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THE VALUES OF WETLANDS: LANDSCAPES AND INSTITUTIONAL PERSPECTIVES

The value of wetlands: importance of scale and landscape setting

William J. Mitsch [a,]*, James G. Gosselink [b]

[a] *School of Natural Resources, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210-1085, USA*
[b] *Rt. 1, Box 496A, Rock Island, TN 38581, USA*

Abstract

Wetlands have value because their functions have proved to be useful to humans. The unit value for some wetlands also increases with human development (agriculture and urban) because of increased use and/or increased scarcity. Yet, paradoxically, its functions can easily be overwhelmed in areas of heavy human development, thus lessening those values. Thus wetlands appear to work best in the landscape as spatially distributed systems. Also, the value is partially dependent on where they are found in the landscape, e.g., the degree to which a wetland is open to hydrologic and biological fluxes with other systems, including urban and agricultural landscapes. A paradox of assigning values to wetlands and other ecosystems is that it can argue for the replacement of one system with another if a landscape view is not taken. Estimates of percent of landscape for various functions, e.g. water quality or flood control, are presented. It is suggested that a range of 3–7% of temperate-zone watersheds should be in wetlands to provide adequate flood control and water quality values for the landscape. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Wetlands function as part of the landscape with or without the presence of humans. They have value because many of their functions have proved to be useful to humans. We (Mitsch and Gosselink, 1993) summarized this point: ‘The reasons that wetlands are often legally protected have to do with their value to society, not with the abstruse ecological processes that occur in wetlands… Perceived values arise out of the functional ecological processes… but are also determined by human perceptions, the location of a particular wetland, the human population pressures on it, and the extent of the resource.’ In that book (Mitsch and Gosselink, 1993, 2000) we went on to suggest a few general principles that should

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* Corresponding author.

E-mail address: mitsch.1@osu.edu (W.J. Mitsch).

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be remembered when attempting to estimate the value of wetlands.

1.1. Wetlands are multiple-value systems

Wetlands do not just do one thing. They perform many processes simultaneously and therefore they provide a suite of values to humans. Optimizing for one is usually at the expense of another.

1.2. Most valuable 'products' of wetlands are public amenities

While wetlands do provide economic 'payoff' to individuals, mainly through the population values described above, most of the services of wetlands accrue to the public at large. Thus wetland protection is, properly, the domain of a representative government working in concert with private landowners. Compensation for these values has become a controversial topic.

1.3. The relationship between wetland area and marginal value is complex

Traditional economics supports the general concept that the less there is of some commodity, the more valuable it is. This is the general economic law of scarcity. The concept sometimes applies to wetlands. When there are extensive wetlands in a given area (e.g. the Louisiana delta, the Everglades area in Florida) the conversion of wetlands to other uses is often viewed as a social necessity because there are many more available wetlands elsewhere. In areas where almost all natural wetlands have been drained (e.g. Europe, Midwestern USA, etc.), the desire to conserve what few wetlands are left is often very strong. However, the idea of wetland conservation does not always work even in areas where almost all natural wetlands have been drained, and where critical thresholds exist that define the minimum ecologically acceptable amount of wetlands in a given region. If wetlands are too small, functions such as support of certain mammals or storage of floodwater (for mitigation of floods) no longer exist.

1.4. Commercial values are finite, whereas wetlands provide values in perpetuity

Wetland functions and thus values have the potential to last for a very long time. Modern agriculture or industrial/commercial activity are generally unsustainable and resource-depleting (soil loss; use of fossil fuels) so the lifetime of these human-based alternatives is short-lived. Even large public works projects have time spans of 50–100 years. A corollary of this point is that once wetlands are lost through development, the loss of their functions and values is often irreversible.

1.5. Comparison of short-term economic gain from a non-wetland commercial use of a piece of landscape, with long-term wetland values is often not appropriate

The social trap of assigning value to wetlands, in addition to the danger of comparing ecosystems, is that it will always be possible to find a more profitable use for the land if short-term economic analyses are made. For example, wetland value estimates cannot compete very well with the economic return of corn and soybeans in the Midwestern USA so drainage will always be economically favored over wetland conservation if traditional cost-benefit analysis is carried out.

