1

Introduction

1.1 Problems, policy and management of wetlands

It is now widely recognised that wetlands provide many important goods and services to human societies. Examples include drinking water, flood mitigation, water quality control, fish products and recreational and residential opportunities. The non-use values that society attributes to wetland species and ecosystems can also be significant (Turner *et al.*, 1998a). Wetland ecosystems are, however, under stress from human activities, in particular changes in land use with concomitant habitat loss and fragmentation, resource extraction, drainage and reclamation, and pollution. Not surprisingly, wetlands are currently receiving considerable attention in environmental science and policy.

Wetlands all over the world are threatened, in spite of various international agreements and national policies to protect them. There are a number of fundamental reasons for this (see also Turner *et al.*, 2000). Market failures exist because of the public good aspects of many wetlands and consequent lack of property rights for certain wetland goods and services. In addition, economic activities such as agriculture, industry and water abstraction trigger externalities for other stakeholders. These stakeholders include direct, indirect and even non-users of wetland goods and services. Next, there is a failure of information and a lack of understanding of the multitude of values associated with wetlands as a result of the complexity and 'invisibility' of spatial relationships between groundwater, surface water and wetland vegetation. A final reason is the frequent failure of policy intervention. There is a notable lack of consistency among policies in different areas, such as economics, agriculture, environment, nature protection and physical planning.

A spatial matching among hydro-ecological processes, economic processes and physical planning is needed to reduce the stress on wetlands and to facilitate the return of their goods and services. Integrated wetland research combining the social and the natural sciences can support such a spatial matching and also helps to solve problems of information and inconsistency among various government policies. This book presents an introduction to such research. The sciences most concerned with the study of wetlands are earth sciences (in particular hydrology), biology (in particular ecology) and social sciences (in particular economics). This book focuses on these core disciplines as well as on integration frameworks and modelling approaches. It also offers a detailed account of an empirical integrated study conducted for a region of the Netherlands. This will illustrate both the potential and the problems of the proposed integrated research.

The issue of 'wetlands', most particularly the restoration of wetland ecosystems, is currently topical in the Netherlands, a nation born of the battle to win land from the water. The Dutch strategy towards its wetlands has historically focused on building dykes and developing systems of ditches, canals and pumps to drain the land. Unfortunately, the mismatch between land and water levels is likely to be aggravated by climate change, which is expected to cause a rise in sea level as well as increased precipitation with more frequent and higher floods in winter (Können, 1999). Meanwhile, drainage leads to land subsidence, particularly in areas with peat soils. Drainage exposes the peat component of soils to the atmosphere and triggers its mineralisation. In some areas, soil levels are subsiding by as much as 1 cm per year. Continuation of drainage and constructing higher dykes could very well contain the effects of climate change, but only at a significant cost. This cost includes not only the cost of raising the dykes and greater effort to drain the land but also the consequences of a flood – not if, but when it occurs – and the disaster it will inevitably trigger (Helmer *et al.*, 1996).

There are various social and economic aspects in the debate on water management in the Netherlands. One of the aims of land drainage is to facilitate agricultural activities. This sector is undergoing change as the result of a number of factors. These include reduced European Community (EC) subsidy, growing environmental restrictions and diseases such as bovine spongiform encephalitis (BSE) and the foot-and-mouth epidemic in 2001. Changes in the agricultural sector could make it possible to break the vicious circle of drainage and subsidence, thus opening up land to alternative uses or agricultural practices. One obvious alternative land use is nature, a scarce resource in the densely populated Netherlands. A flexible approach to water, focusing more on adaptation than on defence, is now being considered. Higher water levels in selected areas would seem to be inevitable, and this could offer a number of opportunities for the restoration of wetlands and their goods and services.

Despite recognising these opportunities, changing land use is not easy. The limited experience to date has shown that local stakeholders, particularly farmers, resist change. There are competing goals for nature and a lack of institutional power in the water management community. The limited sense of urgency in some sections of Dutch society constrains land use change, which already needs a long lead-time for its implementation.

