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To cite this article: Coman Valentina *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **616** 012013

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General Framework for Ecosystem Assessment for Measures to Adapt and Mitigate the Effects of Climate Change

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Abstract: The effects of climate change are becoming more intense in the last decades. Moreover, according to many official reports, climate changes are directly affecting ecosystems and their services. To assess the impact of climate change on ecosystems, various methods are being used in order to identify changes and interactions with other pressures such as degradation or fragmentation. Adaptation and mitigation measures on the effects of climate change generally include land use changes and land use practices. In order to assess the effectiveness of adaptation and mitigation measures, the services provided by ecosystems and their status are monitored. The paper presents the general framework for evaluating adaptation and mitigation measures and it is based on research from reference works that generally recommend how to evaluate adaptation and mitigation measures. A local adaptation of the mitigation and adaptation framework is presented, by identifying methods for assessing state indicators and ecosystem services. Depending on the availability and accuracy of the data, are proposed methods structured on different levels of detail such as: statistical data, field measurements, modeling software. The application of the proposed methods was verified in a case study: Divici Pojejena wetland, for which detailed methods of assessing the state and services of ecosystems were used.



1. Introduction

Climate change is defined by the IPCC (The Intergovernmental Panel on Climate Change) working group as status changes that can be identified by changes in the environment and/or changes in climate properties, either due to anthropogenic or natural causes which persists for at least 10 years. Climate change directly affects ecosystems and their services [1], but also the reverse relation is valid - the importance of ecosystems to provide mitigation and adaptation services [2]. By assessing the state of ecosystems, information about their ability to provide services for human well-being can be analyzed. The state of ecosystems is composed by the product of the factors represented by the natural state and anthropogenic pressures [3].

Wetlands, in addition to other ecosystem types, play a key role in carbon sequestration and storage, helping the environment to withstand the effects of climate change. These ecosystems, preserved or restored, are important for sustainable development through the various functions they have, such as water quality control or groundwater replenishment [3], being special living environments located at the border of terrestrial and aquatic ecosystems [4]. Wetland ecosystems are vulnerable to changes in water quantity and quality supply and it is expected that climate changes will have more pronounced effect on them, with variation in hydrological regimes with global variability [5]. Regarding adaptation and mitigation measures on the effects of climate change, these usually include land use changes and land use practices. Such changes in land use can affect the provision of goods and services of different ecosystems. Therefore, adaptation measures can generate synergies and trade-offs between a range of ecosystem goods and services [6].

Adaptation consists in anticipating the negative effects of climate change and taking appropriate measures to prevent or minimize the damage they can cause, as well as to take advantage of opportunities that may arise [7]. Adaptation involves an ongoing risk management process. Mitigation measures relate to quantitative reduction measures of greenhouse gases (GHGs) or by increasing their removal from the atmosphere. Measures to increase CO₂ removal from the atmosphere include land use change practices and management practices for carbon storage in plants, trees and soil; atmospheric CO₂ capture by designed chemical reactions and storage in geological reservoirs; or terrestrial biomass conversion into energy while capturing and storing CO₂ [8]. One method of adapting wetland ecosystems to the effects of climate changes is to prevent or decrease additional stress that may negatively impact their status.. Hydrological maintenance, pollution reduction, vegetation control and protecting biological diversity and integrity of wetlands are important activities for maintaining and improving the resilience of wetland ecosystems, so that they continue to provide important services in current climatic conditions [9]. The ecosystem approach contributes to the necessary adaptation measures as part of the adaptation strategy [10]. Adaptation/mitigation measures can be included in the concept of "Nature Based Solutions" (NBS) [11].

In this paper is presented the adapted framework for the assessment of ecosystem-based adaptation/mitigation measures (derived from DPSIR framework). Also, the methods used for the assessment of indicators, as part of the framework state - pressures - provided services - response - impact, were classified on three levels of details. The methods for indicators assessment were tested in a study case, following the general recommendations as MAES framework and the latest research projects [6], [12].

2. Experimental

2.1. Method

DPSIR (Drivers - Pressures - State - Impact - Response) is a theoretical framework used to systematically rank the information needed to analyze environmental problems, on one hand, and to identify measures to solve them, on the other hand (Figure 1) [13]. Thus, the drivers (D) exert pressures (P) on the ecosystems state/condition (S), affecting, at some point, habitats and biodiversity (I) and consequently the services they can provide. Decision makers will implement relevant responses (R) by taking measures against the negative effects [3].

