Building an ecosystem-based activity accounting framework. An illustration for marine and coastal ecosystems

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Abstract

Since 1990s, there has been a growing interest to incorporate in the national accounts the environmental assets and ecosystems. This accounting approach, called as environmental or green accounting, aims at adjusting the conventional accounting indicators in order to have a better measure of welfare and sustainability. In this line, the United Nations have built a satellite account devoted to the environment: *the system of economic-environmental accounting* with an extension to ecosystems. The Word Bank tries to calculate a genuine saving by incorporating the resource depletion and environmental damage. This article gives some important criticisms of these present accounting experiences in the light of the aim and the concepts used in the system of national accounts (SNA). Because of these criticisms, an accounting framework related to ecosystem issue is constructed more consistent with the concepts of the SNA. This article proposes to evaluate the production and employment associated with activities based on the ecosystem. Two types of activities are distinguished: activities using the ES for their production process and activities aiming at regulating the supply of ES. For the first type of activities, we extract from the national accounts the industries using the ES in their production process. The production frontier of the system of national accounts (SNA) was extended to incorporate household production coming from the recreational activities. For the second type of activities, we extract from the national accounts the public sector aiming at regulating the ES by showing explicitly the accounting equilibriums: supply-demand equilibrium (i.e., the production and final demand) and input-output equilibrium (i.e., the production process). An illustration is carried out for marine and coastal activities.

Keywords: environmental accounting, ecosystem services, ecosystem-based activity accounting, household production

JEL code: E01, Q56, Q57

1. Introduction

Since 1990s, the number of studies devoted to the issue of ecosystem services (ES) has been increased exponentially (Fisher et al., 2009). ES are generally defined as the services provided by ecosystem and contributing to the human welfare. A major part of these studies focuses on developing methodologies to calculate the monetary values of ES. The main reason for such calculations is explained by the fact that the actual conservation policy is not enough developed, since ES have a “missing” price (Baker and Ruting, 2014; Folmer and Van Ierland, 1989). According to the welfare economics model, the price of goods and services in a competitive market is an economic indicator of the contribution of these goods and services to the social welfare. Since ES have a “missing” price, their contribution to the social welfare would be undervalued and thus the expenditures for ecosystem conservation would be underestimated. The monetary valuation methods aim at correcting this failure by calculating the contribution of ES in the social welfare. This would improve the knowledge required for policy-makers to implement efficiently an ecosystem conservation policy. Two approaches have been developed to value ES: the monetary valuation approach and the accounting approach.

The monetary valuation approach is trying to calculate the total economic value of ES by using the concepts coming from the welfare economics model. This approach developed in environmental economics is largely dominant in scientific studies. The total economic value, including use and non-use values, corresponds to the net willing to pay indicating the sacrifice that an individual is ready to make to enjoy ES by keeping constant its welfare level. The net willing to pay is defined as the difference between the total willing to pay reduced by the production cost. Costanza et al. (1993) were the first authors to attempt to calculate the value of ES for the world. They found that the average annual value of ES is equal to $33 trillion. One of the major international initiatives relative to the ES valuation is the *Millennium Ecosystem Assessment* (MEA, 2003). It involved more than 1,300 scientists all over the world. However, the results are not expressed in monetary value. *The Economics of Ecosystems & Biodiversity* (TEEB) aims at providing the theoretical framework to value ES in monetary units (De Groot, 2010). The methodology indicated in the TEEB was applied for some countries in every continent and also in global. For instance, Brander and Schuyt (2010) estimate that the value of the 63 million hectares of wetlands in the world is equal to $3.4 billion per year. This methodology was also applied in one region of a country. For example, Zandersen and Termansen (2013) estimate for the region of North Zealand in Denmark the recreational value of the forest: from €5,200 per ha and per year to €14,850 per ha and per year for the forests with the highest per hectare value and from €200 to € 320 per ha per year for the forests with the lowest per hectare value. Nowadays, there are also some important national initiatives to value ES in different countries like the project “Mapping and Assessment of Ecosystems and their services” (Maes et al., 2013) for Europe and the project EFESE for France.

In parallel, a second approach, called as accounting approach, was developed in order integrate the environmental assets in the accounting framework. Contrary to the first approach, it does not calculate the total economic value of ES, but the price of ES consistent with the accounting framework. This approach aims at correcting the conventional accounting indicators calculated in the national accounts in order to provide a better measure of welfare and sustainability (Mäler et al., 2008). In this line, it is also called sometimes as the welfare accounting. It is known as environmental accounting or green accounting. The conventional Net Domestic Product (NDP) integrates the defensive expenditures that do not contribute to the increase of the welfare. For instance, a rise in health expenditure coming from the environmental degradation contributes to the increase of the NDP. Besides, the NDP does not include the depreciation of environmental assets coming from the depletion of environmental resources. In this sense, NDP says nothing if the present production is sustainable. Since 1993, a satellite account called as "*System of environmental-economic accounting*" (SEEA, 2012) was developed by the United-Nations in order to incorporate the environmental assets in the national accounts and to estimate the defensive expenditures. The conventional accounting indicators are adjusted in order to take into account the depletion of natural resources. This adjusted GDP was called also as "green" GDP. The World Bank has developed this approach to calculate the "genuive" saving or adjusted net saving. It would correspond to the monetary measure of the wealth. This saving is calculated from the measure of net saving coming from the national accounts that is increased by the education expenditures and that is reduced by depletion of natural resources and the pollution damages. For example, for Madagascar in 2008, the net national saving was estimated at 7.22% of Gross National Income (GNI), the education expenditures at 2.64% of GNI and the genuine saving at 6.99% of GNI. The World Bank also estimates the contribution of environmental assets (i.e., the natural capital) to the wealth. Natural capital contributes only to 3% in the wealth of OECD countries while it contributes until 25% in the wealth of developing countries. However, the SEEA focuses on natural resources. An experiment was carried out by the United-Nations to extend the SEEA to ecosystems: *The SEEA Experimental Ecosystem Accounting* (2012). The WAVES project, supported by the World Bank, aims at helping developing countries to construct ecosystem accounting. Weber (2011) proposes a methodological framework to the European Environment Agency to construct ecosystem capital accounting for Europe.

