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Economic Values of Danube Floodplains

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The Danube floodplains are shared by several countries and provide a complex ecosystem with various habitats or biotopes. Three of them have been selected, forests, grasslands and wetlands, which produce services of value to society. Examples of the ecosystem's services are water purification, biodiversity, flood control, wind protection and food supply. In order to make appropriate estimates of these services, ecosystem models are needed to describe how these services are produced and how they are linked to the economies of the countries concerned. Such models are not currently available. Therefore, this study makes rough calculations of values by transferring results obtained in other studies to the Danube floodplains. The services subjected to valuation are provision of input resources, recreation and nutrient purification. The estimated total annual value of the existing Danube floodplains amounts to ECU 374/ha. The total annual value of the entire actual area of Danube floodplains corresponds to ECU 650 million per year. Approximately two-thirds of this value is obtained in Romania. The value of the land as a nutrient sink accounts for about one-half of the total value. It should be noted that the calculations are based on several simplified assumptions and the results must therefore be interpreted with caution.

Keywords: Danube, floodplains, economic values, forest, grassland, wetlands.

1. Introduction

The fact that rivers are such a symbol of endurance and changeless change is what makes their environment a touchstone for the whole issue of our relationship with the natural world (Purseglove, 1989). Floodplains belong to rivers like the breath to the body. For hundreds of years man has sought to control flood levels and erosion to protect settlements and agriculture. Today, we are facing a situation where the floodplains only cover a marginal percentage of their original expanse, and most of them are irretrievably lost by drainage or the construction of hydropower plants and dikes (Dister, 1989). The main causes of man-made changes to the floodplain forests were

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the need for agricultural exploitation, the protection of buildings and agricultural land against floods, and the exploitation of timber for the needs of the population and industry (Vasicek, 1985). Such policies can be justified by economic arguments if their associated benefits are at least equal to the costs.

The calculation of costs includes the estimation of the engineering cost for converting the floodplains and the associated loss in the value of services provided by the floodplains. The first type of cost is relatively easy to calculate. The estimation of the second component, losses in environmental services, requires information on the functioning of the floodplains and valuation in monetary terms, which is far from being trivial for complex ecosystems like floodplains. The purpose of this study is to present a framework for the estimation of functional value of floodplains in monetary terms with the Danube floodplains as a particular example.

The Danube floodplains, like many others, contain a variety of biotopes and represent a unique environment. Throughout history, floodplains have provided local societies with products such as different types of wood, fish, biodiversity and hunting. As a result of efficient turnover of nutrients such as nitrogen and phosphorous, floodplains have also had an important impact on water quality. These kinds of values have often not been included when estimating the costs and benefits of various development projects such as the construction of dams for irrigation of arable land or the provision of electricity. The numerical example of the Danube floodplains includes the valuation of forests, fish, fodder, recreation and nutrient sinks.

The explicit estimation of the values of several services provided by wetlands and floodplains has been carried out in only a few studies (e.g. Thibodou and Ostro, 1982; Farber and Costanza, 1987; Gren, 1995). In most of the wetland valuation studies, one or a few of the functions are included (see Gren and Söderquist, 1994 for a survey). Most of these studies are applied to wetlands and floodplains in the US and Asia. Their value as sources for recreation has been included in several studies of US wetlands. In Asia, wetlands have been valued mostly for their provision of inputs to the production of marketed goods, such as forests and fish.

None of the surveyed studies were applied to such a large and, in many respects, diverse area as the Danube floodplains. This study is therefore specific, not only for the explicit treatment of several environmental services, but also for the large area involved; the Danube floodplains cover 17 377 km^2. The necessary information required for an appropriate valuation in monetary terms is not available for the entire area. Estimates of values in monetary terms are therefore obtained by transferring results from other studies.