1.6. Values are influenced by cultural bias and economic system

There are good reasons why we wish to protect nature; developed countries, having taken care of the basic needs of their citizens, are particularly involved in protecting ecosystems, including wetlands, for their aesthetic as well as more functional attributes, not all of which translate into direct economic benefit. Other cultures, where the basic needs of food and shelter cannot be taken for granted, have a different view of the economics of wetlands. Many cultures do live in and among wetlands and use them for daily subsistence—the production of food and fiber. Yet they generally leave the normal wetland functions intact. The values that we ascribe to wetlands are not separate from the institutions and culture from which we come.

Ascribing economic value to wetlands has been an exercise frequently practiced in the past 25 years. Starting with the publication of 'The Southern River Swamp—A Multiple-use Environment' (Wharton, 1970) and 'The Value of the Tidal Marsh' (Gosselink et al., 1974), a significant number of papers have discussed attributed values to wetlands for the services that they provide (e.g. Mitsch, 1977; Farber and Costanza, 1987; Costanza et al., 1989; Turner, 1991; Barbier, 1994; Gren et al., 1994; Gren, 1994; Bell, 1997). Costanza et al. (1997) took these types of calculations one step further by estimating the public service functions of all the earth's ecosystems, including wetlands.

This paper considers a number of landscape and scale phenomena that make generalizations about wetland values particularly difficult. These include the following:

1. *The scale principle* — wetland values are different, accrue to different 'stake holders', and probably have different importance depending on the spatial scale on which we base our estimations.
2. *The marginal value paradox* — fewer wetlands do not necessarily imply greater value in situations where human populations have overwhelmed the functions of the last remaining wetlands.

Table 1
General categories of wetland values at three different ecological scales (from Mitsch and Gosselink, 2000)

Ecological scale	Value
Population	Animals harvested for pelts Waterfowl and other birds Fish and shellfish Timber and other vegetation harvest Endangered/threatened species
Ecosystem	Flood mitigation Storm abatement Aquifer recharge Water quality improvement Aesthetics Subsistence use
Biosphere	Nitrogen cycle Sulfur cycle Carbon cycle Phosphorus cycle

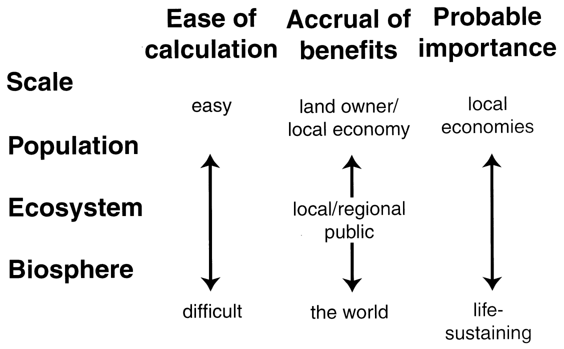

Fig. 1. Ease of calculation, accrual of benefits, and probable importance of values of wetlands at different ecological scales.

3. *The hydrogeomorphic principle* — wetland values depend on the hydrogeomorphic location in which they are found.
4. *The ecosystem substitution paradox* — if different ecosystems are ascribed different values in a given landscape, recommending the substitution of more valuable types for less valuable ones would be a logical extension of economic analysis.

Given these phenomena, the paper then considers the question of how much area of a watershed needs to be wetland for certain watershed-scale ecosystem values to occur.

2. The scale principle

The values of wetlands occur at three levels of ecological hierarchy — population, ecosystem, and biosphere (Table 1). The ease by which we can quantify these values are in the order: population > ecosystem > biosphere, yet the importance of the values may be in the opposite order (Fig. 1).

Ecological populations, generally harvested for food or fiber, are the easiest values to estimate and agree on. The wetland environment provides pelts from muskrats, mink and beaver. Waterfowl can be hunted or simply observed in wetlands. Fish and shellfish use wetlands as spawning and

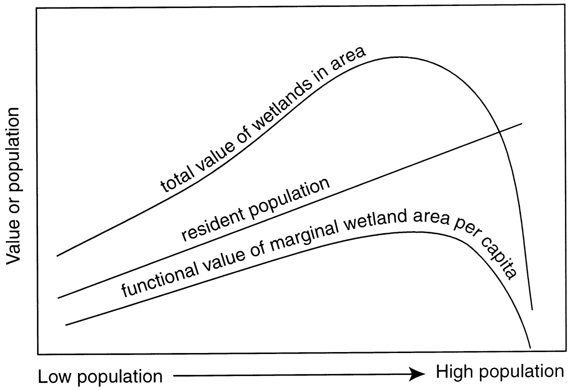

Fig. 2. Overall value of additional wetland area to a given region as a function of human population nearby (based on figure by King, 1997). Overall value is a product of population times functional value per capita. Functional marginal value of additional wetland per capita does initiallly increase as population increases as wetlands are becoming rare. At some point of population density, however, these functions become taxed with pollution, lost corridors, etc. and marginal functional value drops precipitiously for additional population increase.

