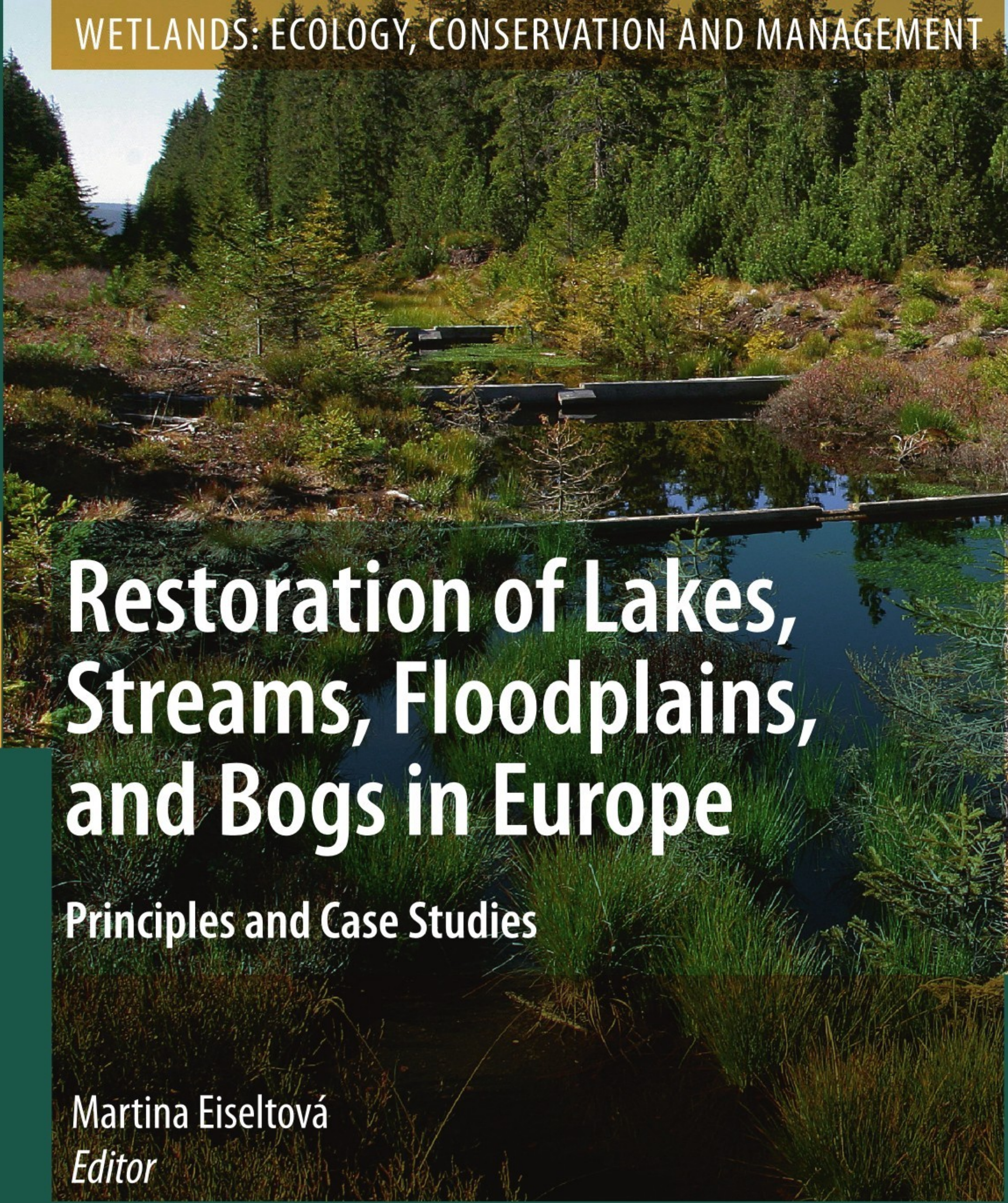
WETLANDS: ECOLOGY, CONSERVATION AND MANAGEMENT



Restoration of Lakes, Streams, Floodplains, and Bogs in Europe

Principles and Case Studies

Martina Eiseltová
Editor

Springer

Restoration of Lakes, Streams, Floodplains, and Bogs in Europe

Wetlands: Ecology, Conservation and Management

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Aims & Scope:

The recognition that wetlands provide many values for people and are important foci for conservation worldwide has led to an increasing amount of research and management activity. This has resulted in an increased demand for high quality publications that outline both the value of wetlands and the many management steps necessary to ensure that they are maintained and even restored. Recent research and management activities in support of conservation and sustainable development provide a strong basis for the book series. The series presents current analyses of the many problems afflicting wetlands as well as assessments of their conservation status. Current research is described by leading academics and scientists from the biological and social sciences. Leading practitioners and managers provide analyses based on their vast experience.

The series provides an avenue for describing and explaining the functioning and processes that support the many wonderful and valuable wetland habitats, such as swamps, lagoons and marshes, and their species, such as waterbirds, plants and fish, as well as the most recent research directions. Proposals cover current research, conservation and management issues from around the world and provide the reader with new and relevant perspectives on wetland issues.