2. Ecological functions of the floodplains

A floodplain is defined as a geographical area of a river system which, over geological time, has evolved with the river system. The functioning of the ecosystems of the floodplains is characterised by periodic inundation. This study focuses on three floodplain ecosystems, namely wetlands, grasslands and forests. In most cases, forest habitats are found close to the rivers, and are composed of a variety of tree species, such as willows, poplar, ash, elm and oaks. Together with the wetlands, grasslands and other floodplain biotopes, they form a mosaic linking the rivers. When identifying benefits of the three types of ecosystem, the following key issues should be highlighted (Dister *et al.*, 1990):

- Floodplains help to reduce the effect of floods

- The waters of the floodplains contribute greatly to the self-purification of the Danube
- Large surfaces of inundated floodplains make a remarkable contribution to the quantitative and qualitative regeneration of groundwater
- In case of accidental spills they can serve as a refuge for river-related organisms
- Through their richly structured habitats and refuges, floodplains provide ideal living conditions for a variety of plant and animal species
- Floodplains have enormous merit as recreational areas, offering a unique outdoor experience
- Floodplains may serve as nutrient sinks

The climatic function of floodplain forests is also very important, as they affect the mesoclimate of nearby agricultural lands by increasing evaporation and absorbing heat during periods of drought. In many places, tracts of floodplain forests act as barriers against strong winds blowing through neighbouring valleys, thus preventing drying up and erosion of agricultural land (Vasicek, 1985).

In general, floodplains are rich in biodiversity. Biodiversity may imply several types of values. A certain composition of species guarantees a bank of genetic resources which are scientifically valuable. Genetic resources can also be available for the identification of crops that can be cultivated in the future (Swanson, 1992). Further, an ecosystem which is rich in biodiversity is usually appreciated as a source of recreation.

The wood biomass of the forest floodplains can be used for different purposes, depending on the quality of the trees. Trees such as oaks are used for the production of furniture and trees of lesser quality for the pulp and paper industry, or are used as bioenergy. The forests are habitat for deer that may provide a food resource. They are also regarded as valuable recreational sites, especially in spring, as the first sign of spring appears in the alluvial forest.

The grasslands are used by farmers to feed their cattle. Grass is used for pasture but is also harvested for stored fodder. The hay may also be exported. For example, about 50 years ago, the hay from the Moravian grasslands was exported as fodder for horses in Vienna. A type of orchid found in the grasslands was used as a medical herb for horses. The grasslands also provide food resources for species living in the surrounding forests and wetlands.

We thus conclude that the ecological functions provided by the floodplains are of value to society for water purification, providing resources used in the production of furniture, paper and pulp and energy, wind protection, provision of food resources to humans and other species, recreational opportunities, and biodiversity. It is also important to note that habitats within the floodplain ecosystem are inter-related. For example, the wetlands and forests are the ecosystems for birds and deer which feed on the grasslands. A change in either of these biotopes will have an impact on the population of these species.

3. A framework for estimating values of Danube floodplains

The Danube floodplains, like many other ecosystems, can be regarded as open systems with links to other ecosystems and to human society. They receive inputs from other ecosystems and also from the sun. The outputs or ecological services of the floodplains can be exported to human society and/or to other ecosystems. Synergetic effects take place within the floodplains. One example is that birds and deer, which are found in wetland and forest habitats, feed on the grasslands. The floodplains also export services to other ecosystems; for example, water purification, which is beneficial for downstream stretches of the river and its tributaries, also benefits migrating freshwater species which in turn might be hunted by predatory birds nesting in the forest. The associated impact on river production of, for example, fish, then provides an indirect value of the floodplains.

Thus, if we know the relationships between different habitats and how these are linked to society we can calculate both the direct and indirect value of the ecosystem services. It should be noted that all services are calculated on the basis of their links to society, which can be measured in monetary terms. For example, the value of the grassland for feeding deer is estimated by the value of hunting deer. However, if not estimated properly, there is a risk that some services may be counted twice. In the case of grasslands, which are valuable grazing areas, part of their value is accounted for when estimating the value of hunting deer. To avoid this, the value of fodder is deducted from the hunting value so that only the hunting "value added" is included.

In the following, methods for estimating different types of ecosystem services are briefly reviewed. Calculation of the value of restoring floodplains and the estimation of loss in environmental values from converting floodplains into other land uses are briefly described.

