in quantity do not result in changes in price;

♦ **CASE 2** - changes in quantity induce changes in price

CASE 1 – No Change in Prices

If the change in output - denoted by ΔQ - is small relative to the current total market for Q, or the change in resource inputs is small relative to the market for that variable factor of production, then we can assume that the output and resource input prices will remain constant after the change in Q or R. In this case, we can simply **multiply the expected change in output or inputs by market prices to derive a measure of the economic value** (V) of the projected change.

♦ For changes in productivity, we can calculate a **gross margin** (tot value of output minus variable costs) for each unit of output, then multiply this by the projected change in output
♦ For changes in **resource costs**, we can calculate the unit cost of variable factors, then multiply this by the projected change in resource use
♦ Alternatively, in both contexts, we can use **total (farm) budgets** (i.e. gross output minus gross input) for the 'with' and 'without' cases.
♦ In the case of productivity changes, we can also estimate changes in **land values** (per hectare) for the 'with' and 'without' climate change cases

Valuing Changes in Productivity Using Data on Gross Margins

$$gm_k = P_k^0 - VC_k^0$$

P_k^0 = the market price (adjusted, if necessary) for a unit of product k (the subscript '0' refers to the without climate change case), and

VC_k^0 = the variable costs of producing a unit of product k.

Then we multiply the projected change in output by the gross margin per unit – that is:

$$V = \Delta Q * gm = (Q_k^1 - Q_k^0) * gm_k$$

Vk = the economic value of the decrement (increment) in the output of product k ,

Q_k^0 = the projected output of product k in the without climate change case, and

Q_k^1 = the projected output of product k in the with climate change case.

Valuation Based on Changes in Resource Costs

$$V_i = \Delta R i * mc_i = (R_i^1 - R_i^0) * mc_i$$

V_i = the economic value of the decrement (increment) in production costs associated with the use of resource input i ,

mc_i = the adjusted marginal cost of resource input i,

R_i^0 = the projected use of resource input i in the without climate change case, and

R_i^1 = the projected use of resource input i in the with climate change case

Valuation Based on Total Budgets

$$f(Y_1,\ldots\ldots,Y_m;X_1,\ldots\ldots,X_n)$$

where Y_i is a set of feasible outputs i (e.g. cereals, crops, horticulture, livestock, etc.) and X j is a set of production inputs j (e.g. feed, seeds, fertiliser and lime, investments, etc.). The net margin (or net income) (which we denote by ' Z ') from producing a given set of outputs can be represented by:

$$Z=\sum_{i=1}^{m}\left(Y_i\times P_{yi}\right)-\sum_{i=1}^{m}\left(X_j\times P_{xj}\right)$$

where *P*yi is the adjusted price of output i and *P*xj is the adjusted price of input j.

Therefore, the cost (benefit) of an adverse (beneficial) climate change impact to producers is given by the change in net income margin – that is:

$$\Delta Z = Z_1 - Z_0$$

Valuing Changes in Productivity Based on Land Values

$$V_j = A_j * \Delta L_j^0 = A_j * (L^1{}_{j \to k} - L_j^0)$$

Vj = the economic value of the decrement (increment) in value of land use type j (e.g. agricultural or forestry land),

A j = the total affected area of land use type j (e.g. hectares of grazing land)

L_j^0 = the adjusted market price of land use type j in the without climate change case, and

$L^1{}_{j \to k}$ = the adjusted market price of land use type j in the with climate change case

Annualised / Capitalised value

CASE 2 – Induced Price Changes

If the change in output is large enough to affect market prices, then we must resort to the relevant supply and demand curves in order to value ΔQ.

In order to evaluate the induced change in price some information on the **price elasticity of demand** for the affected marketed good/service is needed

$$\xi = \frac{(\Delta Q / Q^0)}{(\Delta P / P^0)} = \left(\frac{\Delta Q}{\Delta P}\right) \times \left(\frac{P^0}{Q^0}\right)$$