The DPSIR general framework has been adapted for the case of ecosystem-based adaptation/mitigation measures as follows:

- Climate changes are considered a mechanism (driver).
- Pressures are considered events caused by climate changes affecting ecosystems (e.g. extreme temperatures and extreme rainfall).
- The state of ecosystems is characterized by state parameters; the functions of ecosystems and the services they provide are related to state parameters.
- Adaptation and mitigation measures are addressed in response to the effects of climate change.
- The impact of adaptation and mitigation measures is assessed in relation to the state of ecosystems.

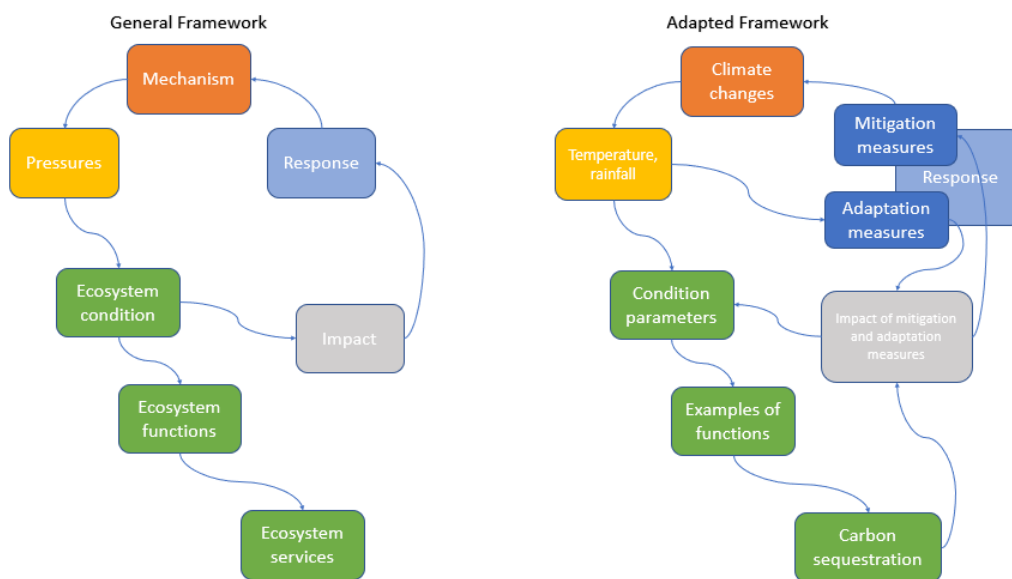


Figure 1. General DPSIR framework adapted for the ecosystem-based adaptation/mitigation methods.

The following steps are focused on the "Impact of adaptation/mitigation measures" and the general methods for assessing the effect of these measures, by quantification of the pressures, state and services provided by ecosystems. Adaptation services can be identified and evaluated for the use in support of human well-being and the properties of the ecosystems underlying adaptation services must be managed in order to conserve biodiversity and existing ecosystem services [14]. Ecosystem assessment can have different objectives, one of which is to reduce risks, including those associated with climate changes as adaptation measures [15]. MAES framework is used to quantify indicators for pressures, state of ecosystems and their services [12].

To quantify some representative indicators for wetlands, adapted to the local level, methods divided on 3 levels were used, depending on the degree of difficulty and the availability of data. The indicators were used to describe the state of the ecosystem, depending on the pressures exerted on it, and the services provided. The 3 levels are grouped as follows: a) Level 1, by indirect measurements (statistical data, satellite data, information from management plans), b) Level 2, by direct measurements (field activities, questionnaires, satellite data, laboratory analyzes), and c) Level 3, by advanced analysis and modeling (use of software, conducting studies) [18].

Local-scale analysis is relevant to the “bottom-up” approach to the process of assessing ecosystem services at regional and national level by extrapolation of the results. The case study can also be useful for the “top-down” approach (from national to regional or local level) for assessing the effects of measures and for the calibration of the methods for assessment of the ecosystems and services they provide [17]. This paper presents the additional researches regarding the assessment of ecosystem based adaptation/mitigation measures to climate change effects by pressures-state- ecosystem services framework using the previous studies from Divici-Pojejena wetland [3, 14, 15, 17] and the latest studies and recommendations in domain [12,18]. Examples of used methods, their classification on 3 tier levels and the resulted values of measured indicators for pressures and ecosystem services are exposed.

