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Ecosystem services of self-cleaning deltaic wetlands: conceptual remarks

Servicios del ecosistema humedal deltaico autolimpiante: observaciones conceptuales

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Contents

ABSTRACT:
Services of the self-cleaning deltaic ecosystem experienced pollution by mercury are assessed. A total of 9 specific services are established, as well as the relevant economic benefits. Importantly, some of these are linked to the past and future self-cleaning. For instance, the unrealized damage from pollution and the absence of immediate need for technological changes at the polluting coal-utilizing power plant are among economic benefits. The established specific ecosystem services can be brought in correspondence with the basic categories of such services.
Keywords: Economic valuation , Ecosystem services , Mercury pollution , Self-cleaning , Wetlands.

RESUMO:
Se evalúan los servicios del ecosistema deltaico autolimpiante que experimenta la contaminación por mercurio. Se establecen un total de 9 servicios específicos, así como los beneficios económicos pertinentes. Es importante destacar que algunos de ellos están vinculados con el pasado y el futuro de auto-limpieza. Por ejemplo, los daños no realizados causados por la contaminación y la ausencia de una necesidad inmediata de cambios tecnológicos en la planta de energía que utiliza carbón son algunos de los beneficios económicos. Los servicios ecosistémicos específicos establecidos pueden ponerse en correspondencia con las categorías básicas de tales servicios.
Palabras clave: Evaluación económica, Servicios ecosistémicos, Contaminación por mercurio, Auto-limpieza, Humedales.

1. Introduction

Ecosystem services are one of the most hotly-debated topics of the modern science, and this topic is in the core of the ecological economics. Its basic principles were developed, particularly, by Westman (1977), Cairns (1995), and Costanza et al. (1998), and the relevant ideas were later conceptualized by the Millennium Ecosystem Assessment (2005). According to the latter, there are four basic categories of ecosystem services, namely supporting, provisioning, regulating, and cultural categories. Each of them contributes in complex way to the human well-being on the local, regional, and global scales. These services are also important for various discussions of the issues of restoration, environmental marketing, and investment planning (Palmer & Filoso, 2009). Presently, services of different types of ecosystems and relevant economic benefits are in research focus. Ma et al. (2013) summarized the previous experience of this research.

Wetlands are among the most important ecosystems on the Earth because of combination of high biodiversity, dense vegetation, large amount of freshwater, rich agricultural resources, historical importance, etc. These are of utmost importance as a kind of unique natural heritage (some wetlands are protected with the Ramsar Convention) and also source of food and the other goods for the people. These ecosystems are often under significant anthropogenic pressure, but some of them are able for self-cleaning. The noted "simple" facts determine the importance and the high economic value of services provided by these ecosystems. The objective of the present paper is to establish the ecosystems services of deltaic wetlands, which experience natural and anthropogenic pollution by mercury (Hg-pollution), but resist to this influence with self-cleaning mechanisms. The study is urgent to form the conceptual basis for further judgments of the economic benefits of such peculiar ecosystems.

2. Theoretical background

The amount of the professional literature on ecosystem services of wetlands is enormous, and it continues rising. This can be explained by the diversity of the both wetland ecosystems and the relevant socio-economic benefits. Some main research findings that form the theoretical background of the present study are considered below.

According to Cheng et al. (2016), wetlands can provide ecosystem services of all basic categories, i.e., supporting, provisioning, regulating, and cultural services (cf. Maltby and Acreman, 2011; Mitsch et al., 2015). These depend much on the ecological functions of a given ecosystem (McLaughlin & Cohen, 2013). Unfortunately, previous studies of these services have been biased, even in the case of Ramsar sites (McInnes et al., 2017; see also Zhang et al., 2009). Chen et al. (2009) put the understanding of the wetland services in the temporal frame and provided economic assessment with regard to finite and infinite time horizons. Ibarra et al. (2013) concluded about the potential enhancement value and the opportunity cost of these services. Li et al. (2016) warned about possible double counting of values when wetlands services are simply listed and then considered individually (cf. Song & Zhang, 2014).