Behind these constraints lie questions regarding the gains and losses associated with wetland restoration, the answers to which depend on our knowledge of how wetland systems function. This book is about wetlands, and particularly about raising water levels to restore wetland ecosystems. However, mostly it is about methods and how to analyse and to trade off possible gains and losses from wetland management.

1.2 What are wetlands?

The English language is filled with many descriptive terms for what is becoming generally known as wetlands. Most of us will have heard of terms such as swamp, marsh, mire or bog. These terms often have local meanings that differ across regions and differ again from scientific and legal definitions. A glossary of selected wetland terms is presented in Table 1.1. The term wetlands is, in part, an attempt to encompass all this diversity in a single term. A precise definition poses challenges (Maltby *et al.*, 1996), with more than 50 definitions of wetlands in the literature (Dugan, 1990). Two definitions are offered here to give an idea of why this term remains difficult to specify.

The first is in Article 1 of the Ramsar Convention on Wetlands (held in Ramsar, Iran: Anon., 1997): '. . . areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed six metres'. In short, wetlands are wet land. Land use and land cover have no bearing on the designation of wetlands under this definition. Indeed, wetland conservation and management are not well served by such a broad definition. For example, in these terms, the western part of the Netherlands would be considered wetlands, with Amsterdam and Rotterdam indistinguishable from remnant wetland ecosystems, agriculture, drained polders and lakes.

Natural scientists, and ecologists in particular, would argue that the Ramsar definition of wetlands ignores the physical and ecological processes triggered by water saturation. An alternative definition addresses these aspects (National Wetland Working Group, 1988): '. . . any land saturated with water long enough

Table 1.1 *Glossary of selected terms relating to wetlands*

Bog. A peat-accumulating wetland that has no significant inflows or outflows and supports acidophilic mosses, particularly *Sphagnum* spp.

Carr. A peat-accumulating wetland that receives some drainage from surrounding mineral soil and usually supports shrubs or woods rather than herbaceous vegetation (see fen)

Fen. A peat-accumulating wetland that receives some drainage from surrounding mineral soil and usually supports marsh-like vegetation (see carr)

Marsh. A frequently or continually inundated wetland characterised by emergent herbaceous vegetation adapted to saturated soil conditions. In European terminology, a marsh has a mineral soil substrate and does not accumulate peat

Mire. Synonymous with any peat-accumulating wetland (European definition)

Moor. Synonymous with any peatland (European definition). A ‘highmoor’ is a raised bog; a ‘lowmoor’ is a peatland in a basin or depression that is not elevated above its perimeter

Peat. Incompletely decomposed remains of plant and animal life that has accumulated under extremely wet conditions

Peatland. A generic term for any wetland that accumulates peat

Reedswamp. Marsh dominated by *Phragmites* spp. (common reed)

Swamp. Wetland dominated by trees or shrubs (US definition). In Europe, a forested fen or reedgrass-dominated wetland is often called a swamp (see reedswamp).

Vernal pool. Shallow, intermittently flooded wet meadow, generally dry for most of the summer and autumn

Wet meadow. Grassland with waterlogged soil near the surface but without standing water for most of the year

Sources: Mitsch and Gosselink (1993); Pons (1992).

to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to a wet environment’.

This second definition provides a useful starting point for the analysis of wetland management. The need for management often stems from economic use, which may trigger or depend on hydrological changes within a wetland. These changes will, in turn, affect the processes emphasised by this definition, even to the extent of precluding them.

For example, wetland ecosystems in the western part of the Netherlands have been subject to agricultural use for some 1000 years. Agricultural use is dependent on the manipulation of water levels, achieved by an extensive system of ditches, canals, dykes and pumps. Is it useful, therefore, to exclude this agricultural land from consideration as wetland because past and present water management is directly aimed toward constraining saturation? While the current management climate is seriously considering, and experimenting with, higher water tables and the return of agricultural land to nature, water levels in the Netherlands will continue to be managed as sea levels rise and the land subsides.

A wide range of different wetland classifications is in use around the world. However, no single classification could be expected to meet all the needs of different wetland inventories (Anon., 2001). The Ramsar classification of wetland types is presented for illustrative purposes in Table 1.2. The primary factors that it uses to distinguish between different types of wetland are the influence of marine waters, which force the presence of salt-tolerant species or halophytes, and the influence of humans.

