Project N° : 0369927

SPICOSA

SPICOSA : **S**cience **P**olicy **I**ntegration for **Co**astal **S**ystems **A**ssessment

"Formulating economic processes within Coastal Systems:

a guide to integrating the socioeconomic dimensions in numerical models, with examples from study site applications"

José A. Pérez Agúndez[1], Pascal Raux[2] & Melissa M. Mathews[2]

[1] Ifremer (Marine Economics Department), UMR-Amure,

[2] Université de Brest, UMR-Amure

Integrated Project funded by The European Community
Under the Sixth Framework Programme
Priority 1.1.6.3
Global Change and Ecosystems

TABLE OF CONTENT

Summary

Coastal systems are characterised by a high level of complexity since there exist many different relationships between nature (ecology) and society (socio-economy) difficult to apprehend. That complexity currently drives towards unsustainable paths when at least one of their components of sustainability fails Based on a system approach, the SPICOSA approach developsa multidisciplinary assessment framework with a balanced consideration of the Ecological, Social and Economic sectors of Coastal Systems. This System Approach Framework (SAF) is used to explore the dynamics of Coastal-Zone Systems and potential consequences of alternative policy scenarios. This process starts with the design of the system to be analysed. In a second step, the main components and processes structuring the system have to be translated into a mathematical language for the purpose of numerical modelling. The construction of exploratory scenarios enables a better understanding of causes and effects of sustainability failures.

This support paper focuses on the formulation of the socioeconomic dimensions of coastal systems for integrated assessment and is based on material supplied by the SPICOSA's 18 study sites activities (SSAs). The work sequence consists in two main steps. Firstly, an individual SSA analysis synthetically describes the main components that support the formulation of the economic process. More precisely, the socio-economic processes are enlightened by "entity" of the model (basic component in terms of sector, group of stakeholders, institutions, etc). These processes mainly concern production, consumption, investment and innovation. Each process is then described taking in account (1) the mathematical formulations adapted to each case in accordance with the specific core issue, (2) the specific function or role that these processes play in the model, (3) the decomposition of this formulation into elementary components (parameters, state variables, forcing, etc.) according to a common grammar defined by the SPICOSA methodology and (4) the description on how these processes are linked to the other components of the model. Moreover, feedback processes are described in order to better understand systems dynamics, including the adaptive behaviour of stakeholders depending on the institutional context and the management framework. Secondly, this basic information supplied by the first step is used to achieve a cross-sectional analysis enabling a comparison of best practices of socio-economic processes formulation. Different comparisons can be done in terms of entities modelled, type of process analyzed or the way on how they are formulated.

1. INTRODUCTION TO SYSTEM FORMULATION:

The overall objective of SPICOSA is to develop a self-evolving, holistic research approach for integrated assessment of Coastal Systems, so that the best available scientific knowledge can be mobilized to support deliberative and decision-making processes aimed at improving the sustainability of Coastal Systems by implementing Integrated Coastal Zone Management policies. The integrated approaches aim to apprehend the complexity of the nature-society relationships encompassing the links between the elements of the systems analyzed and taking into account their different socio-economic and ecological dimensions. Face to this complexity of coastal systems, system approach has proven to be a useful concept for the purpose of managing natural resources in the context of multiple ecological and social concerns.Based on this system approach, a multidisciplinary assessment framework is developed with a balanced consideration of the Ecological, Social and Economic sectors of Coastal Systems. This System Approach Framework (SAF) is used to explore the dynamics of Coastal-Zone Systems and potential consequences of alternative policy scenarios. Achieving this objective requires a restructuring of the science needed to understand the interactions between complex natural and social systems at different spatial and temporal scales, including the overall economic evaluation of alternative policies.

The SAF approach mainly consists in (i) identifying a policy issue based on a participative process, (ii) design the system (the conceptual model scheme) in relation with the policy issue, (iii) formulate this model (the updated model) and (iv) evaluate and simulate the model.This step by step approach is a problem oriented one built under a system modelling framework and integrating the ecologic, economic and social dimensions of coastal systems. It requires first a design process of the systems to be analysed following by a mathematical formulation as the support of the numerical modelling procedures.Formulation is the way of translating all components and processes structuring the systems studied into a common mathematical language. This codification enables to quantify and qualify the web of interactions (causal, dependencies, feedback...) between all the elements of the system and then its own dynamics.This support paper focuses only on the socioeconomic dimension and its formulation.

In order to implement this formulation of socioeconomic processes, it is necessary to preliminary linked these processes to an "Entity". Entity is here defined as a group of actors having or developing an action within the system(group of economic agents, sectors, stakeholders, governance bodies…). The relationships between entities and with ecological components can be complex. Consequently, an inventory and an in-depth description of every socio-economic processes associated to the model should be implemented before entering into the mathematical formulation step. The purpose will be then to detail more or less simple, more or less complex processes that govern the entities within the system. According to the approach developed by SPICOSA, the formulation is cascaded into several steps which will be briefly reminded on section 3. It describes the way of formulating general processes in general and socioeconomic ones in particular.

Based on a preliminary work on system design (Mongruel et al. 2010), the aim of this support paper is first to build a bridge between design and formulation in order to implement the SAF approach and then to enter in the engine room of the formulation process. To that purpose it will aim at structuring an overview of the waysthe different study sites implemented the formulation of socio-economic processes and to a general framework.

1.1 Reminder of system approach and system dynamics; introduction to formulation

The integrated approaches aim to apprehend the complexity of the nature-society relationships encompassing the links between the elements of the systems analyzed and taking into account their different socio-economic and ecological dimensions. Coastal systems are complex socio-ecosystems demonstrating non-matching scales, surprises (non-linearities), interconnection with other systems, memory effects, choke points… In that frame system approach is a useful concept for the purpose of managing natural resources in the context of multiple ecological and social concerns. The implementation of system approach will aim at:

- ✓ Modify the feedback loops path that are at the core of the coastal systems dynamics i) by placing at the core and considering public policies as control factors over the fate of systems; ii) by developing a knowledge more integrator of ecological, social and economic dimensions; iii) presented under scenarios approach and iv) based on a deliberative approach of the interface between scientific knowledge and public policies, for issues identification as well as for the evaluation of Science's products;
- ✓ Integrate ecological, economic and social systems;
- ✓ Take into account dynamics through feedback loops;
- ✓ Scenarios based analysis (control factors).

Compared to the analytical approach that reduces the considered system to simple constitutive elements in order to study them separately and analyse their interaction with the system (suitable to homogenous systems), the system approach is a more global approach, focusing on interconnections between sub-systems and going from the general to the particular. It puts forward the hypothesis that the system structure is much more interesting to forecast its behaviour rather than having a detailed knowledge about its initial conditions, and to issue some general rules devoted to a better understanding of those systems and to drive them.

Systems and general structure of systems:

"A System is a configuration of parts connected and joined together by a web of relationships to serve a particular purpose" (for instance a car, a plane, the human body, an organization, an economy, a regional system, a coastal system, etc.)

The junction and integration of this web of relationships create emergent properties of the whole (that is more than the sum of the parts). Parts of the system can be systems on their own, and systems can be parts of bigger systems. They fit in a hierarchy. For instance:

- the engine of the car <the car <the car in the transportation system;
- the fisherman in the fishing community <the fishing community <the fishing community in the global economy;

System approach relies on the mathematical formulation of cause/effect relations, the objective being to assess how the system evolves over time (stability, 'overshooting', thresholds effects). General structure of systems can be then defined by:

- State variables representing successive (over time) states (stocks, levels) of systems:

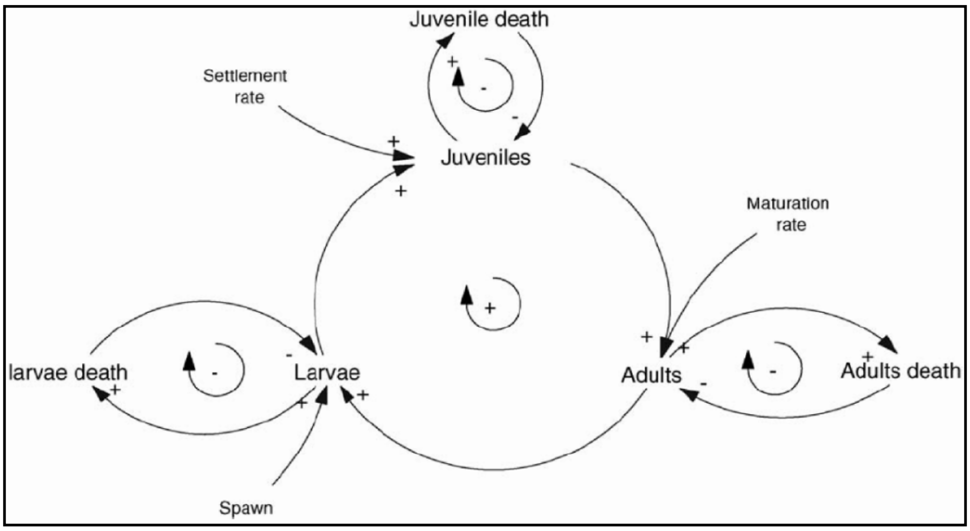
    - Integration of instantaneous variations through time
    - Number of inhabitants, pollutants concentration, number of enterprises...
- Rate of change representing activities and processes leading to changes in the systems' state:
    - Decision rules, continuous function
    - Investment rate, growth rate, …
- Interactions between variables determining action rules:
    - Positive, negative feedback loops
    - Limits and boundaries within those interactions take place

Historically system approach was first used for the analysis of the living organism as a system. A classic case is the energy allocation in a living organism and asymptotic growth (von Bertalanffy 1968). This firstly allows identifying and defining several important concepts related to systems:

- Behavior rules or laws such as energy fluxes (processes), energy accumulation (state variables) and feedback (causal)
- Boundary: environmental conditions are represented by forcing variables; if the organism influences its environment, system's limits will take into account some other processes and state variables.
- Mathematical formulation: integration of differential equations.
- Emerging property: asymptotic growth, reproduction effort.

It was then extended to the study and analysis of population dynamics with the definition and use of **life cycle and feedback loops** and their **mathematical formulation** as illustrated by Bald et al. (2006) on Figure 1.

Figure 1 : Causal loop diagram model, for the gooseneck barnacle management model from Bald et al. (2006)



Mathematical formulation: $\frac{\partial n}{\partial t} = G.\frac{\partial n}{\partial w}$ with G the Growth Rate

Main references related to the history of systems analysis and systems dynamics are as follow:

- Forrester 1961, Industrial Dynamics
- von Bertalanffy 1968, General System Theory
- Forrester 1968, Principles of Systems
- Forrester 1969, Urban Dynamics
- Meadows/Randers/Meadows 1972, 2004, Limits to Growth (analysis of socio-eco-systems dynamics, consequences of existing limits, importance of non linearities). The overshoot issue (overpassing the carrying capacity of dynamic system) is addressed under 3 conditions: i) growth, acceleration, rapid change of the system, ii) existence of a limit beyond which the system is not able to remain unchanged, iii) delay and error of assessment in the responses set to keep the system below the limits
- Morecroft 2007, Strategic Modelling and Business Dynamics

1.2 Framework designed to implement the formulation step of socio-economic processes

Following the design step that output the conceptual model, the schematic of the system to be modelled has to be translated into state variables, rates of change and interactions between variables determining action rules (**feedback loops**) leading to a stock and flow diagram or a causal diagram. Limits and boundaries within those interactions take place have to be defined too. Consequently, this formulation step requires the identification of activities and processes leading to changes in the systems.

When several arrows in the causal diagram return to one factor, it created a closing path or a loop. Since the relationship is done dynamically, it gives some feedback to the original factor, called feedback loop (Teknomo). Such feedback loops are used to represent and capture system dynamics. They can enhance or buffer changes that occur in a system (for instance interest rate in savings account). They can be positive (enhance or amplify changes) or negative (where increased output from the system inhibits future production by the system)[1].

To represent the model there's a need of a common language, as a way of thinking and as a modeling tool. Several tools and types of diagrams may be used and the system can be broadly designed to identify the interactions and variables.Evidences and reasons for such a common language are obvious when implementing a similar process or approach over numerous study sites. The adopted language and common grammar is expressed in details in the chapter over the SAF formulation (Bacher et al. 2008) based on conceptual diagrams and symbolic languages developed by Jeffers (1978), Jorgensen (1986) or Odum (1996, 2000).

[1]Usually, limitations occur, and this is advocated by Meadows et al. (2004) in their simulation of Limits to Growth (Bacher et al. 2008).Bellinger (2004) also stresses the importance of time scales and delays, with consequences on the perception of the system dynamics by stakeholders.

To identify and represent socio-economic processes by a set of variables, rates of change and feedback loops[2], it is proposed a step by step approach through the definition of a typology of socio-economic entities.

Socio-economic processes are enlightened by "entity" of the model (basic component in terms of sector, group of stakeholders, institutions, etc). These processes mainly concern production, consumption, investment and innovation. Each process has to be then described taking in account (1) the mathematical formulations adapted to each case in accordance with the specific core issue, (2) the specific function or role that these processes play in the model, (3) the distribution of this formulation into elementary components (parameters, state variables, forcing, etc.) according to the common grammar defined by the SPICOSA approach (Bacher et al. 2008) and (4) the description on how these processes are linked to the other components of the model. Moreover, feedback processes are described in order to better understand systems dynamics, including the adaptive behaviour of stakeholders depending on the institutional context and the management framework. Secondly, this basic information supplied by the first step is used to achieve a cross-sectional analysis that allows for a comparison of the best practices of socio-economic processes formulation. Different comparisons can be done in terms of entities modelled, type of process analyzed or the way on how they are formulated.

The main socio-economic entities listed in the different study sites are detailed according to the following typology (Table 1).

Table 1: Framework of typology of socio-economic entities and related/associated processes

Entities typology	**Entities**	**Processes**
Economic sectors		
Users/ consumers		
Institutions in charge of regulation		
Institutions providing goods and services		
Lobbies		

This typology of socio-economic entities and attached Entities and Processes is used over the study sites and the Table and its completed structure is provided in annex. The way to deal with is the purpose of section 3.

[2]In the field of economics, models do not always use mathematical formulation. For instance they can be qualitative such as some non stochastic models involved in some aspects of social choice theory, qualitative scenario planning in which possible futures (future events) are played, or non numerical decision tree analysis.

1.3 Recommendations before entering into the engine room of formulation

It is important to underline that although being a socio-economic process formulation it is not disconnected from other subsystems. This formulation takes place in an integrated approach and cannot be reduced to a coupling between different parts of the systems. It is a key issue to avoid the more traditional way of thinking separately the different subsystems (socio-economic, ecologic) and trying to couple them by trying to establish some hazardous links a posteriori. The socio-economic processes are here considered and identified in an integrated way; they are thus designed and formulated in accordance to their web of relationships with other systems components.

It is to be related to the hypothesis that it is much more interesting to forecast system's behaviour rather than having a detailed knowledge about its initial conditions. This is also underlined through the emergent properties of systems as addressed at the *general structure of systems* subsection of the present document and through the definition of the emergence principle by Bellinger (2004): "Associated with the idea of system is a principle called emergence. From the mutual interaction of the parts of a system there arise characteristics which cannot be found as characteristic of any of the individual parts.One has to study the system to get a true understanding of wetness. Studying the parts will not provide an appropriate understanding".

The message is to start with simple models that integrate disciplines. Add detail later and only if it is necessary. Integration of disciplines requires simpler, not complex, models. So contrary to common thinking, the more integration represented in the model, the simpler the model needs to be to allow for testing, detecting feedbacks, time delays and to allow for use by scientists from different disciplines or end users with different backgrounds.

Design the system and the conceptual model claims for creativity in the way of developing approaches for reproducing and explaining system complexity using relatively simple concepts and theories. Often, problems arise from dynamics' complexity. To solve such problems, one needs to find, detect and model significant feedbacks and time delays that exist between the components of the system, not add as many components as possible.

2. FROM DESIGN TO FORMULATION

In accordance with the general methodology developed in theSPICOSA project, several steps can be distinguished in the implementation of the formulation processes. Before the formulation step itself, the conceptualization of the model with a logic diagram enables the enlightening of the global structure of the system, the frontiers delimiting its extend and the way of its elements are linking between them. This step is explained in depth in the documentation related to the system design of the SAF method (Tett, 2010 and Mongruel et al. 2011).

The characterization of the structure must detail the whole of elements which constitute the system, the way in which they are hierarchically dependent as well as the functional bonds between them. A system must be integrated by at least two elements in interaction (Hall and Day, 1977). The integration of one liked great number of elements makes it possible to have a finer comprehension of reality but on the other hand that is done with the detriment of an increasing complexity.