3.1. VALUATON OF ECOSYSTEM SERVICES

In traditional economics, total value has usually been divided into use, option, and non-use values from an anthropocentric point of view (Krutilla, 1967). Use values provided by the floodplain ecosystem can be divided into three categories:

– inputs for production of marketed goods and services
– production as eco-technologies
– consumption goods

Examples of ecosystem services used as inputs in production sectors are forest, fish and fodder. Services used for consumption are hunting and recreation. By eco-technologies, we mean the use of ecosystems as cleaning technologies. The use of wetlands as nitrogen sinks is one eco-technology which has received great attention over the last 10 years (see Section 4.3). Wetlands are also regarded as sinks for pesticides (Rodgers and Dunn, 1992), which affect the living conditions of specially adapted species. The social value of the forests' uptake of carbon dioxide, used as a measure for mitigating the effects on global climate change, have also been calculated (Hultkrantz, 1992).

The value of floodplains as resources for production of marketed goods is calculated as the changes in producer profits and consumers welfare (e.g. Freeman, 1993). If the change in supply of the resource has no impact on the final consumer price of the product, the associated value is calculated as the corresponding change in the cost for producing the output in question. A decrease in the supply of, say, wood will then increase the cost for producing paper or furniture. The value of wood is then the sum of increases in costs for all sectors using the input in question. In order to estimate such a value, information is required on the producer cost functions. If the change in the supply of the ecosystem input is large so that the prices of consumer goods are affected, we must add this effect to the change in producers' profit. When the supply of wood to the paper and pulp industry decreases, the industry may respond by adjusting the supply of outputs. The associated impact on the output price can be high or low depending on the shape of the demand function for paper. An increase in the price of outputs implies a decrease in consumer welfare. Thus, in order to calculate the value of the floodplain services as inputs in production of other goods and services, we need equilibrium models of all the countries involved.

The value of the floodplains as an alternative environmental cleaning technology (eco-technology) is calculated in the same way as the value of inputs. For a given environmental target, the value is estimated as the total savings in costs obtained by introducing the eco-technology where the impacts on producers and consumers are included. Further, we must also calculate the nutrient abatement capacity of the floodplains. This capacity is determined by several factors and differs for different floodplain sites (e.g. Mitsch, 1992).

Use values for consumption can be estimated by so-called indirect or direct methods. For an excellent review of the theoretical foundations of these methods, see Johansson (1987). Indirect methods are used for estimating the change in the expenses of goods that are either complements or substitutes to the environmental goods (e.g. Mäler, 1974, 1992; Freeman, 1993). For example, filters for cleaning the air in homes are a substitute for clean air. A reduction in air pollution will then improve the air quality and reduce the expense of filters. The value of improved air quality is then measured as the decrease in expense of filters. Another example is the outlay for transportation to a certain park or another ecosystem that is appreciated and provides recreational opportunities. The value of the park in question can then be measured by the visitors' transportation costs. They would not pay these costs if they did not assign the park at least the value which cover the costs. This method has been frequently used when estimating recreational values.

Direct methods imply that the demand for environmental change is measured by means of a constructed or hypothetical market (e.g. Mitchell and Carson, 1989). People are asked for their willingness-to-pay or for their required compensation to accept a certain environmental change (Contingent Valuation Method). Another direct approach is to ask for their ranking of certain alternatives (Contingent Ranking Method). This method is, however, much criticised (e.g. NOAA, 1993). One reason is the respondents' high requirements for information on the ecosystem that is subjected to valuation. This is most often not scientifically available for complex ecosystems like floodplains. The direct method is therefore suitable for valuation of specific environmental goods that are familiar to the respondents, such as clean drinking water.

Direct methods are applied when estimating option value and existence value. Option value involves some kind of uncertainty influencing the individual's choice. Existence value can be defined as "...the value some individuals place on the knowledge of the mere existence of gifts of nature, even when they feel certain they will never have or choose an opportuity to experience them in situ." (Krutilla and Fischer, 1975, p 124.)