The second approach has received a lot of debates between on one hand the welfare accountants and on the other hand the national accountants (Gadrey and Jany-Catrice, 2005). According to the national accountants, the welfare accountants confuse economic growth and welfare. Economic growth is defined as the increase of the gross domestic product (GDP). It is the sum of all market value of goods and services and the production cost of public administration. It accounts all observed monetary flows carried out during a given year to produce goods and services. The GDP aims at measuring the outputs, i.e. the quantities produced. However, it is indifferent with the outcomes, i.e., the results in terms of satisfaction and welfare. The outcome is another issue outside the scope of the national accounting. Furthermore, the concepts used to estimate the measure of welfare or sustainability are not consistent with the concepts used to construct the national accounts (Bos, 1997) making difficult the interpretation of these adjusted accounting indicators (Aaheim and Nyborg, 1995).

This article aims at developing an accounting framework to integrate the ecosystem conservation issue consistent with accounting principles. Unlike the environmental and green accounting, we are not trying to estimate a value for ecosystem services. We prefer to calculate the value of production and the employments associated with activities based on ecosystems. We distinguish two types of activities: activities using the ES for their production process and activities aiming at regulating the supply of ES. The production frontier of the system of national accounts (SNA) was extended to incorporate household production coming from the recreational activities.

The first section describes and criticizes the present experiences in green and environmental accounting. The second section presents the accounting framework for the ecosystem-based activity accounting with an illustration for marine and coastal ecosystems.

2. The attempts of integrating the value of ecosystems in the national accounts

There are currently two experiences to integrate the value of ecosystems in the national accounts: green accounting and environmental accounting. The table in annex 1 summarizes the major differences between these two types of accounting. This section aims at describing and criticizing these accounting approaches, since our ecosystem accounting proposal is based on the criticisms of them.

2.1. The experience of the green accounting

The article of Weitzman (1976) presents the theoretical framework of the green accounting. He gives a welfare interpretation of the net national production (NNP) which is considered as the largest permanently maintainable value of consumption. This interpretation is based on the solution of a Hamiltonian program. This is the maximisation of the sum of the discounted consumption subject to the production possibilities and a given level of capital stock at the present time. The solution of this program is that the revenue should be equal to the consumption plus the net investment. It represents the maximum welfare actually attainable from the present time on along a trajectory economy. The definition of this revenue is similar to than the NNP used in the national accounts. However, to give a good interpretation of welfare, the net investment should incorporate all sorts of capital and not only the produced capital that is already recorded in the SNA. Therefore, it is essential to add the net investment coming from the natural capital in the NNP to have a welfare measure of an economy. According to this definition, green accounting is based on the weak sustainability, assuming a substitution between natural resource asset and the produced asset.

According to Mäler (1991), the article of Weitzman (1976) represents the basis of the construction of a welfare accounting as an alternative to the Keynesian accounting based on the balance between the total supply and the total demand, on savings and investment in reproducible capital. A welfare accounting requires that the goods and services should be expressed in optimal prices, i.e., prices leading to the maximization of the sum of consumer and producer surplus. In this line, Mäler (1991) states that "thus, with the convexity assumption, the use of optimal prices will give the correct indication of welfare changes, irrespective of whether the economy is on the optimal trajectory or not. It follows that the prices must in general be accounting prices and not actual market prices". It thus differs with the accounting principles used in the national accounts to value goods and services produced within the economy on the base on the current market prices incorporating the market imperfections. However, the measure of the NNP in the national accounts is, in fact, based on the current market and no the optimal prices. In this sense, the value of the NNP expressed in current prices is a disturbed measure of welfare. However, the welfare accounts point out that this measure of NNP is a "proxy" measure of the welfare (Hartwick, 1990) and the estimated net investment coming from the nature should be estimated with the optimal prices.

The studies in green accounting are interested to know how the flows related to the natural capital should be integrated to measure NNP as a welfare measure. For instance, Hartwick (1990) argues that the Gross National Product (GNP) incorporates the priced resource inputs. The economic depreciation of natural resources capital should be deducted of the GNP to arrive at a correct estimate of the NNP. Mäler (1991) advocates to deduct in the NNP the flow of environmental damage, to integrate the value of net change in the stocks of all assets and the investment in the enhancement of the stocks of natural resources should be treated as intermediary products. The studies concerning the development of the green accounting methodology have been continued (Asheim, 2000; Asheim and Weitzman, 2001; Asheim and Hartwick, 2011; Hartwick, 2011)

The green accounting was extended to the issue of ecosystems and their services (Boyd, 2006; Boyd and Banzhaf, 2007). Ecosystems are considered as a fixed asset like the natural resources. The value of ecosystems is derived from the value of their ES. Final ES correspond to the final products of nature to be consumed directly or indirectly by individuals. Boyd and Banzhaf (2007) indicate how to integrate in the GDP the value of final ES to arrive of a measure of a green GPD. They advocate that the final ES should be weighted by their virtual prices corresponding to their marginal willingness to pay and aggregated in the same way as the market goods and services. This requires to separate in the value of ES the price and the quantity. The challenge is to define physical units to determine the quantity of ES. Mäler et al. (2008) present the theoretical methodology to include ecosystem values in the national accounts according to green accounting concepts.

In a nutshell, the green accounting, based on the welfare economics model, is a welfare accounting. Thus, the economic justification of integrating the environmental resources and ecosystems in the national accounts is based on an attempt to measure a value of welfare within an economy.

2.2. The experience of environmental accounting

Unlike the green accounting, the environmental accounting values natural resources and ecosystems by using as far as possible the accounting principles used in the national accounts. An international initiative was elaborated to construct a satellite account focused on the natural resources. This is known as the System of Environmental-Economic Accounting (SEEA).

