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Research Article

Estimation of Monetary Values of the Ecosystem Services Flow at the Tidal Elbe River

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Most ecosystem services are regarded as free goods (i.e., priceless). This paper estimates monetary value of the ecosystem services after renaturalizing the navigation channel in the Kreetsand's area along the tidal section of the Elbe River. The river channel is basically reconnected to its floodplain which is currently grassland. The paper used benefit transfer method whereby values from previous studies are adopted to estimate total economic value of the ecosystem services provided by the study area. The results show that total economic value of the ecosystem services flow at the Kreetsand's shallow water area is €0.83 million/year. Nevertheless, the value seems to be underestimated due to errors inherited during valuation. After 44 years, the value will accumulate to €36.5 million, which is equal to the project investment cost estimated to be around €36.6 million. Based on the cost-benefit analysis results for the project, it is concluded that river renaturalization is the best option because it increases ecosystem services flow. The paper recommends that a similar study should be conducted to include more ecosystem services and ecosystem goods such as fish and water used for industrial purposes.

1. Introduction

Ecosystem goods and services are vital resources for sustaining life on earth [1]; they contribute to human well-being directly and indirectly. Generally, changes in the ecosystem and the associated functions impact human well-being by influencing flow of ecosystem goods and services on which human beings depend. Moreover, when human activities are unsustainable, they alter ecosystems and their functions, which in turn affect human livelihoods. The coexistence between ecosystems and human well-being is therefore continuous and unavoidable with the existing knowledge and technology. Nevertheless, the 2005 Millennium Ecosystem Assessment Report (2005) noted that the relationship between people and ecosystems kept on changing within the previous two decades of the 20th century and during the first decade of 21st century, which were some of the most remarkable changes. These changes are mainly due to human population growth concurrently with demand for food and other ecosystem goods and services and increase in human mobility over landscapes, leading to conversion of pristine ecosystems [2]. In addition to the above, ecosystem degradation and its associated decrease in flow are linked to ignorance on values of the natural capital and which ecosystems contribute to human well-being. Generally, this is a result of the ecosystem services being regarded as free goods [2–5]. Thus, they are priceless and difficult to handle in the market systems [3, 5, 6]. Ecosystems are thought to have no contribution in terms of quantifiable economic indicators, and they are often invisible in decision making concerning land management options. Nevertheless, their utility contribution to human well-being cannot be denied, and their demand always exists [2, 4, 7]. As human beings and the central agents to whom ecosystem goods and services are defined, continuing to enjoy the natural capital without quantifying its values will only compromise human lives in the long run. Although there are arguments that we should protect ecosystems services for moral and aesthetic reasons, there are many other reasons; thus we need to evaluate ecosystem services to guide our choices and decisions [2].

According to Costanza et al. [1], estimation of the ecosystem services value is a hard endeavor. It should be conducted to initiate ecosystem services approximation process and perhaps make potential values of the services known to its consumers. Costanza and colleagues further argued that even if the estimation is impartial and associated with lots of errors, it is worth conducting to stimulate debate concerning ecosystem service value estimations. There are some efforts employed today to develop market for ecosystem services through creation of schemes that give the investors a limited right to trade on ecosystem services [8]. In these schemes, regulations are used to create demand for services by limiting the accessibility and defining of ownerships [8]. The above are generally aimed at correcting market failure on the ecosystem services. An estimation of the values of ecosystem services using unit area per biome for seventeen ecosystems showed that the value ranges between $16 and 54 trillion per annum, with an average of $33 trillion.