There is a broad spectrum of the wetland services, including carbon sequestration (Zedler & Kerchner, 2005). For instance, these include wildlife habitat, fisheries support, and water quality improvement in the case of the Great Lakes coastal wetlands of the USA and Canada (Sierszen et al., 2012). It is established recently that deltaic ecosystems can provide highly-specific services (e.g., for rice farming), and the rise of some services may lead to the fall of the others (Berg et al., 2017). The latter complexity was also noted earlier, among the others, by Hansson et al. (2005). As shown by Jessop et al. (2015), it is impossible to enhance all services at the stage of wetland restoration. Blackwell & Pilgrim (2011) demonstrated that small-scale wetlands can bring a lot of benefits despite of their size, although consideration of greenhouse emissions should be considered properly for final judgments. Acharya (2000) demonstrated that in addition to the well-known services of wetlands, there may be indirect services linked to groundwater resources maintenance.

The economic valuation of the wetland services is a complex task, which requires consideration of various costs and benefits (Zhang et al., 2009; Song & Zhang, 2014). The example of such valuation for the wetlands in Beijing shows their total value reaches as much as 3 ~bln USD. Chaikumbung et al. (2016) valuated wetlands in developing countries economically. They considered several services provided by these ecosystems (recreation, disturbance regulation, water regulation, water supply, nutrient cycling, erosion control, gas regulation, water treatment, biodiversity habitat, food production, raw materials, and culture). These specialists concluded that urban and marine wetlands are more valuable than the other types and also noted highly-complex (generally uncertain) relationships between the ecological and recreational functions of these ecosystems. The national approaches for the wetland services valuation are also discussed actively in the literature (e.g., Chen & Yao, 2014; McInnes et al., 2017).

Finally, some researchers demonstrated the utility of the wetland services valuation for various practical needs. For instance, Cohen-Shacham et al. (2009) presented the approach permitting identification of stakeholders involved into the wetland management. Womble & Doyle (2012) suggested the trading ecosystem services and applied this to the wetlands. Gunderson et al. (2016) employed the idea of wetland services for the discussion of adaptive governance and adaptive management.

This brief overview of the previous findings implies that the present knowledge of wetland ecosystem services is extensive, but yet to be comprehensive and well-systematized. Two main challenges are as follows. First, wetlands provide specific services that require proper identification in each given situation in additional to the general services that are reflected by the by the Millennium Ecosystem Assessment (2005). Second, the economic valuation of the wetland services should be done with regard to the relative importance of the services and the temporal frame in which these are provided.

3. Material and method

This study is based on the conceptual assessment of specific ecosystem services of self-cleaning deltaic wetlands. The example of the latter, which serves as an object of study, is real, although slightly idealized; the location is not disclosed because of some stakeholder interests. It should be understood as a kind of abstract example, which characterizes very generally the processes of natural and anthropogenic Hg-pollution and self-cleaning in deltaic wetlands.

The analyzed example is shown on Figure 1 and explained briefly below. Mercury and its chemical compounds are highly-toxic to plants, animals, and humans, and these are important environmental pollutants (Steinnes, 2013). It is established that

Figure 1. General schema of mercury transport in the analyzed example
Source: Own construction