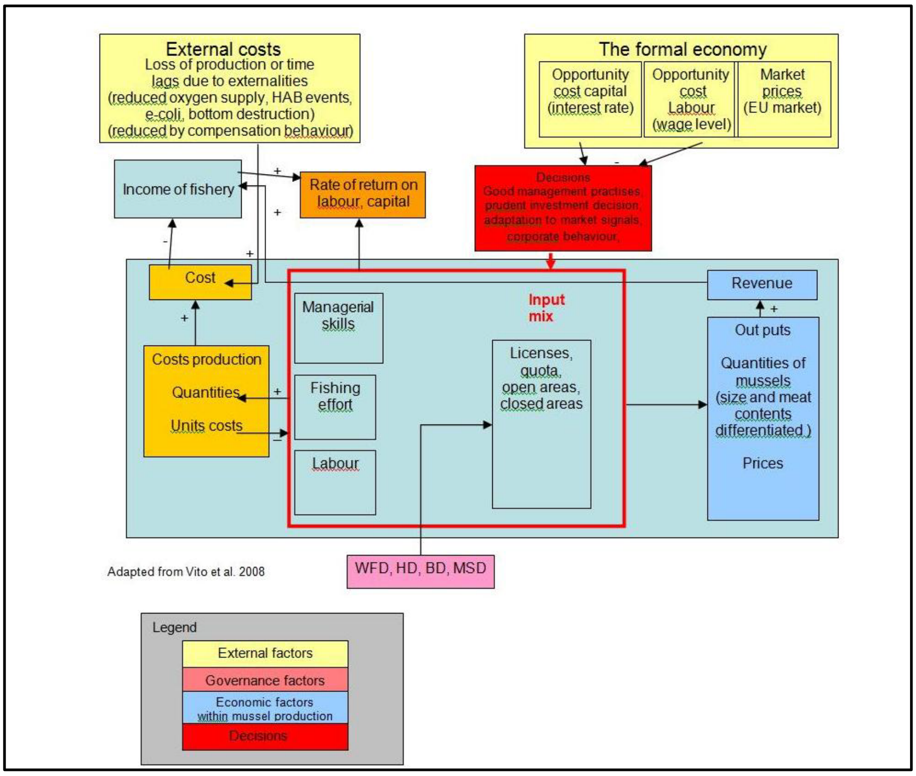
2.1 Cause effect relationship structuring the socio-ecosystem dimension of systems

One the system is design in previous steps, it is necessary to characterize each cause-effect relationship which determines the functional linking all the components of the system (see for instance Hall and Day 1977, Forrester, 1968). This enables to describe how each element is influenced by the other elements of the system. These links can induce positive or negative effects depending on the increase or decrease of flows and stocks that they lead under the dynamics of the system. Functional diagrams enable an easier representation of these relations but at this stage there is no distinction between the nature of the different elements of the system because the formulation of processes can integrate the different ecological, economic and social dimensions of each component. This chapter only will focus on the socio-economic dimension of these processes.

The DPSIR framework of theSPICOSA approach is well adapted to this linear reasoning of causes /effect representations before its mathematical formulation because each element of the system induce "pressures" on other elements and consequently states variables can be modified. The global dynamic can be generated then by adapted responses after measuring the impacts of changes.

The way of emphasizing these case and effect relationship chain will be illustrated by some basic examples of modelling works fromSPICOSA SSAs. **A First example** (figure 2) illustrates the internal economic relationships into the mussel fishery module of the Limfjorden model (SSA5). The focus of the subsystem model is to increase and optimize production and revenue obtained by the mussel producers by selling the mussel products (Dinesen et al. 2008). Mussel fishery production in the Limfjorden is determined by the combination of different production factors (input mix) depending on the comparative prices of these factors, on the prices of end products (contained in the "formal economy" box) and on environmental risk factors ("external costs" box). The intensity of use of production factors influences the total output and then revenue function and the total production costs required. The final balance between revenues and costs determines profits (named in the model "income of the fishery") and the return on the production factor remuneration.

Figure 2 : Conceptual model for private economic income from mussel fishery in SSA5 Limfjorden(Dinesen et al. 2008)



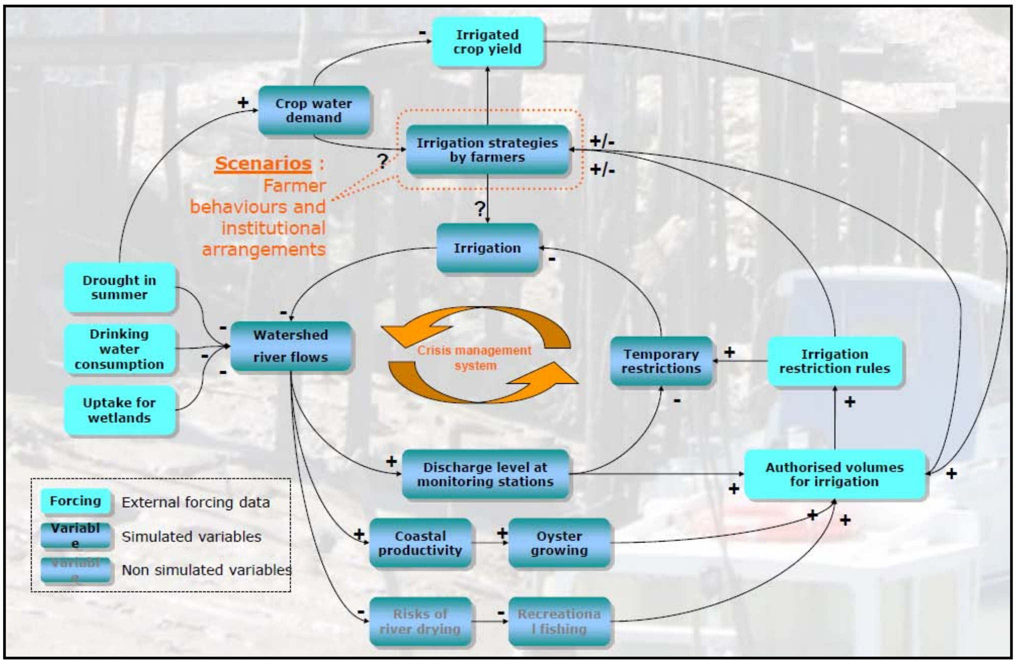
The positive and negative signs reveal the effects of stocks and flow in the production sub-model. A decrease or increase in cost of production such as fishery effort and labour would lead to a positive or negative effect on the quantities of mussel production gained. The cost of production will determine the amount of input mix the producers can afford to have (Dinesen et al. 2008). But these links are not always infinitely correlated and can be truncated by limiting effects such as:

- ✓ The limited quantity of fishery licenses which relies on spatial and environmental planning.
- ✓ Accessible stock of labour and opportunity costs of labour
- ✓ Costs of fishing effort and opportunity costs of effort
- ✓ Opportunity costs of negative externality reduced oxygen supply, HAB events, e-coli pollution and benthic disturbance and destruction

A second example is related to the freshwater water allocation model of the PertuisCharentais model (SSA 10). In this model there is high number of relationships linking different anthropogenic activities which share the same limited water resource. Following the diagram of figure 3, the irrigation strategies of farmers are positively or negatively affected by the water management sub-system, depending on the state of the freshwater resource. These strategies are conditioned as well by the crop water demand which depends on environmental conditions. In case of scarcity of water, the dissatisfaction of the crop water demand drives to plants stress and then to a decrease on the total yield. The intensity of the freshwater use by the agriculture sector represents high risks of penury for other uses or ecologic services placed downstream mainly in the driest periods when the needs are the highest and the supply of water is the lowest. The main uses or services which can be directly affected by water scarcity are:

- ✓ human consumption,
- ✓ support of biodiversity in secondary rivers
- ✓ water as supplier of nutriments dissolved and as a regulator of salinity for growth in shellfish farming
- ✓ water as a support of cultural services (angling)

Figure 3 : The cause & effect relationship chainin the PertuisCharentais model (SSA 10)



Irrigation impacts negatively the watershed river flow. This water flow is positively correlated with the coastal productivity (influencing positively as well to oyster growth) and then the economic performances of shellfish farming companies. The economic importance of this sector at the local scale can have positive effects on the freshwater allocation mechanisms because they can claim more restriction for irrigation or the supply of additional water stocked in dams. This links generate feedbacks and dynamics on the system.

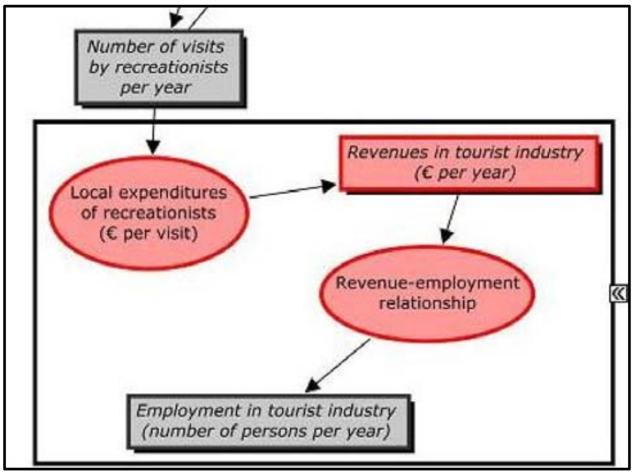
Management options considered as possible scenarios to be tested are new regulations for a more efficient use of freshwater from irrigation, technological innovation with new crop rotations which require less water consumption and adapted policies requiring taxes for irrigation, and funding for sustainable systems, (Prou et al. 2009).

2.2 Description of stocks and flows in the system

Stocks and flows are related to variables that play different functions into the system model.Stock variables measures cumulative effects of some elements during the time. For instance, the total amount on capital cumulated by a company depends on the investment rate. Each additional investment is added in the company asset and then increases their capital intensity. On the other hand, depreciation of perishable capital decreases the total amount of capital of companies and then may have consequences in their economic dynamics.

Flow variables are measured over a lap of time which corresponds with the time path of the model. They can be formulated by differential equations. For instance, the profit is an economic variable measuring the flow of money remunerating the capital over a specific unit of time (generally an annual accounting year is considered). This flow can be allocated to feed the company funds or to reinvest in capital which are stock variables.

Figure 4 : **Representation of stock and flows within Himmerfjarden(Franzén, Kinell, and Söderqvist 2008) : *SSA4 Himmerfjarden* (The economic components are in red and the social components are in grey)**



In the Himmerfjarden model (SSA4) a direct effect between the attractiveness of the coastal zone analysed and the economic impact of touristic activities. The number of visitors by of the site over the year represents a flow of people which influences the local expenditure by visitor and then the annual revenue of the sector. All those state variables represent flows but they condition the employment of the local aura. The number of employees is a socioeconomic stock variable which is modified by the dynamics of the system.. Employment in tourist industry (number of persons per year), revenues in tourist industry (€ per year) and number of visits by recreationists per year are stocks influencing the tourism industry. The flows are represented by local expenditures of recreationists (€ per visit) and revenue-employment relationship. Local expenditures of recreationists provide the revenue for the tourism industry. The revenues are used to pay for the employment of workers within the tourism industry.

3. Specification of the socioeconomic formulation related to main issues in coastal zones.

3.1 Identification of the main socioeconomic entities

The model builds cause effect relationships between socioeconomic and ecological structures which interact. Prior to the mathematical formulation, it is necessary to describe the entities which are modelled and the methodological approach under which they are analyzed. That enables the possibility to identify the most adapted formalization and more precisely the way by which specialized literature to build these numerical models. This initial framing is the support base to build modules or sub-models for their integration in the system.

Each socio-economic entity is composed of stakeholders (different from those of the other entities). Their links are basically structured by functional relations. They can be composed of producing economic sectors of goods or services, groups of users or consumers, institutions suppliers of public good or services, regulating institutions, lobbies (consumer associations, NGOs, etc). The role of these entities in the system depends on what is encompassed by their activity (mainly production, consumption and regulation which can be combined inside the same entity) and on the objectives they target (maximization of the profit, defence of the nature, equitable management of collective goods, optimization of consumption, etc). A unique entity can cumulate several functions and processes. That complexity lets difficult the distinction between the purely economic universe, recreation and philanthropic or altruistic universe. In addition, there can be also combinations between actions and regulations.

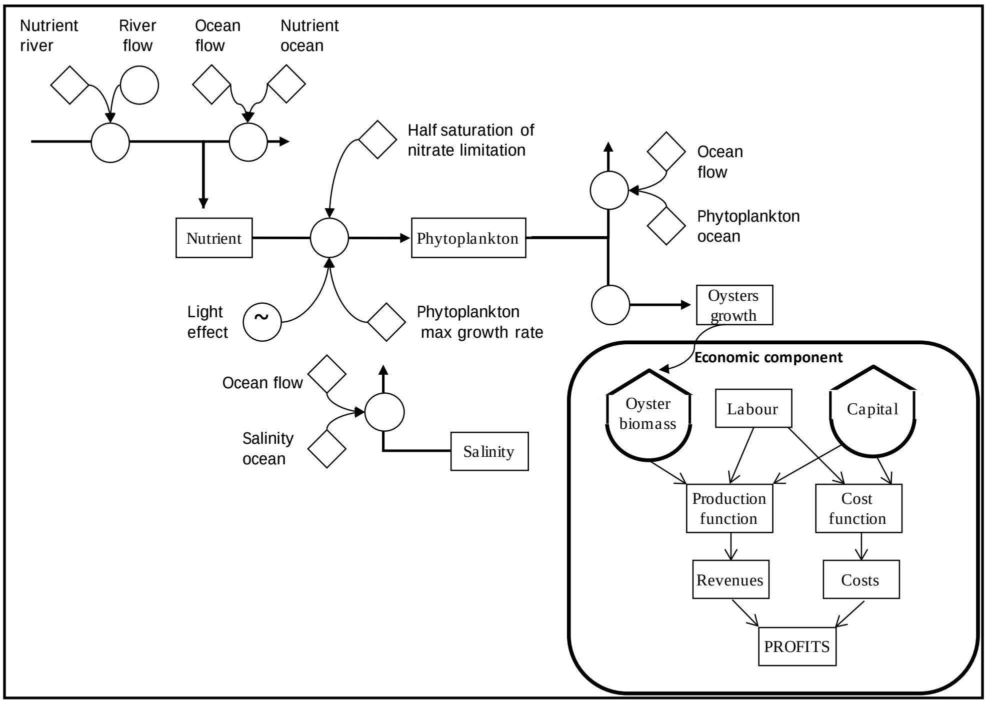
The second stage consists in identifying the economic and social processes which govern the actions of each entity in the model. Several processes can be identified inside the same entity. Thus for example a professional fishermen group can integrate production processes related to their economic activity, but they can also implement investment processes, innovation or even regulation ones in the context of co-managementfor instance. These different processes can be modelled independently into the sub-model "fisheries" and are likely to complete but under a higher complexity framework.

3.2 The structure of the system and the reformulation of the knowledge

The elements of a system and their interactions define its structure. The real world can be considered as a hyper-system madeofan infinity number of components and relations extremely complex. The human cognitive capacity can only take into account a quite limited dimension of systems. But complexity and uncertainty which characterize the socio-ecosystems must be managed by taking in account that the role of systems modelling does not consist in imitating reality but only in exploring the behaviour of a system (Jakeman et al., 2008) in order to explore alternative scenariosofsustainability or the range of possible futures.

The interactions into the systems can be of different nature according to whether the links are caused by exchanges of matter (biomass, energy, substances, etc.) or money. The first type of links can be illustrated by the primary resource generation necessary to the growth of the shellfish cultures. In these biological processes, the energy exchanges light and chemical substancesconstituting the principal components for the phytoplankton blooms which are used as the main food for oysters. This matter is used by the shellfish farming sector as a natural resource for targeting their economic objectives. This is illustrated in the following figure N° 5.

Figure 5 : A bio-economic conceptual model of shellfish farming



The socio-economic sub-systems can integrate monetary and matter flows insofar as they are regulated mainly by commercial relations or by exchanges of goods and services against money. In the case of shellfish farming, economic activities are regulated by monetary masses. The intensity of production factors necessary to produce goods and services and their monetary remuneration associated generate flows of money resulting in a final profit state.