feeding locations and we, in turn, harvest the result. Timber such as cypress (*Taxodium*) wood and plants such as *Spartina* (salt cord grass), *Juncus* (rush), *Phragmites* (reed), and *Zizania* (wild rice) are harvested for a variety of wetland goods. Although the link between landowner and timber harvest is direct, many wetland-dependent resources (fish, shellfish, ducks, geese) are considered public, not private, resources. The landowner may profit from leasing his land for hunting or fishing, but neither he nor the owner of duck nesting grounds thousands of kilometers away gains directly by harvesting the wetland-dependent species grown on their land. Similarly, in the case of a migratory aquatic resource such as fish or shellfish, a coastal wetland owner has no control over the harvest, nor does he profit from it because of his ownership.

At the ecosystem scale, wetlands provide flood control, drought prevention, and water quality protection. These are referred to as ecosystem services because they are provided most effectively when the abiotic and biotic parts of the ecosystem are synchronized. Wetland plants under hot, eutrophied conditions produce excess carbon, microbial communities proliferate, and anaerobic conditions exist in the sediments. Under these conditions wetlands may remove high concentrations of nitrates through denitrification and hence improve water quality. Even flood control, principally a physical factor that depends on basin morphometry and location in the watershed, can be enhanced or altered by the presence of plants to slow down currents, increase transpiration and shade water. These ecosystem values are real, but their quantification is difficult and the benefits are generally regional and less specific to individual land owners.

At the highest level, the biosphere, we know the least about values, and benefits accrue to the entire world. Wetlands are estimated to cover about 4 to 6% of the world's land (Mitsch and Gosselink, 1993), yet they are > 20% of the landscape in boreal regions where great expanses of peatlands are found (Gorham, 1991). It is likely that one of the most important roles of wetlands may be as linchpins of global climate change by sequestering and releasing a major proportion of fixed carbon in the biosphere (Mitsch and Wu, 1995).

3. The marginal value paradox

The term 'value' such as the value of pollution control or nature appreciation depends on human perceptions. Thus, either in the absence of human population or in situations where population is so dense as to make wetlands nonfunctional, wetland value is low or zero (Fig. 2). As human populations increase from low to high, the marginal per capita value of wetlands first increases for two reasons, both having to do with increased wetland scarcity per capita: first, human population; and second, the conversion of wetlands to other nonwetland uses such as housing and highways. Thus a higher human population implies that there is less land per capita available and therefore, on average, fewer but more precious wetlands (Fig. 2). But the marginal value of wetlands increases with human development (agricultural and urban) only to a point as wetland functions begin to be lost. For example, far ranging mammals are eliminated as wetlands become smaller sized and fragmented; aquatic species are lost as wetlands become isolated from streams. Sediments and pollutants stress other wetlands. When human population increases to the point where the land is an urban-suburban sprawl, a wetland's functions can easily be overwhelmed with too much pollution or even too many bird watchers. In this circumstance wetlands are no longer effective in reducing floods, sequestering pollutants, or even supporting a diverse biota that is of interest to hunters, anglers, or bird watchers. Thus wetland value appears to be maximum when distributed spatially across a landscape that is not dominated either by cities or agriculture, but one that balances nature and human enterprises.

To illustrate this point, a wetland in a natural riparian landscape may transform small quantities of naturally produced stream nitrate-nitrogen to nitrogen gas and support a range of fish, terrestrial animals and birds. In the absence of either an upstream or downstream human population (not likely except in the most remote locations on earth) this wetland is considered of little value to humans. When a town develops upstream of the wetland and large quantities of nutrients and sediments enter the wetland, generated by land clearing, agricultural fertilization and urbanization, its value to humans rapidly increases. As a second town develops downstream, the value increases even further. But eventually, when the riparian system loses its natural functions because it is leveed off from the river or destroyed for any number of legitimate human enterprises, the system can be overwhelmed and no longer perform the services the community has grown to expect.