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Preface

In my life I have had many wonderful opportunities to meet and work with top scientists – people who have devoted their professional life to research in wetland ecology and applied their scientific knowledge to practical wetland conservation, including wetland restoration. For me this has revealed a new world – a passion for understanding the play-rules of nature, for discovering its wisdom and divining the relationships between the members of an ecological community and their multiple feedback loops. It also instilled in me that wetland restoration has to be based on deep understanding of natural processes, understanding the position and functioning of wetlands in a wider context of the landscape and that one can learn from both successful and less successful restoration activities, if they are well described.

A big challenge with us today, and which indeed sometimes appears almost insurmountable, is to overcome the sectoral divide in water resource management. Due to our unsustainable management of water resources, water (and especially clean water) is becoming a scarce commodity and hence there arises a conflict: between environmentalists, who require sufficient water supply for the biota and nature, and human society's overall consumption of water resources – whether it be the use of water for electricity production, agriculture irrigation, industry use or supply of drinking water. The conflict is ever growing. Current scientific and administrative structures in society tend to keep these sectors apart – and in a state of competition rather than cooperation.

When it comes to land/water links the situation is also highly complicated as the land and water management is again in separate hands and the understanding of land and water resource management interactions not widely adopted. My recent job in the agricultural field has revealed to me that the prevailing response of agricultural research to the threat of climate change and increasingly widespread droughts has been plant breeding or even gene manipulation in order to develop crops that will maintain high yields with reduced consumption of water. But lower water uptake means lower evapotranspiration and hence reduced humidity and hotter and drier local climates, and thus only aggravating the overall problem of water shortages. Another outcome of climate change is also the greater fluctuations in dry and wet periods, i.e. droughts interchanging with floods, as observed in recent years. All this, one may conclude, calls for the re-creation and return of more wetlands and water-saturated soils into our landscapes.

The irreplaceable role of wetlands in landscape functioning has become ever much clearer, while the destruction and damage of wetland ecosystems has become ever more widespread. Increasingly, wetland ecologists began to turn their attention to wetland restoration, and in the past 40 years an extensive experience in wetland restoration has been gained. This is a field that is rapidly developing, bringing more experience and allowing fine tuning to some early restoration approaches. As is stressed in this book, wetland restoration is not usually a simple or straightforward task. It often requires a sound scientific understanding of general wetland ecology and – as wetlands are not isolated systems – also an understanding of their position and functional role in the broader context of the landscape. Generally speaking, wetland restoration requires cooperation between different sectors – and a communication between a diverse number of disciplines such as: hydrology, geology, wetland ecology, botany, and zoology; and more recently, socio-economy can also help by offering new aspects of wetland functions and their benefits to humans. An understanding of wetland development is essential too, as wetlands are not static ecosystems but are gradually evolving. For wetland ecosystem restoration to be successful in the long-term – to be sustainable – space and time factors must also be taken into account. All this means that wetland restoration cannot follow a standard prescription, step-by-step; however, the experience that has been gained in other restoration projects, and presented in the form of case studies, can provide a valuable source of information and guidance. Valuable lessons can be learned from well-described restoration projects; at least, those that were completed and their achievements evaluated with the help of a well-designed monitoring programme.

The origin of this book lies in an integrated wetland management training programme launched by Wetlands International in 1992. From 1992 to 1998, I had the pleasure to coordinate a series of international training courses addressing different aspects of restoration of various wetland types – shallow lakes and fishponds, streams and their floodplains, and peatbogs. Later on, further training courses were organised under the auspices of the Ramsar Convention (an international treaty on wetlands) through the Czech National Ramsar Committee, and also since 1997 in cooperation with the UNESCO Man and the Biosphere Programme. The focus of these courses was to bring course participants up-to-date with not only the current available theoretical knowledge and advances in wetland ecology required for successful wetland restoration but also with the experience gained from practical wetland restoration projects implemented in the field. Furthermore, the aim was to allow the exchange of expertise between scientists and wetland managers, between ecologists and engineers, and above all to bridge the gap between the various sectors involved in land and water resource management. Out of this experience was born this book.

Bridging the gap between ecologists and engineers is the big challenge in natural resource management: to start an equal dialogue between ecologists trying to understand natural processes and who accept a certain level of unpredictability when dealing with ecosystem management, and engineers who, used to the power of calculations, expect predictable and precise outcomes from their interventions within natural systems. The recent disastrous floods experienced almost every-where around Europe have hopefully taught us an important lesson – nature cannot be so easily ‘ordered about’ and ‘precise’ calculations can be wrong. Thus the dialogue that tries to close our gaps in knowledge between the experts of different fields should be based on observations of natural processes, searches for variability and diversity in solutions, an acceptance of a certain level of flexibility and adaptability to changing conditions, and the ever-fluctuating network of nature itself – the web of life. The information, knowledge and experience collected in this book should provide a valuable overview of the key causes and processes that lead up to ecological degradation and give suggestions for possible solutions.

The first chapter of this book is about water – the water cycle and its role in the landscape. Its main message is the need for sustainable and coordinated land and water use. Arguments that there is an urgent need to return more water and natural vegetation to the landscape as well as criteria for the assessment of landscape sustainability are presented. The chapters that follow – on wetland evolution, development of aquatic vegetation, the trophic interactions and the food chain in water bodies – give an insight into the functioning of shallow water bodies and wetlands and their development within the landscape influenced by human interventions. The following chapters (Chapters 6–17) are then focused on individual restoration projects implemented in the field, presenting a spectrum of restoration activities addressing different types of wetland ecosystems – shallow lakes, streams and their floodplains, and bogs – that may serve as guidelines and provide useful information and inspiration for future projects. My hope is that the book will become a valuable resource material to experts from many different fields and help unite their views on the irreplaceable role of water and wetlands in the landscape.