The wetland ecosystems of the Vecht floodplain, which is the focus of the case study presented in Chapters 5 to 10, may be designated as non-forested and forested peatlands and correspond to categories U and Xp in Table 1.2. Peatlands differ from other wetlands in their combination of interrelated hydrological, chemical and biotic factors, which results in a decrease in decomposition relative to plant production. Organic matter, or peat, accumulates. Peatlands represent an important terrestrial carbon sink, with an estimated 450 Pg, or 25% of the world's terrestrial carbon, currently stored in them (Gorham, 1991; Woodwell *et al.*, 1998). Non-forested peatlands are also known as fens and bogs; forested peatlands are also called carrs. Fens and carrs are typically mesotrophic or eutrophic, with their hydrology strongly influenced by groundwater. Bogs receive their water only from precipitation and are characterised by low water flows. Bogs are acidic ecosystems dominated by oligotrophic species such as *Sphagnum* mosses.

1.3 Wetlands in the Netherlands

The basis for wetland development in the Netherlands was laid some 10 000 years ago. Mean annual average temperatures less than 11 °C, and regular rainfall of about 760 mm per year, meant that there was a surplus of precipitation over evaporation that exceeded 150 mm. This led to waterlogging. These macroclimatic conditions triggered the development of fens, bogs and carrs. Waterlogging was further facilitated by a geomorphology comprising a flat, deltaic landscape of river terraces and glacial moraines. The development of these ecosystems peaked around 3000 years ago; since when they have declined drastically. This decline has been particularly severe over the last 1000 years and can be attributed to the influence of humans (Pons, 1992). This influence began with catchment clearance and its impact on river discharges more than

Table 1.2 *Ramsar classification system for wetland type*

Marine/coastal	
A	Permanent shallow marine waters
B	Marine subtidal aquatic beds
C	Coral reefs
D	Rocky marine shores
E	Sand, shingle or pebble shores
F	Estuarine waters
G	Intertidal mud, sand or salt flats
H	Intertidal marshes
I	Intertidal forested wetlands
J	Coastal brackish/saline lagoons
K	Coastal freshwater lagoons
Zk(a)	Karst and other subterranean hydrological systems
Inland wetlands	
L	Permanent inland deltas
M	Permanent rivers/streams/creeks
N	Seasonal/intermittent/irregular rivers/streams/creeks
O	Permanent freshwater lakes
P	Seasonal/intermittent freshwater lakes
Q	Permanent saline/brackish/alkaline lakes
R	Seasonal/intermittent saline/brackish/alkaline lakes and flats
Sp	Permanent saline/brackish/alkaline marshes/pools
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools
Tp	Permanent freshwater marshes/pools
Ts	Seasonal/intermittent freshwater marshes/pools
U	Non-forested peatlands
Va	Alpine wetlands
Vt	Tundra wetlands
W	Shrub-dominated wetlands
Xf	Freshwater, tree-dominated wetlands
Xp	Forested peatlands
Y	Freshwater springs, oases
Zg	Geothermal wetlands
Zk	Subterranean karst and cave hydrological systems
Man-made wetlands	
1	Aquaculture ponds
2	Ponds
3	Irrigated land
4	Seasonally flooded agricultural land
5	Salt exploitation sites
6	Water storage areas
7	Excavations
8	Wastewater treatment areas
9	Canals and drainage channels, ditches
Zk(c)	Karst and other subterranean hydrological systems

Source: Anon. (1997).

2000 years ago, but has been greatest with human settlement over the last 1000 years. The main human use of wetlands has been for agricultural purposes. Conversion of wetlands to agriculture initially required their drainage and subsequently the continuous management of water levels.

Today, the remnant wetlands of the Netherlands are made up of a number of different types. The western half of the Netherlands is under the direct influence of the sea and rivers. Water tables are close to the surface and the sedimentation of clay is prominent. Hundreds of years ago, these areas were frequently under water as a result of flooding from the sea and from rivers. Today, they are constrained by dykes and drainage systems. Between the coastline with its dunes and the eastern parts of the country there was once a large plain where wet conditions supported the development of marshes, fens, carrs and bogs.