Generally, valuation of ecosystem services involves determining changes of their quality and quantity and their impact on human welfare. The effect of these changes to human welfare can be detected as cost or benefit in the market or nonmarket systems. The study on which this paper is based was conducted to estimate monetary value of ecosystem services provided by a shallow water area created to mimic floodplain functions along the tidal section of Elbe River. The monetary values of the ecosystem services are used to carry out a cost-benefit analysis for the project implementation so as to motivate decision makers and support implementation of similar projects along River Elbe, or other similar ecosystems. Hamburg Port Authority has been using River Elbe as a navigation channel for many decades now. As the demand for shipping of the goods to and from the metropolitan region of Hamburg and the surrounding regions increased, Elbe River has been modified to allow passage of ever-increasing sizes of ships through deepening, straightening, and disconnecting the river channel to its floodplains. Those modifications have changed the structure and ecology of River Elbe. Changing in river morphology has led to tidal pumping effect, which is causing high sedimentation at the port basin. In year 2004, for instance, over 8-million cubic meters of sediment needed to be dredged from the tidally influenced Hamburg area [9] (HPA, 2005). High sedimentation along the port basin reduces channel depth, hence interfering with landing safety of ships. The Port Authority has used various techniques to control sediment and ensure safety landing, but the techniques have not been sustainable and are costly. Some of the techniques implemented include dredging and sediment trapping [10, 11]. Sediment dredging and relocation of dredged materials are associated with several limitations including interruption of ecological processes and land/water pollution. Dredged material has been report to be contaminated by heavy metals such as As, Cd, Hg, and Zn and organic contaminants such as PCB, dioxins, and PAHs originating from upstream industrial activities [9] (http://tide-project.eu, 2012). A study by Hajšlová et al. [12] found high level of brominated flame-retardants (BFRs), BDE 47, and other halogenated persistent organic pollutants (POPs) in fish in the Elbe River. The chemicals are associated with the widely used industrial chemicals in the Elbe River Basin.

In addition, Hamburg Metropolitan spends roughly about €30 million per year on treatment, relocation, and disposal of the dredged material (HPA, 2005). Cost-benefit analysis is carried out based on the fact that previous techniques used to manage the navigation channel and the port basin have been unsustainable. Creation of shallow water, which is regarded as river ecosystem renaturalization, is a sustainable option. The analysis is therefore used to convince decision makers that the new technique (river renaturalization), which also takes into account creation of habitat for species, which are ecologically and culturally significant to the people of Germany, does not only reduce sedimentation but also increases ecosystem services flow from the river to the Hamburg Metropolitan region. Monetary valuation of the ecosystem services is carried out so that it can be compared with the amount spent to renaturalize 47 ha of the tidal River Elbe. The renaturalization technique is one of the green techniques currently being adopted for management of ports in Europe, including Hamburg port in Germany [13]. In addition to restoring river morphology, river renaturalization is also looked upon as transformation towards multistrategies of flood protection where natural features are combined with hard structures, like dikes, to bring the benefit of the natural processes into the flood mitigation. Renaturalizing of the navigation channel creates strategic habitats for attracting high value biodiversity. In addition, the technique in Environmental Impact Assessment laws recommends the creation of new habitats or biological improvement to increase carrying capacity of the area to compensate for loss of habitat, especially those falling under habitat directives standards, Bird Habitats Directives or Natura 2000 (Habitats Directive, 92). Various EU directives recognizing that principle cause of biodiversity loss is habitat degradation; hence, creation of network of conservation areas is one of the priorities [4]. Renaturalization is currently also recommended as a flood control technique around Europe, replacing dikes and hard infrastructures. The paper is expected to motivate decision makers and attract projects of this nature in other areas. Therefore, the paper compares economic values of the ecosystems goods and services with the investment costs for construction of the shallow water area. The main objective is to reveal the hidden benefits of channel renaturalization in terms of ecosystem services.

2. Materials and Method

2.1. Materials

2.1.1. Study Area. The study area in which this paper is based is the Elbe River Estuary. The Elbe is one of the most significant river systems in Central Europe, originating 1390 m above sea level in the Karkonosze Mountains of the Czech Republic. The river flows 364 km through the Czech Republic and 630 km through Germany passing through the federal states of Saxony, Saxony-Anhalt, Lower-Saxony, Hamburg, and Schleswig-Holstein. From downstream of the weir at Geesthacht until it flows into the North Sea, about 140 km long estuary which is dominated by the influence of

(a)

(b)

Figure 1: (a) An aerial photo showing Kreetsand's area before project implementation. (b) A 3D model of the area after project implementation.

the tide. Hamburg Port, the largest port in Germany and the third largest port in Europe, is found on the tidal section of Elbe River, making the river an artery of the metropolitan region of Hamburg and an important federal waterway. The Elbe estuary is ecologically important nursery and feeding habitat for smelt and eel, which are traditionally important for German culture [14, 15].