Prague, December 2009 Martina Eiseltová

In memory of Jaroslav Hrbáček, an outstanding Czech limnologist who sadly passed away a few days before this book was published.

Acknowledgments

The concepts presented in this book are the results of many years of experience with wetland restoration in different parts of temperate Europe – an experience gained by many outstanding wetland ecologists and excellent teachers. My first acknowledgment must therefore go to the authors of individual chapters who kindly agreed to contribute to this book. Many of them served as lecturers on training courses in wetland management and restoration that have been organised since 1992 – first by the International Waterfowl and Wetlands Research Bureau/Wetlands International from the UK and later by the Wetland Training Centre, located in Třeboň, Czech Republic. During these training courses a nice team of people got together and created the core contributors to the present publication. Many others joined later. Amongst these was Sake van der Schaaf, to whom I am indebted for help with reviewing the manuscripts dealing with the restoration of mires.

The final strength to complete this book I gained during a recent study tour to vast areas of wetlands in Belarus, Lithuania and Poland – just seeing the sheer dimension of these still well-preserved wetlands gave me a glimpse of how the landscape elsewhere in the temperate zone might have looked like in the past – before human intervention with the hydrological cycle, drainage and reclamation of land for agriculture and urban settlements took its toll. Walking bare-footed through the mats of *Sphagnum* was such a refreshing experience – one which should be offered to as many people as possible. There is no doubt that the immense spirit of wetlands would turn people on to protecting these invaluable habitats once they have experienced their power. My thanks here go to the nature itself and people who strive to protect her.

This book is a result of almost 20 years devoted to the promotion of scientific knowledge in wetland management, restoration and conservation through international training courses. During that time I met many wonderful people both in the role of course lecturers and course participants. The exchange of knowledge, experience and ideas was always enriching and without these encounters this book would not come into the world.

I would like to dedicate this book to three outstanding wetland scientists I have met and worked with throughout the years, Sven Björk from Sweden, Willy Ripl from Germany and Jan Květ from the Czech Republic. They have always been extremely kind and offered much needed support. Furthermore, I am very grateful to Max Finlayson and Jan Pokorný for giving me valuable advice and guidance in the early years of my professional life.

My final thanks are reserved for my family, my husband Steve Ridgill who kindly joined me in the effort of preparing this book for publication and has painstakingly read all the contributions and improved the English of many, and our children Philip and Nathalie who gave us the space and time to work.

Prague, December 2009 Martina Eiseltová

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Chapter 1
Criteria for Sustainable Restoration of the Landscape

Wilhelm Ripl and Martina Eiseltová

Abstract Water, matter and energy are the three basic requirements for any ecosystem to thrive. Studies of natural processes in a central European virgin forest have brought us an understanding of how nature closes the cycles of water and matter and evenly dissipates the incoming solar energy that runs processes. As a result, climatic events, such as precipitation, runoff and temperature, are evenly distributed in time and irreversible matter losses remain low. By minimising matter losses nature prolongs its life-span, i.e. enhances its sustainability. When compared to agricultural landscapes, we can reveal the main mistakes of human interference with natural processes that lead to the opening of cycles, bringing about high irreversible matter losses. Investigations have shown that areal matter losses measured in agricultural catchments in Germany are some 50–100 times higher than those from unmanaged land in a virgin forest. As matter losses are mainly connected to water run off, every disturbance to the hydrological regime has a vital impact on landscape sustainability. Extensive drainage, including that of wetlands and transformation of rivers into drainage channels, has such a negative impact. This chapter brings forward the argument that for greater landscape sustainability it is essential to restore and return more wetlands and natural vegetation cover to the landscape and restore natural dynamics to rivers and streams. Criteria suitable to assess the sustainability of land use are proposed as being: solar energy dissipation and water and matter recycling within the smallest delimited area, such as a catchment or sub-catchment.

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Keywords Dissolved matter losses • Energy dissipation • Sustainable land management • Virgin forest • Water and matter cycles

1.1 Introduction

Humans have greatly modified the natural forms of most large rivers – constraining them into straightened river channels and cutting them off from their floodplains by impoundments. The lowering of the groundwater table and the drainage of a large number of wetlands have led to a serious impoverishment of the landscape with respect to surface water bodies and water-saturated soils. Whilst the restoration of individual wetland sites has been attempted for more than 40 years now, there are hardly any restored wetland sites that would be sustainable in the long term without further intervention – because of the negative impacts caused by unsustainable land use within their catchments.

Years of experience in wetland restoration have shown that wetlands function in the context of the wider landscape and that for any lake, river or wetland restoration to be sustainable in the long term, restoration must start in the catchment. Land use within the catchment must be optimised in such a way that the determining processes acting both on and within the catchment, namely – the dissipation of solar energy, and the recycling of water and matter – are maximised. If this is not the case, then any restorative measures undertaken just within the immediate borders of the wetland itself will be of relative short duration only – for example, a lake treated for increased eutrophication will quickly deteriorate again if the input of nutrients from the catchment – the probable source of the eutrophication in the first place – has not been reduced.