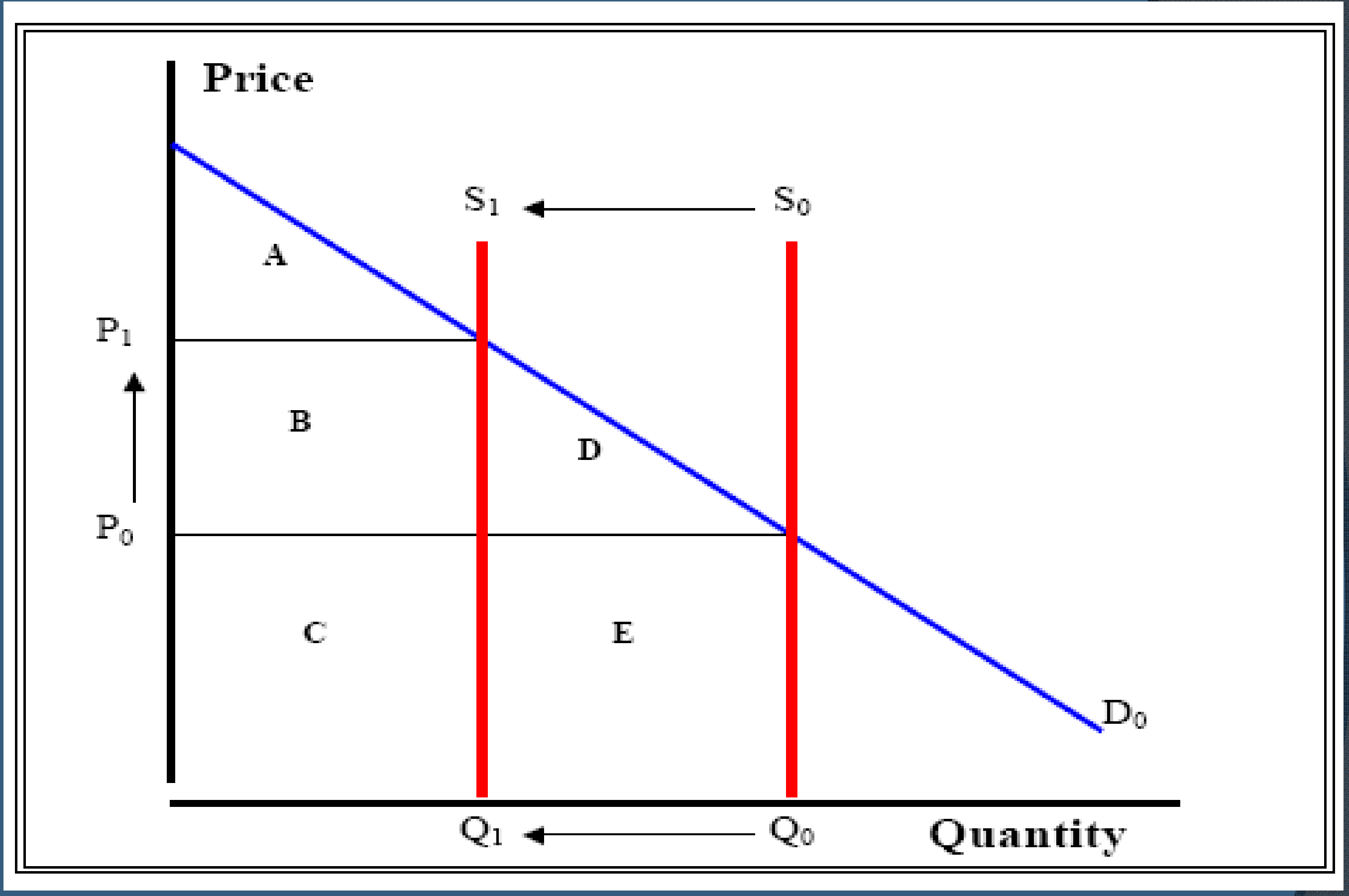
where $\Delta P = P^1 - P^0$ and $\Delta Q = Q^1 - Q^0$

Hence, given ξ, , Q^0 Q^1 and P^0, the above equation can be solved for ΔP, from which P^1 can be readily derived, since $\Delta P = P^1 - P^0$

In general, an induced change in price is likely to bring about changes in consumer and producer surplus. An example is given below. For the particular situation depicted in this example, the change in consumer and producer surplus - i.e. the economic value of the projected ΔQ - is:

$$Value\ \Delta Q = \frac{1}{2}(\Delta Q \times \Delta P) + (\Delta Q \times P^0)$$

Valuing a Change in Output When Prices Change



The net loss of ***consumer surplus*** is equivalent to the area **D**, while the net loss of ***producer surplus*** accruing to fishery operator is equivalent to the area **E**.

