
# The **CLIMSAVE** Project

## Climate Change Integrated Assessment Methodology for Cross-Sectoral Adaptation and Vulnerability in Europe

# Report on the development of the conceptual framework for the vulnerability assessment

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October 2010

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## 1. Introduction

In order to develop a vulnerability and adaptation framework for the CLIMSAVE project, a comprehensive literature research was carried out. We reviewed more than 70 papers, journal articles and book chapters to deepen our knowledge concerning terms such as adaptation, adaptive capacity, vulnerability, resilience, etc. and to identify the relations between those elements.

The key findings of this literature research were collected in a matrix, which served as a solid basis for our further work. Based on the findings of the literature review we outlined a vulnerability framework in which we related those key terms to each other.

This report provides the selected definitions, the conceptual framework for the CLIMSAVE project and an explanation of the framework.

## 2. Definitions

This section provides a set of definitions based on the literature review and on the discussions at a CLIMSAVE Workshop in Brussels in June 2010. These definitions are used further within the framework. Each term is defined first in a rather broad and abstract way. The related bullet points indicate in more detail how we understand the specific terms in the CLIMSAVE framework.

There is a huge amount of literature on vulnerability with countless definitions. In this short paper we present a selection of definitions that can be operationalized within the CLIMSAVE project.

**DRIVERS:** A driver is any natural or human-induced factor that directly or indirectly causes a change in an ecosystem (MEA, 2003).

- A **direct driver** unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy.

- An **indirect driver** operates more diffusely, often by altering one or more direct drivers, and its influence is established by understanding its effect on direct drivers.

- In CLIMSAVE the following definition of drivers is most relevant: *"the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns"* (Gabrielsen and Bosch, 2003, 117 pp. 8, EEA, 2007, p. 13).

**PRESSURES** induce environmental change (Impacts). Usually these changes are unwanted and are seen as negative (damage, degradation, etc.). According to the EEA, pressures are "*developments in release of substances (emissions), physical and biological agents, the use of resources and the use of land by human activities*" (Gabrielsen and Bosch, 2003, Maxim et al., 2009).

- In CLIMSAVE we distinguish between endogenous pressures (which appear from inside the human-environment system being studied) and exogenous pressures (which appear from the outside of the human-environment system).

**VULNERABILITY:** The broadest definitions of vulnerability consider it to be a function of exposure, sensitivity and coping capacity (see, for example, Birkmann (2006) who examines more than 25 different definitions, concepts and methods to systematise vulnerability).

- Broadly speaking the vulnerability of a system, population, or individual to a threat relates to its capacity to be harmed by that threat. **It is essential to stress that we can only talk meaningfully about the vulnerability of a specified system[1] or exposure unit to a specified hazard or range of hazards (Adger et al. 2005).**

- Vulnerability is a **dynamic characteristic** – a function of the constant evolution of a complex of interactive processes (Adger et al. 2005).

- Fraser (2009) concludes that the way forward in vulnerability research is to combine an ecosystems resilience approach with an entitlements approach.

- Other authors, such as Vogel and O'Brien (2004), stress that vulnerability is multidimensional and differential (varies among and within social groups), scale-dependent (time space and units of analysis) and dynamic.

- Hence, potential impacts (the resultant of exposure and sensitivity) and adaptive capacity constitute a region's vulnerability. In the A-TEAM project[2] vulnerability was assessed as the degree to which an ecosystem service is sensitive to global change, plus the degree to which the sector that relies on this service is unable to adapt to the changes.

- In the CLIMSAVE project the vulnerability of a specified human-environment system will be assessed by considering the exposure of the system to pressures and the availability of coping capacity.

[1] A system consists of a (larger) number of elements and their characteristics as well as the relationships between these elements and interactions with the surrounding environment. A system is a whole and as such can be delimited from its surroundings. The relationships between its elements manifest themselves by the exchange of material, energy, or information and are decisive for the structure of the system. We talk about two groups of the Earth subsystems: natural systems and socio-economic systems or mixed systems. Some examples of natural systems are: oceans, forests, deserts, ponds, or even atoms. Socio-economic systems are systems founded by people, such as economic or political systems, businesses, cities, regions, or the European Union. In socio-economic systems, people (inter)act. These systems have artificial boundaries and are also defined by humankind. Socio-economic systems are able to learn; they can set and also change goals when adapting to new conditions within the above-mentioned structures and rules. The individuals in socio-economic systems - the people, that is - think about their behaviour, relate with others, and reflect on their actions and the consequences of their actions. They are also able to turn a crisis into a learning opportunity and become better able to cope with similar situations in the future (Jäger 2008).