The first version of the SEEA dates from 1993. This SEEA 1993 aimed at exploring the different issues concerning how to account the interactions between the economy and the environment. The SEEA is viewed as a satellite account of the System of National Accounts (SNA), enabling to provide a greater degree of freedom to concepts and valuation than conventional national accounts. Different issues explored in the SEEA 1993 are the estimation of the effective environmental costs coming from environment related defensive activities, the construction of physical accounts, imputed environmental costs at market values. The latest approach aims at calculating the environmentally adjusted domestic products by deducting in the Net Domestic Product (NDP) the imputed environmental costs of industries. According to the SEEA, the GDP calculated in the SNA is not a good measure of welfare, since it does not integrate the degradation of natural capital. For instance, the increase of defensive expenses to offset the degradation of natural resources implies an increase in GDP. The environmentally adjusted NDP should provide a better measure of welfare. It could be approached with the NNP as a measure of welfare (Weitzman, 1976). In this line, the SEEA, like the green accounting, is based on the weak sustainability (Lintott, 1996). The SEEA 1993 proposes also the contingent valuation in order to assess the impact of environmental degradation on well-being. It is important to mention as a possible extension for the SEEA the accounting of environmental services. These were classified into 3 services: disposal services (Ex.: absorption of residuals coming from economic activities), productive services of land and consumer services (Ex.: recreational services). In this line, environmental services are the services provided by the natural asset. They are viewed as the output of production activities of nature. This extension can be seen as an embryo of the ecosystem accounting developed later by the SEEA.

The latest final version of the SEEA dates of 2012: "The SEEA central framework" (SEEA CF, 2012). It focuses on 3 specific issues on environmental accounting, that is, the compilation of physical supply and use tables, functional accounts (such as environmental protection expenditure accounts) and natural resources assets. Compared to the SNA, the SEEA extends the asset boundaries by incorporating the environmental assets. These are expressed both in physical and monetary units. Thank to these asset accounts, the depletion is calculated. It is defined in physical unit as "the decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units occurring at a level greater than that of regeneration". However, it is difficult to estimate the monetary value of environmental assets, since almost of them are not traded in the market. When there is not market, the SEEA recommends to use the discounted value of future returns, known as the net present value. This valuation method requires to calculate the environmental return to industries, i.e. the resource rent, to estimate the value of future returns. The monetary amount of depletion corresponds to the physical depletion multiplied by the average of unit rent between the initial and the final accounting period. The monetary value of natural resource depletion is then incorporated into the sequence of economic accounts to calculate the depletion adjusted net added value. This calculation leads then to estimate the depletion net adjusted saving, interpreted as the resources available to increase the overall asset.

Since 2013, The SEEA was extended to the ecosystems. The methodology is explained in the document "SEEA Experimental Ecosystem Accounting" (SEEA EEA, 2013). The main motivation for developing ecosystem accounting is coming from the development of international initiatives such as WAVES and TEEB. An ecosystem is considered as an asset and the flow coming from the ecosystem asset is called ES. The SEEA EEA extends the set of services relatively to the SNA by integrating ES, but excluding the abiotic resources included in the SEEA CF. A geographical information system (GIS) approach is needed to delimit the different ecosystems. Boundaries for specific ecosystems are generally drawn on the basis of the relative homogeneity of ecosystem characteristics and, in terms of having stronger internal functional relations than external ones. Units used by the SEEA EEA to define ecosystem boundaries are "Land Cover / Ecosystems functional Units" (LCEU). LCEU is disaggregated in Basic Spatial Units (BSU) which is a grid of $1km^2$ on a map. Each BSU is defined by a set of ecosystem characteristics. A LCEU is the sum of BSU having a homogeneous set of ecosystem characteristics. For instance, European Environment Agency has developed the Land Cover aiming at mapping the ecosystem boundaries for Europe (Weber, 2007). The physical ecosystem account aims at indicating the flow of ES expressed in physical unit (such as tonnes) coming from the different LCEU. In order to value in physical unit the degradation of ecosystems, it is important to construct a physical account like the SEEA CF to estimate the part of different origins (i.e., natural or human origins) explaining the change in ES between the beginning and the end accounting periods. The SEEA

EEA defines the degradation as the reduction of capacity by an ecosystem to deliver a broad range of ES, caused by the action of economic units (including households). The next step is to value in monetary unit the degradation of ES. **One of the major challenges of the SEEA EEA is to define monetary valuation methods consistent with the accounting approach to provide a monetary value of ES.** Like the environmental asset, almost all ES are not traded in a market. The unit resource rent, indicated in the SEEA CF, is not well appropriated to value ES. First, it is suitable only for activities using the provisioning services. Second, some strong market conditions should be in place to the unit resource rent reflects the price of ES. Nowadays, The SEEA EEA considers the simulated exchanged value approach developed by Campos and Caparrós (2006, 2011) as the best approach to value ES. Campos and Caparrós (2006) construct a hypothetical market to estimate the price of ES. It is the price leading to the equilibrium of the supply and the demand functions for ES. The demand function can be estimated by the valuation approaches (such as the contingent valuation) while the supply function represents the marginal cost required to supply ES. The monetary value of degradation is the reduction of ES expressed in monetary units caused by economic units. Like the SEEA CF (2012), ecosystem degradation is then integrated into the sequence of accounts. The value added is expanded to integrate the value of ES. To estimate adequately the net value added, it should also incorporate the degradation of ecosystems. This leads to a measure of the "green GDP".

In a nutshell, environmental accounting aims at integrating the ecosystem asset in the national accounts in order to adjust the conventional accounting indicators with the ecosystem degradation. However, this accounting approach is faced with important methodological issues to value ecosystem services, since a large part of them are not traded in a market and not integrated in the economic activities.

2.3. The limits of these present experiences according to the accounting principles indicated in the SNA

However, green and environmental accountings face with some important limits that are important to mention.

First, green and environmental accountings assume that the market is possible for all ES. However, as indicated by Aaheim and Nyborg (1995), the market for ES does not work. To market works well, the consensus between suppliers and consumers is required to know about what the marginal value of the good is. However, for ES, there is no consensus between suppliers and consumers. According to Aaheim and Nyborg (1995), this implies that the estimated value of the environment will have a different interpretation depending on the measurement technique used, since different methods simply measure different values. Green GDP calculated in the SEEA is thus difficult to interpret.