Cost-based Approaches

When the cost of a climate change impact cannot be measured directly – that is, the impact has no observable market price – we can base the valuation on supply or resource cost data

♦ **averting** or **preventative expenditures:** the cost of reducing or avoiding the climate change impact on the exposure unit before it occurs. the expenditure incurred in order to avert damage can be viewed as a surrogate demand for the current level of environmental quality. The environmental damage – in this case from climate change – can be assumed to be at least as much as the amount that the individual (or organisation) pays to avert the damage. E.g.: sea defence system

♦ **replacement costs** (**restoration costs** or **corrective expenditures**)**:** the cost of replacing the good or service provided by the affected exposure unit after the climate change impact has occurred

Preventative Expenditures (1)

Preventative expenditures are in fact ***adaptation costs***, so that the adaptation cost is used as a proxy for the impact cost (no use as a benefit in cost/benefit analysis)

Minimum estimate of the impact cost, since it does not include any measure of ***consumer surplus***

In some cases individuals will receive ***benefits from the averting behaviour*** over and above the costs incurred

The ***main advantages*** of the technique are that:

♦ preventative expenditures are common and are therefore likely to be a useful data source;

♦ it relies on observable – as opposed to hypothetical – market behaviour

Preventative Expenditures (2)
General Procedure

Step 1

Identify and quantify the climate change impact to be valued.

Step 2

Identify and estimate the expenditure incurred to avoid the climate change impact.

Step 3

If practical, indicate the value of any ancillary benefits that can be subtracted from the value estimate derived in Step 2.

Step 4

Calculate the total cost of the impact as follows:

total cost of the climate change impact (€)

=

the number of affected units

x

the preventative expenditure (€ per unit)

Replacement Cost (1)

The replacement cost technique assumes that the costs incurred in replacing productive environmental assets damaged through climate change can be measured, and interpreted as an **estimate of the benefits** that flow from the assets

Main advantages:

♦ replacement costs are **calculable** and that, as with the preventative expenditure approach;

♦ there are **no ancillary benefits** resulting from the expenditure unrelated to the climate change impact reversed

The replacement cost technique can be used to estimate the cost of both **marketed and non-marketed** climate change impacts, but relies on replacement measures being available, and the **cost of those measures being observable**.

Example: the replacement cost method is likely to be useful in costing the impacts of climate **change on building and infrastructure**, but **less applicable to habitat/biodiversity** or objects of **cultural heritage** which are essentially irreplaceable.

Replacement Cost (2)

General Procedure:

Step 1

Identify and quantify the climate change impact to be valued.

Step 2

Identify and estimate the expenditure incurred to replace (or restore) the asset damaged as a result of climate change.

Step 3

If practical, indicate the value of any ancillary benefits that can be subtracted from the value estimate derived in Step 2. In practice it is more straightforward to indicate their importance in qualitative terms.

Step 4

Calculate the total cost of the impact as follows:

total cost of the climate change impact (€)

=

the number of affected units

x

the replacement/restoration cost (€ per unit)

Relocation Cost Technique

The relocation cost technique is a variant of the replacement cost technique. Here, the actual costs of relocating a physical facility or household - because of changes in the quality of the environment – are also used to approximate the potential benefits of preventing the environmental change

e.g.: relocating a water intake from changing precipitation rates
Incremental cost of relocation – that is the difference between the total cost streams with and without the 'new' intake - can then be taken as a proxy for the value of the climate change impact on water resource supply

Shadow Projects

A particular type of replacement cost: estimate of the **cost of replacing the entire range of environmental goods and services** that are threatened by climate change (marketed and non-marketed)

Social cost of adaptation measures – that is, to include some of the externalities that arise from the implementation of selected adaptation projects: e.g. constructing a reservoir in order to improve water supply may entail the clearance of an area of woodland as externalities

Planting and maintenance costs of a ‘new’ woodland area, which provides the same output of goods and services as the original woodland, can be taken as a proxy for the foregone value of the original woodland

Surrogate and Constructed Market-based Approaches

These techniques value impacts either indirectly using the market price of surrogates for the affected good/service (e.g. **hedonic analysis** or **travel cost**) or based on values observed in hypothetical or constructed markets for the affected good/service (e.g. **contingent valuation**)

Analysts should generally consider using the **surrogate market** techniques to estimate values only when no markets for the cost or benefit exist.

Similarly, only when there is no evidence available from surrogate markets should evidence from **constructed markets** be used

it is unlikely that **primary studies** will generally be undertaken due to the **time**, **resources** and **expertise** that they require. Instead, each of the techniques is described in order to provide a basic understanding on how to use **benefit transfer**.

Hedonic Techniques

Environmental quality often affects the price individuals are willing to pay for certain goods/services (e.g. additional charge for rooms with a ‘sea view’)

Econometric models can be used to examine the contribution of specific ‘attributes, including environmental ones,’ to property prices or wage rates

Property value approach: is conducted on housing data and measures the welfare effects of changes in environmental goods or services by estimating the influence of environmental attributes on the value (or price) of properties.