This scheme represents the simplest way of ecology and economy interaction. A more complex relationship chains can be included in the system. As a first example, the excess of nutrients can generates some negative effects on the oyster farming activities due to eutrophisation, toxic algal blooms, anoxia processes, etc. Secondly, some processes considered as exogenous in the model as weather conditions could be integrated as internal dynamic factors. Thirdly, the economic reality of the shellfish farming is more complex. Behaviours of companies are conditioned bymany different factors (individual and collective action, resource access limitations, environmental and geographical constraints, institutional requirements, market dynamics, technology changes, etc.) which determine their strategies and their performances. Moreover, other economic and recreational activities can modify the internal conditions of this simplest bio-economic model. All these potential additional components can be a support of a more real representation. However, uncertainty related with many of those components and the exponential complexity of their processes calibrationmay drive to weakness and non functional models.

Following this system approach, the construction of operational models must be based on comprehensive structures enabling the understanding of functioning of the world represented. This must be previously supported by the design of the system structure, its frontiers and its complexity level. The smartest strategies should be based on trade-offs between realism and simplification of operational needs.

As for other disciplines, models in economics have a simplification function, leading to a selection of variables. In economics, simplification is particularly important according to the huge complexity of economic processes. This complexity is explained by the diversity of factors determining the economic activity: individual and collective action, resources limitations, environmental and geographical constraints, institutional requirements, etc. This will make more difficult the selection of relevant variables and relationships.

Hierarchy

The structuring in different hierarchical sub-structures enables the decomposition of systems into smaller parts, which can be similarly decomposed into other smaller elements integrating a lower level and so successively. The elements which integrated the same level are supposed to be submitted to processes determined by the same properties and are differentiated from those of other levels. This is for instance the case of matter which composed the universe by it is regulated by different properties depending on their consideration at micro-system or macro-system physic scales.A hierarchy is then composed of levels. But the analyses of a system does not necessary require their inclusion into a hierarchy. However, the interest of this procedure is to explore the emergence of properties coming from different structure levels, and to analyse how they can affect the dynamics of the system or the change on emergent structures into the system. Dynamics of higher level sub-systems should fully affect those composing lower structures. Inversely, dynamics affecting sub-systems of lower structures may affect partially sub-systems of higher structures or not affect them at all.

Example: shellfish farming can be composed by groups of companies characterised by a similar type of structure or by a similar economic behaviour. A higher level of hierarchy can be structured by the shellfish farming sector and this can be included into the local economy of a territory. At the sector level, the shellfish farming can be delimited at a production basin or at a national scale, etc. At an individual action level, some divergences can appear for instance for the primary resource share. At higher levels, a collective action can be implemented for the defence of corporatist interests (for instance for claiming to policy makers additional marine space, policies targeting an increase of environmental quality, etc.).

3.3 The boundaries of the system

Systems are opened by definition. That means that theoretically an infinite relationship chain can link all the elements of the universe. However, the objective of modelling is not to imitate the real word but only to represent part of this reality at a scale sufficiently relevant in terms of complexity enabling the exploration of the system dynamics and the analysis of future scenarios. Consequently, an obvious simplification is required by defining the frontiers distinguishing the system analysed from the outside world. This is a basic process for determining the main material and information flows which have to be considered into and out of the system, which processes are endogenously determined and which ones are externally affecting the system (driving forces). This design highly conditions the control variables that can be used to explore any modification of the system.

3.4 Description of the elementary components of processes

A first stage consists on defining the elementary components and processes of the model taking in account stocks and flows which are linked with the cause / effect relationships enlightened in the previous "Design" step. This process will enable the description of variables, processes, equations and parameters for all the components of the system. The main components of the system are the following:

- ***State variables***: They represent successive states (stocks, levels, etc. by time step) of certain elements of the system (for example level of profits released by an economic sector, costs of exploitation being related to the levels of production…)

- ***Forcing functions:***They represent of effect cause relations between the system and other exogenous mechanisms. They can vary in time but they are not directly submitted to the internal changes of the system. As an example, the climatic change operates on a planetary scale but it may impact delimited coastal systems. Consequently, the increase of temperature of the planet will not be affected by the dynamics of this coastal system. Some socio- forcing economic variables are for example the rate of the population growth, the price of goods and services whose market delimitation exceeds the geography of the analyzed territorial system, etc.

- ***Parameters:*** are constant dependent quantifications of variables in a function. They are integrated in the model from external knowledge (experimental or expertise) or from other studies which can supplied by the scientific literature. They can be of different nature of their role: for example in the modification of state variables (example: investment rate, economic choices of marketing by type of distribution channel, or in changes of flows and processes.

- **Decision rule**s:They are events which appear at one given moment during the interactive dynamic processes of the model. They can be used in systemic modelling by different ways

    - Threshold effects

    - Temporality rules

    - Smart rules

- **The control functions**: are basically parameters of the system which are voluntarily controllable. They are used to include/understand the modifications which the system can undergo when their values change. Consequently, by this way the system can be controlled.

Relations entre variables définissant la manière dont elles sont reliées (ex : fonctions de production ou combinaisons techniques de capital et de travail, effets feedback, etc.)

3.5 Dynamics in the economic system: identification of feedbacks

In this economic system, dynamics will depend on the accumulation function of capital determined by the amount of capital available and the reinvestment (Wang et al. 2001). This accumulation is reduced due to depreciation of physical capital (infrastructures have a limited span life). According to assumptions made, another potential dynamics can involve the case of endogenous technological development (role of investments in technological progress as quoted above). It can also be the case of prices being impacted by supply and demand through elasticity. The economic production process is rather linear as opposed to some ecological processes. But some of the economic forcing impacting the process can follow non linear processes such market prices.

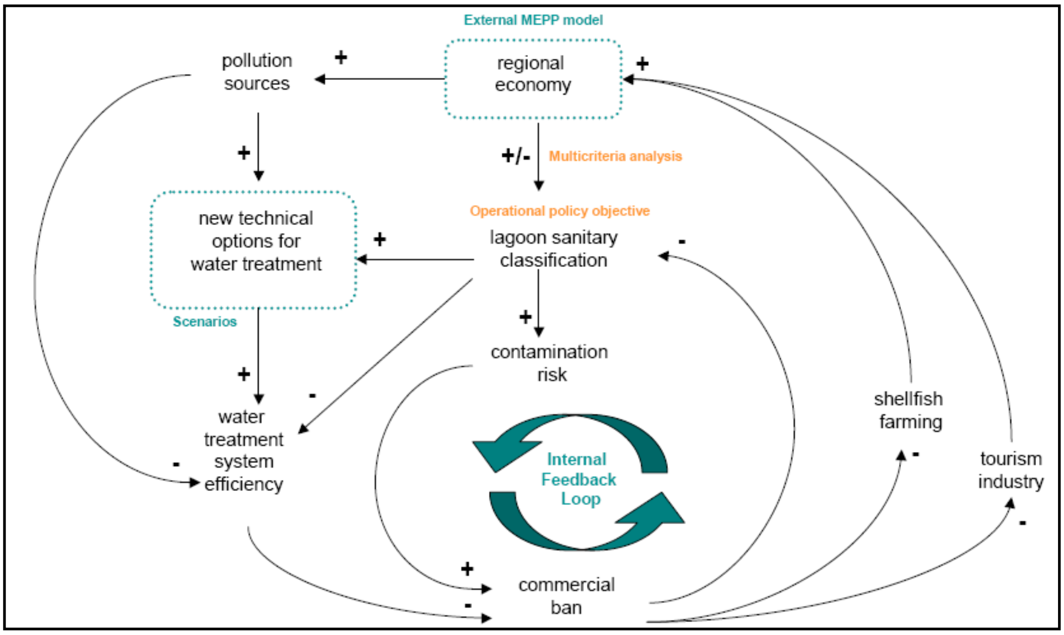
The economic system is of course not closed. Considering together the economic and ecological subsystems, the output production is then the results of inputs transformation (including natural resources) through an economic and ecological process. An additional output consisting in emissions and pollution is then produced. Emissions as well as investments have a feedback function. The production function (F) will then also depend on the Emission function (E) and on the stock of ecological resources (S) representing the ecological process: F [K,L,A,E,S], with E [A,Y] where Y is the level of output.

Coupling the ecological systems will induce a dynamics over the economic system through policy response and economic behaviour. A static economic system can thus be made dynamic by coupling to the ecological system. This is discussed, assessed and illustrated at the section dealing with coupling ecological and economic sub-systems.

This logical relation chain Cet enchaînement logique de relations fonctionnelles peut être illustré par le diagramme structurel du modèle SSA13 (Etang de Thau). Il permet de mieux comprendre les liens entre les différentes entités du système ainsi que le sens des interactions

This logical sequence of functional relations can be illustrated by the structural diagram of model developed in the SSA13 (Thau lagoon). It enables a better understanding of the links between the different entities of the system as well as the cause and effect interactions.

Figure 6 : Representation of feedback loops in the Thau lagoon model (SSA13)



The core issue modelled in this site is the microbiological contamination of the Thau lagoon. It represents the receptacle of water masses coming from the catchment area and thus the microbiological charge dissolved in them. The diagram of the relations between the elements of the system presents a relative linearity from the sources of effluents in the upstream part of the catchment and the anthropogenic activities developed in the downstream part of the catchment and which support the impacts of this contamination. Thus, the anthropogenic activities in general and the economic ones in particular (gathered under the "regional economy" module) cause a positive flow of bacteria. Part of the bacteriological concentration of the basin is abated by the water treatment systems (negative relation between concentration and abatement). The bacterial concentrationdissolved on the water masses are after spilled and diffused on the lagoon potentially affecting shellfish farming and bathing activities. For minimizing the sanitary risks, the European regulation[3] provides monitoring protocols for warranting the sanitary water quality and the safety of human consumption. It provides as well two main management measures: the classification of production depending on their current healthiness and short-run bans of commercial sales in case of occasional surpass of the monitoring results compared to the maximum admissible thresholds. In case of commercial ban, economic impacts are related to the stop of environmental good and service provisioning by the areas concerned. Regarding the productive sectors, production and bans of commercial sales imply reports of activity which lead at short-run to decreases of revenues. At long-run, the recurrence of these events can attain the image of production. The economic losses of the productive sectors can be assessed by (i) the surplus losses of producers caused by the decrease of offer due to bans of commercial sales and (ii) the decrease of market prices due to lower demands (image damages). Consequently, a better classification of the sanitary quality of water of the lagoon (which directly related to the frequency of bans) would induce a positive effect on the risk of sanitary ban because the threshold of bacteriological concentration tolerated is lower. Consequently, a stronger risk of sanitary ban generates more negative effects on the shellfish farming and tourism activities.

This chain of linear relationships becomes dynamic by the existence of feedback loops. Firstly, as mentioned before, the classification of the lagoon in terms of water quality depends on the frequency of sanitary bans observed during the previous years. So a decrease on the water quality would result in higher number of sanitary bans and thus at long term downgrading the lagoon scoring. Secondly, economic impacts on the economic activities and amenity losses for recreational activities can results from these sanitary bans. Economic activities of the lagoon constitute a component of the local economy: directly or via the effects induced on other economic sector. This positive correlation is enlightened in the diagram X. The feedback effect is explained by the fact that changes induced on the system have direct consequences on the intensity of the regional economy and then on the bacteriological effluents. This leads to the system dynamics coming from forcing variable changes.

3.6 Scaling

Some differences with ecological systems may also appear in scale modelling. Any pattern observed in nature is the result of processes acting on many spatial and temporal scales. At the endless question of modelers about the best scales of resolution to use in modelling processes, Levin (1992) answers that *"the problem is not to choose the correct scale of description, but rather to recognize that change is taking place on many scales at the same time, and that it is the interaction among phenomena on different*

[3] Regulation (EC) No 854/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption.

scales that must occupy the attention". Some attempts have been made to propose hierarchy of scales and survey of scales in models, and especially for spatial scales (DeAngelis et al. 2003). Reader should also refer to the specific section of WP3's deliverable about system design.

The time scale

In economic systems, if times scales are as multiple as in ecological modelling, their definition is strictly driven by the economic activity. For instance in aquaculture the time scale will be defined by the duration of one operational cycle of production (one crop). Aggregation of results will follow on a larger scale in order to compare different production systems (usually one year of operation). Time variations in price and costs parameters are another issue related to time scale. Looking at markets and price formation, time scale can range from a half day to years if the price is considered as exogenous in a simple assumption.

In economics, the issue of time is also related to the issue of discounting the future. The issue is to provide a means to compare cash flows at different times on a meaningful "like to like" basis. Discounting is the process of finding the present value of an amount of cash at some future date. The discounted value of a cash flow is determined by reducing its value by the appropriate discount rate for each unit of time (read also WP2's deliverable D2.1 section 3.2.1). Time on return on investment is another key issue related to time scale in economics that will drive and explain pressures over resources.

The spatial scale

In terms of spatial scale, the economic system can present important differences with the ecological system considering the sector of activity. If spatial location of production systems (micro level) in an ecosystem is of importance – differences in environmental quality may impact the efficiency of production – spatial scales can also differ from the ecological ones and take place outside the ecological system or the "system mapping" as designed in WP3 (macro level). For instance part of the production factors can be imported; on the same way part of the production (output) can be exported or some prices may depend on international markets. Information can also depend on different areas or economic interregional interaction patterns may also exist.

This can impact indirectly the ecosystems (through forcing functions):

- foreign demand for output can push for non environmental friendly local production and ecosystem degradation (micro);
- in some cases local supply of inputs can be read in terms of an additional pressure over the resource, when intermediate production of inputs is also impacting the ecosystem (macro).

Economic assessment reveals a multidimensional aspect and it will lead to two approaches in terms of scaling: the macro-economic and the micro-economic scale with related issues in terms of modelling.

4. FORMULATION OF THE SOCIOECONOMIC PROCESSES

The system approach is based on mathematical formulation of cause / effect relationships. Consequently, the objective of the formulation is basically to assess the way in which system evolves on time. That enables the possibility to analyze dynamicsof systems and more precisely their stability or instability under some exploratory assumptions. The quantification of key threshold effects previously identified can enlighten system swing, irreversibility effects, etc.

Economic models in the system approach

As well as in other disciplines model in economics is a theoretical construct representing economic processes by a set of variables and logical and quantitative relationships between them. But if models are also simplified frameworks designed to illustrate complex processes, in the field of economics they do not always use mathematical formulation. For instance they can be qualitative such as some non stochastic models involved in some aspects of social choice theory, qualitative scenario planning in which possible futures (future events) are played, or non numerical decision tree analysis.

Quantitative models are applied to many areas of economics and several methodologies have emerged more or less independently of each other. The following few examples attempt to illustrate different types of models:

- Constrained optimisation models: are based on principles such as profit or utility maximisation; applied at microeconomic scale.

- Aggregate models: applied at more macroeconomic scale, they deal with aggregate quantities such as output, price or interest rate. Outputs are expressed in vector of goods and services. As well, price is a vector of individual prices of goods and services. This is the case of the Leontief Input/Output models (I/O) or the Computable General Equilibrium Models (CGEM). At a lower level, the market chain analysis (also called supply chain analysis) and economic table are other tools used to provide a simplified framework of the economic system. Connected with environmental issues, those tools are described and explained more in depth in WP2's deliverable D2.1 at section 4.5 and Appendix C). Supply chain analysis and economic table will be more suitable to capture smaller scale effects, especially since I/O matrix are too aggregated. But aside CGEM which are quite heavy models to implement and are out of the scope of the SPICOSA's SAF for SSAs, such tools are rather static if they are not coupled with environmental issues. Nevertheless, possibilities exist for calculating dynamic technical coefficients (I/O).

Represent the processes, state and forcing variables using stock/flow symbols. Several diagrams may be suitable, according to the amount of details needed to represent the whole system.

A basic framework for the economic subsystem model and its formulation

In a first basic framework, the ecological system can be considered as a "black box" so that the economic system is independent of the environment. This can be easily justified as if the profitability of the economic process is not ensured, then there's no more environmental issue to deal with. This "economic sustainability" is a key issue. If technical ability is a precondition it will fail if it is commercially uneconomic. Economic failure may stem from production, technical or cost problems, or from marketing problem. If there's no expectation that economically viable projects are possible, there are no environmental issues that matter, nor social equity, income distribution or regulations issues.

The production of output is then independent of ecological processes: no inputs are natural resources and outputs do not generate emissions and pollutions (so called externalities[4]). Output will then consist in consumption goods (C) and Investment (I), the latter being seen as an output based on reinvestment of production or reimbursement of initial capital. Investment is the translation in money of infrastructures built in order to produce C). Another simple view of a production system is a system based on some infrastructures and a combination of production factors (inputs) to produce an output. Inputs will consist in capital (K), labor (L) and technologies or technological development (A). The production function F (formulating the production process of the output) will depend on K, L and A: F [K,L,A]. This economic system can be made more complex according to economic theories and paradigms (market competition vs. free market, endogenous technological progress, etc.).