Understanding natural processes is an important pre-requisite to implement sustainable land management and/or restoration of the landscape. Observation of nature and learning from natural communities of plants, animals and microorganisms brings us an understanding how nature utilises its resources in a sustainable way (in nature, what is ‘waste’ for one organism becomes a resource for another, i.e. the processes are coupled together and ‘wastes’ are kept to a minimum). Reuse and recycling are the rules of nature. This knowledge can then help us to design criteria essential for assessing whether our management of nature and the landscape is sustainable or not. It should be stressed that sustainable management of natural resources is our only possible way to sustain life on our planet. In the next few paragraphs we will explore the most important advances of science that have helped us to understand the self-organising process of nature and the sustainable conditions of living systems.

For a long time in history, due to the limitations of classical physics, the way how to achieve sustainable conditions was unclear. With classical thermodynamics, which necessarily considered an approximation to equilibrium conditions, only processes that went from structured to unstructured conditions were thought to be possible. A breakthrough to the understanding of living systems was offered by

Schrödinger who came up with his 'order from disorder' theory using the help of non-equilibrium thermodynamics. Schrödinger described the self-organisation of living systems, taking energy from outside, i.e. being open systems with regards to energy flow, and using it to produce, within themselves, a more ordered (structured) state (Schrödinger 1944, in Schneider and Kay 1994). It was Schrödinger who recognised that 'living systems operate in a world of energy and material fluxes' far from equilibrium (Schneider and Kay 1994).

Another important contribution to the description of self-organising systems was the theory of 'dissipative structures' by Ilya Prigogine. Prigogine discovered that under dynamic conditions, far from equilibrium, a kind of self-organisation is possible (Prigogine 1980; Prigogine and Stengers 1984). Structuring is enabled by the sorting of material under dynamic conditions – carried out at the interface between two different states, i.e. solid/liquid or gas. For example, sand grains of different sizes on a beach, under the influence of a rolling wave of water, undergo acceleration and then fall under the influence of gravity, and end up sorted on the beach in waves – as ripples in the sand. Similarly, sand dunes are the result of sorting by the wind. Equally, life and living structures are the result of dynamic, structured processes rather than of random ones. This is important to have in mind when addressing landscape sustainability.

Yet another concept important when dealing with sustainability is the concept of the so-called r- and K-strategies introduced by Mac Arthur and Wilson (1969) that shows the importance of material re-cycling – as space becomes a limiting factor then recycling (the coupling of processes) becomes increasingly critical. At the beginning of any ecosystem development – say an ecosystem developing on bare land – the first plants to colonise the place are so-called 'r-strategists', plants with high reproduction rates, fast growth and high productivity. These pioneer plants quickly colonise the open terrain and their populations increase rapidly while they are unrestricted by a shortage of nutrients or lack of space. Such a phase of high productivity is also called a pioneer phase or r-phase where energy dissipative productivity is the aim and organisms are selected accordingly. The rapid expansion phase of the 'r-strategists', however, is soon replaced by their fast disappearance as they are outcompeted by 'K-strategy' organisms. 'K-strategists' are better suited for survival in a crowded or limited environment, though net productivity becomes lower and biomass grows more slowly. 'K-strategy' is characterised by team work: functionally diverse organisms (such as decomposers, consumers and producers) achieve local recycling, and are therefore suited for a sustained development under the conditions of local natural resource limitation.

A similar development to that in nature can also be found in the development of our human societies. Initially, we were surrounded by abundant natural resources – be it fossil fuels, extensive forests, clean water and air, and fertile soils. Accordingly, we have adopted the development mode of 'r-strategists'. This has, however, led to severe limitations and to the overexploitation of natural resources in many parts of the world. It is, therefore, necessary to accept that we are now in a transition period to a new phase. Non-renewable resources are quickly becoming depleted, initially extensive primary forests have been largely destroyed, clean water has become scarce and soil fertility largely reduced. Further survival and development of our societies will require a change from a production-oriented economy to a recycling-oriented communication-and-socialisation-related economy in order to achieve sustainability.

Above we have briefly described the scientific progress that was necessary to gain understanding how nature, through the process of self-organisation, tends towards enhancing sustainability. In the following text we will give a more detailed description of processes that lead to sustainable development of ecosystems and also show how humans interfere with this sustainability by the prevailing current management of land and water. Some general rules for landscape restoration are proposed.

