MAREA

Deliverable D.T2.2.1

Regional tools for assessing feed-backs and trade-offs between marine ecosystem and anthropocentric systems

Part 1: Methodology for the social-economic models implemented in the geoportal

30.11.2022

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1. Introduction

A regional tool to assess feed-backs and trade-offs between marine ecosystem and anthropocentric systems was developed together with WP4. The product of the tools is the customized socio-economic models on the MAREA geoportal (also shown as economic models on the platform or mentioned as environmental accounting model on some MAREA material) (see Output O.T4.1 and Deliverable D.T4.2.1). This deliverable provides the methods and functions behind the socio-economic models on the MAREA geoportal, as well as the data sources of the parameters in the models.

The customized socio-economic models on the MAREA geoportal are a couple of socio-economic algorithms that are used to value the ecosystem services by linking the published ecological and ecosystem services layers in the PlanWise4Blue with the collected economic data. The users can customize some of the economic parameters in the models. With different ecological and ecosystem services layers under different management scenarios, the model could assess how the values change under different management scenarios and quantify trade-offs between different management options. In a case the models are based on the same management scenario, it is possible to evaluate trade-offs among multiple ecosystem services by identifying which services have higher values. Currently, the MAREA geoportal (see Output O.T4.1) only demonstrates 2 models for 2 types of ecosystem services under one business-as-usual scenario with the setting of current environmental and human use conditions. The geoportal will be further extended to have more models for other ecosystem services, different management scenarios, or connect to the ecosystem services output layers from the cumulative impacts assessment tools on the same geoportal (see Deliverable D.T4.2.1) in future projects.

The two developed models are for the provisioning services of blue mussel aquaculture and global climate mitigation services (blue carbon), whose details will be further explained in sections 2 and 3. For both models (and the models that will be included in the future), the used valuation approaches and algorithms (will) follow the accounting principles of the System of Environmental-Economic Accounting – – Ecosystem Accounting (SEEA EA) (UN, 2021). Therefore, with proper management scenarios, the output values from these socio-economic models can be used to evaluate the value of the potential supply of ecosystem services, the value of ecosystem services supply or the partial value of ecosystem assets provided by certain areas or a specific habitat type, and some of which will be usable to compiled ecosystem services supply or asset account (see Deliverable D.T2.1.1)

2. Ecosystem services value of blue mussel farming

Blue mussel farming is a novel and developing field of aquaculture in the Baltic Sea. The interest has grown in the region recently in improving the methods of blue mussel cultivation due to its potential in removing excess nutrients from the sea. Additionally, initiatives to develop new products from blue mussels have started to emerge even though the unique characteristics of the Baltic Sea cause some challenges to their cultivation. The average size of a blue mussel is smaller than in the other parts of the EU mainly due to the lower salinity levels of the Baltic Sea. Generally, Baltic Sea blue mussels have been considered too small for human consumption. In the EU producer prices have been sometimes so low that mussels farming has not been economically feasible with all production techniques (Avdelas et al., 2020). Recently in the Baltic Sea area, new methods have been developed to valorise the Baltic Sea mussel through novel processing techniques to make mussel production more profitable (Adler et al., 2022).

As most of the blue mussel farming are not yet commercialized (Jernberg et al., in prep.) and the ecosystem services layers embedded in the geoportal provide the potential production amount if the blue mussel farm will be established there, the values that are evaluated from the social-economic model are also the potential values if the blue mussel farms are established. As aquaculture is one of the provisioning services, the valuation of resource rent was used to value the flows of ecosystem services (NCAVES and MAIA, 2022, UN, 2021).

2.1 Functions for resource rent and asset calculations

Following function revised from NCAVES and MAIA (2022) and UN (2021) was used in the geoportal for determining the annual resource rent for blue mussel cultivation in the pilot area:

$$RR = p * y * w - C_{op} - C_{inv} - C_{oth} - D_{inv} - D_{oth}$$

Here RR is the resource rent or so-called yearly value of the mussel provisioning services for the farmed mussels. Variable p is the producer price (per tonne live weight) of blue mussels. Price levels are assumed to change in time with a fixed inflation rate (see next sub-section). Production y is the volume of mussels that can be harvested from an area in the geoportal in tonne dry weight. Variable w is the conversion factor from dry to live weight. In the MAREA geoportal, $y * w$ are given from the published ecological and ecosystem services layers provided in geoportal based on the given scenario. C_{op} are the operational costs per year and C_{inv} the yearly investment costs of the mussel farm that have been annualized from the total investment cost at the beginning when the farm is established to the cost per year. Other investment costs per year are written as C_{oth}, which also been annualized. D_{inv} refers to the depreciation of fixed capital per year (from the initial costs of the farm) and D_{oth} to the depreciation of other fixed capital per year.