Second, the residual rent approach supported by the SEEA to estimate the value of ecological inputs has some important criticisms. Firstly, the rent gives a good value of ecological inputs only in the specific case where the natural resources are managed in a sustainable way. The reality is yet very different. Then, the rent cannot discriminate the value of different ecological inputs used by an economic activity. For instance, the shellfish farming uses both provisioning and regulating services. The calculation of the rent of shellfish farming cannot determine the contribution of each ES. Finally, the calculation of residual rent requires to know precisely all input prices. However, this is not the case in reality because of problems coming from the hidden subsidies and market imperfections (Ex.: monopoly or oligopoly rent). For example, the French environmental agency estimates the rent coming from the fisheries by adopting the residual rent approach (Commissariat Général au Plan, 2011). It estimates that the rent contributes to 30% of the value added of the fishery industry. It indicates that this result is unrealistic, since the critical situation of the French fishery. It concludes that this rent incorporates all sorts of hidden subsidies and market imperfections that are not possible to account. To conclude, the calculation of residual rent to value ecosystem services are in fact very difficult, not to say impossible.

Third, the simulated exchange value approach supported by the SEEA to value ES which are not traded and not used by the economic activities calculates the optimal prices. They are difficult to estimate because not observable. The calculation of the optimal prices requires the construction of a very-intensive economic model to compute the demand and the supply functions for each ES. The needed data is a major barrier to implement such model.

Fourth, the value of ES based on the welfare economics model is not consistent with the accounting principles. As stated by Bos (1997), the current exchange value does not correspond to the theoretical notion of prices under the perfect competition derived from the neoclassical model on which the welfare economics model is based. The annex 1 provides a comparison between the welfare economics model (or neoclassical model) and the accounting principles indicated in the SNA. The major distinction between these two approaches is that the welfare economics model uses the hypothetical market to estimate the optimal prices while the accounting principles are based on the current market prices coming from the observation. The current market prices integrate the market imperfections that are not taking account in the optimal prices. In this line, the Hicksian income estimated by the simulated exchange value approach developed by Campos and Caparros (2006) is different than the current income employed in the national income. Therefore, by mixing the current market prices and optimal prices, Hicksian income and current income, environmental and green accountings add in fact two different values that are not comparable. It poses the serious problem of the interpretation of the “green GDP”.

Fifth, ecosystem accounting requires to estimate both the quantity and the price of ES in order to value them, i.e., the output value of ecosystem processes (Bos and Banhzaf, 2007). It is difficult, and even impossible, to quantify and so to put a price to estimate the exchange value of ES (Vatn, 2000). It is explained by different reasons. A large part of ES is not observable. For instance, oyster farming need phytoplankton (considered as a provisioning service) to feed their oysters. However, it is difficult and, even impossible, to quantify the number of phytoplankton eaten by oysters. The difficulty to quantify ES increases the problems to estimate a unit price. The quantification of ES poses also the problem of the choice of physical units. For instance, ecosystems provide recreational services. What is a physical unit of recreational services? The area (in km^2) devoted to ecosystems? How to incorporate the quality of ecosystems? There are a number of issues that are difficult to solve. Moreover, a large part of ES is pure public goods that are not appropriable. This is for instance the case of oxygen produced by photosynthesis that is essential for the human well-being.

Sixth, to put a price to ES implies a process of commodification. This is not ideologically neutral (Kosoy and Corbera, 2010), since it considers that all ES can be traded in a market like an economic goods and services. The calculation of a value according to the accounting principles should be as far as possible ideologically neutral. It should describe the complex interactions of ecosystems and human activities based on the observation.

Seventh, the most important limit concerning green and environmental accountings is that it does not integrate the efforts carried out by the society to benefit ES. On the contrary, the national accounts aim at calculating the mobilized resources – payments of primary inputs (labour and capital), expenses of intermediate commodities - required to produce goods and services. In other words, the value of production finances the resources required for the production process. In this line, an ecosystem accounting should be interested in the mobilized resources carried out by the society to benefit ES. Contrary to the statement of the MEA, individuals do not benefit for free a large part of ES. For instance, individuals should mobilize resources to benefit recreational services provided by the ecosystems. The green and environmental accounting, by estimating hypothetical optimal prices, indicates rather the *potential* efforts that an individual is ready to make to envoy ES, than its *efforts really carried out* to benefit ES.

Since the different limits exposed above, an alternative accounting approach is proposed. It is based on ecosystem-based activity approach which is more consistent with the national accounts. The next section aims at exposing this accounting framework.

3. An ecosystem-based activity accounting

The theoretical framework of an ecosystem-based activity accounting is first presented. The accounting principles are then exposed.

3.1. The theoretical framework of an ecosystem-based activity accounting

The pathway from ecosystem structure and processes to the human well-being is usually represented by the figure 1. For instance, TEEB uses this representation.

< Insert figure 1 >

Ecosystem processes are dependent on the ecosystem condition and extent. Ecological function is seen as an output of ecosystem processes. It represents the potential of ecosystems to provide services to individuals. The functions become ES only if there is a social demand for this function. ES are thus considered as the link between the ecological component and the human wellbeing. ES provides then benefits to individuals. The ecosystem accounting values these benefits by estimating both the exchange value of ES and the quantity of ES consumed by people.

