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CHAPTER ONE

Peatland restoration and ecosystem services: an introduction

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1.1 Setting the scene

In September 1997, the airports of Singapore and Kuala Lumpur shut down for several days. Fires from drained peatlands in Indonesia, over 1000 km away, were emitting vast clouds of smoke causing haze and poor visibility across large parts of South East Asia in the extremely dry El Niño year. Schools and businesses had to close, and people were admitted to hospitals with acute breathing problems. The amount of CO_2 emitted from these fires was equivalent to 13–40% of annual global emissions from fossil fuels (Page *et al.* 2002). Economic losses due to the 1997–1998 wildfires exceeded several billion US dollars (ADB 1999).

In the hot August of 2010, people in Moscow were advised to stay at home, keep their windows closed and wear gauze masks to avoid inhaling ash particles when walking on the streets. Again the cause was fires, this time raging across nearly 2000 km^2 of degraded peatlands in Russia. Carbon

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monoxide levels in the capital reached six times the maximum acceptable levels and death rates doubled due to heat and smog (Barriopedro *et al.* 2011).

These fires, resulting from peatland drainage and degradation that made them vulnerable to fire, dramatically highlight the huge liability that peatlands pose once degraded, especially in a changing climate. In sharp contrast, there is now wide recognition of the importance to human well-being of ecosystem services delivered by the peatland environment, not least the wildlife that underpins those ecosystem services. While peatlands cover not even 3% of the world's surface, they hold two times more carbon than the entire global forest biomass pool, and represent more than 30% of the total global soil carbon store (see Chapter 4). As long-term carbon sinks, they provide crucial global climate-regulating services. If not safeguarded, however, the release of this carbon could further exacerbate climate change.

The range of peatland ecosystem services is far greater than simply their role in the carbon cycle. Pivotal peatland ecosystem services further include, for example, the provision of high-quality drinking water derived from peatland catchments. Peatlands also play a role in flood-water regulation, especially in lowland or coastal settings. Importantly, peatlands constitute old and rich palaeoecological knowledge archives, as their waterlogged soils preserve both natural (pollen, macrofossils) and anthropogenic (artefacts) organic materials, and the study of peat cores has greatly contributed to our understanding of global climate change. Peatlands are often open and wild landscapes and provide a sense of place and socio-cultural connection for communities as well as important breathing spaces for millions of people to enjoy. Globally, peatlands represent some of the largest unfragmented (semi-) natural habitats, hosting nationally and internationally important biodiversity. Peatlands therefore form a globally and nationally important natural capital.

1.2 Why publish this volume now?

The current extent and rate of peatland degradation and the resulting loss of ecosystem services severely threaten the livelihoods of people and erode options to mitigate and adapt to a changing climate. With 2 Gt CO_2 emissions per year, degraded peatlands are already responsible for nearly one-quarter of the carbon emissions from the land-use sector. Globally, emissions from drained peatland have increased more than 25% since 1990, especially because of peatland drainage in the tropics (Joosten 2009c).

The scale and economic value of peatland ecosystem services are significant, yet often undervalued or taken for granted. Despite these manifest services, across the world peatlands have been and continue to be seen as worthless wastelands. Activities to 'develop' peatlands for exploitation of

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resources, such as livestock grazing, timber collection, plantations for pulp wood, oil palm and other crops, and peat extraction for fuel and horticultural growing media, led to widespread drainage. In Europe, the majority of peatlands have already been subject to degradation over the last century, with enhanced drainage for agricultural intensification and forestry from the 1940s onwards. In many countries, such as UK and Germany, less than 20% of peatlands remain in near-natural condition (Joosten and Clarke 2002; Bain *et al.* 2011; JNCC 2011; Bonn *et al.* 2015). Peatlands are modified or destroyed through extraction or conversion to other land uses, or are subject to severe erosion due to external pressures on the vegetation. Many peatland species are showing marked population declines. In many European countries, most socio-economic drivers for exploitation have ceased, while there are still pressures from the horticultural use of peat, peat-fired power stations and emerging energy-related developments, such as biofuel maize production, hydro-electricity or windfarm developments on peatlands. Nevertheless, 80% of the CO_2 emissions from agricultural land use in Europe are derived from peatlands (Joosten, Tapio-Biström and Tol 2012).