Wage differential or **wage-risk approach:** the hedonic analysis is applied to wage data – to measure the value of changes in morbidity/mortality risks – it is often referred to as the “compensating”

Hedonic Property Value Approach (1)

STEP 1 – Estimate a Hedonic Property Price (or **implicit price**) Function

$$P_h = f\,(S, N, E)$$

P_h = the market price of the property
f = The function that relates the house characteristics to price
S = The different structural characteristics of the property
N = The different neighbourhood characteristics of the property
E = The different environmental attributes of the property

Fixing the level of all the structural characteristics of a property and the neighbourhood characteristics, we are able to focus on the relationship between the **property price** and the **environmental attribute**

The estimation of a hedonic price function is usually done using a multivariate regression technique. Data are taken either on a small number of similar residential properties over a period of years (**time series**), or on a larger number of diverse properties at a point in time (**cross section**), or on both (**pooled data**).

Hedonic Property Value Approach (2)

STEP 2 – Derive the Marginal WTP Function

By partially differentiating the estimated hedonic property price function with respect to E we obtain the **implicit price** (or **marginal WTP function**) of the environmental attribute – that is

$$\frac{dP}{dE}$$

This **partial derivative** is interpreted as the price paid by the household for the last unit of the environmental attribute, purchased by choosing a given property instead of another one with a unit less of the environmental attribute, other things being equal

As such, the **marginal WTP function** represents each household's benefit from a marginal improvement in E, and it cannot be used in general to determine a non-marginal change in E

Each marginal WTP function represents only one observation on the relevant inverse demand curve – from which measures of consumer surplus for changes in E are derived

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Hedonic Property Value Approach (3)

STEP 3 – Estimate the Inverse Demand Curve

A ‘second stage’ regression is required to identify the **relevant inverse demand curve,** that is found by regressing the marginal WTP function on the observed quantities of E and some socio-economic characteristics of households – e.g. income, size, etc. .

STEP 4 – Estimate the Change in Consumer Surplus

The area under the **inverse demand curve** - between two levels of E - represents the average change in consumer surplus caused by the expected change in E. By aggregating the **consumer surplus of all households** we obtain the overall value of the change in E.

The ‘second stage’ regression requires a large amount of data from several housing markets – data which are often not available or expensive to obtain. Thus in practice, only the first stage of the process is usually carried out, and the resulting cost-benefit estimates treated as first approximations

Wage Differential Approach

The hedonic wage function:

$$W = f\ (Q, X, R)$$

W = Wage rate in each occupation
Q = Qualifications/skills of worker
X = Job attributes such as unionisation, desirability, etc
R = Workplace risk, e.g. risk of death

The partial derivative of this function with respect to R is the wage premium for accepting an additional risk of 1 death more (value of a prevented fatality - VPF)

Strengths/Weaknesses of Hedonic Analysis

- The method is versatile: to be adapted to environments with similar demand and supply characteristics
- The results of hedonic studies are sensitive to the econometric assumptions adopted (the empirical results depend critically on the functional form selected)
- Studies require a considerable amount of data, which may be difficult and expensive to collect; such studies tend to be very time-consuming

TRAVEL COST (1)

Information on visitors’ total expenditure to visit a site is used to derive their demand curve for the services provided by the site

The fundamental insight that drives this model is that if a consumer wants to use the (recreational) services of a site, he has to visit it

The travel cost to reach the site is considered as the implicit or the surrogate price of the visit, and changes in the travel cost will cause a variation in the quantity of visits

TRAVEL COST (2)

The basic (zonal) travel cost model defines a trip demand curve for a given recreational site from zone j as:

$$\frac{V_j}{P_j} = f(TC_j, X_j)$$

where

V_j = the total number of trips by individuals from zone j to there creational site per unit of time,