1.2 Self-organising Natural Systems – Studied in a Virgin Forest

Investigations were carried out in a small untouched virgin forest in Austria (Rothwald virgin forest of 3.5 km^2, altitude between 900 and 1,900 m asl, see map – Fig. 1.1) between February 1999 and December 2004. Water flow and the coupled matter flow processes were monitored by automatic devices – temperature probes,

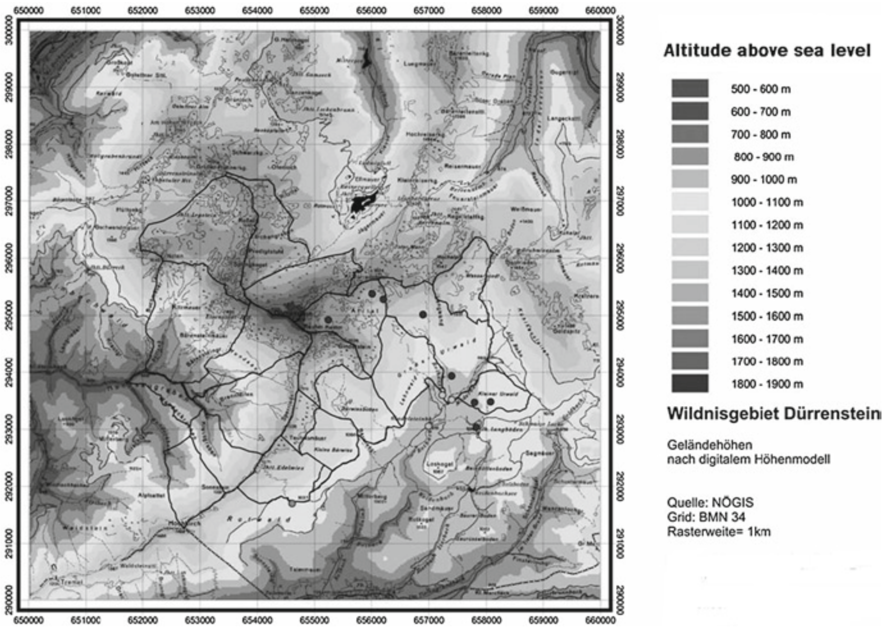

Fig. 1.1 Physical map of Rothwald virgin forest, Austria. The studied area is delineated by black line, black dots show the location of temperature sondes

pressure and water level gauges with high time resolution. The aim was to reveal the most important natural processes in its spatiotemporal distributions leading to sustainable structures.

1.2.1 Water and Matter Cycling in the Virgin Forest

The data obtained in the virgin forest showed very clearly the unique feedback-control character of unmanaged areas. The most amazing property of this site was the very damped and even distribution of climatic events such as precipitation, runoff and temperature in time. The temperature amplitudes between day and night almost never exceeded 8–9°C during the summer (Ripl et al. 2004). Despite the relatively high precipitation in this area (over 1,000 mm $year^{-1}$) the runoff from the virgin forest was very low and restricted mainly to the period of snow melt (February until May), with water very low in ionic content (see below). Since, in the studied area of the virgin forest, there were no periods of overheating or areas that would dry out, the conclusion was that very short water cycles with a frequency of 1 day or less prevail.

In water-saturated conditions of the virgin forest, the amount of dead organic matter and debris is much higher than in managed forests due to the fact that in a virgin forest nothing is removed or harvested from the area, and the decomposition of organic matter is much slower due to the water-saturated conditions. The debris layer is 2–4 times higher in the Rothwald virgin forest than in the neighbouring managed forest (Splechtna K. personal communication, 2000) The water-retaining capacity is so high that water runoff within and from the virgin forest during summer took place only when rain events exceeded more than 35–50 mm a day (Ripl et al. 2004). The water was mostly absorbed in the fibrous debris layer at the surface of the soil. The high water-holding capacity was further increased by the frequent occurrence of large holes created by the uprooting of fallen dead trees. These holes become successively filled with litter, keeping the water-holding capacity of the site at a very high level.

The high debris content at the soil surface and the abundance of holes retaining water lead to the permanently high water-retention capacity in the virgin forest. Evapotranspiration from the virgin forest is maximised since the debris layer never dries out. Thus decomposition of debris is to a large extent controlled by the low redox-conditions due to the relatively small solubility of oxygen in water. During the period of study, the soil, close to the soil surface, was moist, and in many cases fairly water-logged. During summer no observable overheated areas occurred at any time within the boundaries of the virgin forest; temperatures were quite evenly distributed and excessive wind events were very scarce.

Despite the climatic change observed elsewhere, in the virgin forest the snow cover lasted every year from about mid-November until almost the end of May. The water analyses of melted snow samples showed extremely low conductivity values. From 17 samples a median of 0.6 mS m^{-1} at 20°C and a pH of 6.27 were obtained (Table 1.1). These results indicate that there was a much quicker turnover of water