In other parts of the world, peatland destruction has only started in recent decades. Especially in the tropics, loss of peatlands is now taking place at an unprecedented scale. In South East Asia, peat swamps are rapidly deforested to make room for short-lived oil palm and pulp wood plantations. Estimates of loss exceed 60% of the original resource and the extent of pristine peat swamp forest in western Indonesia (Kalimantan and Sumatra) has already become negligible (Dommain, Couwenberg and Joosten 2011; see also Chapter 14). The degradation is leading to increased incidences of severe fires, flooding and threats affecting health and livelihoods of communities. In the boreal region in North America, Canada is experiencing rapid peatland destruction for tar sand extraction with extensive loss of habitat.

In the majority of cases, exploitation of peatlands for agricultural and forestry produce as well as for fuel (provisioning services, see below) is a major driver of change (Bonn *et al.* 2009) leading to dramatic impacts on the potential of peatlands for ecosystem-based climate mitigation and adaptation, water regulation, biodiversity conservation and ultimately human well-being.

1.3 Policy context

Peatland restoration and sustainable management therefore should be at the heart of high-level national and international strategic decision making to deal with climate change and the way land and water is managed. There is encouraging progress, including the renegotiation of the Kyoto Protocol and other instruments under the United Nations Framework Convention

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on Climate Change (UNFCCC), the Wetland (Ramsar) Convention and the Convention on Biological Diversity (CBD), the European Union (EU) Common Agricultural Policy (CAP) reform, and the implementation of the EU Water Framework Directive (WFD), which all recognise the need to conserve peatlands for their essential ecosystem services and for underpinning biodiversity.

Specifically with regard to climate change mitigation and adaptation, peatlands are of major current interest because of their importance as carbon stocks and the potential for climate change-induced changes to the carbon stored in peat. Interest in restoration of degraded peatlands is likely to increase in order to help meet stringent targets to offset greenhouse gas (GHG) emissions established by recent intergovernmental negotiations. Global climate change discussions under the Kyoto Protocol have agreed that carbon savings from rewetting drained peatlands may be used to meet emissions reduction targets, alongside those from other land use and land-use change and forestry (LULUCF) activities such as new forest planting (see Chapter 15). This is an important decision in giving global legitimacy to peatland restoration. Likewise, the 2010 Nagoya protocol (COP 10 Decision X/33) specifically recommends the restoration of degraded ecosystems and ecosystem functions in particular with regard to peatlands as major carbon stores.

Restoration of peatlands is a low hanging fruit, and among the most cost-effective options for mitigating climate change.

Achim Steiner, UN Under-Secretary General and Executive
Director UN Environment Programme (UNEP, 2007)

Internationally, land management for carbon has been recognised by the Food and Agricultural Organization of the United Nations (FAO), who launched a Global Organic Soils and Peatlands Climate Change Mitigation Initiative in May 2012 to share knowledge and promote sustainable land use and restoration of organic soils, including peatlands, to increase the mitigation potential through agriculture (Joosten, Tapio-Biström and Tol 2012).

Nationally, there are a number of high-profile government initiatives for new peatland policy and practice, as well as recent country-wide peatland assessments such as the IUCN UK Commission of Inquiry on Peatlands (Bain *et al.* 2011), the BOGLAND Sustainable Management of Peatlands in Ireland report (Renou-Wilson *et al.* 2011), the peatland habitat assessment in Finland (Kaakinen *et al.* 2008) and others.

Peatland restoration can therefore play a pivotal role in fulfilling international and national obligations and safeguarding important ecosystems services for society.