Specifically, the study on which this paper is based was conducted at the Kreetsand's area where the Elbe River channel is reconnected to its floodplain (renaturalization) to restore the river morphology. Reconnection has resulted in tidal influenced wetland (Figures 1(a) and 1(b)). The process involved model simulation in which model results were used to design habitats within the area in a way that improves ecosystem services provisioning while reducing tidal energy and asymmetry and hence reduces tidal pumping and sedimentation. Reconnection of the river channel to its flood plains has restored ecosystem services such as tidal energy dispassion and sediment control compared to dredging and sediment trapping. Generally, this is a pilot project which, if yielding convincing results, will be implemented in other areas of the River Elbe and beyond for similar purposes.

2.2. Methods

2.2.1. Estimation of the Economic Value of Ecosystem Services and Goods of the Kreetsand's Shallow Water Area. Total ecosystem services value (TEV) of the Kreetsand's shallow water area was estimated using revealed preference and stated preference methods. TEV is defined as the sum of benefits that a particular ecosystem offers to human beings [4, 7, 17]. It includes use and nonuse values [18] (Diamantedes et al., 2002). Five ecosystems services: water purification through nitrogen removal, climate regulation, flood prevention and aesthetic information, existence values of landscape, and biodiversity and sedimentation regulation (maintenance of the river channel depth) which are provided by the Kreetsand's shallow water area were evaluated. The five ecosystem services were selected to capture use values and nonuse values of the Kreetsand's ecosystem services. The beauty of landscape and biodiversity represents nonuse value derived from people's appreciation to the nature and their willingness to conserve them.

Benefit transfer was used to obtain total economic values of ecosystem services of the shallow water area. Results/values from some other study were adopted. Benefit transfer is defined as the use of research results generated at one site or context, which are extrapolated or transferred to another site or context; or conversely, information needed at a policy site is inferred from an existing body of research.

Benefit transfer was used because of difficulties in obtaining actual values for the ecosystem services and their aesthetic values [19, 20]. According to Paul et al., 2012, and Deck and Chestnut [19], when properly applied, benefit transfer provides accurate estimates. The following steps were used to adopt values from various studies as recommended by various authors:

(a) Transferred values were defined; this involved searching for relevant studies and relevant values to be transferred [16, 21–24] (Bräuer, 1993; Pithart 2008).

(b) Transferability of values considering the similarity of sites was assessed, for instance, in cases where communities living in the area were involved, and population characteristics of the involved communities were considered for the original study and the current study [20].

(c) Evaluation of the quality of the study and values to be transferred was conducted. This step involved assessing the quality of the original study to reduce transformation error [20].

(d) Adjustment of values to be applicable for the current study area also was performed. Adjustment of values involved harmonizing units of measurements and values between the original study and the current study on which this paper is based [20].

2.2.2. Estimation of the Economic Value of Aesthetic Information and Existence Value of Biodiversity. The economic value of the aesthetic information and existence value of the Kreetsand's shallow water area was estimated by transferring values from a study, which was originally conducted by Dehnhardt and Meyerhoff [21]. The study by Dehnhardt and Meyerhoff [21] was selected for value transfer to the Kreetsand's shallow water area because it was conducted in similar environmental conditions. Contingent valuation method was used in the original study, whereby people's willingness to pay for improving preservation of biodiversity and habitats along the River Elbe floodplain was elicited

Table 1: Flood mitigation strategies involved for determination of better flood risk mitigation strategy.

Strategy (scenarios)	Kilometers along the river	Area in hectares (ha)	Storage capacity in mio (m^3)	Flood risk mitigation strategy
DS + 1 (dike heightening)				Implementation of the design standard of a 100-year recurrence interval with an additional freeboard of 1 m for all dikes in Sachsen
DR I (dike shifting)	*117–536*	*34658*	*738*	*dike relocation (uncontrolled operation) of 60 potential sites*
DR II (dike shifting)	120.5–536	9432	251	Dike relocation (uncontrolled operation) of the 33 potential sites identified in the IKSE action plan
POL A (controlled retention)	117–427	25 576	494	Controlled operation of 31 potential sites for retention polders identified in the IKSE action plan
POL P (controlled retention)	180	4557	138	Controlled operation of only the largest 5 potential sites for retention identified in the IKSE action plan
POL H (controlled retention)	427	9909	112	Controlled operation of the 8 existing retention polders, at the mouth of the River Havel near Elbe

Source: de Kok and Grossmann [16].

Table 2: Annual flood risk avoidance for each flood risk mitigation strategy.