Next chapters describe the formulation of main economic processes which system modelling can deal with. They are defined and also illustrated by some relevant examples reviewed from the SPICOSA study case material supported. There is no only one way of formulating those processes. Each case is adapted to the knowledge existing and to other needs or constraints of the model. These examples must be taking in account as examples of implementing and integrating formulation of socioeconomic processes into the models.

4.1 Production processes

Basically, production is an economic activity generating an added value from the combination of production factors (inputs) which are basically capital and labour. The outputs resulting from these processes are goods and services. Operators can be private or public. In the first case, companies produce under the objective of generating economic rents. In the second case, public institutionscan provide public good and services but the objective is more frequently guided by the increase of the common welfare.

Next paragraphs will illustrate by examples from SSAs modelling works the way of formulation production processes taking in account a variety of strategies of formulating. This is mainly conditioned by the knowledge available and by the more adaptive way of proceeding depending on the structure of each model.For each example, the production processes will be put into the global context of their systemic model. For better understanding the way of formulating these processes, we will be interested on describing what determines the processes analysed and how them induce effects to the other elements of the systems.

4.1.1 The example of the Shellfish farming in the Limfjorden SSA5

The Limfjorden study site performs a model which integrates a shellfish farming sector specialised on the mussel production. The core issue is related with the interaction between mussel production and eutrophication in the Limfjorden. This negative proces directly impacts the mussel fishery which is the most important economic activity in the fjord. The key interaction linking the socioeconomic and the environment components is the biomass of large mussels targeted for production (shell length higher than 4.5 cm). A conversion factor is used to link the applied unit for biomass (Tons estuary^{-1}) in the economic model to the unit used in the Ecological model (mmol C m^{-2}). Also, the economic

[4] Externalities from business activity are side-effects of the activities of a business or other businesses for which no economic payments (e.g. compensation) or costs are involved. They can be positive or negative depending on if they are favorable or not.

model representing the activity of this fishing activity is based on data from the entire Limfjord (landings, costs etc) and these were scaled down to Skive Fjord using a conversion factor based on landings and fishable areas (>2 m depth).

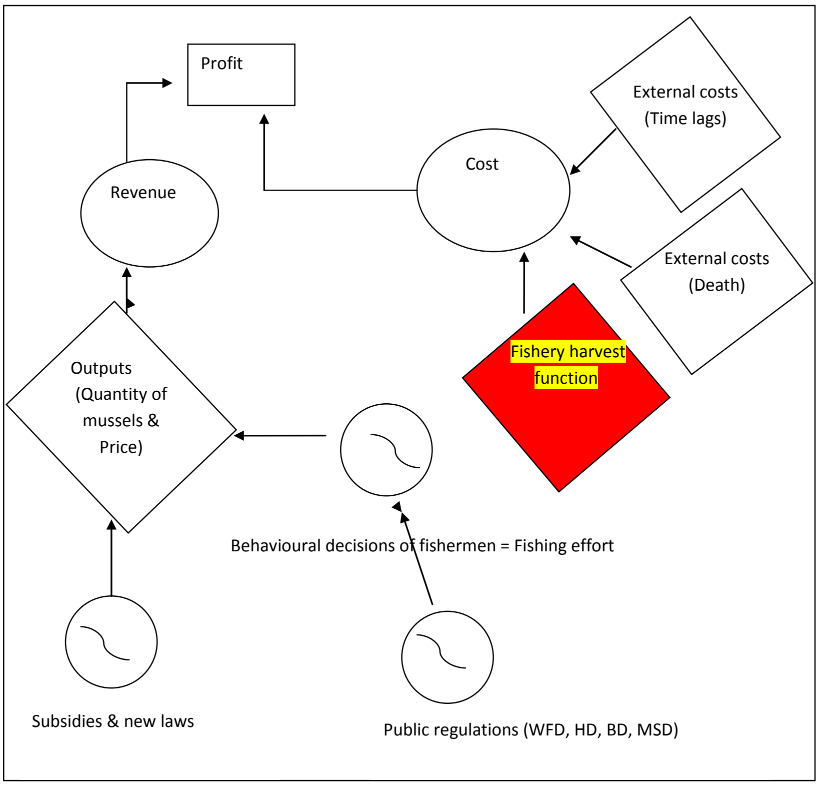
The assessment of eutrophication in the model is only restricted to the impacts on the mussel fishery. Eutrophication drives to a mower physical growth of the mussels and consequently on a decrease of the total biomass. In addition, both this processes are suspected to generate harmful algae blooms (HABs). Further, the occasionally situations with hypoxia and anoxia are an additional cause of mussel mortality.

Focusing in the production, this process Y (ton per year) is calculated by combinations of production factors influencing it; which are mainly labour (L, measured in full time equivalent) and Land (measured in ha). L and A act are control variables determined by the farmer (Dinesen et al. 2009). The production model is adapted from the Cobb-Douglas production function (Dinesen et al. 2009). The function and its corresponding variables are illustrated below:

$$Y = \alpha A^{\beta} L^{\gamma}$$

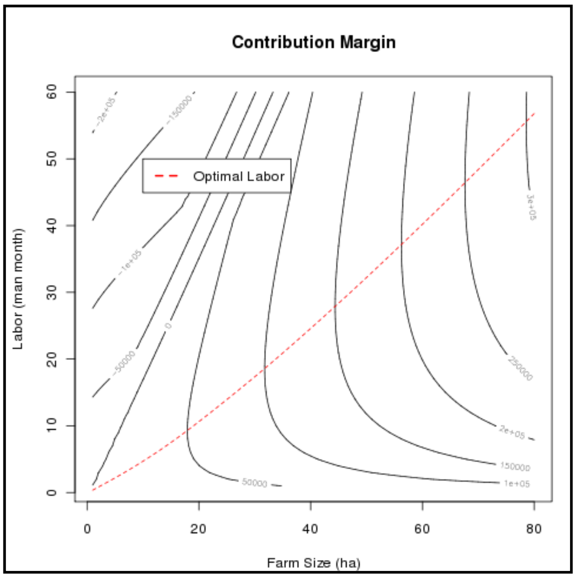
where the parameters α is the total factor productivity (TFP), and β and γ are respectively the output flexibility of land and labour(Dinesen et al. 2009). A log-Linear model has been used to calibrate the parameters α, β and γusing quantitative information collected from mussel farmers' expectations. A mean production function estimated is $Y = 2.538 A^{0.4195} L^{0.7043}$. The simple diagram of the production process module is represented in figure X

Figure 7 : Mussel Production Model in Limfjorden(Dinesen et al. 2008)



The key economic evaluation method used in this model was the change in contribution margin, that is, the change in private benefit under the scenarios as compared to the base-line scenario, for the industries directly impacted by changes in the state of the environment. To create a production possibility frontier function, the total factor productivity was multiplied by a coefficient of 1.3. With these parameters and the multiplication of 1.3, the Cobb-Douglas production function encompassed nearly all of the mussel farmers' estimations of production (Dinesen et al. 2009).

Figure 8 : Figure 1 Expected contribution margin as a function of A, area (in ha) and L, labour (in man month). The dash red line indicates the optimal level of labour input given a fixed farm size (Dinesen et al. 2009)

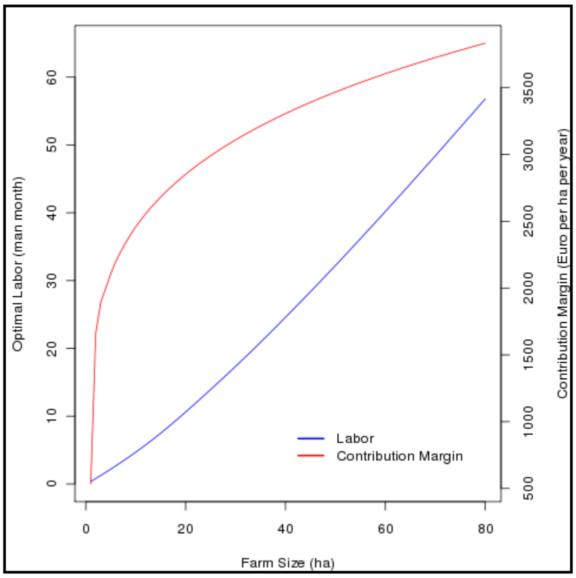


For assessing profits at different levels of production, cost and prices functions need to be specified.Concerning costs, the model only considers those related to the labour factor. According to Dewan and Roth 2009, labour cost is placed at W = 3894 € month^{-1}. Anticipated farm price of the blue mussel production for the seven companies in the Limfjorden which includes the account statistics of aquaculture production during the year 2007 are within the range of 0.567-1.3420€ kg^{-1} mussel wet weight. Quality and expected farm price are dependent on the intensity of labour. The mathematical formulation of price was formulated using a linear increasing function of labour input per hectare (Dinesen et al. 2009)

$$p(L,A) = \begin{cases} 0.567 & \frac{L}{A} < 0.4 \\ -0.753 + 3.3\frac{L}{A} & 0.4 < \frac{L}{A} < 0.635; \\ 1.342 & 0.635 < \frac{L}{A} \end{cases}$$

where constants of 0.4 and 0.635 depict the minimum and maximum of the expected labour intensity. Consequently, profits (contribution margin) can be assessed at different levels of production factors intensity.

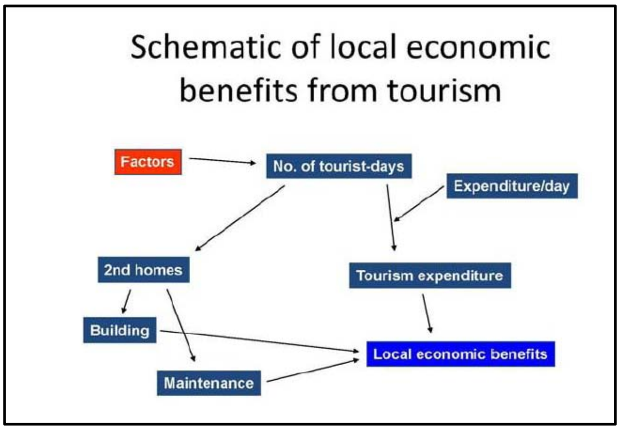
Figure 9 : Expected increase in return to scale with respect to farm sizes:(blue line), model of the optimal level of labour input as a function of the farm size; and (red line), model of the contribution margin density in 1000 € ha^{-1} $year^{-1}$(Dinesen et al. 2009)



4.1.1 The example of tourism in the Sondeledfjorden (SSA6)

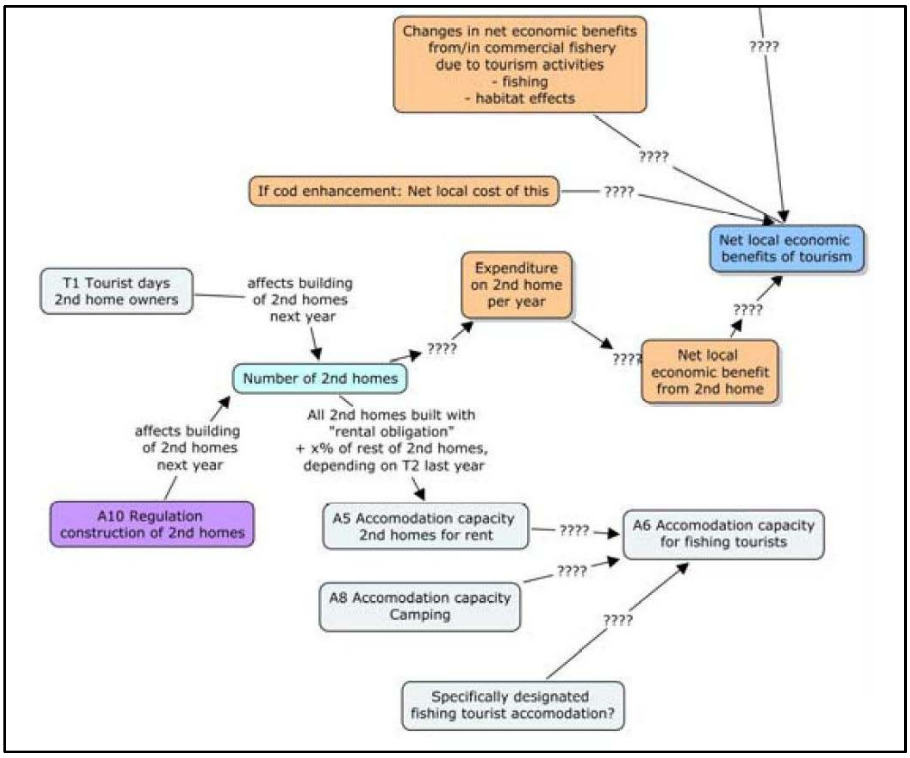
The core issue in this study site relies with the interactions between the tourism sector and the ecosystem services of the Sondeledfjord. The attractiveness of this site is due to the natural capital of this site which strengthens the high frequency of visitors in summer. Moreover, an important activity of angling, mainly targeting cod,has been developed reinforcing as well the number of visitors.The development of the touristic sector induces direct and indirect benefits for the regional economy. However negative effects are produced by a higher pressure on the local coastal cod stock and by generating conflicts of use with other local users of the fjord system. The aim of the model is to develop a tool enabling the exploration of trade-offs between different objectives driving towards sustainability considering impacts of tourists, economic development and the reduction of conflicts of use. The links between the environment and the economic components focuses on local economic benefits for tourism which depends on the frequency of tourists.The economic sub-model of the Sondeledfjorden model related with the economic benefits from tourism is illustrated in Figure 10 (next).

Figure 10 : Schematic of local economic benefits (Mokness et al. 2009b)



The effects of tourism are twofold. Firstly, expenditures per tourist have positive effects on all kind of service sectors. Direct and indirect impacts can be measured by input-output models. Secondly, tourism generates an increase of demand for second homes. In some cases, tourists directly invest in a second home and frequently spend holiday's time in this region. Other kind of tourists rent them for their stage. A demand of new constructions for renting business is also developed by local residents. This example only focuses on the economic benefits from the tourism industry on the construction sector. To illustrate this modelling exercise,we will consider the production process of building and maintenance of second homes and its links with the other components of the model.

Figure 11 : Second homes construction and maintenance (Mokness et al. 2009a)



Orange boxesrepresent the contribution of the industry of second homes construction and maintenance to the net local economic benefits of tourism. It is a summer home production process with tourism as its main entity. This production process is intertwined with the regulation process (purple colourbox) and it is formulated as follows. The current number of second homes in one year relies on the previous year's number and also the additional summer homes that have been built during the last year. The demand for tourist days for 2nd home owners influences the rate of construction of new second homes but it is restricted by regulation on construction of 2nd homes. The assumption is that growth within the number of 2nd homes is proportional to growth in demand for tourist days by 2nd home owners but restricted by how many 2nd homes have been accepted for construction (R_{50}) (Mokness et al. 2009a).

The equation a_{50_t} represents the total number of 2nd homes in the current year(t), after new 2nd homes have been built within the current year.

$$a_{50_t} = \begin{cases} a_{50_{t-1}} + \beta_{50}(T2_{t-1} - T2_{t-2}) & \text{if } a_{50_{t-1}} < a_{50_t} < R_{50} \\ R_{50} & \text{if } \quad a_{50_{t-1}} + \beta_{50}(T2_{t-1} - T2_{t-2}) \geq R_{50} \\ a_{50_{t-1}} & \text{if } \quad a_{50_{t-1}} + \beta_{50}(T2_{t-1} - T2_{t-2}) \leq a_{50_{t-1}} \end{cases}$$

The elementary components within the equation are:
T2t-1 = Number of tourist-days last year
T2t-2 = Number of tourist-days two years ago
β_{50} = (1 / number of persons pr 2nd home) / number of day in use
DELTA a50 equation is the number of 2nd homes constructed in the current year.
DELTAa50=$a_{50_t} - a_{50_{t-1}}$

There are two ways in which summer homes contribute to the net local economic benefits through two mechanisms, by the net benefits from construction and by the additional services related with maintenance.

a. **When they are built** (Mokness et al. 2009a)

The net local economy is generated when the summer homes are built by generating different types of costs incurred by utilizing local services and goods (assumption that 100% local utilization except building costs with 50%). The costs considered here are a) the costs of building and maintenance of 2nd homes in the county where Risør are and nearby counties b) sale of ground c) cost related to the ground preparations (water supply, electricity and road, sanitation) and building costs.