The asset value for mussel farming can be determined as the sum of the annual resource rent values of the farm in its lifetime:

$$VA_{mussel} = \sum_{t=0}^{T} \frac{RR_t}{(1+d)^t}$$

In this function, VA_{mussel} is the value of the asset when the provisioning services of blue mussel farming are considered, which is the net present value of the future flows of the provisioning services of blue mussel farming. The function offers a possibility to add up the asset values of other ecosystem services when those values are available and when they are under the same scenario provided by the same habitat or same areas. t is the year after the mussel farm project start T is the lifetime of the mussel farm project and RR_t is the annual resource rent at year t after the mussel farm project start. d is the discount rate. Sections 2.2 and 2.3 will further explain the functions and data sources of the suggested value of price and cost.

2.2 Producer Prices

Currently, producer price data of blue mussels is lacking in the MAREA countries (Finland, Estonia, and Latavia) as the blue mussel farms are not yet commercialized. In the Baltic Sea region price data is available in Denmark and Sweden among others. Swedish prices were slightly lower on average. Thus, the producer price for blue mussel was extrapolated from Danish data (Danish Fisheries Agency, 2022) to demonstrate the calculations in the geoportal, but the producer price extrapolated from Swedish data (Eurostat, 2022a) are also provided in the user guide (see Output O.T2.2.1). Blue mussel prices have varied in the last few years, so the average price of 2016 – 2020 was used as a producer price in the calculations. When price data becomes available in Estonia, Latvia and Finland or the users have their own data sources, the prices are changeable on the geoportal.

The demonstrated producer prices at the initial year (p) were derived using purchasing power parity (PPP) and producer price index (PPI) to convert the Danish or Swedish prices to Estonian, Finnish and Latvian price levels (Eurostat, 2022b; OECDa, 2022). Historical prices from Denmark/Sweden were transformed to 2020 levels using the PPI of each country, from which averages were computed. From these averages, market prices in 2020 in Finland, Estonia and Latavia were estimated by using 2020 PPP. The abovementioned calculation estimated the price at the 2020 level. However, future prices will be needed when calculating future resource rent (RR_t) in calculating the asset value or in the case that the farms would be established sometime after 2020. In these cases, the future prices (p_t) that are used to calculate the future resource rent could be estimated by multiplying the initial price in 2020 with an estimate of an inflation rate i:

$$p_t = p * (1 + i)^t$$

p_t is the price in year t after 2020, p is the price in the 2020 price level and i is the inflation rate. In the demonstrated case, "inflation rate (i) = 2%" was suggested to be used as it is European Central Bank (2022) target value.

2.3 Costs

Since blue mussel farming is still practiced on a small scale in the Baltic Sea area (e.g., Baltic EcoMussel, 2003; Minnhagen et al., 2019), high-quality cost data is not public available. Some pilot projects have been carried out in the region. The costs of mussel farming vary greatly depending on the technique used and the physical qualities of the farm site, and thus costs can be different between regions (Gren & Tirkaso, 2021; Kotta et al., 2020; Ozolina & Kokaine, 2018). Also, all costs are most likely going to decrease when production levels increase due to economies of scale (Gren & Tirkaso, 2021).

For the demonstration of the calculations in the geoportal, we used the newest and the most valid cost estimates from recent Estonian pilot projects (personal communication with WP4). Costs could be divided into three categories: investment costs, other investment costs and operational costs. Based on these pilots, it was assumed that the expected lifetime for investment costs is 20 years and for other investment costs 10 years. All costs were estimated in Finland and Latvia from Estonian levels by using purchasing power parity (PPP). It is worth noting that in the demonstrated calculations, other investments were renewed since their lifetime was shorter. For investment costs, linear yearly payment was assumed; for depreciation, a sum-of-the-digits method was used (OECD, 2001).

Investment costs and depreciation per year differ based on the project year as investment costs are discounted to the starting year of the project and the annual value of depreciation decreases non-linearly. Discounting emphasizes costs that take place in the near future over more distant costs and in the chosen depreciation method the value of the asset declines more rapidly in the first years of the project. Below the costs of mussel farming are given as a function of time. For future scenarios, the changes in operational costs could be estimated by using an inflation rate (see Table 1). A discount rate was used to annualize the investment cost to calculate the resource rent (see Table 1). The annualized investment cost from the total investment costs and depreciation costs are calculated in equations listed in Table 1:

Table 1 Functions for determining annual costs and depreciation

variables to calculate resource rent	Equations	
Operational costs	$C_{op} = J * i^t$	t = 0,1,2
Investment costs	$C_{inv} = \frac{K/T}{((1+t)^r)}$	t = 0,1,2…T
Other investment costs	$C_{oth} = \frac{L/T_O}{((1+t)^r)}$	t = 0,1,2…T
Depreciation	$D_{inv} = \frac{K(T-t+1)}{(\frac{T(T+1)}{2})}$	t = 1,2,3…T
Depreciation (other)	$D_{oth} = \frac{L(T_O-t+1)}{(\frac{T_O(T_O+1)}{2})}$	t = 1,2,3…T

where C_{op} = operational costs in year t, J = operational costs at the base year or the year of the project start to operate, i = inflation rate C_{inv} = investment costs in year t, K = total farm investment costs spent to invest fixed capital at the beginning of the mussel farm established, T = lifetime of the investment, C_{oth} = other investment costs in year t, L = total other investment costs that also spent to invest facilities at the beginning of the mussel farm established, but with shorter lifetime and can be re-invested before the lifetime of the mussel farm end, T_O = lifetime of other investments, t = year, r = discount rate, D_{inv} = depreciation of fixed capital of the investment and D_{oth} = depreciation of other investments. The demonstration value of each variable/parameter on the geoportal can be found in in the user guide (see Output O.T2.2.1)

3. Ecosystem services value of blue carbon (global climate mitigation service)

Blue carbon or the so-called global climate mitigation service has two components: carbon sequestration and carbon stock (UN, 2021). Based on a recent ecosystem accounting valuation technical report (NCAVES and MAIA, 2022), carbon sequestration and carbon stock apply different valuation approaches when estimating the value of ecosystem services.

3.1 Ecosystem service value of carbon sequestration

The value of the ecosystem services of carbon sequestration can be estimated as follow:

$$VE_{(CSR,y)} = A_{(e,y)} * CSR_{(e,y)} * PCSR_y$$

- $VE_{(CSR,y)}$is the value of the ecosystem services of carbon sequestration (CSR) at the specific year (y). The unit of $VE_{(CSR,y)}$ is EUR/year.
- $A_{(e,y)}$ is the size of the area of the specific ecosystem type (e), e.g., mussel or seagrass, at the specific year (y), e,g., 2020. For the model of carbon sequestration, the unit of $A_{(e,y)}$ can be a hectare or km^2 but need to be consistent with $CSR_{(e,y)}$.
- $CSR_{(e,y)}$ is the carbon sequestration rate of the specific ecosystem type (e) at specific year (y). The unit of $CSR_{(e,y)}$ can be tC/hectare/year or tC/km^2/year but need to be consistent with $A_{(e,y)}$.
- $PCSR_y$ is the carbon price for the carbon sequestration rate for specific year (y).

$A_{(e,y)} * CSR_{(e,y)}$ is given from the published ecological and ecosystem services layers provided in the geoportal based on the given scenario. Based on NCAVES and MAIA (2022), the market price of CO_2 emission allowance in EU emissions trading systems (EU ETS) is the "best available estimate" and is recommended for $PCSR_y$, for ecosystem accounting purposes. Thus, the yearly average based on the historical daily price of CO_2 emission allowance in EU ETS from ICAP (2022) was used for $PCSR_y$, for y between 2009-2021. For y = 2022, the minimum and maximum daily prices between 01/01/2022-28/06/2022 from ICAP (2022) was used for $PCSR_y$. There are two reasons of using minimum and maximum daily price rather than the average price in 2022. First, the prices after 28/06/2022 are not available yet when the price data was downloaded for developing the geoportal. Second, the minimum and maximum price levels are needed to connect the projected price for y between 2023-2050. The unit used in the original price data in ICAP (2022) is EUR/tCO2 nominal price level. All prices have been transferred to the 2020 price level using the GDP deflator (EU 17 countries) from the OECD database (OECD, 2022b) and converted to unit of EUR/tC by using 1 tC = 3.67 tCO2 (Salcone et al., 2016).