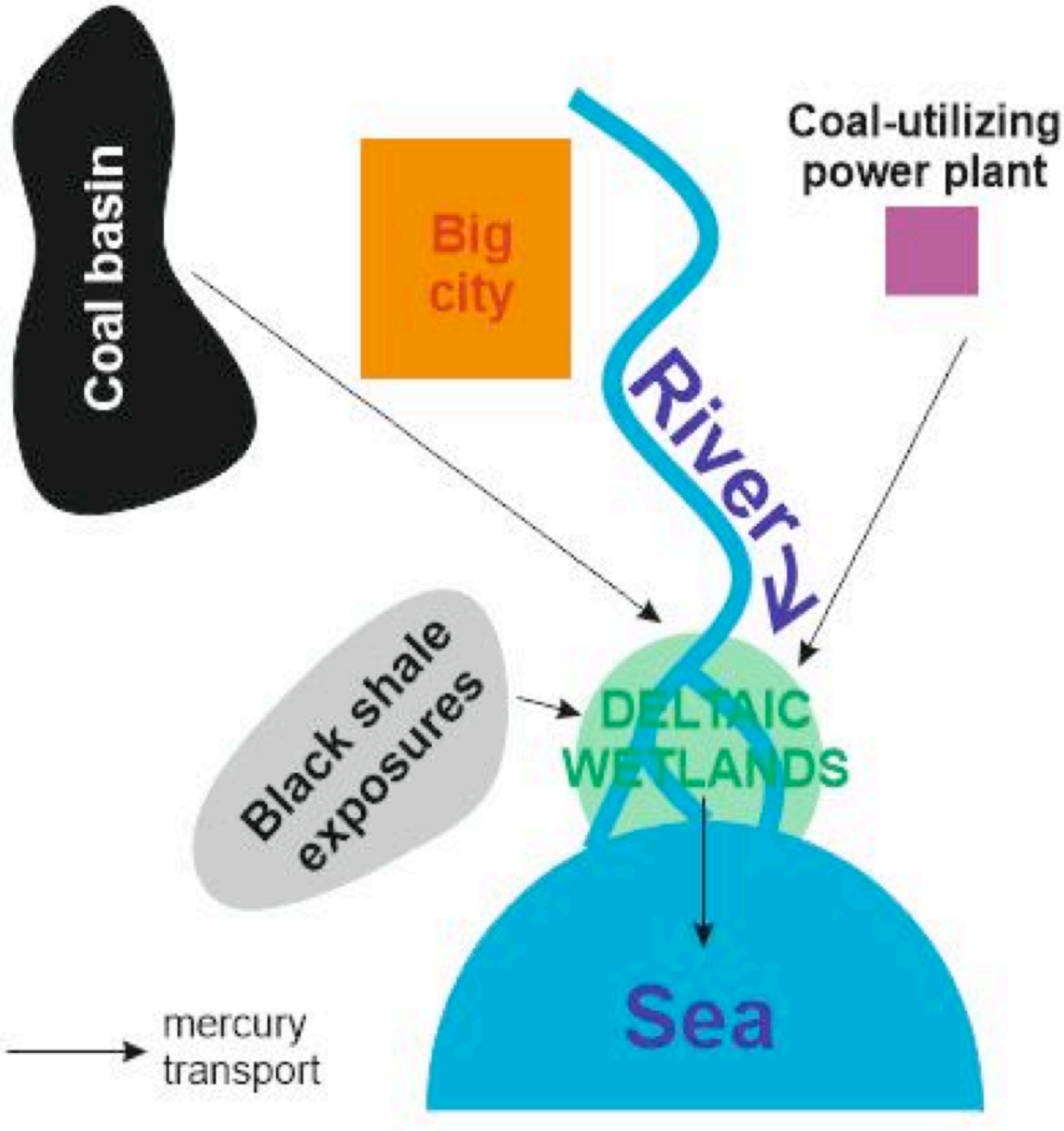
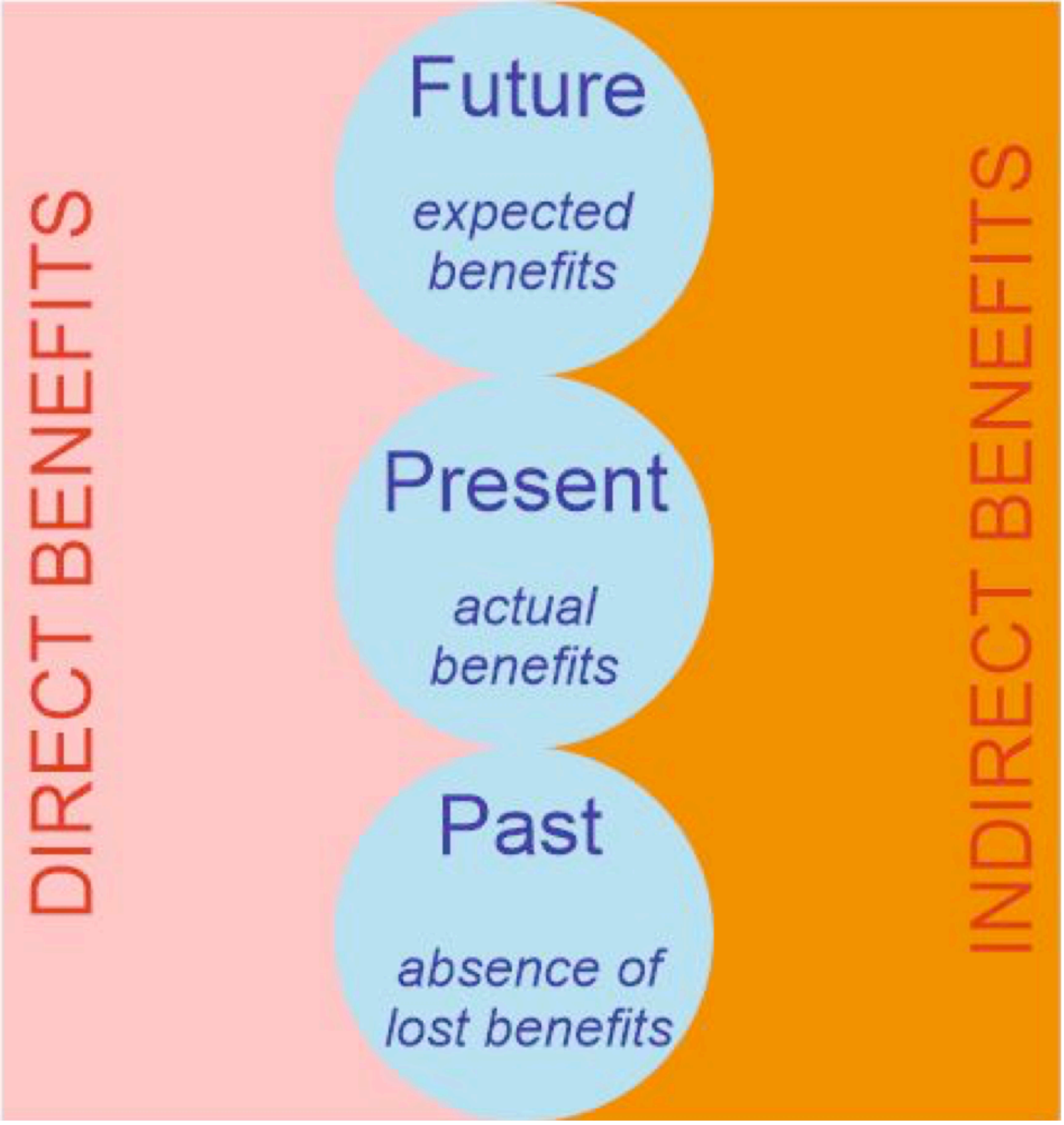