Based on data from other/larger regions, investment and maintenance costs for 2nd homes are assessed as follows:

Table Per 2nd home constructed: 2006 costs that go to local actors (1000 NOK):

Ground	500
Preparation ground	80
Materials and work	540
SUM	1120

A multiplier of 1.3 is consideredas an estimator of the net local economic benefits per 2nd home built. Hence, according to 2006 data, the net local economic benefits=1.3*1120000=1 456000NOK. Consequently, local economic benefits in a single year per 2nd home built within the year = 1 456 000 NOK. Local economic benefits from newly constructed homes are (L6)

$$\text{Equa (3.8): L6} = 1\,456\,000 \text{ NOK} * \begin{cases} \beta_{50}(T2_{t-1} - T2_{t-2}) & \text{if } < R_{50} \\ R_{50} & \text{otherwise} \end{cases}$$

The elementary components within the equation are;
T2t-1 = Number of tourist-days last year
T2t-2 = Number of tourist-days two years ago

b. **The maintenance needed** (Mokness et al. 2009a)

Maintenance costs per 2nd home per year which lies within the range of 2163-5486 NOK for the year 2002 are estimated from (Dybedal 2006). The highest estimation was utilized as the real estate value of Risør is very dear and valued between 0.32-0.69 for municipalities that are less densely populated than around Risor. The highest local share and the multiplier of1.3 are used for calculating the net local economic benefits per 2nd home per year

Net Local Economic Benefits = 1.3*0.69*5458=4896 NOK

L7=a50t-1 * 4896 NO

4.2 Investment processes

Investments are processes implemented by companies (or by public institutions) enabling the acquisition of capital necessary for implementing their production functions to produce goods or services. Capital acquisitions can be driven have development objectives (increase of the production, productivity) or the replacement of capital due to wearing or depreciable of assets.

In spite of the heterogeneity of investment processes, its formulation can be framed into two main types:

- Investment linked to a substitution of capital due to depreciation. The wearing of the fixed assets caused bycurrent activity of producers is considered regarded as a running cost and consequently is annual accounting documents. In practice, that results in a reduction of the recorded benefits. Accounting rules also enables the integration of provisioning as running as costs. This is a way of managing the capital replacements for maintaining a level of reinvestment which guarantees the company stability. The quantification and the formulation of these processes do not represent a complex task.
- On the other hand, the investment processes related to nonroutine economic strategies are more difficult to apprehend. They can be determined by complex mechanisms such as rational anticipations, strategies of growth, diversification, integration; etc. The way of formulating these processes depends on each case and on the type of economic approach used. As an example, investment can be simply conditioned by the level of profitability of companies. In case of benefits, a partial amount can be allocated to remunerate the capital and another part can be used for the reinvestment in the company. The investment rate selected depends on the economic strategies of each actor (cycle of live of the company related to developments and retry, diversification, etc.)

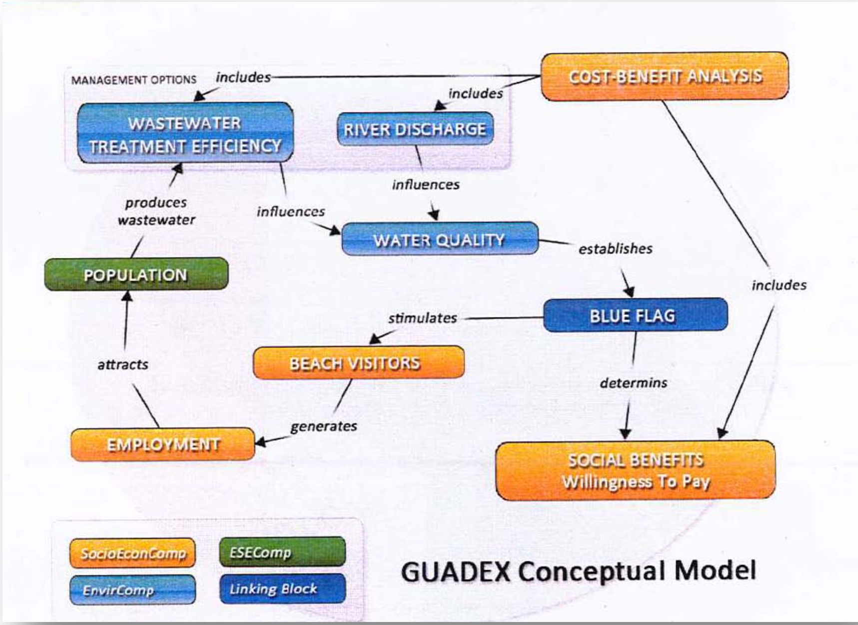
4.2.1 The example of the Guadiana Estuary

The model developed in the Guadiana estuary for supporting integrated cost benefit analyses related with the improvement of the water quality especially for recreational bathing purposes. Investment and operating costs of different Waste Water Treatment Plantsareconsidered. Consequently, the link between the environmental and the socio-economic components is based on the following assumptions:

- ✓ An improvement in water quality (represented by the variable fecal coliforms concentration and N:P:Si ratios) leads to an increase in the economic benefits provided by that resource. These benefits have been calculated using Contingent Valuation Methods (willingness-to-pay) for residents and visitors of Guadiana estuary.
- ✓ The estuary's trophic state (N:P:Si ratio) affects fish population, which will have an economic impact on fisheries and consequently on employment.

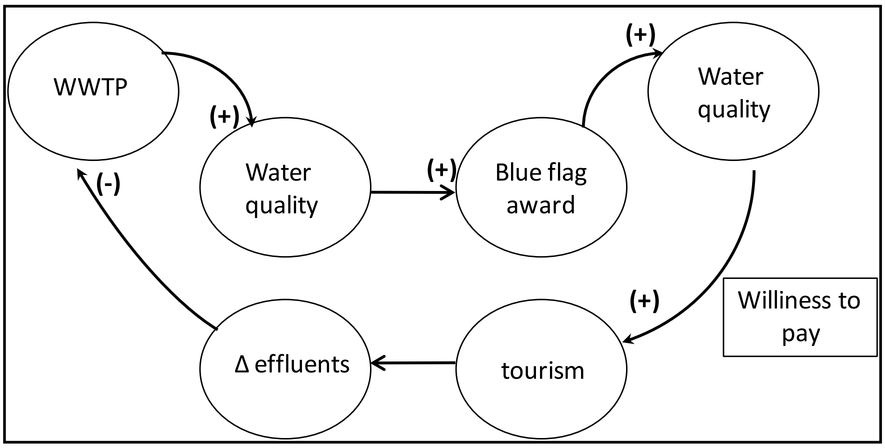
- ✓ Water quality has an impact on beach attractiveness that can be translated to the number of visitors to the surrounding beaches and to employment.

Figure 12 : Conceptual model of the Guadiana Estuary. Box colours represent the modelled dimensions: environmental (light blue), socio-economic (yellow) and integrated response (green)



The relationship chain is based on the proposal that a better WWTP efficiency directly affects the water quality and consequently the blue flag award qualifying the quality of beaches for bathing. This label induce a positive effect on touristic attractivenessand then on the global economy of the region. However, the increase of environmental pressures related with an increase of population may decrease the performance of the WWTP and require at mid and long term new investments to manage the additional pollution generated.

Figure 13 : Conceptual mode of relationships between tourism and water quality in the Guadiana study site



The focus is to compare the efficiencies between the WWTP in terms of treating sewage (Boski et al. 2009). The mathematical formulation of the investment is highlighted in table 2(Garcia et al. 2008).

Table 2: Waste Water Treatment Plant (WWTP) Investment Mathematical Formulation(Garcia et al. 2008).

Name	Process	Variables	Units	Equation
WWTP Investment	Design and Construction	Variable cost Fixed Cost Effort (Labour cost per year)	Euros	WWTP Investment = Variable cost + fixed cost + effort
	Maintenance and Improvement			
	Monitoring			

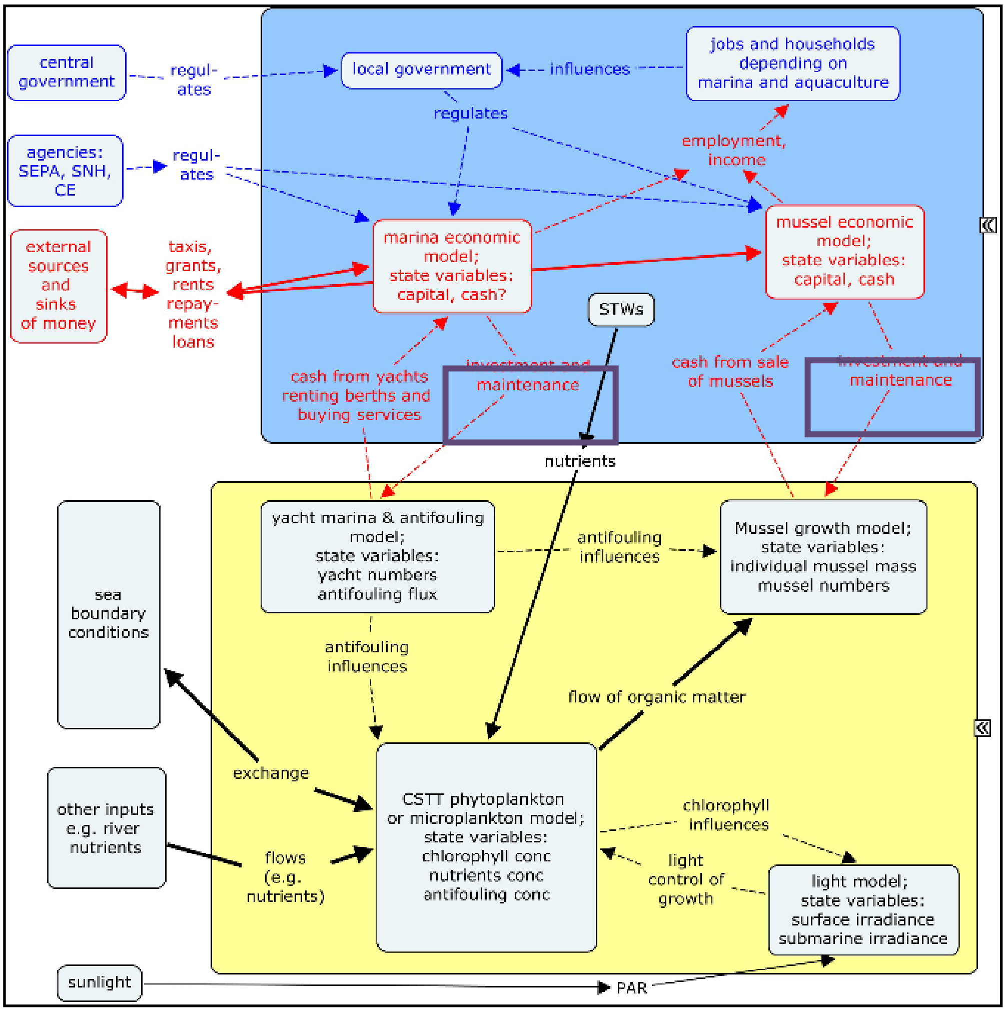
The model compares different efficiencies of waste water treatments than could be implemented in the Guadiana estuary. However this purpose became irrelevant due to the finished construction of the WWTP in Guadiana, hence there was a shift in purpose of the model. The new purpose is described in the following paragraph

Hence, the model would demonstrate its great potential as a decision support tool, illustrating the consequences of a predetermined policy option and its related impacts, both at a socioeconomic and environmental level. It allows, as an example, to assess if the features of a given WWTP project are in fact over-projected (the investment is above the required one to assure a good estuarine water quality), or under-projected (the investment does not assure a good estuarine water quality).

4.2.2 The investment processes in the Clyde (SSA7)

The main issue linking environment and economic development in the Clyde study site refers to potential conflict between a marina and a mussel farm through antifouling practices that may impact phytoplankton growth and thus negatively influence the growth of mussels in Loch Fyne. The model is driven by the number of yachts berthed in a marina. These yachts exert pressure on the system through the anti-fouling compounds applied to their hulls which slowly leach into the water column. Anti-fouling may affect phytoplankton by reducing their ability to photosynthesize which in turn reduces their growth. This could potentially have a detrimental impact on locally farmed mussels as they derive a large part of their nutrition from the consumption of phytoplankton.The obvious links of the ESE was the interactions between biophysical factors, production of mussels and economic outputs. The driver of system change came from pollutants from the yachts, which in turn influenced by economic factors that drive tourism and development.

Figure 14 : Scheme of the Clyde system model



There are two investment processes in this model. **The first refers to the economy of Marina**. The marina model attempts to estimate the changes in spending that are associated with the tourist activity surrounding a new marina in Loch Fyne. It calculates the predicted increase in regional jobs and the increase in revenue entering the Scottish economy by using data in the form of input output tables and economic multipliers. The marina model has also planned for a reinvestment strategy whereby if the marina is profitable; 20% of its revenues will go back for reinvestment in new leisure facilities and investment and development applications (human capital) (development of rural communities).

Table 3: Equation of the socioeconomic module of the system

Number of boats visiting the marina	Economic Impact = Number of boats × Av. spend/visitor × Multiplier
Average spend per boat [the average spend per visitor]	Economic Impact = No of Tourists × Average spend per boat × Multiplier
Revenue	Revenue = Price – Cost
Price	Price= No of boats in marina x [(Money/boat/stay)/Av. length of stay]
Average length of stay	Price= No of boats in marina x [(Money/boat/stay)/Av. length of stay]
Costs	Costs = (Average salary × No of Employees) + (CapitalDepreciation Rate) + (Revenue × Taxation Rate)
Average Salary	Costs = (Average salary × No of Employees) + (CapitalDepreciation Rate) + (Revenue × Taxation Rate)
Depreciation rate	Costs = (Average salary × No of Employees) + (CapitalDepreciation Rate) + (Revenue × Taxation Rate)
Employment Multiplier I and II	Jobs=employees*employment multiplier
Re-investment	When revenue = -ve, re-investment = depreciation, when revenue = +ve, reinvestment = revenue x20%
Income multiplier	Money = Revenue*Income Multiplier

The second investment process refers to the economy of the mussel farming sector. Investments depend on the performance of companies. In a first stage, revenues are assessed for mussel farming. They rare linked with the size of the farm and biologic productivity (mainly explained by the growthof the mussels).

Equation (a) $$\frac{dRevenue}{dt} = \left(\frac{Harvest * \frac{Mass}{C} * Price * M}{t}\right) - Cost$$

Equation (b) $$Cost = \left(\frac{Employees * Pay}{Days}\right) + (Revenue * Taxation) + (Capital * Depreciation) + Seed$$

Harvest = number of mussels harvested
Mass = the mass of single mussel from equation
C = conversion of Mass in mg C back to mg
t = conversion of mg to tons
Price = the price of mussels per ton
M = a factor to convert mussel flesh biomass, the unit of the ecological model, to the weightincluding mussel shells which will be the marketable weight
Cost = running cost of the farm
Employees = Farm/4; assuming three employees are needed from a farm with 12 lines
Pay = Average wage cost per year of one full time employee

Days = 360 to give cost per day ***Revenue*** = the revenue of the mussel farm from equation 7 ***Taxation*** = rate of taxation ***Depreciation*** = rate of depreciation ***Capital*** = Farm capital from equation 9 ***Seed*** = the cost of seeding the mussel lines

In this model, the dynamics investment is directly linked with the revenues

Investment = Revenue*0.2(Capital*Depreciation)...if Revenue ≥ (Capital*Depreciation)

And consequently, the stock of capital is modified by the amount of investments each period:

Equation (c) $\frac{dCapital}{dt} = Investment - (Capital * Depreciation)$

The initial values for the economy of the mussel farm come from a Loch Fyne mussel farm which markets the mussels at a premium price selling directly to restaurants (Wilson pers. comm.) (Table 13.1.5)

Social impacts

Economic multipliers published by the Scottish Government for each sector are used to calculate the impact of local businesses on the local economy. In terms of employment, multipliers were used for assessing direct and induced employment changes. Scaling down factors is used for the Firth of Clyde region which represents around 75% of all of Scotland (McKenzie, 2006).