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1.4 Practice context

In practice, there are encouraging signs that these policy signals from the international community are translating into practical action to conserve and restore peatlands with increasing expertise to restore damaged peatlands across the world. The relevance of peatlands and peatland restoration is reflected progressively in the quantity of public and private expenditure on restoration. In Europe, major peatland restoration efforts are on the way in many countries supported by agri-environment schemes and the EU LIFE programme. Over 210 major EU LIFE projects funded by the European Commission have included peatland restoration, and, for example, over 120 peatland restoration projects have been conducted in the UK alone (www.peatlands.org.uk). After the 2010 fires, extensive peatland restoration was launched in the Moscow area of the Russian Federation. In North America, a lot of wetland restoration takes place, e.g. the multi-million-dollar restoration project of the US Everglades. Wetland restoration initiatives are generally less specifically focused on peatland restoration, except for some re-vegetation after peat extraction (see Chapter 10). In the tropics, the Association of South East Asian Nations (ASEAN) has endorsed an ASEAN Peatland Management Strategy providing the framework to guide interventions for managing the peatlands in the region (Chapter 19). Progressively, private carbon markets for peatland restoration are also being explored (Bonn *et al.* 2014; Von Unger *et al.* 2015).

Across the globe, there is increasing experience in peatland restoration for biodiversity and ecosystem services. Embracing an ecosystem service framework, new avenues are being trialled as exemplified by case studies throughout this volume through:

- planning and decision making;
- participatory conservation approaches involving stakeholders across sectors through innovative public–private partnerships;
- dealing with novel techniques and technical difficulties in peatland restoration and monitoring success;
- wise use and sustainable management of peatlands (Joosten and Clarke 2002; Quinty and Rochefort 2003).

1.5 Scientific context

The scientific study of peatlands has expanded rapidly (Charman 2002; Wieder and Vitt 2006; Rydin and Jeglum 2013), in particular in response to the increasing recognition of the role of peatland systems in global carbon

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cycling (e.g. Baird *et al.* 2009; Page, Rieley and Banks 2011a). Scientific research on restoration of peatlands (Box 1.1) has typically been less extensive. Despite some excellent work on approaches to restoration (Wheeler *et al.* 1995; Brooks and Stoneman 1997a; Quinty and Rochefort 2003; Schumann and Joosten 2008a) and on restoration impacts (e.g. Kivimäki, Yli-petäys and Tuittila 2008; Carroll *et al.* 2011), this field has had a lower profile than global peatland science.

Recently, however, the balance between peatland science engaged with the Earth System Science agenda and applied work on degraded and restored systems has become more even. In part, this is a function of the emerging appreciation of peatland carbon storage and the growing apprehension that peatland degradation may constitute a significant feedback to global climate change. Together with the increasing focus of environmental policies on land use and land-use change, this concern has stimulated the study of peatland restoration and the impacts of restoration on ecosystem function and services.

Peatlands have to be addressed in a fundamentally interdisciplinary way drawing on, among others, the disciplines of ecology, geomorphology, hydrology, soil chemistry and socio-economics. One of the hindrances to restoring peatlands is that the various disciplines have not fully joined up to provide a cohesive evidence base for peatland action. For example, where and how will restoration bring the greatest GHG benefit? How do vegetation, peat type and spatial distribution of drainage blocking influence runoff attenuation and how do these affect downstream floods? How can we learn from the environmental archive preserved in peat about recovery and timing of land-use and climate change, and apply this knowledge for future management? Which political tools and economic incentives are needed to align restoration and sustainable livelihoods in these economically marginal areas? This volume, written by scientists from across the disciplines, practitioners and policy makers will attempt to address some of these key questions.

Box 1.1

What are peatlands?

Peatlands are areas with a naturally accumulated layer of peat at the surface. As permanently waterlogged ecosystems, peatlands have no closed nutrient cycle. Semi-decomposed plant material, mainly of mosses, reed and sedges but – especially in the tropics – also wood, is laid down as peat, thereby removing carbon from the atmosphere. These conditions explain the unique capacity

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of peatlands for long-term carbon sequestration and storage, including the preservation of palaeo-environmental and archaeological organic remains.

Peatland ecosystems are highly diverse and vary from extensive boreal paludified forests and tropical peat swamps to upland blanket bogs and small spring mires (see Chapters 2 and 3). Overall, peatlands constitute around 20 wetland categories in the Ramsar Convention Classification System, over 40 habitat types of the EU Habitats Directive and over 60 types of Endangered Natural Habitats of the Bern Convention (Joosten 2008). Peatland distribution is mainly determined by climate and topography, with a high prevalence of peatlands in the subarctic, boreal and temperate-oceanic regions and in the tropics, particularly in South East Asia (Lappalainen 1996).