This linear representation of the interaction between ecosystems and individuals has some important drawbacks. It does not describe well the complex interaction between ecosystems and individuals. For instance, this representation does not incorporate the links between ecosystems, human activities and individuals. We consider that the human activities are central because in most cases, people interact directly or indirectly with ecosystems thanks to human activities. In our framework, the human activities must be seen as a broader view than the SNA. We integrate the household activities that are not always recorded in the SNA (Ex.: hiking). However, individuals interact directly or indirectly with ES thanks to human activities and, the relation between these two is complex. In this line, we propose the following definition of the ES: “ES are the biophysical contributions to the human activities and to the human well-being”. However, it is important to define what the biophysical contributions really are. According to Boyd and Banzhaf (2007), ES is a pure biophysical contribution. This implies that ecosystems interact with human activities by providing only inputs. On the contrary, Edens and Hein (2013) consider that the ES is an outcome of the combination of ecosystem processes and human activities, since ecosystems are more or less modified by people. According to this approach, there are some human activities aiming at regulating the ecosystem processes in order to maintain or to increase the ES. We adopt in our framework the approach defended by Edens and Hein (2013).

In our theoretical framework, it is essential to distinguish two types of ES:

- For the first type of ES, individuals receive freely the benefits of ES
- For the second type of ES, individuals should mobilize human and economic resources to benefit ES

Concerning the first type of ES, the human intervention is not required to benefit the ES. This concerns essentially regulation services. For instance, this is the case of oxygen provided by ecosystems thanks to photosynthesis. For the second type of ES, the resources mobilized by the society to benefit ES are carried out within human activities. The monetary amount of the production of activities indicates the financing of all inputs (i.e., human and economic resources) required in order to the society benefits the ES. For instance, the production of aquaculture activity finances the payment for labour and capital and also the expenses for intermediate goods and services in order that the oysters benefit the ES to grow and to be then consumed by people. The production of professional fishing activity finances all inputs required to catch fish and shellfish in the sea. The production of recreational activities (including household production) finances all required inputs leading to individuals approach ecosystems.

The welfare economics model aims at valuing the contribution of different goods and services (defined in a broad sense, i.e. economic and not economic goods and services) in the utility of individuals, through the estimation of the exchange value. **It represents *the potential efforts* that people are ready to make to enjoy ES. On the contrary of the welfare economics model, our framework is interested in the *actual efforts* made by people to benefit ES**. **In this line, our framework is more consistent with the national accounts, since the last one aims at valuing the actual effort made by the society (through the payment of primary inputs – labour and capital - and the expense for intermediate commodities) to produce goods and services.** The welfare accounts are not in the scope with this approach.

The figure 2 shows the links between ecosystems, ecosystem services and human activities in our theoretical framework.

< Insert figure 2 >

In this figure, the arrows in black represent the monetary flows that are accounted in our accounting framework. On the contrary, the arrows in blue indicate the non-monetary flows that are not recorded in our accounting framework. This figure checks the accounting equilibriums: The total monetary input should be equal to the total monetary output for each human activity and the total supply must be equal to total demand for each product coming from human activities.

According to this figure, ES are an output of ecosystem processes. Individuals benefit the ES in two ways: either indirectly through the achievement of human activities or directly and indirectly for free. Concerning the human activities, ES are an essential ecological input for the production. These activities should mobilize resources –payments of primary inputs (labour and capital) and the expenses for intermediated commodities - in order to benefit the ES. This is the case for example for aquaculture, fishing and recreational activities.

However, ES is sensitive in ecosystem processes, since they are an output of them. Ecosystem processes are dependent on ecosystem condition and extent. They require some inputs in order to work well. These inputs are in most cases the combination of ecological inputs and human-based inputs, since ecosystems are more or less modified by humans. Ecological inputs could be the internal flow within the ecosystem processes. For instance, the fish in the sea are used as a food for the fish caught.

Some human activities can act on the ecosystem processes in order to increase the ES. This is for example the case of the construction of walking trails in order to increase the recreational services provided by the ecosystems. The link with human activities can be strong, since these two types of activities are very interdependent. Hiking activity requires the construction of walking trails. However, at general, human activities– by including activities benefiting from ES - cause pressures in ecosystem processes, since they emit harmful residuals for ecosystems. For instance, the seaport activities emit pollution in the sea like the hydrocarbon pollution or heavy metals pollution. Nevertheless, some human activities aim at reducing the pressure coming from the human activities in order to ecosystem processes continue to provide ES. This is the case for example of the sewage treatment plants.

According to this figure**, two human activities are distinguished in our ecosystem-based activity accounting: i) activities using ecological inputs provided by ecosystems in order to produce goods and services and ii) activities aiming at maintaining or regulating ecosystem processes**. Our accounting framework aims at estimating the monetary value of production for these activities.

The table 3 describes the accounting indicators for activities based on marine and coastal ecosystem services.

< Insert Table 3 >

This table has the interest to link adequately the ES with accounting indicators associated with human activities which are recorded in our accounting framework. For each human activity, both supply and demand accounting indicators are indicated. These indicators are usually calculated in the national accounts like in the input-output table. The supply indicators focus on the production approach, i.e. the production process (intermediate and primary inputs). On the contrary, the demand indicators check the production according to the demand side, i.e the financing of the production process (the sales of products for private sector and the budget for financing the production cost for public sector). In this table, it is important to note that one ecosystem goods or service can be used for many human activities. For instance, the water quality is utilised both by shellfish farming and by recreational activities. Besides, one human activity can consume different ecosystem goods and services. For instance, recreational activities consume both water quality recreation services.

An important issue for ecosystem management is to know if the consumption of ecological inputs is sustainable, that is, if the present consumption of ecological inputs does not reduce the potential of ecosystems to provide ecological inputs in the future. This issue is important, especially for activities extracting natural resources like fishing. In this line, we recommend to construct a physical account linked to natural resources consumed as inputs by the activities. The methodology is similar than presented in the *SEEA Central Framework* (2012). This physical account aims at recording the stock and flow for each species during the accounting period. This flow is decomposed between natural components (growth in stock, normal losses) and human components (Gross catch/harvest and reclassification). By comparing between the monetary and the physical accounts, it is possible to know if the monetary value of production is a sustainable production. In other words, to know if the actual value of production will not involve a decline in the value of production in the future.

After presenting the accounting framework, the accounting principles are then explained.