[2] http://www.pik-potsdam.de/ateam/

**EXPOSURE** is the degree, duration, and/or extent in which the system is in contact with, or subject to, the perturbation (Gallopìn 2006).

- Exposure …is dependent … on the attributes of the climate stimulus (adapted from Smit and Wandel, 2006).

- In the CLIMSAVE project, exposure is the link between the pressures and the five types of capital available in the human-environment system or exposure unit. It refers to the amount of exposure of the system to the pressures and is characterized by the degree, duration, nature and/or extent to which the system is in contact with, or subject to, the pressure.

**EXPOSURE UNIT** (Study Unit) [is] the system considered to be at danger, and may be defined in terms of geographical extent, location and distribution of a variety population of receptors at danger (UKCIP Glossary 2003).

- A system or exposure unit may be a region, population group, community, ecosystem, country, economic sector, household, business or individual (Adger et al. 2004).

- In the CLIMSAVE project, an exposure unit is a human-environment system.

**COPING** is defined as the manner in which people and organizations use existing resources to achieve various beneficial ends during unusual, abnormal, and adverse conditions of a disaster event or process (European Spatial Planning Observation Network, in: Levina and Tirpak, 2006).

- Up to a certain threshold the outcomes of climate change variations are beneficial or negative but tolerable, so a system can cope with them. Beyond these thresholds a system is vulnerable.

**COPING CAPACITY** can be increased with adaptation measures while adaptive capacity already includes coping capacity plus possible adaptation measures and cannot be increased beyond a certain point (Levina and Tirpak 2006).

- [Coping] capacity can be an inherent property of the system, i.e. it can be a spontaneous or autonomous response.

- In the CLIMSAVE framework the inherent property of the socio-economic system is the coping capacity. It depends on the amount of capital that can be deployed quickly to cope with exposure to pressures.

**ADAPTIVE CAPACITY** is the ability of a human-environment system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2007).

- Adaptive capacity is the **potential** of a human-environment system to adapt. Adaptive capacity can be transformed into adaptation which can lead to enhanced coping capacity. A system often requires time to realize its adaptive capacity as adaptation.

- Adaptive capacity can only diminish *future* vulnerability. Adaptive capacity has no direct implications for current vulnerability (Brooks 2003).

- General adaptive capacity, for example, can be seen as a function of wealth, population characteristics such as demographic structure, education and health; organizational arrangements and institutions and access to technology; and equity, to name only the most salient variables (Burton et al., 2009).

- In most of the literature there is no distinction between adaptive capacity and coping capacity – but they are not necessarily equivalent and the relationship between them will depend on the nature of the hazard in question. Successful coping does not necessarily equate to adaptation, although lessons learned from a hazard event may result in the implementation of adaptation measures designed to increase the coping capacity of the system to similar future hazards (Adger et al. 2005).

- The principal determinant of a society's capacity to adapt to climate change is likely to be access to resources. As such access is determined by entitlements, which are often the product of external political factors, it makes sense to include in our construction of an index of adaptive capacity factors representing processes operating at the super-national scale but which have consequences at the sub-national level. Poverty, inequality, isolation and marginalization can all undermine entitlements of individuals and groups (Adger et al. 2005). The capacity to adapt, that most fundamental aspect of human behaviour is, by its opportunistic nature, so situation-specific and dynamic that predictive understanding may be extremely difficult to achieve. It may well prove impossible to model the adaptive process from "first principles" with the science of adaptation limited to description and eschewing prediction, an interesting philosophical dilemma (Adger et al., 2005).

- According to the IPCC TAR, factors that determine adaptive capacity to climate change include economic wealth, technology and infrastructure, information, knowledge and skills, institutions, equity and social capital.

- Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancement of adaptive capacity reduces [future] vulnerabilities and promotes sustainable development (Smit and Pilifosova 2001). Alternatively, adaptive capacity may depend upon policy, planning and design decisions carried out in response to, or in anticipation of, changes in climatic conditions (adapted from Willows and Connell 2003).

- In the CLIMSAVE project adaptive capacity refers to the potential of the human-environment system to adapt in the face of exposure to pressures and depends on the availability of capital (social, financial, natural, human and physical capital) to do so.

**RESPONSES:** Faced with a change in ecosystem services, the humans in the exposure unit can **adapt** by improving their coping capacity in order to be more resilient to the pressures, or they can **mitigate** by reducing the pressures and/or drivers of change.

- In the CLIMSAVE project the focus is on adaptation. Mitigation in the form of reducing exogenous pressures or drivers of change are not considered explicitly in the

CLIMSAVE project, although they could certainly be part of the scenario narratives and thus provide context for the assessment of vulnerability hotspots.

**Adaptation** is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented. (UNDP 2005 in: Levina and Tirpak, 2005)

- Different types of adaptation can be distinguished (Lemmen et al. 2008):
  - based on intent: autonomous (scale dependent definition) or planned adaptation;
  - based on timing (relative to climate impact): reactive, concurrent or anticipatory adaptation;
  - based on temporal scope: short term or long term adaptation;
  - based on spatial scope: localized or widespread adaptation.

- Adaptation to climate change can be reactive or pro-active. Reactive adaptation to climate change is a process of gradual coping. Pro-active adaptation involves planned action aimed at preparing for climate change and its possible adverse impacts, in an attempt to minimize those (Abramovitz et al., 2002).

- Planned adaptation refers to realized adaptive capacity that aims at enhancing coping capacity of socio-economic systems or at increasing resilience of biophysical systems. If more hazards occur, a greater adaptation effort is required in order to decrease socio-economic vulnerability.

- In general it is possible that although the adaptation effort is strong and comprehensive measures are implemented, the adaptive capacity can be depleted, which leads to an increasing social vulnerability.

- Adaptation depends upon the capacity of systems to adapt, and also on the will or intent to deploy adaptive capacity to reduce vulnerability. The mere existence of capacity is not itself a guarantee that it will be used (Burton and Lim, 2005).

- Adaptation is the process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change (UK Climate Impact Program, UKCIP, 2003).

- Adaptation is adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability. Adaptation is important in the climate change issue in two ways - one relating to the assessment of impacts and vulnerabilities, the other to the development and evaluation of response options (Smit and Pilifosova 2001).

- In the CLIMSAVE project adaptation is the process by which capitals are deployed to improve the capacity to cope with the exposure to future pressures on the human-environment system.

**Mitigation** is the *"anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases"* (IPCC, 2002, p. 69). Any reduction of greenhouse gas emissions, for example, contributes to a mitigation or at least deceleration of climate change, which reduces threats and pressures on humans and non-humans.

**CAPITALS:** The word "capital" is used to describe a stock of anything from which anyone can extract a revenue or yield (Porritt, 2006).

**Natural capital:** The term natural capital developed in the late 1980s as an attempt by ecological economists to frame the natural resource stock within economic terminology.

- As a very basic definition, Pearce (1992, in Stern 1995) states that many authors agreed to use the term for "*the aggregate of natural resource stocks that produce inputs of services or commodities for the economy. Some of the components of natural capital may be renewable resources."*

- Ekins et al. (2003) emphasize that those resource stocks extend the mere concept of "land" and include various renewable and non-renewable dimensions that create life-supporting functions and services. Examples for these are the life support functions provided by biological diversity or the ozone layer (MacDonald et al. 1999).

- Daly (1994, in MacDonald et al. 1999) puts emphasis on natural capital as a stock as opposed to the resulting goods and services, which are characterized as flow.

- Another critical differentiation to the definition of the concept was added by Beckley et al. (2002), who included a time perspective and the focus on natural capital that is considered *important* for the economy. "*Historically, the only natural capital assets that really counted were those that were combined with labour to create commodities. Today, wealth is also generated by combining labour in the form of services with amenity dimensions of natural resources. As well, environmental services provided by natural resources are receiving increased recognition."*

- Porritt (2006) defines natural capital as any stock or flow of energy and matter that yields valuable goods and services. This includes resources, some of which are renewable (e.g. timber, grain) and others that are not (the most well-known these days being fossil fuels). Natural capital also includes sinks that absorb, neutralize or recycle waste. In the CLIMSAVE framework this definition of natural capital is used.