Table 2
Examples of wetland position in the landscape and related probable values

Position in landscape	Enhanced value
In-stream wetland	Fisheries, organic export
Riparian wetland	Detrital production; sediment retention; wildlife corridor; flood control; nitrogen and phosphorus retention; migratory song-birds
Isolated basin	Groundwater recharge; flood control; waterfowl; amphibians
Coastal (fringe) wetland	Fisheries; offshore productivity; waterfowl; storm buffer

4. The hydrogeomorphic principle

The value of wetlands depends on both their hydrogeomorphic position in the landscape and the positions of human settlements, near and far, who find value in these ecosystems. Their hydrogeomorphic position means the degree to which a wetland is open to hydrologic and biological fluxes with other systems, including urban and agricultural landscapes. As stated by us (Mitsch and Gosselink, 1993): 'Regional wetlands are integral parts of larger landscapes—drainage basins, estuaries. Their function and their values to people in these landscapes depend on both their extent and their location. Thus, the value to man of a forested wetland varies. If it lies along a river it probably has a greater functional role in stream water quality and downstream flooding than if it is isolated from the stream. If situated at the headwaters of a stream, a wetland would function in ways different from those of a wetland located near the stream's mouth. The fauna it supports depend on the size of the wetland relative to the home range of the animal. Thus to some extent each wetland is ecologically unique. This complicates the measurement of its 'value'.'

4.1. Geomorphic position

In a geomorphic sense, wetlands can be classified as in-stream systems, riparian systems, isolated basins, and coastal (fringe) systems (Table 2). The different types of wetlands can provide different values. In-stream wetlands process large amounts of water and inflows approximately equal outflows. But high productivity of these systems translates to enhanced aquatic food chains and export of detrital material. This location is particularly vulnerable during flooding and might be unpredictable in its ultimate stability. It has the advantage of potentially 'treating' a significant portion of the water that passes that point in the stream. A riparian wetland fed primarily by

Table 3
Estimated unit values of ecosystems (from Costanza et al., 1997)

Ecosystem	Unit value \$ ha^{-1} yr^{-1}
Estuaries	22 832
Wetlands	14 785
Lakes/rivers	8498
Forest	969
Grasslands	232

a flooding stream allows flood events of a river to deposit sediments and chemicals on a seasonal basis in the wetland. The wetland captures flooding water and sediments and slowly releases the water back to the river after the flood passes. Riparian systems provide corridors for animal movement along the river, and also a zone of transition between uplands and aquatic systems in the transverse direction (Mitsch and Gosselink, 2000). Coastal or fringe systems, as generally found along coastlines, are important to productivity in the off-shore waters.

4.2. Upstream versus downstream

The relative flood control advantages of several small wetlands in the upper reaches of a watershed (but not in the streams themselves) as opposed to fewer larger wetlands in the lower reaches has been discussed elsewhere. Loucks (1989) argued that to maintain the pulse control function of wetlands a greater number in the upper reaches of a watershed is preferable to fewer larger wetlands in the lower reaches. A modelling effort on flood control by Ogawa and Male (1986) suggested the opposite: the usefulness of wetlands in decreasing flooding increases with the distance the wetland is downstream.

4.3. Steep versus flat terrain

Wetlands are a phenomenon of naturally flat terrain. However, wetlands frequently develop in steeper terrain as groundwater discharge points. As steep slopes are susceptible to high erosion rates that pollute wetlands with suspended sediments and leached soil chemicals, wetlands in steep terrain are quite susceptible to activities upstream and are less likely to provide some ecosystem functions. However, groundwater-fed steep wetlands adjacent to hilly terrain can provide a valuable and unique habitat in an otherwise upland landscape.

5. The ecosystem substitution paradox

A paradox of assigning values to ecosystems is that, unless we take a landscape view, it can be argued that we should replace a less valuable system, e.g. a grassland, for another more valuable one, e.g. a wetland. Costanza et al. (1997), when estimating the value of the world's ecosystem services, estimated that wetlands are 75% more valuable than lakes and rivers, 15 times more valuable than forests, and 64 times more valuable than grasslands and rangelands (Table 3). A straightforward economic analysis would thus argue for the replacement of forests and prairies with wetlands. While this physical substitution is, of course, not possible in most instances because climatic and hydrologic variables determine what ecosystem occurs in a particular landscape, on a micro-scale it is not only possible to substitute wetlands for grasslands and upland forests, but it is frequently done to meet regulatory requirements of wetland mitigation in the USA. Many question whether the created wetland can achieve the same functional and hence 'economic' value as did the original ecosystem at that site. Some argue that these created ecosystems are doomed to failure (Roberts, 1993; Malakoff, 1998) while others are more optimistic that these systems do indeed provide real measurable value that might even exceed what was at the site previously (Young, 1996).