3.2. The accounting principles

According to the SNA (2008), two types of satellite accounts should be distinguished. The first one involves only the rearrangement of central classification and the possible introduction to the complementary elements, but the accounting principles are fully consistent with the SNA principles. This is the case for Tourism account or Education accounts. On the contrary, the second one uses alternative concepts than those of the SNA. For instance, they can extend the asset valuation with a change in accounting concepts. This is the case for example for the SEEA EEA (2013).

The ecosystem-based activity accounting is totally consistent with the accounting principles set out in the System of National Accounts (SNA, 2009). Contrary to the green and environmental accounting, our accounting is not based on the hypothetical markets, but fully on the observation. The ecosystem-based activities account focuses on the activities based on ecosystems like the tourism account focus on the activities dependant on tourism. The production boundary is extended in order to incorporate the household production for own use. The value of production in our accounting framework should thus be comparable with the value of production indicated in the national accounts.

The ecosystem-based activity accounting classifies the production in four types:

- The production of firms. It includes the market and the non-market production coming from the private and public firms. This is the case for instance of aquaculture, fisheries, sewage treatment, …
- The production of administration. It includes the maintenance and the restoration of ES like sewage treatment, management of protecting areas.
- The production of associations. It corresponds to non-market production. It includes for instance the sportive and leisure associations which are dependent on ecosystems – canoe-kayak, sailing, hiking, …

- The production of household for own use. It corresponds to the recreational - sportive and leisure – production and consumed by households. For example, an individual requires inputs (primary inputs and intermediate commodities) to produce these activities and to consume the products coming from these activities. This is the case of canoeing or kayaking in order to discover the ecosystems. The individuals make this activity by using their own resources without the help of an association or a firm.

The first two types of production are already included in the SNA and it poses no problem. However, the ecosystem based activities accounting integrates also the production of household recreational production for own use that is not recorded in the SNA. It is important to define the accounting principles consistent with the SNA for this type of production.

First, it is important to define what the household production for recreational activities is. According to the economic modelling (Bockstaek and McConnel, 1981; National Research Council, 2004), the household recreational production corresponds to the total inputs by including time – "production time"– required to consume a number of quantity of time – "consumption time" - devoted to recreation.

An important issue according to the accounting framework is to know if the recreational production of household for own use is a productive or a consumptive activity. A third party criterion is used to know if an activity is productive (Reid, 1932). For example, household production for homework is considered as a productive activity, since it can be delegated by a third party. Klumb (2004) deepens the use of the third party criterion to consider if an activity is productive or consumptive. An activity is productive if it is performed predominantly for its outcomes, can be delegated in the third party without the loss of any beneficial effect. On the contrary, an activity is consumptive if it is performed for its own sake and it cannot be delegated to the third party without a loss of benefit. Watching TV or meeting friends are considered as consumptive activities. In literature, recreational activities are considered as consumptive activities, since the fact of angling, canoeing cannot be delegated to a third party without the loss of benetifs. However, in our accounting framework, recreational activities correspond to the mobilized inputs to perform them. The time spent on the site for angling or canoeing –called as consumptive time - is in fact the output of the recreational activities. According to this definition, the production of recreational activities is productive, since it can be delegated to a third party without loss of benefit. The inputs mobilized by households to perform their recreational activities can be delegated to a third party like associations or firms. As household production for recreation activities is productive, they can be incorporated in the national accounts.

It is important now to indicate how the household production for own use should be valued according to the accounting framework. The SNA considers two approaches to estimate the monetary value of production. The first one, preferred by the SNA, is called the output approach. This approach is used when the products are sold in a market. The value of production is equal to the quantity of units produced multiplied by the market price. It is composed of 4 components i) expenses for intermediate commodities, ii) the labour payment, ii) the net return to capital and iii) surplus. This surplus explains the difference between the production value and the production cost. According to economic modelling (Bockstael and McConnel, 1981; National Research Council, 2004), the ES play as a quality for recreational products. For instance, the hourly price for angling is higher if fish is abundant *ceteris paribus*. They are thus incorporated in the surplus. However, all goods and services are not exchanged in the market and have so a missing price. This is the case of public goods like the education or the health. The second best approach of the SNA, devoted to non-market commodities, is to value the production through the production cost. It is called as the input approach. Compared to the output approach, the surplus is excluded. Some accounting studies were carried out to estimate the household production consistent with the national accounts. Eurostat (2003) gives an overview of the accounting principles to estimate the household production. The monetary value of production is divided only in 2 components: i) the expenses for intermediate commodities and ii) the labour payment. The SNA 2008 stipulates in paragraph 6.125 that, by convention, the net return of capital is not included when the production for own use is carried out by non-market producers. In our theoretical framework, the methodology indicated in Eurostat (2003) is applied to calculate the household production for recreational activities. As the household production includes only 2 components, the production value can thus be interpreted as the minimum value.

An important issue for the accounting of household production concerns the payments of labour, since their monetary flows are not explicit. The payment for labour is defined as the "time production" multiplied by a wage rate. The "time production" corresponds to time spent for the preparation of the recreational activities. It includes the time devoted to expend in commodities and to search information for recreational activities and also the travel time. Two methods are explored to estimate the wage rate: the replacement cost and the opportunity cost (Eurostat, 2003). The opportunity cost was abandoned because it is based on the welfare concepts which are not consistent with accounting concepts. The replacement costs are more consistent with accounting principles (Goldschmidt-Clermont and Pagnossin-Aligisakis, 1999, Blades 1997, Chadeau 1992, Eurostat, 2003). The replacement wage can be either a wage from a specialist worker or the wage of a polyvalent worker. Eurostat (2003) prefers the wage of a polyvalent worker, while Poissonnier and Roy (2013) recommend the wage of a specialist worker having the least qualification. In the case of recreational activities, the wage of a specialist worker having the least qualification seems the best. This wage rate is very close to the legal minimum wage for recreational activities. Therefore, the wage rate could be the hourly legal minimum wage.