Figure 2. Diversity of economic benefits provided by the deltaic wetland services and linked to the self-cleaning from Hg-pollution



Source: Own construction

their dynamics in the transitional zone between rivers and seas is complex (Fedorov et al., 2014; Zimovets et al., 2015). The ecosystem services relevant to mercury cycling in wetlands were considered earlier by Marques et al. (2011), Sinclair et al. (2012), and Malczyk & Branfireun (2015). Particularly, these specialists noted the Hg-phytostabilization, the methylmercury production in newly-established wetlands, and the reduction of mercury input. In the analyzed example, there are three sources of mercury. Two of them are natural and linked to the high content of mercury in the rocks of two geological ages exposed and, thus, eroded in the proximity of the wetlands. The third source is anthropogenic and linked to the pollution by the power plant utilizing coals with the high content of mercury (with subsequent wind distribution of pollutants after coal combustion). Although the deltaic wetlands are under significant pressure of pollution from these three sources, the concentration of mercury in delta soils is surprisingly comparable to the levels typical for non-contaminated soils (these concentrations are indicated by Steinnes (2013)). The natural cleaning of the ecosystem occurs at the time of heavy rainfalls, local floods, and wind surges. It should be noted that these phenomena are essential for the very existence of this wetland ecosystem, and, thus, it is possible to tell about self-cleaning (of physical, not biological type).