For y between 2023-2050, $PCSR_y$ was used the projected EU ETS price modeled by Pietzcker et al. (2021). Pietzcker et al. (2021) modelled EU ETS prices in the future in a reference scenario and an ambitious scenario. The reference scenario assumes a linear reduction of factor of 2.2%, with which CO_2 emission reduction will reach a 43% reduction in 2030 and 85% by 2050 with respect to the 2005 level, with a zero-allowance provision reached in 2057. The ambitious scenario is assumed to reach the tightened EU ETS targets in line with the European Green Deal, so the linear reduction factor of 4.26% was applied, with which CO_2 emission reduction will reach 55% total emission reduction by 2030 compared to the 1990 level, and with which a zero-allowance provision will be reached in 2040. In the demonstration case in the geoportal, we used the project EU ETS price in 2045 and 2050 under the reference scenario as the minimum projected $PCSR_y$. In addition, the minimum projected $PCSR_y$ for the rest of the years between 2023-2045 was assumed to be a linear change from minimum $PCSR_y$ in 2022 to $PCSR_y$ in 2045. The same applied for minimum projected $PCSR_y$ between 2045 and 2050. The ambitious scenario project EU ETS prices in 2025, 2030, 2035, 2040, 2045, and 2050 were used for maximum projected $PCSR_y$, and linear change was assumed for $PCSR_y$ in the rest of years in the middle. The ranges between these assumed minima and maxima projected $PCSR_y$ covered most the non-academic predictions on the EU ETS price. For example, expected EU ETS prices from the market expectation surveys and business analysis from IETA&PWC (2022) and EURACTIV (2021) both fall into the ranges between the assumed minima and maxima projected $PCSR_y$ using Pietzcker et al. (2021) modelled EU ETS price.

3.2 Ecosystem service value of carbon stock

The value of the ecosystem services of carbon stock can be estimated as follow:

$$VE_{(st,y)} = A_{(e,y)} * CST_{(e,y)} * PCST_y * R$$

- $VE_{(st,y)}$ is the value of the ecosystem services of carbon stock (st) at the specific year (y). The unit of $VE_{(st,y)}$ is EUR/year.
- $A_{(e,y)}$ is the same case as the $A_{(e,y)}$ for valuing carbon sequestration.
- $CST_{(e,y)}$ is the carbon stock level of specific ecosystem type (e) at the specific year (y). The unit of $CST_{(e,y)}$ can be tC/hector or tC/km^2 but it needs to be consistent with $A_{(e,y)}$.
- $PCST_y$ is the carbon price for carbon socks for the specific year (y).
- R is rate of return that was used to annualize the carbon stock value to a yearly value for the ecosystem service (NCAVES and MAIA, 2022). With the annualized value, the ecosystem service value of carbon stock can be added up with the value of carbon sequestration. To keep it consistent, the value of R needs to be the same as the discount rate or interest rate used in other parts of the model.

$A_{(e,y)} * CST_{(e,y)}$ is given from the published ecological and ecosystem services layers provided in the geoportal based on the given scenario. Based on NCAVES and MAIA (2022), the social cost of carbon (SCC) is recommended to be used as the price for carbon stock. For y= 2015, 2020, 2025, 2030, or 2050, we used the SCC estimated from Nordhaus (2017) DICE revised model as the value for $PCST_y$. For the rest of the years between y= 2015-2050, the linear change was used to estimate $PCST_y$ of those years. The SCC values from the scenarios assuming the discount rate as 2.5%, 3%, and 5% were used. The original SCC values were first transferred from the USD 2010 price level to the USD 2020 price level using the GDP deflator of the United States from the OECD database (OECD, 2022b). Then, the price was transferred to the EU price level through PPP (Eurostat, 2022b) to align with price data for carbon sequestration. Same as for carbon sequestration, the price levels have been transferred from EUR/tCO_2 from the original data sources to the current unit: EUR/tC.

3.3 Ecosystem service value of total blue carbon (global climate mitigation services)

Ecosystem service value of total blue carbon, or said the ecosystem service value of global climate mitigation services, can be then calculate as the function below. Note that the year (y) should be the same for all the three components in the function.

$$VE_y = VE_{(CSR,y)} + VE_{(st,y)}$$

- VE_y is the value of the ecosystem services of the ecosystem service value global climate mitigation services at the specific year (y). The unit of VE_y is EUR/year.
- $VE_{(CSR,y)}$is the value of the ecosystem services of carbon sequestration (CSR) at the specific year (y). The unit of $VE_{(CSR,y)}$ is EUR/year.
- $VE_{(st,y)}$ is the value of the ecosystem services of carbon stock (st) at the specific year (y). The unit of $VE_{(st,y)}$ is EUR/year.

3.4 Asset value of blue carbon

The asset value of blue carbon is not yet included in the social-economic model on the geoportal. However, it could be the development of the model at the next stage. Depending on the scenarios in the future, the asset value of the blue carbon (VA_{carbon}) could be calculated as below:

- Climate change scenario:

$$VA_{carbon} = \sum_{t=0}^{T} \frac{VE_{y+t}}{(1+d)^t}$$

- Baseline scenario:

$$VA_{carbon} = A_{(e,y)} * CST_{(e,y)} * PCST_y + \sum_{t=0}^{T} \frac{VE_{(CSR,y+t)}}{(1+d)^t}$$

The symbols of t, T, and d have the same meaning as the description of the asset value for mussel farming in the last paragraph of section 2.1.

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