Like the production processes in firms, households can produce different products decomposed between a principal product and secondary products. For instance, angling activities can produce a main product angling product and also secondary products like wildlife observation or navigation. In the national accounts, the difference in these products coming from an industry is indicated in the supply table. Like the national accounts, our satellite account should discriminate the main product with the secondary products coming from the household production. In the SNA, the breakdown factor in the production for the different products coming from an activity is the sales revenue. For instance, if the total sales revenue of the industry A is explained by 70% by the sale of product X and 30% by the sale of product Y. The production of products X and Y is assumed to contribute respectively to 70% and 30% of the total production amount of the industry A. In the specific case of the recreational activities, the breakdown factor cannot be the sales revenue, since the products are a non-market. A possible proxy is to use the time which the households affect to the consumption of the different products coming from the recreational activities. For instance, the household production for angling activity is equal to €20,000. Households devote to 70% of the angling time for really angling and other 30% time to navigate and to observe the wildlife. The production of the product angling is equal to €20,000 × 0.7 = €14,000.

4. Conclusion

The ecosystem based activity framework has some interests relative to the present experiences in ecosystem accounting.

First, the value is based on observation and not on hypothetical markets. It avoids all possible problems coming from the valuation of nature. For instance, the accounting of the ecosystems as a fixed asset poses the problem of boundaries of ecosystems. However, ecologists criticise the willingness to delimit the boundaries for ecosystems. As our accounting approach is based on the observation, the data are more robust and reliable than the data estimated by economic models.

Second, the value of ecosystem-based activities can be compared with other human activities recorded in the SNA, since these activities are valued by using the SNA principles. This accounting approach respects one of the key foundations of the accounting principle stipulating that the different values should be comparable. This implies that these activities can be integrated in the different national account tables like input-output table and current accounts.

Third, by combining accounting indicators with physical data, it is possible to know if the monetary value of production is sustainable. According to the concept of strong sustainability, the production is said sustainable if the extraction of natural renewable resources is not greater than their renewable rate, i.e. if the present production will not cause a decrease in future production because of the reduction in natural resources stock. Physical indicators are thus sufficient to know if the actual production is sustainable or not. In this line, ecological indicators based on physical data are also relevant to account the change in ecosystem degradation. By adopting this approach, the conventional national accounting indicators are not adjusted unlike the environmental accounting avoiding the problem of interpretation.

Fourth, this accounting framework is appropriate to compare between on one hand the production of activities dependent on the supply of ES and on the other hand the production of activities aiming at maintaining the supply of ES. This information is crucial for policy-makers to implement an ecosystem conservation program, since it indicates the public costs carried out by the public sector so that the private sector using ecological inputs can supply goods and services for individuals.

Fifth, the implementation of this accounting approach is very cheap compared to the SEEA.

In conclusion**, it seems to be more robust in regards to accounting principles to construct an activity-based accounting linked to ES than to attempt to value the ES themselves.**

Furthermore, the construction of this accounting can offer a very good database for descriptive and simulation studies. In descriptive studies, the construction of this accounting makes it possible to know what the contribution of ecosystem-based activities to the national production (i.e., GDP) is. An input-output analysis can be carried out to know the indirect and induced impacts coming from these activities. Thanks to this information, it is possible to know the vulnerability of an economy to the change in the supply of ES coming from for instance the change in ecosystem condition and extent. Concerning the simulation studies, the figure 2 provides a good basis for modelling the interaction between ecosystem condition and extent, the ecosystem services and human activities.

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Annex 1: difference green accounting and environmental accounting

The Table 1 summarises the difference in concepts between green accounting and environmental accounting.

< Insert Table 1 >

Annex 2: difference in concepts between economic accounting and economic models

The Table 2 summarises the difference in concepts between economic accounting and economic models.

< Insert Table 2 >

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Table 1: Main differences between green accounting and environmental accounting

	Green Accounting	**Environmental Accounting**
Theoretical Framework	Welfare economics model	Satellite account: providing a greater degree of freedom to concepts and valuation than conventional accounts
Accounting indicators	*Net National Product* (NNP) : equal to consumption plus the net investment by integrating the environmental assets	*Depletion (or degradation) adjusted net value added*: the value of net value added coming from the national accounts reduced by the value of depletion or degradation of environmental assets ; *Depletion (or degradation) adjusted Net saving*: the value of net saving coming from the national accounts reduced by the value of depletion or degradation of environmental assets
Estimation of exchange price of environmental resources or ecosystem services	*Optimal price* corresponding to the marginal willing to pay for a quantity of environmental resources or ecosystem services	*price market* (Ex: Fish quota) or by using the concept of the *net present value* by calculating the residual rent coming from the value of production of economic activities

Table 2: Main differences in concepts between economic accounts and economic models

	Economic accounting	**Welfare economics models**
Main feature	Strictly descriptive (no optimization process)	Normative (welfare concept based on optimization process)
Use and non-use value	No estimation of use/non-use value	Net willing to pay (consumer surplus)
Market	Observed market: reflects all kinds of imperfections in the market mechanism	Hypothetical market: market under perfect competition. The market allocates in an optimal way the resources (maximum of the sum of the producer and the consumer surplus)
Price	Current or observed price. Distinction between basic prices (from the supplies of products) and purchasers' price (from the uses of product).	Shadow or fictive price: price corresponding to the perfect competition (equal to the marginal utility).
Exchange value	Current exchange value = current price x quantity	Estimated exchange value = price estimated in a hypothetical market (perfect competition) x quantity
Non-market production	Sum of the cost for the production (no use of hypothetical price). No mark-up in the production costs.	Equal to the estimated exchange value (hypothetical price x quantity). Estimation of a mark-up on the production costs.
Equilibrium	2 identities: 1) Output by industry = Input by industry 2) Total supply by product = total demand by product	Pareto optimal: the equilibrium is attained if the resources are allocated in an optimal way.
Value of asset	Assets are valued by using current market prices	Assets are valued by using the net present value: discounted present value of expected future returns coming from the assets
Income	National Disposable Income: National accounts aggregate calculated from the monetary flows coming from the current transaction	Hicksian income: based on future expectations (revenue, price, interest rate, …).