Flood risk mitigation strategy	Flood mitigation scenarios, values in mio euros					
	DS + 1	POL A	POL P	POL H	DR I	DR II
Protected by dike	0.39	5.82	3.94	0.00	*1.89*	0.00
Not protect by dike	0.00	20.15	9.44	1.36	3.82	0.64
Total	0.39	25.96	13.38	1.36	5.71	0.64

Adopted from de Kok and Grossmann [16].

through interviews [21, 22]. In their study, 1,304 households within the catchment areas of the three rivers in Germany, namely, Elbe, the Weser, and the Rhine, were interviewed based on random samples for each catchment [21, 22]. The Elbe households were considered the ecosystem services users, while the Weser and the Rhine river catchments were considered the nonusers. The nonuser willingness to pay was assumed to include existence value. Questionnaires were designed to acquire respondents' familiarity with the Elbe River and respondents' knowledge about its ecological status in which seven ecological states of the Elbe were presented. Finally, respondents' willingness to pay was assessed by describing the management action to be implemented in the Elbe River floodplains [21, 22].

2.2.3. Estimation of the Economic Value of the Water Quality Regulation Services (Nutrients Retention). Nitrogen was taken as a nutrient for estimation of the economic value of water quality regulation (water purification). Dehnhardt and Meyerhoff [21] and Meyerhoff [22] transferred values for water quality regulation from the studies. Both studies had similar objective, which was to estimate the economic value of the Elbe floodplains as nutrient sinks using the replacement cost method. Dehnhardt and Meyerhoff [21] and Meyerhoff [22] analyzed the nutrient retention capacity of two sites, namely, Sandau and Rogätz flood plains. Retention capacities of these sites were obtained primarily through measurements in the sites and analyzed using the statistical model developed by Behrendt and Opitz [25]. The two sites were relatively similar (Sandau 830 ha and Rogätz 860 ha), but they differed in their capacity for nutrients retention. The Sandau site was the best site, which had a retention capacity of 783 kg/ha/year; Rogätz was the worst site with a retention capacity of 47 kg/ha/year [21, 22]. Rogätz's lower nutrient retention capacity was due to the proportion of the inundated area [23]. The percentage of inundated area of Rogätz was 20% of the total area (860 ha), while the percentage of the area inundated in Sandau area was 88% of the total area (830 ha) within the same test period of 10 days. These values were normalized using literature data [21, 22]. The good site (Sandau) had 450 kg/ha/year and the bad site (Rogätz) had 50 kg/ha/year after normalization [21, 22].

2.2.4. Estimation of the Economic Value of Regulation of Extreme Events through Floodwater Storage. Estimation of the economic values of the regulation of extreme events through flood water storage service was done through value transfer from a study by de Kok and Grossmann [16]. The original study was conducted for 536 km of the Elbe River. Values are therefore transferable to the Kreetsand's area due to biogeophysical similarities between the two study sites. The original site (simulated site) included a point 78 km from the Kreetsand's area. The aim of the original study was to determine a better flood risk mitigation strategy. Therefore, the values obtained in the original study can be used to evaluate Kreetsand's area flood mitigation value.

This study adopted four systematic steps undertaken by de Kok and Grossmann [16] to transfer values for regulation of extreme events through flood water storage from the original study to the present study. The steps are as follows:

Table 3: Economic values of ecosystem services.

Ecosystem services	Monetary values in € (euros per year)
Aesthetic information and existence values (biodiversity conservation and habitat protection)	479,400
Water quality regulation services (nutrients retention)	169,200
Extreme events or disturbance: avoidance of flood risk through floodwater storage	22,000
Climate regulation: carbon sequestration and burial	8,762
Sedimentation regulation: maintenance of the river channel depth	150,000
Total economic value	829362 (0.83 million)

(i) The generation of artificial flood events is based on the statistical analysis of the hydrological data, using discharge data from 1964 to 1995 [16]. The yearly peak discharge was analyzed to obtain the flood frequency in the longitudinal sections of the river stretch from 0 to 536 km. From the peak discharge, artificial flood events were generated [16].

(ii) Flood routing was modeled using the 1D steady-flow hydraulic model HEC-6 and mapped using GIS [16]. The relevant information like dike height and strength, the in-flow rate at the location of the dike breach, the water level in the main channel, and capacity of the floodplain was used to model the flood route [16].