**Manufactured capital:** Highly discussed in its relation to natural capital is manufactured capital, which is sometimes also referred to as physical capital.

- *"Manufactured capital comprises material goods - tools, machines, buildings, infrastructure - which contribute to the production process but do not become embodied in the output and, usually, are 'consumed' in a period of time longer than a year. Intermediate goods, in contrast, are either embodied in produced goods (e.g. metals, plastics, components) or are immediately consumed in the production process (e.g. fuels)"(Ekins et al. 2003).*

- Karvonen (2001) is less strict about the time perspective and uses the term "*accumulation...such as technologies, productive facilities and products*" in the definition.

- Whereas economic schools of thought often see manufactured capital as a substitute for natural capital, there is increasing acknowledgement by ecological economists that the two types complement each other (Costanza and Daly 1992; Holling and Meffe 1996).

- Based on the definition of Porritt (2006), the CLIMSAVE framework uses manufactured capital defined as consisting of material goods - tools, machines, buildings and other forms of infrastructure - that contribute to the production process but do not become embodied in its output.

**Financial capital:** *"Financial capital is the liquid assets…(both public and private), including municipal budgets, individual and household savings, and business cash flow and operating funds." (Beckley et al. 2002).*

- Together with manufactured capital, it is often included in the term economic capital (Williamson et al. *in press*).

- Coming from organizational theory, the following statement regarding the necessity of financial capital by Cooper et al. (1994) seems crucial also for vulnerability to climate change: *"...the availability of financial capital can affect the performance [of the venture] by creating a buffer against random shocks and by allowing the pursuit of more capital-intensive strategies, which are better protected from imitation".*

- The value of financial capital is created the moment it is spent: it does not have an intrinsic value and it is lost if it is given away (Hargreaves 2001).

- Depending on the level of analysis, the financial capital may be productive for the financial capital holder (via interest, dividends... the proceeds of others investing in other forms of capital) and also it can have a flow of insurance value / option value (the comfort of knowing you can use the financial capital if trouble strikes - or, in the absence of financial capital, the angst associated with not knowing how you would cope). Thus it is not totally unproductive. On the other hand, it is merely a 'claim on resources' or shows an 'entitlement'.

- Thus, using the definition of Porritt (2006) for the CLIMSAVE project, financial capital reflects the productive power of the other forms of capital and enables them to be owned and traded.

**Human capital:** *"The concept of human capital is rooted in economic theory and refers to the education, job experience, acquired skills, and the health of individuals"* (Johnson and Stallman, 1994 in Beckley et al. 2002).

- Most economists focus on the learning aspects of human capital and use the assumption that learning capacities are comparable to other natural resources involved in production processes as a basis for this approach (see e.g. Livingstone 1997, Beckley et al. 2002). Learning happens either formally or informally and can be

expressed in various dimensions (e.g. leadership skills, life experience, and tacit knowledge).

- Hudson (1993, in Bontis and Fitz-enz 2002) defines human capital as a combination of "*i) genetic inheritance; ii) education; iii) experience; and iv) attitudes about life and business"*.

- Independent of its sources and ways of expression, Bontis and Fitz-enz (2002) narrow human capital down to "*the sheer intelligence of the organizational member."* Human capital, as opposed to social capital (see below) refers to individual ability independent of the actual opportunity to use it (Burt 1997).

- For the CLIMSAVE project, human capital will be defined as education, job experience, acquired skills, and the health of individuals.

**Social capital:** Human capital is contextually complemented by social capital. The latter is broadly defined as the quality created between people, as a way of predicting the returns created by human capital through a "*person´s location in the social structure of a market or hierarchy" (Burt 1997).*

- More concretely, "*social capital describes relations of trust, reciprocity, and exchange; the evolution of common rules; and the role of networks. It gives a role to civil society and collective action for both instrumental and democratic reasons and seeks to explain differential spatial patterns of social interaction. At its core, social capital theory provides an explanation for how individuals use their relationships to other actors in societies for their own and for the collective good. The collective good, or welfare, has both material elements and wider spiritual and social dimensions. Hence, social capital captures the nature of social relations and uses it to explain outcomes in society"* (Adger 2003).