The emphasis of this book is on temperate and boreal peatlands across the Northern Hemisphere, as the science on peatland functioning and ecosystem service provision is best developed for these. However, tropical peatlands are covered in a special chapter on restoration of South East Asian peat swamps and in the policy chapters, and where chapters refer to a range of case studies across the world.

1.6 Peatland restoration

Ecological restoration can be defined as ‘the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed’ (SER 2004). Restoration activities range from removal of pressures through land-use change to active habitat management, such as rewetting through channel blocking, altering livestock numbers, removing non-native trees or re-vegetating bare peat. The overall goal is to re-wet the degraded peatland to the extent that peat accumulation and associated biodiversity and ecosystem services (see Box 1.2) can redevelop.

Recently there have been calls to define the goals of restoration more clearly, as different people value environmental features in different ways, to take into account both ecological and socio-economic considerations (Choi 2007; Temperton 2007), and to consider synergies and trade-offs between various goals. Typically, provisioning services, such as food and timber supply are more easily valued than regulating or cultural services, such as water purification and aesthetic values of landscapes, or biodiversity. While the focus on provisioning services has often led to the degradation of peatland ecosystems, the recognition of the full range of services that peatlands provide to people can serve as strong motivation for restoration. Often actions focused on restoring biodiversity also support increased provision of ecosystem services (Rey Benayas *et al.* 2009).

In practice, restoration action rarely focuses on restoring a single ecosystem service, but aims for the restoration of a range of functions with

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different perspectives of success over different timescales. It is equally important to appraise the possible trajectories and potential limits of restoration realistically. In some cases a return to the 'original' ecosystem (i.e. similar in structure and function to the former one) may not be possible and novel ecosystems (Hobbs, Higgs and Harris 2009) with a different set of species, but a similar set of services, may emerge.

Importantly, the terms 'ecosystems' and 'restoration' have sometimes been seen to exclude humans. The ecosystem approach, in contrast, aims to align biodiversity conservation with integrated land management and sustainable use (Shepherd 2004). In this volume, we follow the latter approach and look at socio-ecological systems. Human pressures are drivers for degradation, while people are also integral to solutions for restoring biodiversity and ecosystem services to promote human well-being through responsible use of peatland resources and services.

Box 1.2

Peatland biodiversity and ecosystem services

Ecosystem services are functions of ecosystems that provide benefits to human well-being (Mace, Norris and Fitter 2012), such as the carbon sequestration of functioning peatlands leading to climate regulation as a benefit to society. The ecosystem service framework provides a useful tool for increasing the awareness of the relevance of nature to a wide range of sectors (Daily 1997; Potschin and Haines-Young 2011). By appraising ecosystem services we can outline the costs and benefits of different management and policy options, highlighting the best strategies for enhancing sustainable development and human well-being (TEEB 2010). In this way, biodiversity and ecosystem services can be mainstreamed into other sector policies and provide additional arguments for further efforts of conservation and restoration. A failure to account for the full economic values of ecosystems and biodiversity has been a significant factor in their continuing loss and degradation (MA 2005; SCBD 2014). The ecosystem service concept can therefore serve as a tool to enhance our understanding of our dependence on peatland services, to identify (hidden) costs and consequences of peatland management to people. It thereby promotes more informed decision making on trade-offs between immediate human needs and maintaining the capacity of the biosphere to provide goods and services in the long term (Foley *et al.* 2005).

While the term ecosystem services began to be used in the late 1970s as a communication tool to enhance understanding of the interdependence of society and nature (Gómez-Baggethun *et al.* 2010), it received global attention with the publication of the Millennium Ecosystem Assessment (MA 2005). This global assessment has been followed by high-profile international and national

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assessments, such as the study on The Economics of Ecosystems and Biodiversity (TEEB 2010) or the UK National Ecosystem Assessment (UKNEA 2011) that highlighted – including for peatlands (van der Wal *et al.* 2011) – the dangerous loss of ecosystems and the costs of doing nothing to conserve this natural capital. These studies exposed a clear need for evidence-based knowledge of ecosystem services and of the impact of land use and land-use-change drivers, which has led to the establishment of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net).