(iii) Damage assessment involved generation of the values of the elements in risk. The spatial distribution of elements in risk and the relative damage functions were determined. Flood damage was described as the function of percentage value of the element at risk and the inundation depth. Total damage per flood event was calculated using the equation for each segment area of 100 m^2.

(iv) Flood risk assessment is defined as the product of flood hazards and the resulting damage. The damage for each flood event and average annual damage for each mitigation strategy was estimated [16]. The differences in average annual damage across management scenarios were used to evaluate mitigation strategy (Table 1). A mitigation strategy with lower damage values was a better option. These values were compared to the baseline scenario to obtain the flood risk avoidance values. In other words, a social benefit for implementing that mitigation strategy was estimated. Baseline scenario means risk without any mitigation strategy undertaken. Therefore, flood risk avoidance values = baseline value − mitigation strategy value. The flood avoidance values obtained are presented in Table 2.

2.2.5. Estimation of the Economic Value of Climate Regulation Service through Carbon Sequestration and Burial. Economic value for the climate regulation through carbon sequestration and burial service was estimated through value transfer from the study by Pithart (2008) and a study by Grossmann and Dietrich [24]. Values for both studies were transferable because both studies were conducted within ecological and socioeconomic conditions similar to that of the Kreetsand's shallow water area. Total carbon storage capacity was estimated including above ground storage and soil carbon storage. Above ground carbon storage values were transferred from Pithart (2008). The original study estimates were conducted in river Lužnice Floodplain, Czech Republic, in which carbon storage capacity was calculated using annual measurement of CO_2 fluxes between a wetland ecosystem and the atmosphere using Eddy covariance. 7.54 t of CO_2e/ha/year were estimated. Soil carbon storage values were transferred from a study by Grossmann and Dietrich [24]. In their estimation, they followed two steps: first, they investigated the avoided social costs through the reduction of the greenhouse gas emissions using a landscape scale model of greenhouse gas emissions. Water management was the determinant of greenhouse gas emission or storage. They modeled water management scenarios for each segment of the area using WBalMo model system. They divided the area into hydrological response units (HRU) using three soil types: peat, sand, and loam. A monthly groundwater level was determined in each HRU using four water management options/scenarios. From the groundwater levels, greenhouse gas emission probability was determined (greenhouse gas emission is a function of water availability in the soil). The results were used to determine the greenhouse gas emission probabilities. Greenhouse gas emission probability was used to calculate the expected annual average global warming potential (GWP) [24]. The following were the water management scenarios tested for emission reduction potentials through model simulation.

(i) Stabilization scenario, less ambitious (Stab A): this involved reducing land use intensity on fen and grassland and raising water level by 20 (cm) during winter and 40 cm below ground during summer.

(ii) Stabilization, more ambitious (Stab B): it included also low intensity land use on fen soils combined with higher summer water level targets and a longer duration of winter water level targets than Stab A. In addition, summer water targets was raised to 30 (cm) below ground.

(iii) Restoration, less ambitious (Rest A): target water levels for fen dominated subareas (fen area >20% of the subarea) were raised to surface level throughout the year.

(iv) Restoration, highly ambitious (Rest B): target water levels for fen dominated subareas (fen area >50% of the subarea) were raised to surface level throughout the year. All affected arable land and grassland converted to natural wetland habitats.

2.2.6. Estimation of the Economic Value of Sedimentation Regulation: Maintenance of the River Channel Depth. Monetary value for this ecosystem service was calculated from the money spent by the Hamburg city each for sediment handling. Floodplain sediment retention was estimated through simulation in the HEC-RAS model.

3. Results

3.1. Economic Value of Aesthetic Information and Existence Value of Biodiversity. Economic value of aesthetic information and existence value of biodiversity were transferred from the Elbe to the Kreetsand's shallow water area, under two assumptions: (a) the same population from three catchments would be willing to pay for the Kreetsand's shallow water area creation and (b) stated values are influenced by the size of the area. The total value stated (willingness to pay) pledging was €153 million. The total willingness to pay for Elbe floodplain was divided by the total area of Elbe floodplain, which is 15,000 ha to get willingness to pay per ha. The total willingness to pay for Kreetsand's shallow water area was obtained by multiplying the size of the Kreetsand's shallow water area willingness to pay per ha by a total area (in ha) of the Kreetsand's shallow water area. The economic value for aesthetic information and existence value of biodiversity, estimated in the original study through willingness to pay, was €10200 per ha. Assuming that willingness to pay by the respondents is affected by the size of the area, for the 47 ha of Kreetsand's shallow water area, the total willingness to pay was €479,400 per year.