- Due to its vagueness as well as novelty and heuristic power, social capital became a widely used concept in past years, which resulted in different foci of its definition.

- Whereas Coleman (1988) and Woolcock (2001) put emphasis on the structure of social interactions and how this structure is shaped by different norms and networks, other authors (e.g. Lehtonen 2004) focus on sources of these interactions, which might include characteristics of the living area or attitudes and values. Baker (1990) as well as Burt (1992) centre their definitions on the *utilization* by the actors and focus not on the intrinsic value of social interactions but on the mere opportunities created in order to use financial and human capital.

- Gehmacher et al. (2006) define social capital along several dimensions: (i) TNT (ties, norms, trust); (ii) Bonding- Bridging- Linking; and (iii) the three levels (micro, meso and macro). TNT puts emphasis on the meaning of values for quality of life. To agree on common norms and values, which guide our lifestyle, supports strong commitment and leads to high levels of trust. Bonding describes the relationship between people within a group, whereas bridging refers to the relation between different groups and linking to their connection to other levels (like the state or the broader public). Structured on emotional levels, the micro-level refers to close relationships (family and good friends), the meso-level to good relations to groups, communities, people at

work and friends, and the macro-level describes relations to the region, the state, humanity, idols and spiritual engagement.

- In summary and using the definition of Porritt (2006), social capital for the CLIMSAVE project consists of the structures, institutions, networks and relationships that enable individuals to maintain and develop their human capital in partnership with others, and to be more productive when working together than in isolation. It includes families, communities, businesses, trade unions, voluntary organizations, legal/political systems and educational and health institutions.

**FLOWS and STOCKS:** When discussing the capitals in the human-environment system it is important to distinguish between stocks and flows.

- A **stock** is some entity that is accumulated over time by inflows and/or depleted by outflows. Stocks can only be changed via flows. Mathematically a stock can be seen as an accumulation or integration of flows over time - with outflows subtracting from the stock. Stocks typically have a certain value at each moment of time - e.g. the number of population at a certain moment.

- A **flow** changes a stock over time. Usually we can clearly distinguish inflows (adding to the stock) and outflows (subtracting from the stock). Flows typically are measured over a certain interval of time – e.g. the number of births over a day or month.

**RESILIENCE** is best used to define two specific system attributes: The amount of disturbance a system can absorb and still remain within the same state or domain of attraction; the degree to which the system is capable of self-organization (Klein et al. 2004).

- The term refers to three conditions that enable social or ecological systems to bounce back after a shock. The conditions are: ability to self-organize, ability to buffer disturbance and capacity for learning and adapting (Tompkins et al. 2005).

- While the term resilience is not used directly in the CLIMSAVE framework, it is an important attribute that will be referred to in discussions of vulnerability to multiple pressures.

**SENSITIVITY** is the degree to which a system is affected, either adversely or beneficially, by climate related stimuli (IPCC 2001).

- The effects on the system may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC 2001).

- Sensitivity can be positive or negative but has no value orientation. In contrast to exposure sensitivity is a neutral concept; exposure is always linked to harm. Again, the word “sensitivity” does not appear explicitly in the CLIMSAVE conceptual framework, but it is clearly related to the availability of capital to deal with pressures or to mitigate.

**ESB (Ecosystem Service Beneficiaries)** are people who benefit from ecosystem goods and services.

## 3. The CLIMSAVE Framework

The framework shown in Figure 1 is for the CLIMSAVE project. It is not a framework that deals with the concept of vulnerability from a general point of view. In fact the word "vulnerability" does not appear in the framework. Vulnerability is an outcome of the interactions illustrated here. **The current vulnerability to pressures depends on the capacity to cope and that capacity is determined by the amount of capital (natural, physical, social, human and financial) that can be used to deal with the pressures. An "Ecosystem Service Beneficiary" (ESB) is vulnerable, if he/she does not have enough coping capacity to manage when a change of ecosystem services takes place.**

The Framework shows a number of causal relations between the elements. Although the diagram suggests some linearity of the processes, in reality this is, of course, not the case. Rather there will be feedbacks and **the processes are dynamic**. Most importantly, the amounts of the different capitals will change over time, thus changing the capacity to cope.