Table 3: Accounting indicators for activities based on marine and coastal ecosystem services

	Ecosystem Goods and Services	Economic Indicators for Activities using Ecological Inputs	Demand Indicators for Products from Activities using Ecological Inputs	Outlet of Products from Activities using Ecological Inputs
	Provisioning services			
	Fish and shellfish accessible to the commercial fishing sector	Fishing activity : intermediate consumptions, capital and labour; enterprises and employment	Sale value of the products coming from fishing activity (fish and shellfish landed)	Directly or indirectly (via trade sector) to individuals ; to economic sectors in order to be transformed (agro-industry sectors)
	Algae accessible biomass	Algae extracting activity: intermediate consumptions, capital and labour; enterprises and employment	Sale value of algae, own use of algae	To economic sectors : agriculture, chemical industries, ...
	Maerls, shell sand accessible for extraction	Other extracting sectors: intermediate consumptions, capital and labour; enterprises and employment	Sale value of maerls and shell sand	To economic sectors : agriculture, chemical industries, ...
Economic Indicators for Activities producing Ecological Outputs	***Regulation and maintenance services***			
Sewage industry: intermediate consumptions, capital and labour; enterprises and employment	Primary productivity Water quality	Shellfish farming: intermediate consumptions, capital and labour; enterprises and employment	Sale of the products coming from the shellfish farming (oysters, mussels)	Directly or indirectly (via trade sector) to individuals ; to economic sectors in order to be transformed (agro-industry sectors)
Biodiversity management bodies: labour and running costs	Biodiversity support Biochemical cycles, carbon sequestration			
	Cultural services			
Budget allocated to water quality and biodiversity maintenance costs	Recreation services	Recreational activities: intermediate consumptions, capital and labour; enterprises and employment (in associations and firms) or households	Household consumption for recreational activities (time spent for recreation activities)	Directly (via household production for own use) or indirectly (via associations or firms) to individuals
Demand Indicators for Activities producing Ecological Outputs	Aesthetic and symbolic values	Museums and cultural events: value of production factors, employment	Household consumption for cultural activities (time spent for cultural activities)	Directly to individuals

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Figure 1: The pathway from ecosystem structure and processes to human well-being

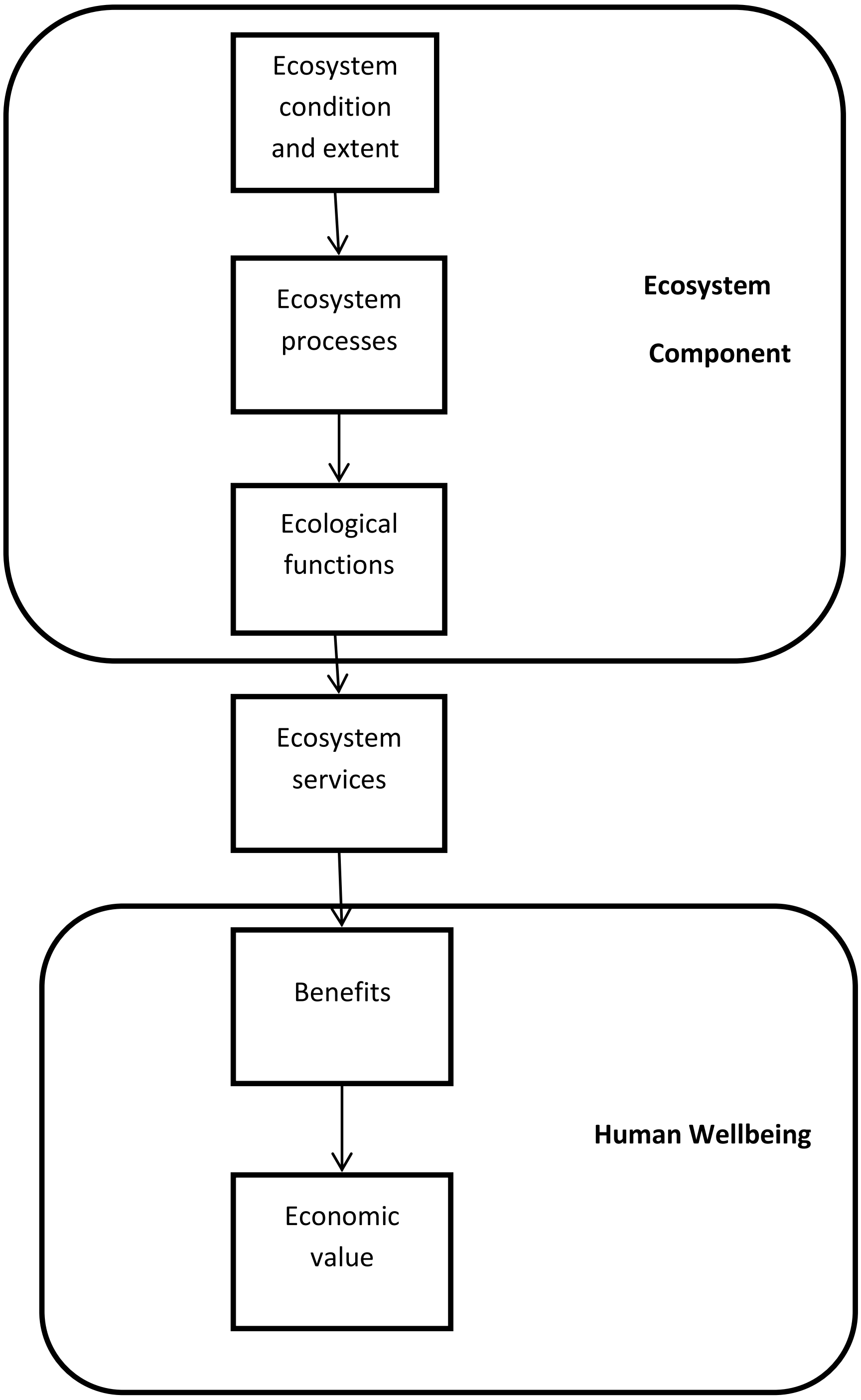

Figure 2: Description of accounting framework