Table 1.1 Chemical composition of melted snow from Rothwald virgin forest

Max		1.45	0.09	7.22	2.55	0.64	0.54	0.97	23.60	1.20	2.85	1.82	0.25	1.09	0.71	5.06	0.26	0.35	0.96
Min		0.26	0.00	4.73	0.01	0.01	0.00	0.25	0.01	0.16	0.05	0.18	0.01	0.03	0.01	0.01	0.00	0.00	0.17
Median		0.60	0.01	6.27	0.03	0.20	0.01	0.53	0.61	0.49	0.62	0.55	0.06	0.30	0.14	0.04	0.06	0.00	0.50
MW		0.72	0.03	6.49	0.19	0.22	0.11	0.55	1.97	0.60	0.80	0.65	0.08	0.34	0.21	0.42	0.06	0.04	0.53
n		17	16	16	17	17	16	17	17	17	17	17	17	16	17	16	16	14	17
Sampling site	Date	Conductivity mS m^{-1} 20ºC	Alkalinity mmol l^{-1}	pH	P_{tot} mg l^{-1}	$(NO_3 + NO_2)$-N mg l^{-1}	NH_4-N mg l^{-1}	N-anorg mg l^{-1}	N_{tot} mg l^{-1}	Cl mg l^{-1}	SO_4 mg l^{-1}	Ca mg l^{-1}	Mg mg l^{-1}	Na mg l^{-1}	K mg l^{-1}	Fe mg l^{-1}	Mn mg l^{-1}	SiO_2 mg l^{-1}	NO_3-N mg l^{-1}
Schnee 402	24.05.99	0.91	0.02	6.09	0.07	0.18	0.11	0.41	1.04	1.02	2.00	0.40	0.10	1.40	0.09	0.12	0.02	0.00	0.40
Schnee 15 cm	15.09.00	0.98	0.02	5.54	0.02	0.02	0.04	0.42	0.74	1.18	2.85	0.89	0.14	0.57	0.37	0.06	0.00	0.00	0.42
Schnee Oberfl.	15.09.00	0.31	0.09	7.22	2.55	0.01	0.25	0.43	23.60	1.20	2.79	1.37	0.25	1.09	0.68	5.06	0.26	0.35	0.43
Schnee Altholz	03.03.01	0.95	0.00	*	0.01	0.48	0.00	0.59	0.71	0.49	0.87	0.55	0.03	0.16	0.07	0.04	0.07	*	0.57
Schnee Altholz	18.03.01	0.57	0.01	6.16	0.03	0.26	0.01	0.51	0.93	0.39	0.20	0.26	0.03	0.53	0.05	0.04	0.01	0.06	0.49
Schnee Altholz	30.03.01	0.53	0.01	6.60	0.03	0.22	0.01	0.53	0.49	0.27	0.11	0.55	0.03	0.03	0.08	0.01	0.02	0.05	0.50
Schnee bei 1000j. Tanne	20.01.01	0.60	0.01	6.01	0.03	0.26	0.00	0.49	0.37	0.37	0.77	0.55	0.08	0.08	0.07	0.01	0.06	0.00	0.44
Schnee bei 1000j. Tanne	12.02.01	0.91	0.05	6.37	0.04	0.21	0.25	0.58	0.61	0.54	0.33	0.73	0.13	0.19	0.34	0.06	0.19	0.00	0.55
Schnee Langboden	13.02.01	0.41	0.01	6.41	0.01	0.14	0.15	0.62	0.12	0.43	0.12	0.36	0.30	0.30	0.14	0.01	0.00	0.00	0.59
Schnee Mitte Rotmösel	22.01.01	0.47	0.02	6.74	0.06	0.09	0.00	0.52	0.01	0.36	0.25	0.18	0.01	0.56	0.01	0.01	0.00	0.04	0.50
Schnee Mösern	02.03.01	1.19	0.01	6.14	0.03	0.64	0.00	0.51	1.44	0.81	0.72	0.73	0.06	0.49	0.20	0.04	0.05	*	0.49
Schnee Mösern	19.03.01	0.37	0.01	6.33	0.01	0.19	0.00	0.25	0.36	0.18	0.05	0.30	0.02	0.03	0.03	0.02	0.07	0.03	0.17
Schnee Mösern	31.03.01	0.26	0.01	6.51	0.01	0.14	0.01	0.74	0.04	0.16	0.07	0.26	0.02	0.04	0.04	0.02	0.10	0.00	0.69
Schnee Mösern	15.04.01	0.94	*	6.80	0.01	0.37	*	0.71	0.65	0.91	1.07	0.77	0.23	*	0.21	*	*	*	0.69
Schnee Sonde	11.02.01	1.45	0.09	6.20	0.04	0.21	0.23	0.61	0.69	0.55	0.87	1.82	0.12	0.30	0.29	0.23	0.08	0.00	0.61
Schnee Sonde Landböden	21.01.01	0.52	0.01	6.54	0.02	0.20	0.00	0.57	0.01	0.34	0.62	0.73	0.05	0.09	0.04	0.02	0.08	0.00	0.52
Schneegrube	13.06.01	0.78	0.02	5.97	0.24	0.20	0.54	0.36	2.19	1.05	1.38	0.30	0.06	0.49	0.20	0.27	0.01	0.00	0.35
Schneegruben-lacke	12.06.01	0.99	0.05	6.04	0.03	0.02	0.21	0.97	0.54	1.03	0.61	0.70	0.11	0.48	0.71	0.78	0.03	0.00	0.96

*No data available

evaporated from the virgin forest in relation to precipitation brought from longer distances away, as such precipitation water would usually have approximately ten times higher conductivity.

At the same time nutrients and minerals were being kept in place, bound within the debris and biomass of the decomposing organisms such as bacteria and fungi. The losses from sites within the virgin forest were thus minimised by the uncoupled water and matter cycles.

1.2.2 The Play Rules of Nature

The study of the processes in the virgin forest has revealed how nature arranges itself to reduce losses and optimise production. The intricate strategies of nature can be demonstrated by tree seedlings benefiting from old fallen trees where they find optimum conditions for their growth. In an unmanaged forest, the renewal of trees usually takes place on the upper sides of trunks of old fallen trees (Fig. 1.2). Here the period without snow cover during which the seedlings can grow is prolonged and also the tree seedlings benefit from the supply of nutrients and minerals made available from the decomposing dead organic matter of the fallen trunks. The rapid changes occurring in the oxidising and reducing conditions on the upper sides of tree trunks – which also means a higher level of microbial activity – offer far better conditions and an improved nutrient supply for the growth of the seedlings.