Equation (e) $Jobs = Employees * Employment\ Multiplier$

4.3 Innovation processes

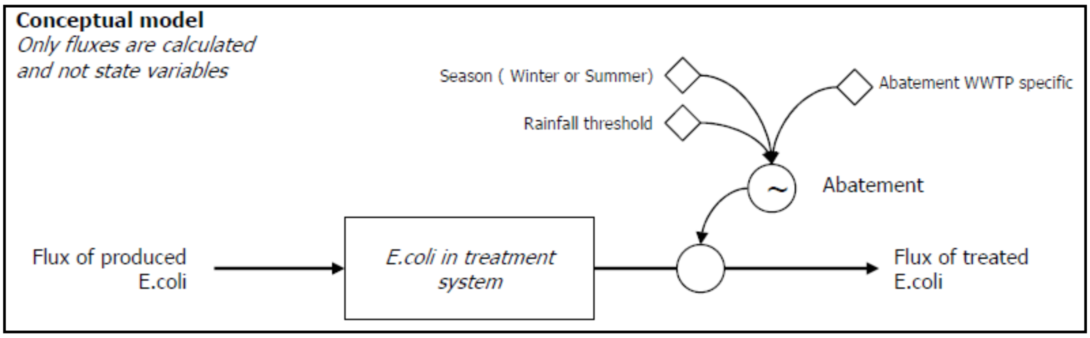
Innovation is a process which leads to changes in the way of proceeding. They can be applied to other socio-economic processes as production and management (institutional innovation). In the case of production, innovation can be of two types: technical and the organisational. The first concerns the implementation new more efficient techniques or technologies driving to higher performances of companies (for example with mechanization, computerisation, etc). The organisational innovation consists in adopting new manners of structuring which also enable the increase of economic efficiency or reduce production costs (in general are linked). With regard to the processes of institutional innovation it consists in creating new governance mechanisms or organisations supporting sustainable management frameworks.

4.3.1 Technical innovation of water treatment: the example of the Thau lagoon (SSA10)

In the case of the microbiologic water pollution in the Thau study site, a way of controlling the water quality is abating the bacteriologic of the catchment by waste water treatment plants. However, the total costs of water treatment grow exponentially with the increase of the bacterial abatement. Consequently, even if it would be suitable to reach absolute purity of water, the economic cost associated would be almost economically impossible to support. Hence, the model explores trades-off of different options into a cost-efficient framework enabling to reach a suitable sustainable level of environmental quality and socioeconomic development.

The improvement of the water quality can be reach by two ways. Firstly, the nominal abatement effort of water treatment can be increased. This refers to the implementation of new treatment plants or to the increase of the existing ones. A second way of implementing the abatement is by using new treatments and that refers to technological changes.

Figure 15 : Conceptual model of the water treatment by WWTP in the Thau lagoon



The efficiency of the treatment depends on the entry and exit flows which are directly determined by the number of inhabitants connected to the WWTP by the weather conditions which accelerate the water flows. In the model this efficiency is known and supplied by other scientific works developed locally.The nominal capacity of each WWTP should be adapted to the local demography. However, this capacity can be modified by the implementation of new technologies. In this case, a simply way of formulating the abatement effects of innovation is including in the equation a weighting coefficient measuring the additional treatment capacity (β).

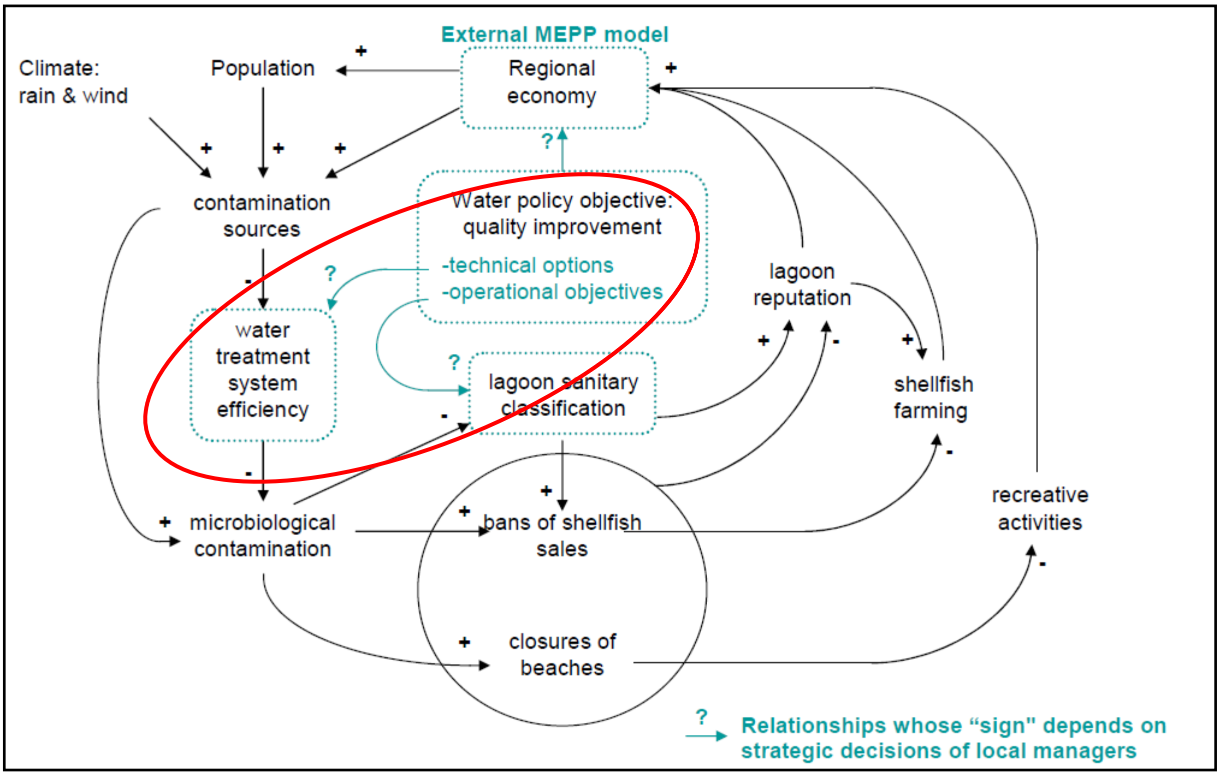
$$\text{Flux}_{\text{treated}} = [\beta] \cdot \text{Flux}_{\text{produced}} / \, 10^{\,\text{abatement(season,rain fall)}}$$

where Flux produced is measured in E. coli/day.

Total cost function of water treatment depend on the nominative capacity of treatment requiring more capital and employment, and on technology (new investments required).

The integration of this module into the system is represented by the next scheme

Figure 16 : Conceptual model of the Thau lagoon contamination (the water treatment in read)



4.3.2 Institutional innovation, the case of the freshwater allocation in the PertuisCharentais (SSA10)

This case study deals with a problem of quantitative management of the freshwater in the Charente river basin.This common resourceis the support of many ecosystemservices. However, the catchment presents large hydrological variabilityand its water flow generally decreases sharply in summerwhen water demand is the highest. This processes lead to water scarcity, drying out of some parts of the catchment and, conflicts between water users, mainly between agriculture and shellfish farming. Agriculture is an important economic activity at the territory while the local shellfish farming represents the first oyster production in France and in Europe. This economic weight gives to these activities an important local political representation.

The local water management plan regulates the freshwater uses by implementing technical mechanisms of monitoring and restrictions in case of shortage. The model developed in this case studyexplores soft institutional which can drive to the improvement of freshwater governance in the Charente catchment. Freshwater management seeks to reduce the welfare losses due to the overexploitation of common-pool resources provided by river catchments and their associated ecosystems. Due to the complexity of the governance system, improving the performances of one coastal social-ecological system is then a matter of searching for the adequate "soft institutional changes".

The current situation regarding irrigation management constitutes the baseline scenario. Farmer practices in the upstream area are based on a projected schedule which distributes the annual use-rights into finalised periods of the irrigation season, while in the downstream area farmers have access to their whole annual use-right at any time. In the second situation, the eventual partial restrictions, which occur during water shortage events, apply to this annual use-right: farmers are therefore encouraged to adopt "myopic" irrigation strategies, especially because they have no incentive to anticipate eventual future reductions of their authorised volumes, which are far much higher than their actual needs. In addition, some farmers of the upstream area have engaged into collaborative irrigation strategies, which consist in organizing water-turns among farmers in some specific locations.The upstream irrigation strategies are assumed to be more efficient as regards their ability to prevent the adverse effects of freshwater scarcity, including crisis events which lead to severe restriction measures for irrigation. Finally, the exploratory scenarios consider the progressive deployment of the supposed best irrigation strategies from the upstream area toward the entire Charente river catchment.

Table 4: Combination of irrigation strategies in the exploratory scenarios

	Upstream area	*Downstream area*
Baseline scenario 0: P/A	Projected irrigation strategy	Annual/myopic irrigation strategy
Exploratory scenario 1: P/P	Projected irrigation strategy	Projected irrigation strategy
Exploratory scenario 2: C/P	Collaborative irrigation strategy	Projected irrigation strategy
Exploratory scenario 3: C/C	Collaborative irrigation strategy	Collaborative irrigation strategy

In order to take into account the influence of the governance system on the agriculture dynamics, the numerical model incorporates the following institutional arrangements: the collective rules which define crisis restrictions (noted *A*) and authorised volumes for irrigation (*C*) and the operational agreements regarding irrigation practices and strategies (*D*). The variables and equations which relate institutional arrangements and agriculture dynamics are as follows:

- ✓ *IDC* is the Irrigation Demand for Crops, estimated by the potential evapo-transpiration and the factor *Kc* which parameterises the influence of the growth stage on crop water needs,
- ✓ *IDF* is the Irrigation Demand of Farmers, depending on local agricultural practices *(IDF* may be expressed as a fixed percentage of *IDC)*, and limited by the capacity of equipments,
- ✓ *ICC* is the Irrigation Consumption of Crops, depending on farmer practices and irrigation authorisations,
- ✓ *PAT* is the Projected volume of Authorised Takings per period, without crisis limitations,
- ✓ *RAT* is the Real volume of Authorised Takings at each time step, considering the past water consumption within the current period and the application of eventual crisis limitations.

At each time step within a given time period *d* (year, 10-days period, week or day, depending on the irrigation schedules), the irrigation consumption of crops is given by:

$$ICC(t) = \min[IDF(t), RAT(t)] \quad (1)$$

Where $$RAT(t) = PAT^d(1-\alpha) - \sum_{t=1}^{t-1} ICC(t) \qquad (2)$$

Thus, the real volume of authorised takings depends on a parameter α whose value ranges from 0 to 1 and which defines the level of temporary irrigation limitations at each time step. The limitation parameters are fixed for each sub-basin by a yearly by-law, and depend on successive “alert” thresholds, the last one being the “cutting threshold” (when the value of the limitation parameter is 1). The number of management thresholds varies from 2 to 4, according to the sub-basins and the season. The model applies the limitation parameters automatically, after having read the monitoring data provided by the hydrological module. When instead of a “myopic” irrigation strategy (former case), the management system requires a projected irrigation schedule based on 10-days periods:

$PAT = \sum_{d=1}^{n} PAT^d$, where n is the number of finalised periods during the irrigation season.

The collaborative irrigation scheme implies that farmers agree not to pump water at the same time. Thus, in addition to PAT and RAT, the implementation of water turns lead to a constraint on IDF: for each farmer IDF is equal to zero one day out of 2, what means that IDF is cut by half at the scale of the watershed when this operational agreement apply.

4.4 Regulation processes

Regulation processes integrate any type of mechanism conditioning other processes in the model. Their nature can be different depending on if they affect socio-economic structures or if they control the dynamics of other processes in the system.Regulation of the processes can be carried out by the imposition of standards, rules or by the implementation of incentives which would enable the achievement of mechanisms driving to sustainability.

The way of formulating regulation processes are divers. They can integrate management mechanisms relatively simple to formulate (for example by thresholds, levels of production per agent, standards of environmental quality,…) or via the structuring of intelligent regulating decisions which would act in the model according to a sequence of conditional logics on which would support the control of other processes in the model.

The main objective of models developed under the SPICOSA approach is to developed management support tools for exploring future dynamics on coastal zones. Consequently, all models of the study sites developed include management processes.

There is no a specific way of formulating these processes. The management of a system can be supported by control variables which enable the modification of key values of variables which determine the system dynamics. Another way of controlling the system is to impose thresholds to variables which must be respected by from anthropogenic activitiesprocesses. The following example of processes can be formulated in the model as regulation processes: the implementation of taxes, the imposition of maximum pollution rejects to companies, ban for certain uses, maximum production levels for companies exploiting natural resources, etc. All those type of rules are purely directive.

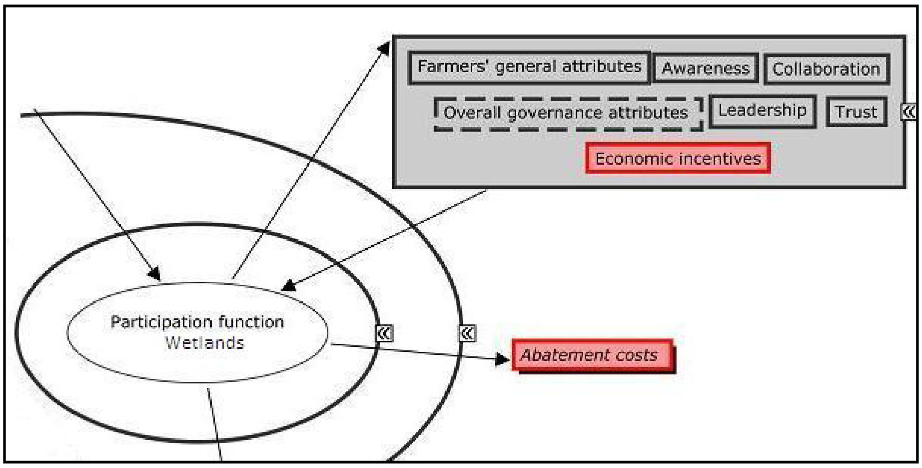
4.5 Induction and driven processes (other social processes)

Inductive processes are considered as those originated by agents or groups of agents with no factual consequences on their own actions but which induce changes on processes involving other agents. This is for instance the case for example of NGO of environmental protection. If they are not conditioned by personal interests, they should not have of economic incentive in particular. However, their actions can induce changes on economic processes of other agents, directly or by lobbying to decision makers. The way of formulating these types of processes can be divers, from simplest (threshold, coefficients, swing effects, etc.) to more complex mathematical formulations (wiliness to participate, social satisfactory functions, etc.)

4.5.1 The participation process in the Himmerfjarden (SSA4)

The socioeconomic component of the model developed in the Himmerfjardenstudy site deals with an eutrophisation issue. Nutrient loading has caused increased turbidity, loss of biodiversity, including submerged aquatic vegetation, deep water oxygen deficiency, phytoplankton blooms and biodiversity loss. The main stakeholder concerned by these the environmental negative effectsare mainly the tourism sector, recreational activities and nature enjoyment. Moreover, public institutions are also concerned because they are in charge of the Water Framework Directive which poses economic challenges for several activities in the area.