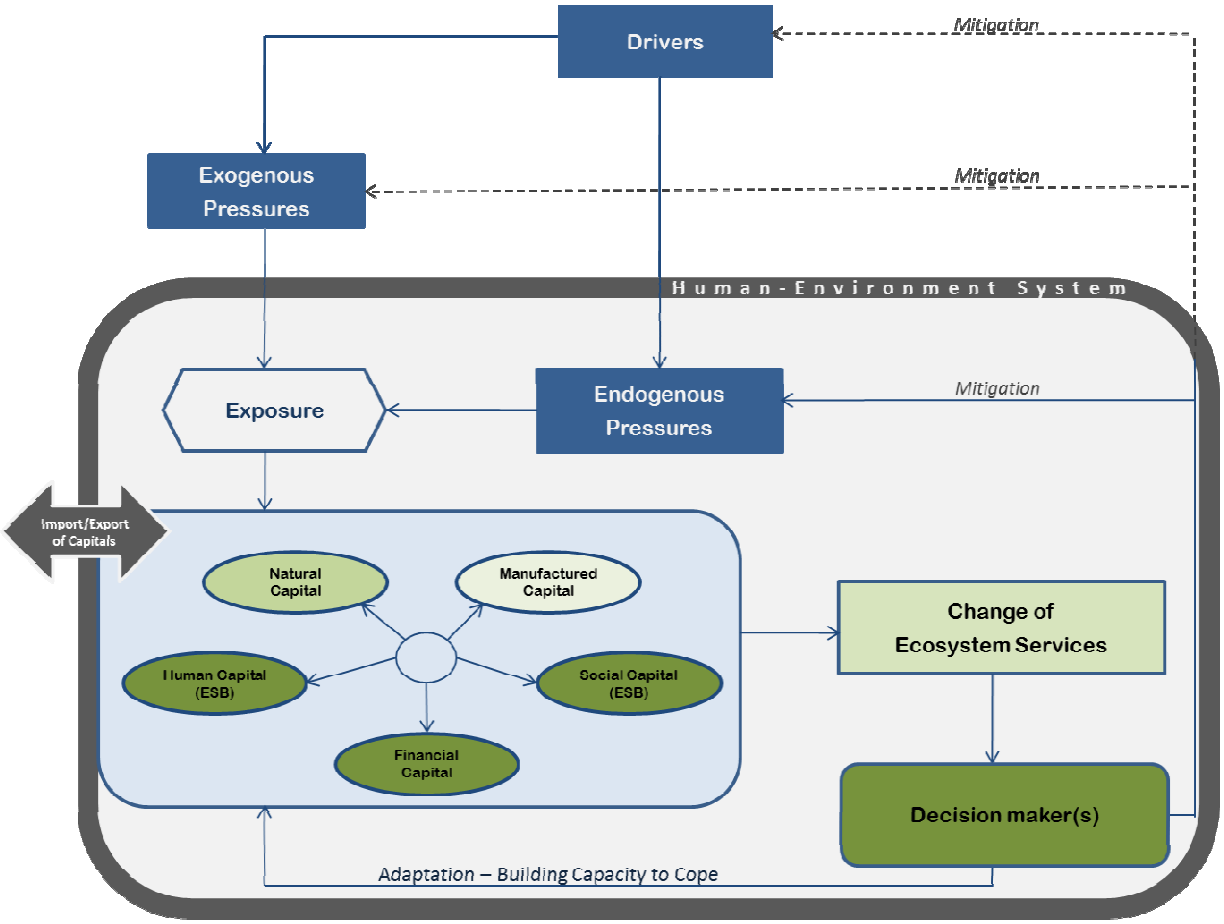


**Figure 1: The CLIMSAVE Framework.**

In Figure 1, the blue boxes indicate drivers and pressures (defined below). The pressures act on the human-environment system (grey border) but their effect on that system is moderated by exposure (defined below), which is thus included in a hexagonal box with no shading (it is a moderator of the pressures). Within the large box in the human-environment system are the five types of capital, which determine both the capacity of the system to cope with the pressures and the capacity of the system to adapt (increase coping capacity) over the longer term. Changes in the amount of capital (in particular natural capital) lead to changes in ecosystem services. As a result of these changes, decision-makers may decide to mitigate (by reducing drivers of change or pressures on the system) or adapt (by using various forms of capital).