3.2. Economic Value of the Water Quality Regulation Services (Nutrients Retention). Since the Kreetsand's area will be flooded daily as per HEC-RAS model simulation and the study area is located within the estuary (it receives high nutrient loads), its retention capacity is equal to that of Sandau (450 kg N/ha/year). Therefore, the total nitrogen retention of the Kreetsand's area was obtained by multiplying the size of the area in hectares (47 ha) by the retention capacity per ha per year (450 kg of N/ha/year). Hence 47 ha × 450 kg of N/ha/year = 21150 kg of N/year. Replacement method was used to obtain the economic value of the nutrient retention service for the Kreetsand's area. The cost of removing 1 kg of nitrogen in the water using a man-made wetland in Germany ranges from €5 to €8 (Bräuer, 1993) [21, 22]. This estimate is higher than a value of €3.07 per kg of N estimated by Turpie et al. [26] in South Africa. Among the reasons for the differences in estimates the method used for estimation and differences between socioeconomic backgrounds of the two study areas are included (i.e., German and South African). The economic value of water quality regulation service of the Kreetsand's shallow water area through nutrient retention is €169,200 per year. In other words, this is the social cost the Hamburg Metropolitan community is saving after bringing a 47 ha section of the Elbe River ecosystem to the near natural state.

3.3. Economic Value of Regulation of Extreme Events through Floodwater Storage. For this present study on which this paper is based, the flood mitigation strategy (according to [16]) which fits Kreetsand's shallow water area situation was determined by comparing Kreetsand's shallow water area characteristics with the simulated site characteristics of the original study. The DR I or dike shifting was selected because the Kreetsand's shallow water area and the simulated flood area in the original study involved dike shifting to secure area for flood water, and they are both partly protected by dike. However, the two study areas differ in floodwater storage capacity. The site had a floodwater storage capacity of 738,000,000 m^3 while the Kreetsand's shallow water area has a floodwater storage capacity of 880,000 (m^3). In order to obtain average annual flood risk avoidance of the Kreetsand's shallow water area, the annual flood risk avoidance for the original study was divided by flood water storage capacity (in cubic meters), to obtain annual flood risk avoidance per cubic meter. The annual flood risk avoidance capacity for the Kreetsand's shallow water area was obtained by multiplying the average annual flood risk avoidance per year by the floodwater storage capacity of Kreetsand's shallow water area.

The DR I (dike shifting) mitigation strategy with the total flood storage capacity of 738 million (m^3) had an average annual flood risk avoidance of €18.6 million per year, which was divided by total storage capacity (738 million (m^3)) to obtain annual flood risk avoidance per cubic meter per year which is €0.025 per cubic meter. The estimated value of Kreetsand's area capacity to regulate extreme floods through floodwater storage service, which will be provided by the Kreetsand's shallow water area, was estimated at €22,000 per year.

3.4. Estimation of the Economic Value of Climate Regulation Service through Carbon Sequestration and Burial. Kreetsand's shallow water area condition is similar to that of the "restoration highly ambitious" (Rest B) because the shallow water area (floodplain) will be water logged all year round and the grassland has totally been converted to a wetland. Moreover, the assumption made to allow value transfer was that groundwater level is equal to that of the restoration, more ambitious (Rest B). The results of the original study presented that carbon emission reduction by the highly ambitious restoration scenario (Rest B) ranged between 3.9 and 7.8 t of CO_2e/ha/year [24]. Therefore, this value was transferred to the Kreetsand's shallow water area. Total carbon storage capacity for the Kreetsand's shallow water area was obtained by summation of the above ground and soil carbon storage per ha. The carbon storage per ha was multiplied by the total area of Kreetsand's shallow water in ha to obtain carbon storage capacity for the total area. The carbon storage capacity of Spadenlander Busch/Kreetsand per ha per year, therefore, includes the above ground and below ground carbon storage. The avoided social cost through greenhouse gas emission reduction was obtained by multiplying the price of 1 ton of

CO_2 gas by the total carbon storage capacity for the Kreetsand's shallow water area. The projected price for 1 ton of CO_2 gas by the year 2020 is 12.17 (www.eex.com/de/, 2012). The estimated economic value of the climate regulation service through carbon sequestration and burial of the Kreetsand's shallow water area is €8762 per year.