Figure 17 : Part of the socio-economic model which focuses on the creation of wetlands(Franzén, Kinell, and Söderqvist 2008)



As main actors who are responsible of this externality, a group of farmers have decided to participate in restoration of wetland spaces. These ecosystems supply filtering services which enable the decrease of nutrients dissolved on the coastal waters and hence the abatement of the eutrophisation processes. The probability to participate for farmers depends on different factors, mainly economic which are included in the formulation process ((Franzén, Kinell, and Söderqvist 2008)

$$Prob(participate) = \frac{e^{(constant+\beta 1\cdot subsidies+\beta 2\cdot timeframe+\beta 3\cdot collaboration+\beta 4\cdot compensations+\beta 5\cdot cap)}}{1+e^{(constant+\beta 1\cdot subsidies+\beta 2\cdot timeframe+\beta 3\cdot collaboration+\beta 4\cdot compensations+\beta 5\cdot cap)}}$$

The list of variables is detailed below:

- ✓ Subsidies: Slider is used to change policy option “wetlands” by changing characteristics for wetland creation. In this case going from 0 to 1 means going from subsidies per hectare and year from SEK 3000 to SEK 4500.
- ✓ Collaboration: In this case going from 0 to 1 means going from current level of collaboration and support to more collaboration and practical support with wetland construction.
- ✓ Timeframe: In this case going from 0 to 1 going from 20 years to 30 years time frames for subsidies
- ✓ Compensation: In this case going from 0 to 1 means going from 50-90% cost compensation to 100% cost compensation (with cap of compensation of SEK 100 000).
- ✓ Cap In this case going from 0 to 1 means going from cap of compensation of SEK 100 000 to cap compensation of SEK 200000.
- ✓ Subsidies coefficient Coefficient in participation function

After estimating the probability to participate, the global participation function can be assessed for the entire of the farming sector:

Participation Function=Probability of participation*number of farmers*number of wetlands in hectare*0.30

when 0.3 correspond to the participatory rate estimatedby an enquiry from respondent farmers answering positively to their interests to participate to wetland restoration programs

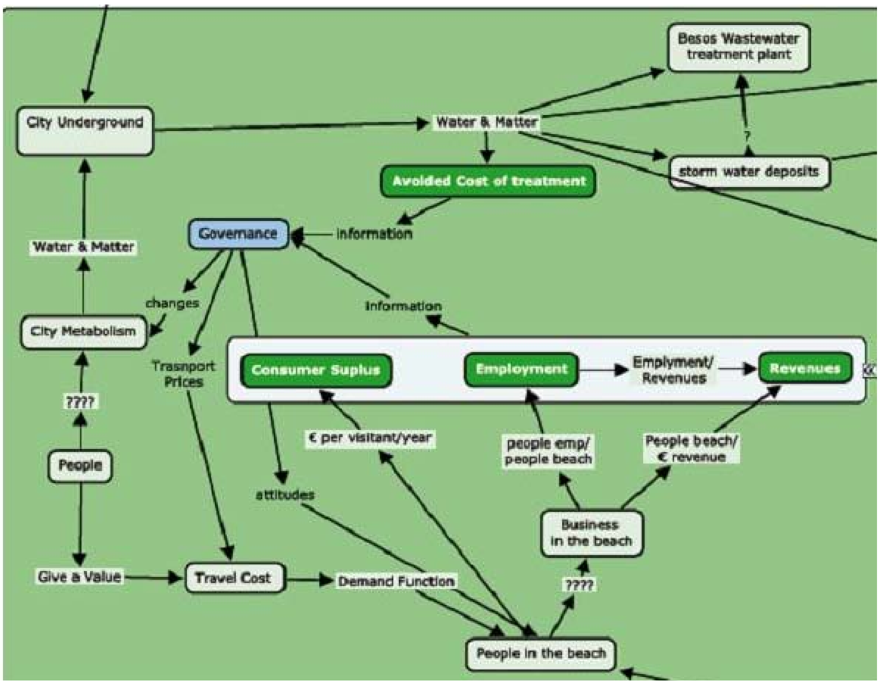
4.6 Consumption processes

Les processus de consommation relevant de démarches d’utilisation de biens et des services par de agents économiques. Les consommations de bien marchands sont relativement simples à formaliser dans les modèles. Il s’agit de mettre en relation des quantités de biens consommés avec les prix des acquisitions. Cependant, la consommation de biens et des services non marchands sont également source de bien-être et peuvent être considérés dans les démarches ces modélisations en appui à des évaluations intégrées. Des méthodes d’évaluation et donc de formulation mathématique de processus de consommation non marchands ont été détaillées dans les guides méthodologiques du projetSPICOSA (WP2). Dans les paragraphes suivants on illustrera la manière d’intégrer ces processus dans des cas d’études traités au sein deSPICOSA.

4.6.1 The example of the consumption of public goods for recreation: the case of the Barcelona beach (SSA12)

The main policy issue of the Barcelona study site concerns the effects of changes in water quality on the aesthetic and recreational aspects of the Barcelona beaches.The economic component of the model has been designed to capture both market and non market values. It is important since most of ecosystem services do not have a market value and they are not taken into account for management. The monetised values of the recreational activities as well as revenues in the business in the beach will enable end-users to better apprehend the economic dimension of the SSA regarding the issue.

Figure 18 : Socio-economic Model of Barcelona Coast



The links between the economic and the environmental dimensions are related to a higher frequency of users when the water quality is higher. There are fifteen inputs to the social component (beach users), and six outputs to the economic component. One of the outputs is the total number of visitors to all the beaches. The other five outputs are the number of visitors to each of the following beaches: "Barceloneta" (from San Sebastian to Hospital del Mar); Nova Icaria; Bogatell; Mar Bella; Nova mar Bella. In the systemnumerical model only the total number of visitors is visibly connected to the economic component. The other variables are connected using the "throw" and "catch" blocks. The rational of the link between the level of "consumption" and the environmental quality is formulated as follows:

- IF level of suspended matter> given threshold
  =>recreational appeal decrease by a given factor
- IF level of suspended matter<given threshold
  =>recreational appeal increase by a given factor

Change in recreational appeal is dependent on number of beach users by day, where the more beach users, the effect is greater

- IF Beach is closed due to bacteria levels exceeding a limit, then recreational appeal decreases by a certain percent multiplied by the number of beach users that day.

- IF the number of beach users is greater than the carrying capacity then the recreational appeal decreases. If it is below, then the appeal increases.

The recreational appeal for that day (where 1 is the baseline number) is multiplied by the number of expected beach users that day to ascertain the actual number of beach users.

This model focuses on the consumption process of recreation along the beach coastline. Consumers consist of beach users and patrons of the local beach bars and restaurants (travel cost and demand function). An important assumption used in the model is the beach users and the users of the restaurants and bars are a different set of customers. This is because the water quality of the beach affects both set of consumers differently (Palanques et al. 2009).

Table 5: Formulation of the demand for tourism in Barcelona

Process name	**Travel cost method (revealed preference)**
Function in model	Non-market valuation of beach based on travel costs
Variables IN	Daily beach users per region of origin (people)
Information IN	Travel cost of users (€ per visitor), population of origin of users (people)
Variables OUT	"Value" of beach (€ per day and year)
Formulation	The Zonal Travel Cost procedure involves two steps. A demand function for the recreation experiences at the site is estimated, and then a separate demand curve for the recreational use is derived, using assumed increases in entry fees. Several independent variables can be used, but in our case, due to a lack of data we just can use one (Travel Cost). Using regresion analysis, the line of best fit may be estimated to infer the relationship between the dependent variable, visitors per 1000 population (V), and the independent variable, travel costs (TC). In our case: $v = a_1 \times e^{-b_1 \times TC}$ Using this equation, in conjunction with travel costs whic have been increased by the addition of various entry fees, a agreggated demand schedule for rntry to the site may be constructed. In our case the demand function results: $y = a_2 \times \ln(x) + b_2$ Being Y the additional costs. The area below the curve is equal to consumer's surplus. Consumer surplus is a measure of welfare obtained from the recreational and aesthetic ecosystem services.
Reference	Widely accepted methodology - Ward & Beal (2000)
Validation data	Values in accordance with studies for other urban beaches. e.g. Martín-López *et al.* (2008)
Extend block(s) number	(5347);

The demand function enables the assessment of quantity and price relationships of consumption processes. The consumer's surplus is then evaluated from modifications of the consumption patterns derived from this function. Conceptually, the consumer's surplus is a monetary evaluation of consumer's satisfaction which related with theconsumption of a given product in a market. Consequently, this indicator is a way of quantifying the effects that the improvements of quality environmental could induce on the wellbeing of consumers using the goods affected by these changes. In addition, the assessment of the consumption frequency enables the quantification of direct and indirect economic impacts which they can involve. In the model, the level of frequentation of the beaches is also connected to the local economic module. It evaluates the economic effects of beaches consumers on other tourism services, in particular on the restoration businesses. The formulation of these relations is synthetically presented in the following table:

Table 6: Formulation of the economic impacts of tourism in Barcelona

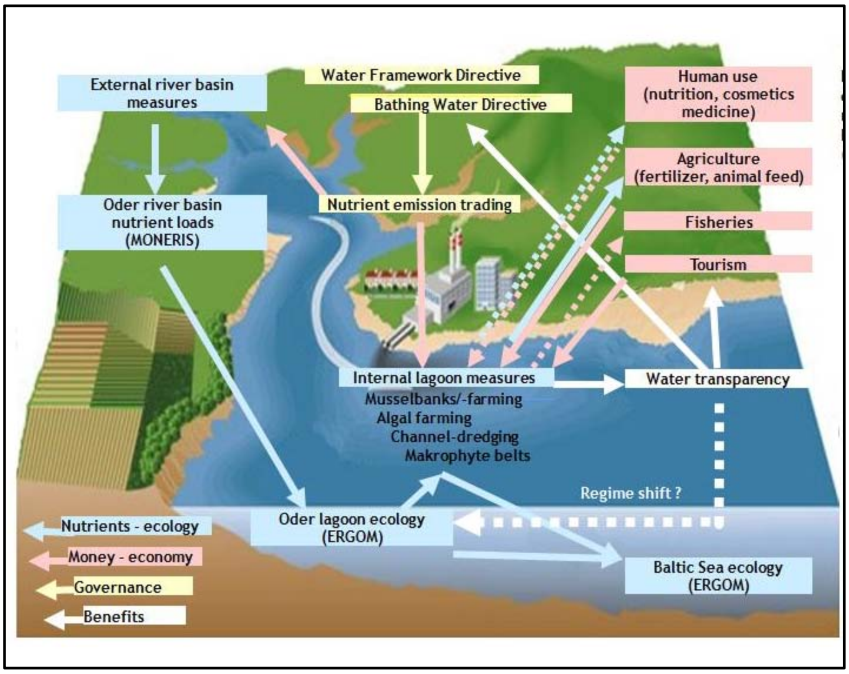
Process name	Customers served at local businesses
Function in model	Calculates the number of customers served at bars and restaurants near the study site
Variables IN	Visitors to beach (people); daily customer turnover (without dimension)
Information IN	Length of beach (m); carrying capacity of beach (people per metre); capacity of bars/restaurants (people); percent of cliente from beach (%)
Variables OUT	Customers served per day (people)
Formulation	The daily customer turnover is the number of times that the capacity of the bar/restaurant is served. It is modelled as cyclical between summer and winter. $turnover = 1.7 - \frac{1}{4}\cos\left(\frac{\pi \times timestep}{182.5}\right)$ The number of customers served is calculated using: $customers = turnover \times restaurant\_capacity \times \left(\frac{\%\_beach}{100}\right) \times \min\left(100{,}100 \times \frac{visitors}{carry\_cap \times beach\_length}\right) + \frac{100 - \%\_beach}{100}$
Reference	Turnover based upon informal dialogue with bar and restaurant proprietors/employees. Customers served is the product of turnover, capacity and visitors to the beach.
Validation data	There is no validation data available
Extend block(s) number	(6567)(0); (6428)(0); (6711)(0); (6842)(0); ((6973)(0)

4.6.2 The example of the tourism demand in the Oder Estuary (SSA3)

The model if this study site deals with the management options for improving the water quality in the Oder Estuary. The modelling of the socioeconomic dimension integrates assessments of market and non market components. These last are not directly evaluable because there is no market price.

Tourism is the major sector generating local economic benefits for the Oder Estuary. Hence, the production and consumption of tourism is given much focus in the model. Water transparency is the link between the ecosystem and tourism(attractiveness relation). In the tourism sub-model, water transparency is taken as an independent variable which influences the demand for beach visits and hence the number of tourists in the beach. For tourism sector, benefits of water quality improvement is analysed by the perception of the water quality, travel cost analysis; contingent valuation method for summer and off season. In the system overall entity are influenced by the water transparency.

Figure 19 : Conceptual Model of the SSA3 (Oder Estuary)



The surplus generated by the tourism sector can be assessed by structuring a demand function relying the quantity of tourism demanded (calibrated by the proxy "number of visitors per year") and exogenous variables including the quality of the good consumed (visitors are mainly attracted by the water quality mainly determined by its "transparency") The demand function of tourism is then formulated as follows:

Tourism demand function

$$D^t = T° * (1 + s^s *(0.017* Wtr^t - 0.034) + (A^t - A°)*0.05) + \sum_{1}^{t} T^{t-1} * (g^t)^2$$

D^t = Tourism demand (number of visitors per year t)

T° = Number of visitors in year 2008 (vector of different types of visitors: overnight stays, campers and day visitors)
T^t = Number of visitors in year t (vector)
s^s = Share of summer visitors (0.55)
Wtr^t = Water transparency [m] in year t (**Wtr^t** ≥0)
g^t = GDP growth rate in year t
A^t = Beach area in year t (A° = 16.000m²)

The improvement of the water quality implies an increase of tourist and then a positive impact on the local economy. The global positives effects are formulated here after.

Tourist expenditures (gross turnover)

$$\sum_{ij} T_i * e_{ij}$$

T_i = Number of visitors of type i; i = 1 visitors staying overnight in Hotels with more than 8 beds, i = 2 visitors staying in hotels < 9 beds, i = 3 campers, i = 4 day visitors

e_{ij} = Expenditures of visitors of type i on goods and services of type j per day

Regional net turnover from tourist expenditures

$$\sum_{ij} \mathbf{T_i * (e_{ij} - VAT_j)}$$

VAT_i = Value Added Tax on goods and services of type j

T_i = Number of visitors of type i; i = 1 visitors staying overnight in Hotels with more than 8 beds, i = 2 visitors staying in hotels < 9 beds,
i = 3 campers, i = 4 day visitors

5. Concluding remarks

The guidelines featured within this document uses the results and experience gained from the SPICOSA project (2007-2011). It contributes to the global scientific knowledge available regarding system approach modelling. This guideline is the second part of a series of guidelines produced for every stage of the completed SPICOSA project.

Within this guideline, the focus is how to translate mathematically the socioeconomic processes previously designed and which integrate the systems modelled. However, there is no a unique and simple way of proceeding in the formulation step. This depends on the knowledge available, on the analytical approach selected and in the needs generated by the representations by the models. For this reason, examples of mathematical formulation efforts using different approaches done by the 18 SSAs serve to give a picture for future researchers on how to proceed in implementing the formulation step.

Therefore, this guideline should be used as spark ideas of illustrations supporting steps and elements which need to be considered in a socioeconomic formulation process and in its integration in a system model approach.

6. BIBLIOGRAPHY

Bacher C., Hopkins T., Maes J., Ribera d'Alcala M., Raux P., 2009 SAF Protocol on CZ System Formulation, SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927, Deliverable D4.3, 122 p.

Bald J., Borja A. &Muxika I., 2006.A system dynamics model for the management of the gooseneck barnacle (Pollicipespollicipes) in the marine reserve of Gaztelugatxe (Northern Spain). Ecological Modelling 194, 306–315.

Bellinger, 2004. Systems Thinking : A journey in the realm of systems. ://www.systems-thinking.org/index.htm

Bert van E., vans Gils J., de Kok J-L., van der Kwast H. and Broekx S., 2009. Report for Appraisal Step, SSA9 Scheldt, The Netherlands, DELTARES, IVM and VITO. SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Bertalanffy L. von, 1968.General System Theory. Foundations, Development, Applications, New York: George Braziller, 296 p.

Boski T., Mascarenhas A., Guimaraes M.H., Sousa C., Chicharo A., Galvao H. and Domingues R., 2009. Scientific Report for Appraisal Step, SSA11 Guadiana Estuary, Portugal.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Caroppo C., Giordano L., Rubino F., Palmieri N., Bellio G. and Bisci P., 2010a. Scientific Report for Appraisal Step, SSA14 Taranto Mar Piccolo, Italy.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Caroppo C., Giordano L., Rubino F., Palmieri N., Bellio G. and Bisci P., 2010b. Documentation Report for Appraisal Step, SSA14 Taranto Mar Piccolo, Italy.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Cokacar T., Tolun L., Donertas A. S., Baban A. and Ergenekon S., 2008. Documentation Report for Formulation Step, SSA 17 Izmit Bay, Turkey.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

DeAngelis D.L., Mooij W.M. and Bosset A., 2003.The importance of spatial scale in the modeling of aquaticecosystems. In Seuront L. and Strutton G. (eds.) Handbook of Scaling Method in Aquatic Ecology: measurement, analysis, simulation, 383-400. Boca RatonFL: CRC Press.

Dinesen G.E., Markager S., Timmermann K., Ravn-Jonsen L., Roth E., Ahsan D.A., Marianne Holmer M., Sverdrup-Jensen S. and Stottrup J. 2009. Documentation Report for Appraisal Step SSA5, Limfjorden, Denmark.SPICOSA (Science and Policy

Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Dinesen G.E., Timmermann K., Markager S., Roth E., Ravn-Jonsen L., Ahsan D.A., Holmer M., Sverdrup-Jensen S. and Støttrup J., 2009. Scientific Report for Appraisal Step, SSA5 Limfjorden, Denmark, DTU Aqua, NERI AU, SDU, IFM.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Dinesen G.E., Timmermann K., Markager S., Morten Hjorth M., Roth E., Ravn-Jonsen L., Sverdrup-Jensen S. and Stottrup J., 2008. Scientific Report for Formulation Step, SSA 5 Limfjorden, Denmark.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Dybedal, Petter. 2006. Economic impacts of tourism in Aust-Agder and Vest-Agder counties 2005. TøI rapport. Oslo: TransportøkonomiskInstituttStiftelsenNorsksenter for samferdselsforksning, December.