2.2. Case study

Divici-Pojejena wetland is located on the left bank of the Danube, after the river is entering Romania. This area is the result of the increased water levels of the Danube, after the construction of Hydroenergy and Navigation System Iron Gates I, covering an area of 440 ha on the administrative territory of Pojejena commune, within Caraş-Severin county (figure 2). Divici-Pojejena wetland is an important region, due to the fact that in 2004, through its inclusion in the Iron Gates Natural Park, it was declared a wetland of international importance - Ramsar site [15].



Figure 2. Location Divici-Pojejena [3].

3. Results and Discussions

Table 1 presents examples of quantification for pressures and ecosystem services indicators, grouped according to data availability and calculation method.

Table 1. Pressure indicators.

PRESSURE INDICATORS				
<i>PRESSURE</i>	<i>NAME</i>	<i>TIER 1</i>	<i>TIER 2</i>	<i>TIER 3</i>
Climate changes	The evolution trend of the average air temperature	Use of climatological databases		
Results: Evolution of the average monthly temperature, analyzed from the meteorological stations Moldova Veche and Drobeta Turnu Severin, for the period 2006-2013, showed that 2012 was the warmest year, the temperatures frequently exceeding 35°C [3].				
Invasive species	Invasive allogeneic species	Statistical data	Field activities, scientific fishing	
Results: From the field activities and electric shore-based scientific fishing, a total of 13 species of fish were identified, 4 of which were invasive (spotted mackerel - <i>Pseudorasbora parva</i> , crucian carp - <i>Carassius gibelio</i> , sleeping guvid - <i>Perccottus glenii</i> and sunbird - <i>Lepomis gibb</i>). There are 12 species of non-invasive plants and 4 species of non-invasive native plants [3].				

Regarding ecosystem services indicators, the use of a certain tier does not depend on the scale of application but depending on the available data and the aim of the assessment the proper tier must be selected. A tier 1 approach can be applied at local level for a general understanding of the presence, absence or abundance of ecosystem services. A tier 2 or tier 3 approach is needed to better understand the effect of national land management measures at local level [18].

Table 2. Service indicators.

SERVICE INDICATORS				
<i>CATEGORY</i>	<i>NAME</i>	<i>TIER 1</i>	<i>TIER 2</i>	<i>TIER 3</i>
Provisioning services	Surface water availability	Statistical data	In-situ measurements	
Results: The delimitation of the wetland was achieved through in situ measurements and mapping activities, resulting in 440ha of wetland area of which 249 ha are covered with water in conditions of normal level on Danube river. According to the data about the surface and depth of the water, it results the available volume of water in the Divici-Pojejena wetland of approx. 3.7 million cubic meters, corresponding to the 249 ha covered with water [3].				
Regulation and support services	Mineralization and decomposition potential - through the indicator – Soil organic carbon		Sampling, in-situ measurements	InVEST calculation program
Results: As result of the application of carbon module of the InVEST modeling software Divici-Pojejena wetland includes high values of stored carbon, between 30-44 t/ha, which correspond mainly to swampy areas with reeds. The average values between 10-30 t/ha are characteristic of the vegetation areas located in the transition areas between the wet and dry area. Relatively low values (0.2 - 5.0 t/ha) are recorded in agricultural areas located in the proximity of the wetland, but also in aquatic areas located near the main course of the Danube [3].				
Cultural services	Number of visitors in the wetland - income from tourism	Statistical data	Questionnaires	
Results: Near the Divici-Pojejena wetland there are 147 accommodation places available, within the 7 tourist reception units [3].				

4. Conclusions

As part of the general framework for ecosystem-based adaption/mitigation measures to climate change effects were presented examples of indicators and the classification of the used methods, applied for Divici-Pojejena wetland. To assess adaptation and mitigation measures applied to the wetland ecosystem, indicators for ecosystem state and their offered services were quantified. To quantify some representative indicators for wetlands, adapted to the local level, methods grouped on 3 levels were used, depending on the degree of difficulty and the availability of data. As it results from the tables in previous section, Tier 1 methods are mainly used, by statistical data. Tier 2 is closely related to Tier 3, being often used together. This set of indicators and the used methods for their quantification can also be used to assess the pressure-state-services of another wetland as part of the general framework for climate change adaptation/mitigation measures. By monitoring the indicators for a relevant period, the relations between pressures - state - ecosystem services can be established and also creates a favorable framework to support decision makers for the selection of proper adaptation/mitigation measures.

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