The soil in the eastern half of the Netherlands consists of sandy layers. Runoff is brought to the main rivers via streams and small rivers, another type of wetland. Small lakes can result if water is still or stagnating. These conditions promote the development of bogs, where the permanently high water tables with nutrient-poor and acid conditions stimulate the growth of mosses (*Sphagnum* spp.). Historically, bogs covered large areas of the Netherlands. Only remnants now remain.

The Rhine, Meuse and Scheldt rivers are fine examples of riverine wetlands. Longitudinal and transverse gradients differentiate these wetlands. Where the rivers enter the Netherlands, the riverbeds are sandy, but the clay component increases towards the coast as stream velocity decreases. Close to the sea, there is a change from fresh to tidal-fresh to brackish wetlands. Transverse gradients – from the centre of the permanent river into the floodplain adjacent to the river – are linked to river discharges. River discharges peak at the end of the winter when the floodplain, bounded by winter dykes, is submerged. Conversely, the smaller discharges in summer mean that these riparian areas dry out. This creates wetlands that are periodically flooded and which are rich in nutrients and minerals; that is, they are very fertile. Apart from the present rivers, remnants of former river courses (e.g. oxbow lakes), as well as ponds that formed when rivers broke through their dykes (in Dutch: *wielen*), may also be found.

The Rhine, Meuse and Scheldt form a delta where they meet the shallow North Sea, resulting in an estuary with a wide range of fresh to brackish or saline conditions. To the north of the delta lies a long coastline characterised by sandy beaches backed by dunes. Further north and east lies the Wadden Sea, with its islands, sandbanks and channels. Tidal marshes, sandy banks, islands, gullies and deeper streams create a patchwork of wetland systems in both the delta and the Wadden Sea.

Water management has always been of paramount importance to the Netherlands. With the increased value being placed on nature in recent decades combined with concerns for the future with possibly serious impacts of climate change, the management of its remaining wetlands and wetland restoration are being given much attention and priority on research as well as policy agendas.

1.4 Wetland research

Existing wetland research can be classified in many ways, including by a focus on:

- hydrological versus ecological processes;
- natural versus social science issues;
- social versus economic problems;
- monodisciplinary versus integrated approaches;
- temperate versus tropical wetlands;
- coastal versus freshwater wetlands;
- single versus multiple use;
- providing services to 'nature' (links in ecological networks, habitat for migratory birds) versus services to humans; and
- nature conservation versus ecosystem engineering.

Wetlands are not just valuable and sensitive ecosystems but are also very dynamic and adaptive systems. This means that, even under pristine conditions, wetlands can significantly change over time in terms of type of vegetation, density of vegetation, type of fauna and open versus closed area. Various frameworks have been designed to address the integrated analysis of ecosystems in general and wetlands in particular (e.g. Berkes and Folke, 1998; Turner, 1988; see also Section 2.4). Terms used in this context are 'attributes' or 'characteristics' (biological, chemical and physical), 'structure' (tangible 'elements' such as plants, animals, soil, air and water) and 'processes' (transformation of matter or energy) (see Turner *et al.*, 2000). Processes include the interactions between wetland hydrology, geomorphology, soil and vegetation (Maltby *et al.*, 1996). Given stable interactions, the provision of goods and services (or functions) can be maintained. Economists have added the notion of values to these goods and services. These are usually classified into use and non-use or passive-use values (Barbier, 1994; Gren *et al.*, 1994). Services, goods and values can be attributed to a range of stakeholders (Turner *et al.*, 2000):

- direct extensive users, who harvest wetland goods in a sustainable way;
- direct exploiters, who extract wetland physical resources in ways that possibly damage the wetlands;

- agricultural producers, who affect water levels in wetlands by the drainage of agricultural land and cause the emission of nutrients to water and soils;
- water abstractors, who affect wetland water tables by using scarce water for drinking water and agricultural irrigation;
- communities close to wetlands, who drain wetlands for land use opportunities (housing, industry, infrastructure);
- indirect users, who enjoy wetland services, such as storm abatement, flood mitigation and water purification; and
- nature conservation groups.