P_j = the population of zone j ,

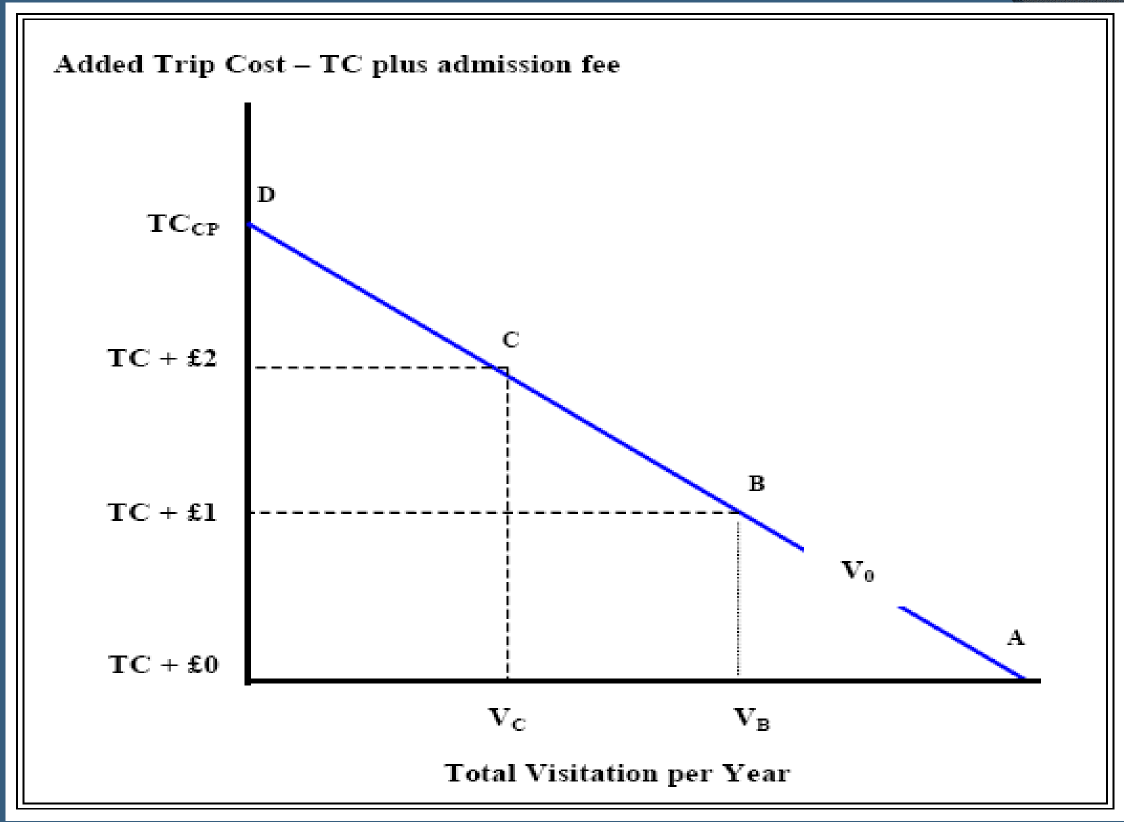
f = the function that relates travel cost and socio-economic characteristics to visitation rates,

TC_j = the travel cost from zone j to the recreational site

X_j = the socio-economic characteristics of the population of zone j , which include, amongst others, factors such as income levels, spending on other goods, the existence of substitute sites, entrance fees and quality indices of n substitute sites.

The above equation is estimated using regression analysis

Demand Function based on Travel Cost



This leads to the creation of a so-called '**whole experience**' demand curve based on visitation rates and not the number of actual visits made. To estimate the **consumer surplus** accruing from the site, the 'whole experience' demand curve is used to estimate the actual number of visitors and how the numbers would change subject to increases in 'admissions fees'

Contingent Valuation Method (1)

In contrast to the valuation techniques described above, which use observed data, the contingent valuation method (CVM) relies on **structured conversations** to elicit directly the values that respondents place on some, usually non-marketed, goods or services

The basic notion underpinning contingent valuation (CV) is that a **realistic, yet hypothetical, market** for buying or selling the use and/or preservation of a good/service can be described in detail to an individual.

Individuals are then asked to participate in this hypothetical market, by **responding to a series of questions**

Contingent Valuation Method (2)

Expressing Preferences in CV Studies

An individual can be asked to express his or her subjective valuation of possible (environmental) changes in different ways: Improvement

The value of the improvement can be measured either by:

- ♦ The individual's WTP to obtain the improvement;
- ♦ The individual's WTA compensation to forgo the improvement

The value of the damage can be measured either by:

- ♦ The individual's WTP to avoid the damage;
- ♦ The individual's WTA compensation to consent the damage

Contingent Valuation Method (3)

The main features of the hypothetical or constructed market include:

♦ A **detailed description** of the good/service being valued (before and after)
♦ A detailed description of the **'payment vehicle'**
♦ The **procedure to elicit** the respondent's valuation. The actual valuation can be obtained in a number of ways, for example by asking the respondent to name an amount, or by having them choosen from a number of options, etc..

Strengths/Weaknesses of the Contingent Valuation Method

Asking individuals **hypothetical questions only provides you with hypothetical answers**, which cannot be meaningfully used to value environmental quality changes

In addition survey-based research is **expensive** and **time-consuming**