Ecosystems in general are controlled in a feedback mode by their physical limitations in interaction with the water balance. The water table oscillations within the

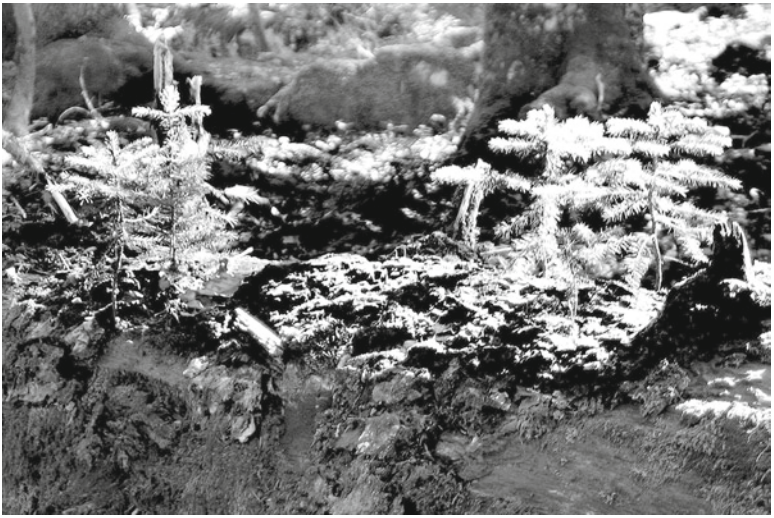

Fig. 1.2 Tree seedlings find best conditions for their development on old fallen tree trunks

debris layer are mainly controlled by plants through evapotranspiration. While solar energy, water and nutrients are the prerequisites of primary production, water uptake is controlled by the activity of plants' roots and by evapotranspiration. Root processes and activity regulate nutrient availability through decomposition of organic matter (see below) and thus primary production. It is therefore most likely that the vegetation cover controls, by means of water uptake and evapotranspiration, the irreversible matter losses, soil fertility and sustainability of the environment.

The water table oscillations within the root zones regulate the redox conditions and thereby the decomposition of debris and transformation of humic substances into mineralised compounds of ionic state that enable plant growth and plant production. Loss-free, localised recycling of matter and water within a minimised area ensures environmental stability with respect to both plant growth and energy dissipation controlled by evapotranspiration and condensation of water – fully utilising the capillary structures of fibrous debris.

Driven by the sun's irradiation water is cycling continuously and is a key in energy dissipation and cycling of matter. As water has a great capacity for carrying energy (i.e. high heat capacity), it makes it a very efficient heater or cooler. When water is evapotranspired by vegetation or evaporated from surfaces to the atmosphere, i.e. it changes from the liquid state to the water vapour, energy is stored in the form of latent heat in the water vapour and the site is cooled down. At the time and place of water condensation, energy is released and the site warmed up. Without water, the energy of the sun's radiation would be transformed into sensible heat and the site overheated in the day time and far cooler at night (the conditions known from the desert areas where, due to the lack of water, the differences between the day and night temperature may exceed 50°C). The attenuation of an energy pulse to a mean level which can be seen as reduced temperature amplitudes is a result of energy dissipation by water (Fig. 1.3). The dissipation or attenuation of the daily solar energy pulse received by the Earth is essential to smooth the temperature gradients between day and night thus creating conditions for high species diversity as only very few species are adapted to big differences in day and night temperatures.

1.2.3 The Dissipative-Ecological-Unit

The concept of the minimum unit system, termed the *dissipative-ecological-unit* (DEU), which has all the elements required for the efficient dissipation of energy, and water and matter recycling, has been introduced by Ripl and Hildmann (2000); and it depicts the strong association between the water retention capacity and detritus accumulation (Fig. 1.4). Steadily increasing resource stability of the DEUs is achieved by reducing water percolation through the soils to the groundwater and

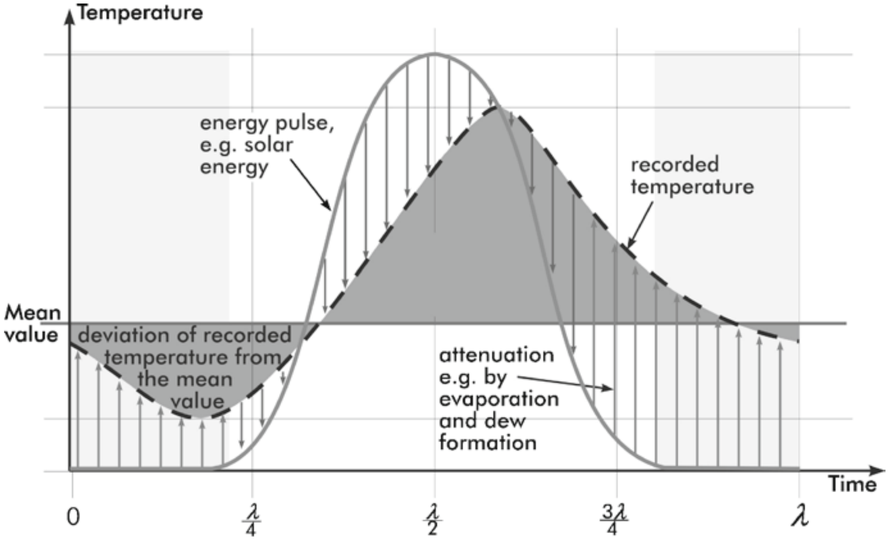

Fig. 1.3 Evapotranspiration and condensation of water vapour play an important role in the attenuation of solar energy pulse, thus reducing temperature amplitudes

instead increasing and short-circuiting the local water cycling within ecosystems by enhancing evapotranspiration.

