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A new perspective on valuating marine climate regulation: The Israeli Mediterranean as a case study

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ABSTRACT

Marine climate regulation, the absorption and deposition of atmospheric carbon in the marine environment, is considered a valuable ecosystem service. Past valuations of this ecosystem service neglected to account for its temporal context, either by equating it with primary productivity, an underlying ecosystem process, or disregarded the temporal aspects related to its supply, thus leading to inaccurate valuations. This study presents a simplified spatiotemporal economic valuation methodology of the climate regulation ecosystem service, intended to address these shortcomings. The valuation was applied to the Israeli Exclusive Economic Zone (EEZ) by accounting for permanent and temporary carbon sequestration and the use of Social Cost of Carbon (SCC) values. Based on different carbon prices, the estimated value of climate regulation within the Israeli EEZ ranges between 265.1 and 1270.9 € km^{-2} $year^{-1}$, which is significantly lower compared with past methodologies applied in other areas.

1. Introduction

During the past decade, the ecosystem services approach has gained increased popularity among ecologists and economists, linking between the physical state of ecosystems and socio-economic welfare (Daily et al., 2009; Jordan et al., 2010). However, compared with terrestrial ecosystems, applying the concept of ecosystem services and Ecosystem-Based Management (EBM) to marine ecosystems has been insufficiently addressed in the scientific literature (Böhnke-Henrichs et al., 2013), mainly due to difficulties in data gathering and the existence of considerable knowledge gaps. This is evident in the case of the eastern basin of the Mediterranean Sea, which is characterized as an ultraoligotrophic (nutrient-poor) environment (Herut et al., 2016; Siokou-Frangou et al., 2010), prone to high anthropogenic pressures and constant environmental changes (Coll et al., 2010; Kress et al., 2016; Lejeusne et al., 2010; UNEP/MAP, 2012), especially those related to climate change (Gertman et al., 2013; Ozer et al., 2016). Coupled with the limited information on its biogeochemical processes, ecosystem composition and functionality, compiling accurate and reliable valuations for the ecosystem services' flows of the Eastern Mediterranean basin is particularly challenging.

Among the various marine ecosystem services, climate regulation is considered a valuable asset to human welfare. In the context of the oceanic environment, climate regulation can be addressed as an ecosystem service rendered by marine ecosystems through the absorption and deposition of atmospheric carbon dioxide (CO_2) within deep oceanic layers by marine organisms, a process often referred to as the "biological pump" (Chisholm, 2000). After its formation by primary producers (such as algae or cyanobacteria) during photosynthesis, organic carbon is exported below the euphotic layer (depths corresponding to 0.1–1% of sunlight reaching the surface layer), where it is subjected to remineralization and solubilization at various depths (Raven and Falkowski, 1999). The fraction of organic carbon that remains within the ocean is dependent on various biogeochemical processes and its residence time within deep oceanic layers dictates the duration of temporary reduction of atmospheric CO_2 concentrations. The benefit derived from the prolonged sequestration of atmospheric CO_2 is the moderation of adverse climate change phenomena, such as extreme weather

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events, health risks or property damage, which are associated with high concentrations of climate-influencing substances in the atmosphere.

The aim of this paper is to assess the climate regulation ecosystem service through quantification of carbon sequestered by marine autotrophic organisms, and to estimate its economic value within Israel's Exclusive Economic Zone (EEZ) in the eastern Mediterranean Sea. The assessment is based on the fate of absorbed atmospheric CO_2 as an indicator of climate regulation and provides a quantitative estimation for the current and future supply of this ecosystem service.

1.1. Climate regulation assessment and valuation

Performing an assessment of ecosystem services requires a contextual linkage to human welfare. In the case of climate regulation, the duration of the removal of climate-changing substances from the atmosphere dictates its benefits to society. Delaying the re-release of these substances results in a temporary lower concentration of greenhouse gasses, thus helping to impede adverse climate change impacts. Past valuations of climate regulation, relying on the methodology set forth by Beaumont et al. (2008), equated climate regulation with primary productivity, i.e., fixed CO_2 by phytoplankton was considered as sequestered carbon and served as the primary metric for the economic valuation of this ecosystem service (Costanza et al., 2014; de Groot et al., 2012; Mangi et al., 2011; Murillas-Maza et al., 2011). In fact, the majority of the organic carbon generated through primary productivity is being remineralized during respiration by marine organisms and outgassed as CO_2 back to the atmosphere in a relatively short span of time. By disregarding the temporal context, i.e. equating primary productivity, an ecosystem process with climate regulation, an ecosystem service, overestimated values might occur. This is due to the high difference between the amount of organic carbon produced during primary production and the actual organic carbon that remains in the system afterwards.