**DRIVERS**

Drivers are the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns. Examples of drivers include population growth and demand for food, water, shelter and mobility. For the CLIMSAVE project these will be provided by the scenarios (WP3).

**EXOGENOUS AND ENDOGENOUS PRESSURES**

Pressures can appear from the inside of a human-environment system (endogenous) as well as from the outside the system (exogenous). The atmospheric carbon dioxide concentration and resulting climate change is an example of a mainly exogenous pressure, if the human-environment system is of small geographical scale. An endogenous pressure could be, for example, a land-cover change within the exposure unit. Both types of pressure (which can be environmental changes or socio-economic changes) affect the exposure unit. As discussed above, an exposure unit may be a region, population group, community, ecosystem, country, economic sector, household, business or individual. In all cases this refers to a human-environment system. In the CLIMSAVE project, for the regional case study, Scotland will be the human-environment system, while at the European level the human-environment system will be geographically defined.

For the CLIMSAVE project exogenous pressures will be provided by the scenarios (WP3). Some endogenous pressures are included in the models used in the Integrated Assessment Platform.

**EXPOSURE**

Exposure is the link between the Pressures (exogenous and endogenous) and the five types of capital available in the human-environment system or exposure unit. It refers to the amount of exposure of the system to the pressures and is characterized by the degree, duration, nature and/or extent to which the system is in contact with, or subject to, the Pressure. If the human-environment system or exposure unit being studied is, for example, a river watershed in an upland area, it would have no exposure to sea-level rise but could be exposed to many other Pressures such as soil acidification, deforestation, long periods of drought, short periods of flooding, a long-term trend of depopulation, etc.

## AVAILABLE CAPITALS

The box that includes the five capitals is equivalent to the "state" in a DPSIR schematic diagram.

**Natural capital** is any stock or flow of energy and matter that yields valuable goods and services. This includes resources, some of which are renewable (e.g. timber, grain) and others that are not (e.g. fossil fuels). Natural capital also includes sinks that absorb, neutralize or recycle waste. Natural capital can be used for adaptation by, for example, planting trees, growing new crops, providing irrigation, etc.

**Human capital** includes the health, knowledge, skills and motivation of an ecosystem service beneficiary, as well as their individual emotional and spiritual capacities. Human capital can be used for adaptation by, for example, using the skills of humans to provide early warning or providing training.

**Social capital** consists of the structures, institutions, networks and relationships of ecosystem service beneficiaries that enable individuals to maintain and develop their human capital in partnership with others, and to be more productive when working together than in isolation. It includes families, communities, businesses, trade unions, voluntary organizations, legal/political systems and educational and health institutions. Social capital can be used for adaptation by, for example, setting up voluntary organizations for emergency help.

**Manufactured capital** consists of material goods - tools, machines, buildings and other forms of infrastructure - that contribute to the production process but do not become embodied in its output. Manufactured capital can be created for adaptation by building dams, water pipelines, sea-walls, hospitals, roads, etc.

**Financial capital** reflects the productive power of the other forms of capital and enables them to be owned and traded. However, unlike other types, it has no intrinsic value - its value is purely representative of natural, human, social or manufactured capital.

As shown in the framework diagram, these forms of capital are connected to each other. In the case of a particular human-environment system, say for example a rural village exposed to the pressure of climate change in the form of increased flood events, humans could cope with floods by investing in manufactured capital and building a reservoir upstream of the village. Human capital in the form of skills could be used to provide better early warning systems and social capital could be used in the form of voluntary organizations that help people most exposed to move when a flood is forecast. Natural capital could be used by planting forests upstream to prevent mudslides and landslides. Thus, the capacity to cope depends on the amount of capital that can be mobilized to respond to pressures. If coping capacity is low (due to lack of capital) then ecosystem services (in this case the natural flood protection) change and the human environment system is vulnerable to the pressures.