3.2. BENEFITS AND COSTS FROM RESTORING AND CONVERTING FLOODPLAINS

The above mentioned estimation of ecosystem values usually refers to current values over a certain period of time. However, when there is a change in the area covered by floodplains, there will also be a change in future supply of associated services. This impact on future benefits must also be included when estimating the cost of converting floodplains into other uses or the benefit from restoring floodplains. Current and all future losses in benefits from environmental services of converted floodplains can then simply be calculated by integrating the annual benefits over all time periods. It should be noted that it is assumed that current management reflects a sustainable use of the environmental services. If this is not the case, future values decrease due to a decline in the production of these services.

If part or all of the converted floodplain is restored, future losses correspond to the sum of decreases in income during the period the floodplains are converted until they are restored plus the cost of restoration. However, if irreversible changes occur which, by definition, cannot be restored, the future losses of conversion amount to the discounted sum of corresponding losses in values.

The calculation of the value of restored floodplains is very similar to the estimation of values of natural floodplains. If there is a cost of restoration, this must be deducted from the benefits. The current and future streams of benefit from restored floodplains also depend on the development in the capacity to produce the ecological services (e.g. Kusler and Kentula, 1990; Mitsch, 1992; Hairstone, 1992). The future value is then probably lower than that of a natural floodplain since we would not expect that a restored floodplain immediately achieves the same capacity as a natural floodplain. Further, when the wetland restoration takes place for a certain reason, for example nitrogen abatement, many other services such as recreation may be excluded. It is claimed, however, that when properly designed for nitrogen abatement, the capacity of restored wetlands may exceed the capacity of natural wetlands after a certain time period (Hairstone, 1992).

4. A numerical example of the Danube floodplains

From Section 3, it is obvious that the models and data requirements for an appropriate valuation of the Danube floodplains are very high. Unfortunately, most of this information is not available. Instead, the numerical examples presented in this section are based on results carried out in other studies. The services subjected to valuation are thus determined by the availability of prior studies. To our knowledge, only one study has been accomplished for the Danube floodplain area (Kosz *et al.*, 1992). This study estimates the value of forests, fish and grasslands as inputs for the production of other commodities and the recreational value of the park. These values are therefore transferred to the entire Danube floodplains. The value of the floodplains as nutrient sinks is calculated by means of a Swedish study (Gren, 1993). Unless otherwise stated, all estimates are made for 1991 and all numbers and calculations referred to are found in Gren (1994).

The total area of the Danube floodplains, 17 737 km^2, is shared by several countries. As shown in Table 1, Romania covers approximately 60% of the total area. Current living standards in the riparian countries are quite different, being relatively high in Germany and Austria and low in the other countries. It is well known that individuals' valuation of most services and goods is dependent on their incomes. We would therefore expect that the valuation of the environmental services is higher in Germany and Austria than in the other countries. When transferring the benefits from the Austrian study to the other countries sharing the Danube floodplains, these differences in living standards are accounted for by the use of the PPP (Purchasing Power Parity) index (OECD, 1992). This index includes only OECD countries and it is then assumed that the living standard of all countries except for Germany and Austria is at the same level as Turkey. This implies that the living standard of these countries correspond to half the standard of Austria.

TABLE 1. Area covered by Danube floodplains

Country	Area (ha)
Germany	45 662
Austria	27 500
Slovakia	5 000
Hungary	51 553
Croatia	350 000
Bulgaria	80 000
Romania	1 028 000
Ukraine	150 000
Total	1 737 715

4.1. INPUT RESOURCE

In the cost-benefit analysis of the floodplain in the National Park east of Vienna in Austria, values of three habitats of the floodplain ecosystem, namely forests, grasslands and wetlands, were calculated as inputs for the production of market goods (Kosz *et al.*, 1992). Due to a lack of general or partial equilibrium models, these values were simply calculated at the market prices of forest products, fish, and fodder for animals. The estimated values per hectare of forests, fodder and fish are ECU 124, 51 and 128, respectively.

The total value of the floodplain as an input for production is thus determined by the composition of the floodplain area by its various habitats. The values per hectare are highest for forest habitats and permanent water. Thus, the larger the area of these habitats the higher the floodplain value. In the National Park, the forests, grassland and water areas under study account for about 61%, 13% and 21% respectively. The weighted value per hectare and year then amounts to ECU 110.