3.5. Sedimentation Regulation: Maintenance of the River Channel Depth. HEC-RAS model results indicated that 47 ha shallow water area has potential of reduction 20,000 m^3 of sediment after reconnection of the river channel to its floodplain. Since the Hamburg Metropolitan spends €30 million to remove about 4 million m^3 of sediments each year, the shallow water area will help the city save €150,000 (0.15 million) per year.

3.6. Total Economic Value of the Kreetsand's Area. Total economic value of the Kreetsand's shallow water area was obtained through summation of use values and nonuse values estimated in five ecosystem services (Table 3).

3.7. Cost-Benefit Analysis. The total economic value of the ecosystem services provided by the Kreetsand's shallow water per year is €0.83 million/year (Table 3). After 44 years, assuming that the ecosystem services provisioning rate remains constant, the value will sum up to €36.7; thus it will be equal to the implementation costs, which are equal to €36.6 million.

4. Discussions

This study has utilized benefit transfer technique to estimate total economic value of the ecosystem services of the transformed area of Kreetsand. The assumptions were that, before the river renaturalization, there was a small area providing insignificant amount of ecosystem services (tidal forest and tidal reeds). Therefore, its economic value was assumed to be equal to zero. Another assumption was that, before project implementation, Kreetsand's shallow water area was a source of carbon emission to the atmosphere, and there were no authentic values derived from the site by the people. The results indicated that annual return for the project investment in terms of values of ecosystem services was €17,660 ha/year. The results indicated that the total economic value of the Kreetsand's shallow water area ecosystem services in monetary terms was underestimated. Costanza et al. [1] estimated average economic value for world estuaries ecosystem services to be around €18,713 (23,000$) per hectare per year, which is higher than the estimates for the Kreetsand's shallow water area (€17,660 ha/year).

Cost-benefit analysis was conducted based on the two options: estuary renaturalizing option that involves reconnecting of the river channel to its floodplains and mechanical option that involves dredging or sediment trapping. The estimated monetary value of the Kreetsand's shallow water area ecosystem services was compared to the construction investment costs to analyze cost-benefit for the river renaturalization project. The monetary value of the ecosystem services was considered as the return from the shallow water construction project investment, which, in this case, is the cost spent to create shallow water. The initial investment to the project was about €36.5 million. Assuming a constant rate of return, after 44 years, the project will accumulate to €36.5 million, which is equal to the estimated implementation costs. However, the results suggest that implementation of projects of this nature, which improve river ecosystem and reduce sedimentation at the port area (sustainable option), is beneficial over dredging and sediment trapping. The analysis might have inherited errors from the assumptions made and also the monetary value estimation methods adopted (benefit transfer method), but it provides some highlights which can help managers to make decisions on whether to continue with the implementation of similar projects along the Elbe River ecosystem and beyond. Although the primary object of the project implementation was reduction of the sediments at the port area, due to its size, the shallow water area reduces insignificant amount of sediments (approximately 20,000 m^3). However, if the area is expanded to around 9000 ha, it will be able to control 4 million m^3, and probably there will be no need for dredging. A major challenge might be availability of space, considering that the estuary is the heart of the Hamburg Metropolitan. In order to deal with this challenge, a model which increases resistance and increases retention can be designed in order to increase sediments retention within a small area.

5. Conclusion and Recommendation

Conclusion. Ecosystem services flow increases after implementation of the management measure, that is, shallow water area construction. However, a constructed shallow water area of 47 ha reduces only 20,000 m^3 out of 4 million m^3 suggesting for a larger shallow water area to be constructed (9000 ha). River renaturalization is the best option because it increases ecosystem services flow to the Hamburg Metropolitan community, contrary to dredging and sediment trapping which will continue yielding costs associated with ecological disturbance during its implementation. On the other hand, flood plains are disconnected to the river channel as carbon emission sources instead of acting as carbon sinks.

Recommendation. A similar study should be conducted to involve all ecosystem services and goods such as fish and water used for industrial purposes.

Competing Interests

The author declares that she has no competing interests.

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