In setting up wetland research, a number of considerations are relevant. One has to decide about the appropriate terminology and typology of wetlands, their functions and their values. This is important to avoid confusion between interpretations of terms and concepts by researchers with different disciplinary backgrounds. Terms that have at times generated confusion are, among others, ‘threshold’, ‘stability’, ‘equilibrium’, ‘function’, ‘scale’ and ‘value’ (e.g. Muradian, 2001). In addition, one has to demarcate the range and scale of effects to be analysed and assess possible associated thresholds. This is important to keep the analysis both relevant and feasible. This enables one to adopt a local, regional, national or supranational approach (Gibson *et al.*, 2000). Next, one has to assess the causes and mechanisms of wetland change, degradation and loss. Distinguishing between proximate and ultimate causes, and between immediate causes and historical context, can be helpful in decomposing the complexity of relationships. The choice of research methods, notably integrated modelling, spatial modelling, ecological and economic valuation, performance indicators, and evaluation procedures, is an important subsequent step. It defines the framework of integration of natural and social science concepts and data. This is useful in getting to grips with the complexity and ‘invisibility’ of spatial relationships between groundwater, surface water, wetland vegetation and economic values (Turner *et al.*, 2000). Finally, aggregation of economic and environmental indicators can be done through a multicriteria evaluation procedure. It has the advantage that no fixed aggregation function is employed to arrive at a single index, but instead the indicator and spatial aggregation – including choice of weights – can be explicitly based on expressed preferences by private or public decision makers.

The design of instruments for local wetlands management and regional, national and international wetland policy is useful both for the development of scenarios to be studied with the resulting integrated model and for the practical implementation of study findings. The latter should take into account market and policy failures, such as wrong incentives (e.g. subsidies), lack of monitoring and control, lack of property rights or simply lack of policies in general (Turner and Jones, 1991). The inclusion of stakeholder interests, behaviour, conflicts and cooperation, as well as distributional issues in the analysis, can increase the social feasibility of any policy recommendations of the research. Distributional issues can be related to social groups as well as spatial zones or regimes. Ultimately, policy outcomes depend on the selected goals of the analysis for wetland policy and management: efficiency, welfare (including the issue of welfare to whom), costs of public regulation, sustainability, nature conservation, multiple use, etc.

These various considerations explain the wide variety of wetland studies in the literature. From a social science perspective, monetary valuation studies (Barbier *et al.*, 1997; and Section 2.3) and integrated modelling (see Ch. 3) are the two most important categories. In some cases, these approaches can serve as substitutes, while in other cases they can be complementary (e.g. Costanza *et al.*, 1989; and Section 3.4). As a third category, one can consider transferability of information and results of one empirical study to another context, region or country. It requires the choice of transparent methods and indicators. Specific methods such as value transfer, which is based upon statistical (meta-) analysis of past studies, allow for cost-effective generation of present studies (see Section 2.3.2).

As explained in Section 1.1, hydrology, ecology and economics are most crucial to the study of wetlands. It was already noted that a spatial matching among physical planning, hydro-ecological processes and economic processes is able to reduce the stress on wetlands. It can be supported by integrated modelling and scenario analysis and evaluation. This combination can provide information about possible future wetland development, subsequent economic (e.g. efficiency) and environmental (e.g. biodiversity) conditions, including their spatial dimensions, as well as suggest priorities within this development. In the 1990s, there have been many wetland studies focusing on ecological questions, hydrological issues or economic monetary valuation (e.g. Brouwer and Spaninks, 1999; Gopal *et al.*, 2000; Mitsch and Gosselink, 1993; van Dijk and Kwaad, 1998), but very few really integrated studies (see Turner *et al.*, 2000). Chapters 2 and 3 will provide more detail on wetland research as well as on integrated modelling and analysis.

1.5 Scope and objectives

This book discusses the integration of information, concepts and models from the social and natural sciences in the context of wetland research. This