However, the composition of a floodplain ecosystem varies in different parts along the river, and also the relative prices in the different countries' economies. There is no investigation of the floodplains in all countries which can be used in this paper. It is therefore simply assumed that the average composition is the same as in the Vienna National Park. When correcting for differences in living standards, the average value of the floodplains as a source of inputs amounts to ECU 61/ha. The value of the Danube floodplains as an input for the production of market goods amounts to approximately ECU 106 million per annum, if the actual floodplain area is taken as 1 737 715 ha.

4.2. RECREATION VALUE

The various ecosystems in the Danube floodplains imply a potential for considerable value of recreation at local or regional levels. As mentioned in Section 2, the forests are highly appreciated in early spring. In the Austrian study, the recreational value of the National Park was calculated by means of indirect methods (Kosz *et al.*, 1992). The recreational value was estimated as the total costs for transport with and without the inclusion of all other expenditures incurred by the visitors, such as food, hotels, etc.

According to Kosz *et al.* (1992), the Vienna National Park currently has 900 000 visitors per annum. The travel costs of these groups amount to ECU 3·7 million or about ECU 319/ha/annum. When all other costs for visiting the park are included, the value increases to ECU 14 million or 1197/ha. The study also contained a calculation of the value of hunting, which was estimated from the prices paid for permits to hunt in the National Park, which amounts to ECU 36/ha. This estimate includes both the recreational value from hunting and the assessed value from meat. According to a Swedish study, the recreational value of hunting exceeded its assessed value of meat (Mattsson, 1990). The estimated value of hunting is therefore treated as a value of recreation in this case. Applying the estimated travel cost as recreation value plus the value of hunting, the total recreation value of the Vienna Park amounts to ECU 360/ha/annum.

It is, however, questionable if this result can be transferred to other floodplains because of the National Park's location in the vicinity of a big city and the special characteristics of the park. A transfer of the estimated values to other floodplain areas would eventually over-estimate the average recreational value of the Danube floodplains. Due to the lack of more appropriate data it is therefore simply assumed that the average recreational value per hectare corresponds to half of the estimated costs for transportation, amounting to ECU 180/ha/annum. When correcting for differences in living standards between countries the weighted recreation value amounts to ECU 109/ha. Given these assumptions, the recreational value of the Danube floodplains amounts to ECU 175 million per annum.

4.3. FLOODPLAINS AS NUTRIENT SINKS

The concentration of nitrate exceeds the recommendation of the WHO (508 mg NO_3/1) in many groundwater basins in the Danube catchment area and several surface waters suffer from eutrophication (Haskoning, 1994). An important cause is the emission of nitrogen and phosphorous. Latest estimated yearly (1991) loads of nitrogen and phosphorous into the Danube hydrological system amounted to approximately 700 ktons of nitrogen and 95 ktons of phosphorous (Haskoning, 1994). The diffuse sources accounted for 60% and 44% respectively. Residues from pesticides are also found in several groundwater reservoirs. The load of pesticides into surface water was about 46 000 tons a year and the contribution from diffuse sources was 52%. Any improvement in the water quality can be achieved be reducing the emissions of pollutants from point and nonpoint sources.

Another option for improving water quality is to make further use of the floodplains as pollutant sinks (Haycock *et al.*, 1993). Given a certain environmental objective, the inclusion of floodplains as a mitigation measure may decrease the requirement of reductions in pollutants from other sectors. The value of floodplains as sinks for nutrients and pesticides can then be estimated as the associated cost savings obtained in other sectors.

The value of the Danube floodplains as sinks for nutrients and pesticides depends on the costs of other possible mitigation measures and on the specification of the environmental objective. In order to calculate the value, one must calculate the costs for all other measures and then compare the two cost minimising solutions, with and without floodplains as a mitigation measure. To our knowledge, there is no study of cost savings of wetlands or floodplains as sinks for pesticides. We therefore consider only the nutrients nitrogen and phosphorous when estimating the value of the Danube floodplains as sinks of pollutants. Since there exists no study estimating costs of various nutrient abatement measures in the Danube floodplains, we use the results from a study of the Stockholm Archipelago (Gren, 1993).