Forrester J.W., 1961. Industrial Dynamics, Productivity Press, 479 p.

Forrester J.W., 1968. Principles of Systems, Pegasus Communications, 387 p.

Forrester J.W., 1969. Urban Dynamics, Pegasus Communications, Inc., 299 p.

Franzén F., Kinell G. and Söderqvist T., 2008.Informal report on the status of the Formulation Step for the economic and social parts in SSA4 Himmerfjärden, Sweden.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Garcia T., Guimaraes M.H., Boski T. and Sousa C., 2008.Documentation Report for Formulation Step, SSA11 Guadiana Estuary, Portugal.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Hall, C.A.S. and J. Day. 1977. Systems and models: Terms and basic principles. Pages 5-36 in C.A.S. Hall and J. Day, eds. Model as Ecological Tools: Theory and Case Histories. Wiley Interscience, New York. 664 pp. Volume 16, Issue 3, July 1978, Page 242.

A.J. Jakeman, S.H. Chen, A.E. Rizzoli, A.A. Voinov. Chapter One Modelling and Software as Instruments for Advancing Sustainability Review Article. Developments in Integrated Environmental Assessment, Volume 3, 2008, Pages 1-13

Jeffers J. N. R., 1978. An introduction to systems analysis, with ecological applications, University Park Press, Baltimore, 198 p.

Jorgensen S.E., 1986. Fundamentals of ecological modelling, Elsevier Science Ltd (June 1986), Amsterdam,392 p.

Meadows D.H., Randers J., Meadows D., 2004.Limits to Growth. Chelsea Green Publishing Company, 368 p.

Mokness E., Gjøsæter J., Mikkelsen E., Olsen E.M., Sandersen H.T. and Vølstad J.H., 2009a. System Formulation Report Part 1: ExtendSim Model Description, SSA6

Søndeledfjorden, Norway. SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Mokness E., Gjøsæter J., Mikkelsen E., Olsen E.M., Sandersen H.T. and Vølstad J.H., 2009b. Scientific Report for Appraisal Step, SSA 6 Søndeledfjorden, Norway.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

Mongruel R., Levrel H., Mathews M.M., 2011. Defining Economic Dimensions of Coastal Systems A guide to including economics in a modeled coastal zone system, with examples from SSAs, Support paper prepared for the SPICOSA SAF e-Handbook, Ifremer, UMR Amure, Marine Economics Department, 34p.

Morecroft J., 2007. Strategic Modelling and Business Dynamics.John Wiley and Sons, 430 p.

Odum H. T., Odum E. C., 2000. Modeling for all Scales: An Introduction to System Simulation, Academic Press, 480 p.

Odum H.T., Peterson N., 1996. Simulation and evaluation with energy systems blocks.Ecological Modelling 93, 155- 173.

Prou J., Mongruel R., Pérez Agúndez J.A., Bacher C., Vernier F., Bordenave P, Candau J., Delmas F. and Laplana R., 2009. Documentation Report for Formulation Step, SSA10 PertuisCharentais, France.SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927.

SPICOSA, WP2, 2007. Economic Assessment, SPICOSA (Science and Policy Integration for Coastal Systems Assessment) EC FP6 Integrated Project, Project N°0369927, Deliverable D.2.1: Economic Assessment V.08, University of East Anglia, Norwich, 87 p.

Teknomo K, System Dynamics Tutorial, ://people.revoledu.com/kardi/tutorial/SystemDynamic/

Wang S., Nikjamp P. and Verhoef E., 2001.Modelling Externalties between Ecological and Economic Systems, Department of Spatial Economics, Faculty of Economics and Business Administration, VrijeUniversiteit Amsterdam and Tinbergen Institute, Tinbergen Institute Discussion Paper, TI 2001-098/3, 19p.

7. TECHNICAL ANNEX: TRANSVERSAL ANALYSIS FORMULATION TABLE

Aiding the development of this report, a socio-economic formulation table was created (using Microsoft Office Excel) parallel to the writing efforts. An example of the table is illustrated in Tableau 6. The socio-economic formulation table was based on the most up to date material on the mathematical formulation adopted by each of the 18 study sites of SPICOSA. Information was obtained from Scientific and Documentation Reports from Formulation Step, Appraisal Step, Output Step (from www.spicosa.org), and supporting papers (personal communication with SPICOSA coordinators) depending on where the stage of formulation occurred for the individual SSA site. If there was no information to be found, direct communication with the SSA team was conducted. The table will be uploaded onto the online SPICOSA database.

Aforementioned table was created with several main aims:

a) to help in selecting the examples for this document to best illustrate the socio-economic processes and the development of its mathematical formulation

b) as a transversal analysis tool to compare and contrast between SSAs' selection of mathematical formulation (variables, parameters and technical mathematical equations,specific function within the system and links within the system) based on different socio-economic criteria (entity, policy issue, socio-economic concerns, type of socio-economic process and socio-economic assessment methodologies).

Information within the table was selected based on the definition of the headings. Therefore, to clarify how the selection was carried out, the definition and selection criteria for each heading in Table 6 is detailed subsequently. It is to be noted that each heading are linked to all other headings in one way or another. Besides this matter, the scope of the socio-economic criteria is subjected to the limitation of the created model from the 18 different study sites. Hence, the user of the table should keep this in mind while toggling with the table. Every row and column is filled with repetitive data in the Excel sheet to ensure no information is lost during filtering forthe transversal analysis. The socio-economic criteria selected are described in the next paragraphs.

Table 7: Formulation Table

Study Site Application	Policy Issue	Entity	Sub-Entity	Socio-economic Concerns	Type of socio-economic concerns	Type of socio-economic processes	Variables and Parameters	Socio-economic Mathematical Function (Unicode Text)	Specific Function within the System	Socio-economic assessment methodologies	Links within the System	References
SSA 1 Riga												
SSA2 Gdansk												
SSA3 Oder												
SSA4 Himmerfjarden												
SSA5 Limfjorden												
SSA6 Sonderledfjorden												
SSA7 Clyde Sea												
SSA8 Cork Harbour												
SSA9 Scheldt Delta												
SSA10PertuisCharentais												
SSA11 Guadiana Estuary												
SSA12 Barcelona Coast												
SSA13 Thau Lagoon												
SSA14 Taranto Mar Piccolo												
SSA15 Venice Lagoon												
SSA16 Thermaikos Gulf												
SSA17 Izmit Bay												
SSA18 Danube Delta												

Table 8: A section of the completed formulation table

Row	Study Site Applications	Policy Issue	Entity	Sub_entity	Socio-economic Concerns	Type of Socio-Economic Process	Variables & Parameters	Socio-economic Mathematic Function (Unicode Text)	Specific function within the System	Socio economic assessment Methodologies	Links within the system
531	SSA16 Thermaikos Gulf	Sustainable management of mussel farming activity in the area of Chalastra	Shellfish Farming	Mussels	Mussel Production	Investment	Extra labor costs	The calculation of the extra labor costs are also based on the optimum values per production line extra_labor=worker_extra*labor*line_number/365	total costs of a mussel farm establishment taking under account all the major categories of potential cost as: establishment depreciation, equipment depreciation, operational costs, gasoline costs, labor costs (including potential extra work) and legality costs.	Cost - Benefit analysis for the individual farm, and as a consequence for the whole mussel farming activity, in the form of multiple choice panel	The Cost – Benefit model is connected to environmental compo through the farm's an production and it incorporating the numb days with occurrence Harmful Algal Blooms. links between the econ and social are formed the variables "profit mussel farm" and "leg cost"
532	SSA16 Thermaikos Gulf	Sustainable management of mussel farming activity in the area of Chalastra	Shellfish Farming	Mussels	Mussel Production	Investment	Extra labor costs	total_costs=depreciation_es+depreciation_eq+operational+labor+extra_labor+gasoline_costs+legal costs	total costs of a mussel farm establishment taking under account all the major categories of potential cost as: establishment depreciation, equipment depreciation, operational costs, gasoline costs, labor costs (including potential extra work) and legality costs.	Cost - Benefit analysis for the individual farm, and as a consequence for the whole mussel farming activity, in the form of multiple choice panel	The Cost – Benefit model is connected to environmental compo through the farm's an production and it incorporating the numb days with occurrence Harmful Algal Blooms. links between the econ and social are formed the variables "profit mussel farm" and "leg cost"
533	SSA16 Thermaikos Gulf	Sustainable management of mussel farming activity in the area of Chalastra	Shellfish Farming	Mussels	Regulations	Regulation	Number of days (annually) with occurrence of Harmful Algal Blooms	30 days, 30+15days until 180 days (disaster scenario)	Disaster scenario in terms of closure of mussel farm	Cost - Benefit analysis for the individual farm, and as a consequence for the whole mussel farming activity, in the form of multiple choice panel	The Cost – Benefit model is connected to environmental compo through the farm's an production and it incorporating the numb days with occurrence Harmful Algal Blooms. links between the econ and social are formed the variables "profit mussel farm" and "leg cost"
534	SSA16 Thermaikos Gulf	Sustainable management of mussel farming activity in the area of Chalastra	Shellfish Farming	Mussels	Legalities	Regulation	Legal Status	Legal mussel farms cost ¦5000 rent (institutional management scenario) , A fine of ¦10000 is imposed if an illegal mussel farm is caught	Legalities of mussel farming operations	Cost - Benefit analysis for the individual farm, and as a consequence for the whole mussel farming activity, in the form of multiple choice panel	The Cost – Benefit model is connected to environmental compo through the farm's an production and it incorporating the numb days with occurrence Harmful Algal Blooms. links between the econ and social are formed the variables "profit mussel farm" and "leg cost"
	SSA17 Izmit Bay	Improvement of water quality in Izmit Bay	Real estate		Sea water Quality	Investment	P = sales price of an apartment in Turkish Lira (Price of apartments at different locations around the Bay)	P = -131,736 + 940 S + 6,455 (SDD) – 23,488 (NO	Considering that the level of pollution in the sea water is reflected in the price of a property in the region, a regression analysis is conducted to find the relationship between environmental factors and price of housing	Hedonic Pricing, regressional analysis	Sechi Disk Depth obta from the ecolo component also allow u estimate the real es value changes du simulation w constitutes an additi input to the econom

7.1 Socio- economic Entity and Sub-entities

Socio-economic entity can be defined as a group of actors having or developing an action within the system.

As explained in pg 11 of this report, a socio-economic entity is made up of stakeholders. Examples of entities are "producing economic sectors of goods and services" (example; tourism, fisheries), "regulating institutions" (example; Water Framework Directives by the European Commission) and "lobbies" (consumer associations, NGOs etc).

In a study site, several entities can be identified depending on the policy issue and the model constructed by the SSA team. For instance, SSA7 Firth of Clyde has two entities which are shellfish farming and tourism.

Notice that within the table, the wordings have been changed from the ones used by the SSAs within their reports. In fact, Firth of Clyde used the terms mussel aquaculture. Meanwhile, in the table,the terms shellfish farming was used instead. Standardising of the terms used by individual SSAs were carried out to facilitate the procedure of comparing and grouping different entities together (transversal analysis).

The specificity utilised by the SSA is placed within the heading of sub-entity. Hence, "mussels" were placed under this sub-heading.

Study Site Applications	Policy Issue	Entity	Sub-entity
SSA7 Firth of Clyde	Impact of the number of yachts using Loch Fyne on the local mussel industry	Shellfish farming	Mussels
SSA7 Firth of Clyde	Impact of the number of yachts using Loch Fyne on the local mussel industry	Tourism	Marina

7.2 Socio- economic Concerns

Socio-economic concerns are challenges faced by each study site within their socio-economic model. The identification of the socio-economic concern was carried out through careful analysing of the policy issue and the mathematical formulation. We found that within the 18 study sites, the socio-economic concerns can be grouped into the following issues:

a) The specific goals of each stakeholder (example; production optimization: tourism optimization, fisheries optimization in terms of profit maximization)
b) Where degradation of natural capital occur (example; water quality, beach quality, fish stock) caused by different types of pollution and extractive measures caused by human activities (example; agriculture pollution, fisheries overexploitation)
c) When stakeholders' conflicts occur (example; different interest clashes between stakeholders)
d) Regarding control over resources (example; water allocation)

All of the study sites have at least one of the social concerns listed above. The social concern was determined through analysing the policy issue and the mathematical formulation of each SSA. Each mathematical formulation has a corresponding social concern that it is trying to address within the model.

7.3 Type of Socio-economic Process

Within the policy issues of the 18 different study sites, socio-economic processes are divided into five main processes. These are production, consumption, investment, innovation and induction and other social processes. Chapter 4 in this handbook detailed extensively the definitions and details of each process. In this section, a recollection of the important definitions of each process is highlighted in Figure 12.

Figure 20 : Definitions of Socio-economic Processes

Production Process	• *an economic activity generating an added value from the combination of production factors (inputs) which are basically capital and labour (page 19).*
Investment Process	• *Processes implemented by companies (or by public institutions) enabling the acquisition of capital necessary for implementing their production functions to produce goods and services (page 25).*
Innovation Process	• *A process which leads to changes in the way of proceeding. It can be applied to other socio-economic processes (pg 30)*
Regulation Process	• *Regulations can be carried out by the implementation of standards, rules or by implementation of incentives (pg 34)*
Induction and Driven Processes	• *Originated by agents or groups of agents with no factual consequences on their own actions but which induce changes on processes involving other agents (pg 35)*

7.4 Variables, Parameters and Socio-economic Mathematical Function

Of vital importance to the table are the data regarding technical mathematical functions and its corresponding variables and parameters used in each socio-economic model. This represents the common mathematical language that the SPICOSA SSA teams have formulated from their conceptual model.

The type of formulas range from simple mathematical equations to complex mathematical equations depending on the strategy and socio-economic methodology applied.

SPICOSA has promoted a specific grammar to be utilised, however not many of the SSA teams have included this grammar in their reports; hence categorization of the data based on the grammar was not carried out in Excel, despite attempts to do so.

"Variables and parameters" heading are actually the variable and parameter names that were listed in the mathematical equation. This is to aid the understanding of the mathematical equation. For example in Table 7, Y in the mathematical equation stands for "Fisheries harvest function".

A Variable can be defined as a value that could fluctuate within the limitations of the mathematical formulation within the model and policy issue. Meanwhile a parameter is a type of variable where the extent of available values signifies a group of unique cases in a problem.

Unicode Text was used as the function format within Excel while in Microsoft Word the formulas are presented using Microsoft Equation Editor.

Table 9: Harvest function as part of the fisheries socio-economic model

SSA	Variables and Parameters	Socio-economic Mathematic Function
SSA5 Limfjorden	Fisheries harvest function (Tons days-1 at sea)	Y=qSE
SSA5 Limfjorden	Biomass of blue mussels [S] [tons]	Y=qSE
SSA5 Limfjorden	Fishery effort [E] Optimization parameter	Y=qSE
SSA5 Limfjorden	Catchability coefficient [Per days at sea] (q)	Y=qSE

7.4.1.1 Specific Function within the system

The specific function refers to the mathematical function and its particular role within the ESE model.

For instance for SSA1 Gulf of Riga, the entity considered here is fisheries and mathematical formulation is an equation within the Gordon Schaefer model of linear catch-effort relationship. An overall overview of the specific function within the system was undertaken.

Table 10: Harvest function as part of the fisheries socio-economic model

Variables &Parameters	Socio- economic Mathematic Function (Unicode Text)	Specific function within the System
Catchability coefficient for this age group and fishery (q)	SUMq*E, for each age group of fish	This block generates fishing mortalities according to a linear catch-effort relationship, i.e. Gordon-Schaefer model, for age groups 1 to the terminal age.

7.4.1.2 Socio-economic Assessment Methodologies

Mathematical formulations are normally based on the type of socio-economic assessment methodologies selected by the SSA team to answer to the policy issue. Among the range of methodologies used are such as bio-economic modelling, market and non-market valuation, cost benefit analysis and multi-criteria analysis.

7.4.1.3 Links within the System

This heading refers to how the mathematical function and its corresponding variable links to the ESE model. Normally a larger view is adopted and only the linking variable for the socio-economic model is mentioned and the details of the link are revealed under this heading.

An example of data from heading "links within the system" from SSA3 Oder Estuary:

The economic component "mussel farming" is linked to the environmental component "mussel stock". Mussel farming is also linked to the Governance submodel as "hygienic authority" and "environmental authority" influences the amount of funding received for mussel farming.