The conceptual assessment of the proposed example is essentially identification of specific ecosystem services. It is focused on those linked directly to the phenomenon of self-cleaning and, thus, refer to the possible negative effects of the Hg-pollution. The relative economic benefits provided by these services are also identified.

4. Results

The conceptual assessment of the given example of self-cleaning deltaic wetlands (Figure 1) permits identification of several specific ecosystem services. Each of them can be related to the economic benefit(s). The established services are characterized briefly below.

Service SW1: the deltaic wetlands self-cleaning makes possible their direct use for the actual nature protection purposes. Mercury is highly toxic to plants and animals. As a result, the prevention of the Hg-pollution via self-cleaning permits to sustain "healthy" state of the ecosystem. In this case, the economic benefit is the same as brought by the non-polluted natural environment with high heritage value (the latter is typical for the majority of wetlands).

Service SW2: the deltaic wetlands self-cleaning makes possible their direct use in the current fishery development. Generally, Hg-pollution prohibits use of fish resources (natural and farmed), and, thus, self-cleaning allows to avoid this problem (at least, partly). The economic benefit is brought in this case by the non-disturbed freshwater fishery.

Service SW3: the deltaic wetlands self-cleaning makes possible their direct use for the actual recreation purposes. As mercury is environmentally toxic, recreation in the polluted deltaic wetlands is impossible because of two reasons. First, endangered ecosystem is less attractive to tourists. Second, access to Hg-polluted natural resources is dangerous to tourists themselves. Self-cleaning permits to avoid these problems. The economic benefit is brought by the local income from the non-disturbed recreation and ecotourism activities.

Service SW4: the deltaic wetlands self-cleaning permits to avoid expenses for special cleaning and restoration of the wetlands, as well as for technological changes at the coal-utilizing power plant. If the ecosystem is self-cleaned this does not require investments into the prevention of Hg-pollution. Better to say, the investments in the technological modernization are necessary, but chiefly because of the ethical reasons (even if the ecosystem is able to clean itself this does not mean the people have moral right for its pollution). The economic benefits in this case are linked to the absence of some extra expenses for the local nature protection and the industrial modernization.

Service SW5: the deltaic wetlands self-cleaning prohibited lost benefits and damage (unrealized damage) that might have occurred in the case of the absence of self-cleaning. It should be understood that the Hg-pollution (from both natural and anthropogenic sources) has started in the past, and it took place until the problem has been realized. Without self-cleaning, this might have brought some damage (e.g., ecosystem degradation with subsequent expenses for its restoration), as well as led to the lost benefit (e.g., because of impossibility to use the natural resources). In fact, these did not occur because of self-cleaning, and the "healthy" ecosystem functioning gave some positive economic effect in the past. Like in the previous case, the economic benefits are linked to the absence of some extra expenses. However, when SW4 deals with the actual expenses, SW5 deals with the past expenses and the economic profit that was brought because of the absence of the negative effects of the Hg-pollution (e.g., on the local fishery).

Service SW6: the deltaic wetlands self-cleaning creates some potential for continued anthropogenic pollution. Evidently, prohibiting Hg-pollution is an important task that cannot be realized immediately. The self-cleaning gives the local communities enough time for preparation and subsequent achievement of this task. During this time span (from the beginning of the preparation to the end of the pollution), the anthropogenic Hg-pollution may continue with negative effects to be avoided by the self-cleaning. The economic benefit is linked to the absence of necessity of immediate interruption of the work of the coal-utilizing plant, as well as to the possibility to postpone some expenses. The gradual solution of the problem with the Hg-pollution from the anthropogenic source means the absence of some additional expenses for the quick technological changes, as well as the absence of the additional risks linked to the quick re-organization of the technological process (such quick decisions are challenging with regard to the possible unpredictable interruptions in the technological process with subsequent local damage). Finally, the income from the power plant, the local fishery, the local tourism, etc. until the resolution of the problem with the anthropogenic Hg-pollution should be also considered.