In the study of the Stockholm Archipelago, costs for nitrogen reduction measures involving the agricultural sector and sewage treatment plants were estimated. The drainage basin of the Stockholm Archipelago, the Mälar region, covers an area of about 28 000 km^2. The eastern part of the region, where the city of Stockholm is located, is densely populated, while the western part contains more arable land and some forested areas. The drainage basin contains the Mälar lake (about 2000 km^2), which functions as a nitrogen sink. The total annual load of nitrogen from the Mälar region to the Stockholm Archipelago amounts to 8780 tons. The largest single source of nitrogen is sewage treatment plants which account for about two-thirds of the total load to the Stockholm Archipelago. The share of load from the agricultural sector is one quarter. The minimum cost for reductions in the nitrogen load to the Stockholm Archipelago was calculated including these sectors and also restoration of wetlands as a mitigation measure.

In order to calculate the value of restored wetlands as nitrogen sinks, total minimum costs for two reduction scenarios were estimated. Costs were minimised for a reduction in the load of nitrogen to the Archipelago by 50% with and without wetland restoration as an abatement measure. The total reduction level of 50% was chosen because of a Ministerial declaration in Ronneby, Sweden, where the Baltic countries agreed to reduce the nitrogen load to coastal waters by this amount. The associated minimum annual costs were ECU 25 million and 33 million with and without restored wetlands as nutrient abatement options, respectively. The value of restored wetlands as nitrogen sinks thus amounts to ECU 8 million which corresponds to ECU 3·9/kg nitrogen abatement by wetlands. A nitrogen abatement capacity of 100 kg/ha/annum was assumed.

We would expect a lower value per kilogram of nitrogen abatement for several riparian countries due to two factors:

- the current capacity of the sewage treatment plants is lower
- the costs for other mitigation options is lower because of a lower living standard

On the other hand, the Swedish study did not include the value of the wetlands as sinks for phosphorous. The average cost of reduction in phosphorous runoff from arable land in Sweden varies between ECU 11·2 and 33·6/kg P (Elofsson, 1993). We therefore assumed that the value of the Danube floodplains as sinks of nitrogen and phosphorous amounted to ECU 2·8 and ECU 11·2, respectively.

In Haskoning (1994), the nitrogen and phosphorous retention of three Danube arms in Romania were calculated. According to the results, the nitrogen retention corresponded to 0·144 of the total load of nitrogen and phosphorous retention to 0·082 of the total load of phosphorous. The total load of nitrogen and phosphorous to surface waters in the Danube drainage basin amounted to approximately 700 kton and 95 kton, respectively. Assuming that these loads reached the floodplains, their value as a nitrogen sink amounted to ECU 162/ha/year and as a phosphorous sink to ECU 50/ha/year. The annual value of the Danube floodplains as sinks would then correspond to ECU 212/ha.

The total value of the floodplains as sinks for nitrogen and phosphorous amounted to ECU 369 million. This value decreases if more low cost options are available and if the environmental policy is less ambitious. It should also be noted that the Swedish study did not calculate the dispersion of costs for sectors other than the emission

TABLE 2. Estimated values for different countries, ECU/ha/year

Country	Input resource	Recreation	Nutrient sink	Total value (ECU million)
Germany	110	180	212	23
Austria	110	180	212	14
Slovakia	59	97	212	2
Hungary	59	97	212	19
Croatia	59	97	212	129
Bulgaria	59	97	212	30
Romania	59	97	212	378
Ukraine	59	97	212	55

source. Depending on the type of sector, the total cost, including direct and indirect cost, may be either higher or lower than the estimated direct costs of the different nitrogen abatement measures.

4.4. TOTAL ESTIMATED VALUE

The total value of the floodplains for the services under investigation in this study may be calculated as the sum of the above estimated values, assuming that there is no double counting. Under this assumption, the estimated annual total value amounts to ECU 374 ha. The average value of input resource, recreation, and nutrient retention amount to ECU 61 per ha, 101, and 212, respectively. The estimated values vary for different countries, which is shown in Table 2. The total annual value of the entire area of Danube floodplains alone (without its tributaries in the catchment area) is estimated to ECU 650 million per annum. The value of floodplains as an input resource, a recreation source and a nutrient sink amount to ECU 106 million, 175 million and 369 million, respectively.