Within the Israeli Mediterranean, few attempts have been made to evaluate marine climate regulation as an ecosystem service. Mangos et al. (2010) performed an assessment of various marine ecosystem services, including climate regulation, for Mediterranean countries. Their evaluation of this ecosystem service, which was based on the work of Huertas et al. (2009), relied on carbon sequestration originating in the solubilization of atmospheric CO_2, a process which is not related to ecosystems *per se*, and therefore does not fall into the common definition of ecosystem services (de Groot et al., 2010). A recent estimation of climate regulation in the Mediterranean, assessed both non-biological and biological components associated with this ecosystem service, modeling sea-air carbon flux. The assessment resulted in a value €2.7 million per year (100.4 € km^{-2} $year^{-1}$), for the Israeli EEZ (Melaku Canu et al., 2015). This study also revealed that, as a whole, the Israeli EEZ acts as a source rather than sink to atmospheric CO_2, but in the context of ecosystem services, the biological component within the oceanic carbon cycle acts as a sink, which hypothetical absence would cause higher levels of CO_2 outgassing back to the atmosphere.

Another essential aspect of marine climate regulation is the issue of impermanence. It is usually customary to regard carbon as permanently sequestered if its removal period from the atmosphere exceeds 100 years (Murray and Kasibhatla, 2013). However, the amount of carbon which remains within the ocean for shorter periods in effect contributes to the temporary reduction of greenhouse gasses and delays climate change phenomena. Thus, for each given period, the flux of carbon into the ocean can be partitioned into a permanent and impermanent compartments.

This study asserts that in order to properly assess climate regulation, the temporal fate of absorbed CO_2 must be taken into account. In other words, the benefits of climate regulation stem from the duration of lowered concentrations of atmospheric CO_2 due to its deposition in the ocean and that this duration should be assessed against human context. Without accounting for the entire processes involved in the biological pump or their duration, an erroneous calculation of this ecosystem service, both physically and economically, might occur.

Despite the fact that no regular market exists for the climate regulation ecosystem service, its economic benefits can be estimated using indirect valuation techniques. A favored method is the market price of carbon, as established by emission trading schemes. The European Union Emissions Trading Scheme (EU-ETS) represents the largest cap and trade scheme in the world, in which individual emitters are given a certain emissions allowance (cap) and are able to trade with other emitters in order to meet their emissions allowances or to assist others to meet theirs. Trade within this scheme yields a market price for carbon, which can serve as a value for the climate regulation ecosystem service. However, it should be noted that as a valuation tool, this approach has proved to be inconsistent due to the erratic behavior of carbon markets caused by improper permits' allotment, global economic market behavior and uncertainty over future climate change effects (Tietenberg, 2013).

One of the most accepted valuation approaches is the Social Cost of Carbon (SCC), which represents the marginal damages associated with additional increase of greenhouse gasses in the atmosphere. It can also be defined as a level of Pigovian tax that should be applied to CO_2 emissions (Tol, 2008). SCC is often computed using Integrated Assessment Models (IAM), which take into account various socio-economic and climate-related geophysical parameters in order to assess climate change related policies. Among the factors controlling the resulting values of SCC are risk aversion, social discount rate and accompanied uncertainty. These factors are fed into the IAMs' analyses, each employing different methodology, coupled with various assumptions regarding expected changes in production, consumption and welfare. The numerous options associated with these assumptions and parameters result in a wide range of SCC values (van den Bergh and Botzen, 2015). One of the most prominent SCC estimations was performed by the Interagency Working Group on Social Cost of Greenhouse Gases (2016), taking into account the different IAMs and yielding a range of SCC values, depending on the chosen discount rate. Given the fact that SCC valuations are often subjected to general preferences and that no such estimation exist for Israeli context, any such valuation will provide only an approximation of the SCC value suitable for the case study in question. Nonetheless, compared with carbon valuation methods relying on emission trading schemes, SCC exhibits reduced margin of error under uncertain conditions and is more cost effective (Tol, 2017).Unlike other valuation methods, SCC deals directly with climate change damages and it can be argued that the values obtained using this methodology represent more accurately the benefits of the climate regulation ecosystem service.

2. Materials and methods

2.1. Model outline

The assessment of the climate regulation ecosystem service, indicated by organic carbon fluxes to deep oceanic layers and their concomitant economic values, was carried out for the Israeli Exclusive Economic Zone (EEZ) (ca. 27,700 km^2). The valuation extended between the years 1998–2015 in order to derive monthly and