Service SW7: the deltaic wetlands self-cleaning contributes to the development of the eco-image of the region. The "healthy" state of the ecosystem despite of significant anthropogenic pressure in the region underlines sustainable development of the latter. Such an eco-image is important for investment attraction to the region. And these additional investments form significant economic benefit.

Service SW8: the deltaic wetlands self-cleaning facilitates academic tourism. The phenomenon of self-cleaning is interesting itself and attracts attention of scientists. Their visits to the deltaic wetlands for research, experiments, and environmental monitoring may bring some economic income if even minor.

Service SW9: the deltaic wetlands self-cleaning supports the "normal" state of the ecosystem functioning. In such a case, the usual economic benefits from the non-polluted wetlands are expected.

5. Discussion

The analyzed example provides clear evidence of the broad spectrum of specific ecosystem services of self-cleaning deltaic wetlands. Undoubtedly, the similar principle of interpretations can be employed in the cases of self-cleaning from all kinds of pollution, not the only Hg-pollution. Two important issues should be addressed with regard to the above-said, namely the systematization of the knowledge of the economic benefits provided by the specific ecosystems services and the relationship between these services and the basic categories of ecosystem services suggested earlier by the Millennium Ecosystem Assessment (2005).

The established ecosystem services (SW1–9) can bring really different economic benefits. Some of them are direct, and some are indirect. The direct benefits mean economic income from the self-cleaning itself. The indirect benefits are linked to the income generated by the other relevant processes. For instance, this is the case of the local socio-economic development based on the non-disturbed fishery and/or tourism; the "healthy" state of the deltaic wetlands near a big city (Figure 1) improves the quality of the local environment, which is very important for the well-being of the urban residents. Apparently, each of the established ecosystem services can bring the both direct and indirect benefit(s). Very important is that the action of these services differs in time. Some of them (e.g., SW2) act presently and give the positive economic effect "here and now". But some others acted in the past (e.g., SW5) or will act in the future (e.g., SW6). These considerations are summarized on the general schema (Figure 2). Similarly-sounded issues were discussed earlier, particularly, by Chen et al. (2009).

The services established in this study can be related to the basic categories of ecosystem services of the Millennium Ecosystem Assessment (2005). Surprisingly, this is not so easy to do because the phenomenon of self-cleaning is highly-complex, as well as the relevant services. Tentatively, the following relationships can be established: SW9 is supporting service, SW2 and SW7 are provisioning services, SW4 is regulating service, SW1, SW3, and SW8 are cultural services; SW5 and SW6 can be related to all four categories. The present study demonstrates that the judgments of ecosystem services in the temporal frame may be, at least, not less important that making distinction between the basic categories. The understanding of the past, present, and future effects permits better economic valuation. For instance, if to pay attention to the self-cleaning in the past and the future, it becomes evident that the benefits from the deltaic wetlands in the analyzed example are significantly larger than when these are analyzed for the only present. For instance, the unrealized damage and the absence of the extreme urgency for technological changes at the coal-utilizing power plant can be described in the terms of past and future income. Moreover, the example assessed conceptually in the present paper implies that the ecosystem services can be related to the both anthropogenic and natural processes. In fact, two natural sources of mercury exist and the self-cleaning permits the ecosystem to be resistive to their negative influence.

6. Conclusion

This study permits making three general conclusions. First, the ecosystem services of the self-cleaning deltaic wetlands are diverse. Second, these services are specific (even highly-specific). Third, although it is possible to relate the established services to the basic categories, it is also important to focus on their temporal appearance and the relevance to the both anthropogenic and natural ecosystem disturbances for the better economic valuation.

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