A variety of classifications may be needed to suit specific needs of stakeholders and ecosystem assessments (Fisher, Turner and Morling 2009), while for comparison of assessments and for environmental accounting across borders it is useful to employ a unified classification system. Therefore, a Common International Standard for Ecosystem Services (CICES; Potschin and Haines-Young 2011; European Commission 2014) has been developed on behalf of the European Environment Agency, the United Nations Statistical Division and the World Bank, as part of the revision of the System of Environmental-Economic Accounting (SEEA). We use the broad framework suggested to identify peatland ecosystem services (see Table 1.1). The CICES framework builds broadly on the approach of the Millennium Assessment (MA 2005), by using three main categories and dividing these into further subcategories. Supporting ecosystem services, such as nutrient cycling, are classed as intermediate to these final services.

Provisioning services relate to the provision of material and energy by ecosystems, such as wild foods, crops or timber as well as drinking water or biomass-based energy sources.

Regulating services relate to the maintenance of environmental conditions, such as climate regulation through carbon storage and sequestration, regulation of water quality through filtration of pollutants or hazard regulation to protect from disasters.

Cultural services relate to the provision of non-material benefits, such as opportunities for recreation, spiritual and aesthetic experiences as well as the gaining of information and knowledge, e.g. through learning from the peat palaeo-environmental archive about past cultures and climate.

Biodiversity, i.e. the variety of life from genes to species and ecosystems, is linked in various aspects to ecosystem services (Mace, Norris and Fitter 2012). It supports the ecosystem processes that provide ecosystem services, e.g. through nutrient cycling or photosynthesis, often summarised as supporting services. Some specific aspects of biodiversity may directly link to provisioning services, such as crop or livestock species for nutrition, or some species may be linked to cultural services through enjoyment of e.g. wildlife watching. However, not all elements of biodiversity, such as the wide variety of genetic diversity or the breadth of species and ecosystem types, can be directly linked to a current ecosystem service, and to many people biodiversity also has an existence value irrespective of services. For these elements a precautionary approach of biodiversity protection will keep options open for providing future ecosystem services, especially in the light of changing environmental conditions, societal demands or individual preferences.

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Table 1.1 *Peatland ecosystem goods and services, following the proposed Common International Standard for Ecosystem Services (CICES, Haines-Young and Potschin 2012; European Commission 2014).*

Section	Final Services		Examples of benefits provided by peatlands	
	Division	Group	Possibly compatible with peat accumulation	Peat* consuming
Provisioning services	Nutrition	Cultivated crops	*Shorea* species for oil, sago	Carrots, potatoes, oil palm, etc. on drained peatland
		Wild plants and their outputs	Berries, mushrooms, sago, honey	
			Flavours: mire plants for flavouring drinks (e.g. *Menyanthes*, *Acorus*, *Hierochloe*)	Peat flavouring of whisky
		Reared animals and their outputs	Reindeer, red deer	High-density populations damage peat though trampling and grazing
			Low-intensity grazing livestock products (mainly meat)	High-intensity grazing livestock products, most dairy farming
		Wild animals and their outputs	Game, wildfowl, fish	Associated game management may cause drainage and peat damage
		Water for drinking purposes	Drinking water	High abstraction may lead to drainage
	Materials	Construction materials	Plant materials from undrained peatland for roofing, insulation, building, thatching, wattling and veneer	Peat as foundation, building and insulation material, wood from drained peatland
		Paper pulp, cellulose	From undrained peatland: *Phragmites*, *Phalaris*, *Papyrus*	From drained peatland: *Pinus*, *Acacia*
		Absorption, filter and bedding materials	Straw litter	Peat moss litter in stables, peat filters, peat as oil spill absorbent
		Growing media/ potting soils*	Peatmoss biomass, composts	Peat
		Fertiliser/soil improvement	Composts from fen plant material	Peat ashes as K fertiliser, fen peat as N fertiliser, peat as soil improver

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