For the CLIMSAVE project, it will also be important to take into account the possible import/export of the capitals from the exposure unit. In particular, it is clearly possible to import manufactured capital to deal with pressures such as climate change (e.g. importing materials for river bank protection or dam-building). Natural capital from outside the region of study could also be used to cope with pressures (e.g. water storage upstream). Social and human capital are lost, if people move away from the area.

**RESPONSES**

Faced with a change in ecosystem services, the humans in the exposure unit can adapt by improving their coping capacity in order to be more resilient to the pressures, or they can mitigate by reducing the pressures and/or drivers of change. The adaptation could involve, for example, increasing human capital through education programmes, or increasing social capital through establishment of a local flood warning office, or increasing manufactured capital through building new homes away from the flood-prone area. Thus the adaptive capacity also depends on the availability of capitals to be used to improve the capacity to cope with pressures in the future.

In the CLIMSAVE project the focus is on adaptation. Mitigation in the form of reducing exogenous pressures or drivers of change is not considered explicitly, although it could certainly be part of the scenario narratives and thus provide context for the assessment of vulnerability hotspots.

## 4. The use of the framework – Next steps

As indicated above, drivers and pressures will be provided by the participatory scenarios developed in the stakeholder workshops. The first set of workshops will focus on developing the scenario narratives, which will then be quantified. In a second set of workshops the stakeholders can examine how their scenario narratives have been quantified and what impacts ensue. Discussion on adaptation options and the vulnerability concept will also be started during these workshops. The third set of workshops will focus almost exclusively on adaptation options, allowing the stakeholders to play with different options and examine their consequences using the CLIMSAVE Integrated Assessment Platform (IAP).

The models will quantify ecosystem services and changes in them, they will also, in some cases, provide information on capital stocks (e.g. amount of water, forests, soils) and flows (e.g. conversion of forest to agricultural land).

For the discussions on adaptation options, it will be important to make the link between individual adaptation options and their impact on the various forms of capital. For example, the option of building sea-walls uses manufactured capital and some human capital (skills), while the option of setting up a voluntary organization to support citizens during floods builds up social capital, which is “used” but not “used up” during a flood event. So an important next step is to provide an analysis of the linkage between capitals and adaptation options. The availability of capital constrains the choice of adaptation options.

Overall, the linkage between the scenarios, the modelling and the framework are as follows:

- For a selected scenario and associated exogenous and endogenous pressures (from CLIMSAVE WP3), the models will assess the potential impacts on key indicators of the sectors and ecosystem services (which will be dependent on the Exposure). They are potential impacts because they assume no planned adaptation (although there is autonomous adaptation within some of the models).
- Based on the potential impacts on sectors and ecosystem services, the ESB can choose to use some or all of their capitals to modify the potential impacts into actual changes in the sectors /ecosystem services (in order to do this the above mentioned analysis of

the linkages between specific adaptation options and their use of capitals has to be carried out first).

The CLIMSAVE project also aims to provide information on "vulnerability hotspots" and thus a methodology for using the framework to determine "hotspots" needs some consideration. First, based on the literature review above, it is important to be specific about "vulnerable to what?" An exposure unit can be vulnerable to sea-level rise but not to drought, or vulnerable to population increase but not to flooding. Vulnerability to multiple pressures is also important. For instance, as indicated in the literature, vulnerability of agriculture to climate change might be low in an exposure unit but vulnerability to the combination of climate change and changes in food prices on the world market might be high.

The second point to note is the difference between vulnerability to a particular pressure **now** and vulnerability in the **future** (as the literature shows, vulnerability is a dynamic property). Current hotspots of vulnerability to a particular pressure or set of pressures of a particular exposure unit are determined by the exposure to that pressure and the availability of capitals to deal/cope with the pressure(s). Future hotspots of vulnerability to a particular pressure are determined by the exposure and the availability of capitals to adapt and thus increase the coping capacity.

## 5. Acknowledgements

Thanks to Matthias Nocker (SERI Intern) for substantial support with the first version of the framework and the description thereof. This version of the Framework was developed after discussions at a CLIMSAVE meeting held in June 2010 in Brussels and a project meeting in Barcelona in September 2010. It has thus benefitted from the inputs of many colleagues in the CLIMSAVE project.

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