However, if part of the floodplain area is converted to other uses, the loss in values is not the current decrease but also all future decreases in streams of benefits. If the estimated value corresponds to sustainable yield of the floodplains, the losses in current and future streams of benefits are the discounted sums of the estimated annual value. There is a large literature on the choice of the discount rate level. An argument for a zero level is that a positive level would discriminate between generations. A positive discount rate is based on the existence of technological development and on a very small but positive probability of the extinction of man.

If we simply assume that the social discount is 5%, the current and future losses in values from the floodplains amount to ECU 7480/ha. This number increases for lower discount rates and decreases for higher discount rates. For example, if the discount rate is 2%, the losses in value from a development correspond to ECU 18700/ha.

The benefits from restoring floodplains correspond to the above estimates if there are no costs for restoration and if the capacity of the restored floodplains is the same as natural floodplains immediately after the restoration. Both these conditions are likely to be violated and we therefore conclude that the decrease in values from the development of floodplains cannot be totally compensated for by future restoration of the same area. Further, benefits are foregone in the meantime between the time of development and the time of restoration. However, if floodplains are designed for a specific purpose, say nitrogen abatement, the capacity of restored floodplains may exceed the nitrogen abatement capacity of natural floodplains (Hairstone, 1992).

5. Summary and discussion

In this study, an attempt has been made to calculate the value of the Danube floodplains. The floodplain ecosystem consists of a mosaic of different types of habitats, three out of these have been chosen: forests, grasslands and permanent water. The approach used to estimate the total value of the floodplains was to identify and estimate the values from the different selected services produced by the chosen floodplain habitats. The floodplain services were divided into three classes:

–inputs in production of market goods; wood, grass for cattle and fish
–eco-technology (sinks for nutrient)
–consumption (recreation including hunting)

When investigating the needs for an appropriate valuation of the floodplains, it was shown that both ecological and economic models are required. The ecological models should describe the production of services by each of the three habitats and their interlinkages. It is also necessary to have a good understanding of how these systems and their production are affected by a change in the area of floodplains. Equilibrium models are needed to calculate how a change in the floodplain area affects different economic sectors of the society. Models are also required for estimating consumer values of market and environmental goods. All this information was not available and the calculation of values in this study is therefore based on results obtained in two other studies: an Austrian study of a National Park close to Vienna and a Swedish study of wetlands as nitrogen sinks.

The results from the Austrian study were transferred to the entire Danube floodplain area when estimating values in input resources and recreation, which gave ECU 61 and 101 ha/annum, respectively. The Swedish estimates of cost effective nutrient reductions were used to estimate the value of the Danube floodplains as nutrient sinks which then amounted to ECU 212 ha/annum. The total annual value of the floodplains calculated as the sum of these values then corresponded to ECU 650 million or ECU 374/ha. When including current and future streams of benefits from the floodplains, the value amounted to ECU 7480/ha when the discount rate was 5%. It should, however, be noted that there are several assumptions underlying these estimates, so they should be interpreted with caution.

According to the preliminary calculations, the value of the floodplains as nutrient sinks may be considerable and account for more than one-half of the total value. The value of floodplains as an eco-technology is high when the availability of low cost measures is low and when the required reduction in the total load of pollutants is high. However, according to a Swedish study of cost-effective nitrogen abatement, restoration of wetlands is the least costly abatement measure. This implies that the value of floodplains as pollutant sinks may be relatively high even for less ambitious environmental policies.

It should be noted that only a partial value of the Danube floodplains was estimated in this study. Several ecosystems services such as flood protection and provision of biodiversity were not included. The calculated value is therefore probably underestimated. On the other hand, we did not account for the fact that the environmental services produced by the floodplain are interlinked. For example, we would expect that the use of floodplains as a nutrient sink has a negative impact on the recreational value. This implies that our value of ECU 374/ha is overestimated. An appropriate calculation of the value of the Danube floodplains, and other ecosystems, thus requires a good understanding of the functioning of the ecosystem.

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