6. How much of a watershed should be wetland?

A basic question remains: how much of a given watershed should be wetland? This is a particularly good question when considering landscape restoration. Table 4 gives estimates of optimal percent of wetland in landscapes for a few case

Table 4
Estimated area of wetlands required in watersheds for specific values

Value/location	Watershed area, km^2	Percent of watershed recommended as wetland	Reference
Small scale			
General water quality improvement (IL)	378	1–5	Hey et al. (1994)
Phosphorus retention, Great Lakes basin (MI)	208	15	Wang and Mitsch (1998)
Nitrogen control			
Southeastern Sweden	882	5	Arheimer and Wittgren (1994)
Large basins			
Flood control, Upper Mississippi Basin	1.9×10^6	7[a]	Hey and Philippi (1995)
Nitrate-nitrogen retention, Mississippi River Basin	3.0×10^6	3.4–8.8[b]	Mitsch et al. (1999)

[a] Includes 4% of present area as wetlands and an additional 3% restored.

[b] Includes both wetland and riparian zone restoration.

studies. Using the results from the 10 ha of experimental wetlands at the Des Plaines River Wetland Demonstration Project, Hey et al. (1994) suggested that 1–5% of a watershed would be necessary to accomplish the water quality function on a landscape scale that these small wetlands were performing. This estimate was based on the wetland's ability to remove nutrients. In a related calculation, Hey and Philippi (1995) suggested that the restoration of approximately 13 million acres (5.3 million ha) in the Upper Mississippi and Missouri Basins would provide enough floodwater storage ($\approx$ 1 m deep) to accommodate the excess river flow from the disastrous flood in Midwestern USA in 1993 (Table 5). If that 5.3 million hectares were added to the existing 7.7 million hectares in the region, an estimated 7% of the watershed would be sufficient to deal with even extreme event floods on a large scale. To put these numbers in perspective, it was estimated that 9–11% of the landscape was in wetland-type environments prior to European settlement (Hey and Philippi, 1995).

A number of studies have addressed the restoration of wetlands on a large scale to minimize the impacts of agricultural and urban runoff on coastal bodies of water. Hypoxic zones in coastal waters are prevalent around the industrialized world. Two well-studied examples are the hypoxia in the coastal waters of Scandinavia, especially the Baltic Sea; and in the Gulf of Mexico, which is fed by the 3 million km^2 Mississippi River basin. Arheimer and Wittgren (1994) found that about 5% of a watershed in southeastern Sweden is needed to be converted into wetlands to reduce nitrogen transport by 50% to a bay on the Baltic Sea. Mitsch et al. (1999) estimated that 3.4–8.8% of the Mississippi River Basin would have to be converted to wetland and riparian forest to reduce nitrogen loads to the Gulf of Mexico by 20–40%. The percentages

Table 5
Wetland flood storage potential in Upper Mississippi and Missouri River Basins, USA (from Hey and Philippi, 1995)

	Water surface% area (million ha)	% of watershed
Original wetland area estimates		
Hydric soils	17	8.9
Wetland (1780)	18	9.8
Beaver ponds (1600)	21	11
Wetlands		
Existing (1980)	7.7	4
Recommended restoration	5.3	3
Total	13	7

would be lower if wetlands alone were used, and higher if riparian forests alone were used, as wetlands are generally more efficient per unit area in nutrient removal.

7. Conclusions

Several landscape-scale considerations should be taken into account when ascribing value to wetlands. All things being equal, a wetland in a region with moderate but not excessive urban development will have the greatest value because an adequate human population is present to benefit from those values, but the population is not so large as to overwhelm the wetland functions. In a hydrogeomorphic setting, flow-through and riparian wetlands have a better chance of having high values than isolated basin wetlands, although caution has to be taken with this generalization. Finally, in answer to the question of how much of a watershed should be wetland, several examples in Midwestern USA and Scandinavia suggest that an optimum amount of wetlands in a landscape might be around 3–7% (average $\sim 5\%$) in temperate-zone watersheds to optimize the landscape for their ecosystem values, e.g. flood control and water quality enhancement. In all cases, one must consider whether the values of wetlands are based on biological populations living next to and within the wetlands, the wetland ecosystem itself, or the entire biosphere of which wetlands are a small part.

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