An indication of the different efficiencies of various habitats (DEUs) to attenuate the daily energy pulse has been shown by high time-resolution temperature recording (every 20 min) in three different ecosystems – woodland, grassland and arable field (Ripl et al. 1995, 1996). The calculated standard deviation clearly shows that the daily amplitudes of temperatures measured in meadows and arable fields are far higher than those in the woodland. Lower efficiencies of agricultural areas as compared to wooded areas were pointed out already at the end of nineteenth century by Müttrich (1890) who also showed the differentiation between different tree species (Fig. 1.5).

The concept of the dissipative-ecological-unit is further important to demonstrate how nature, when not disturbed by sudden changes in climatic conditions, tends to close cycles of matter, i.e. run an efficient local resource economy, and maintain relatively even temperature and moisture conditions, i.e. environmental conditions without big fluctuations that best suit a vast majority of organisms. In contrast, human society seems to have a long way to go to realise that nutrients and base cations, and also water are becoming a limited resource that must be recycled. Our intensive land use pattern with no or little consideration of its impact on water and matter cycles leads to a higher frequency of large floods but also is a cause of the land drying out, soil fertility failing, and clean water becoming a scarce resource (see also Kravčík et al. 2007; Ripl and Eiseltová 2009).

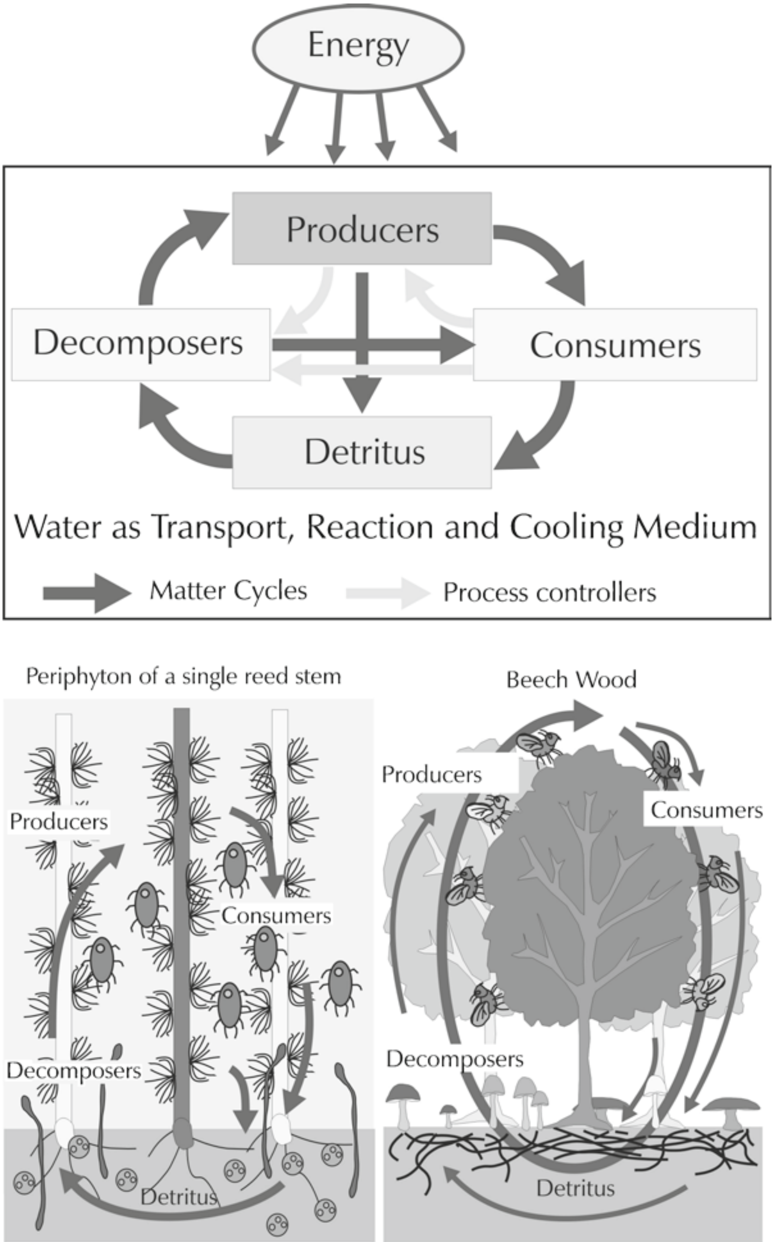

Fig. 1.4 The dissipative-ecological-unit

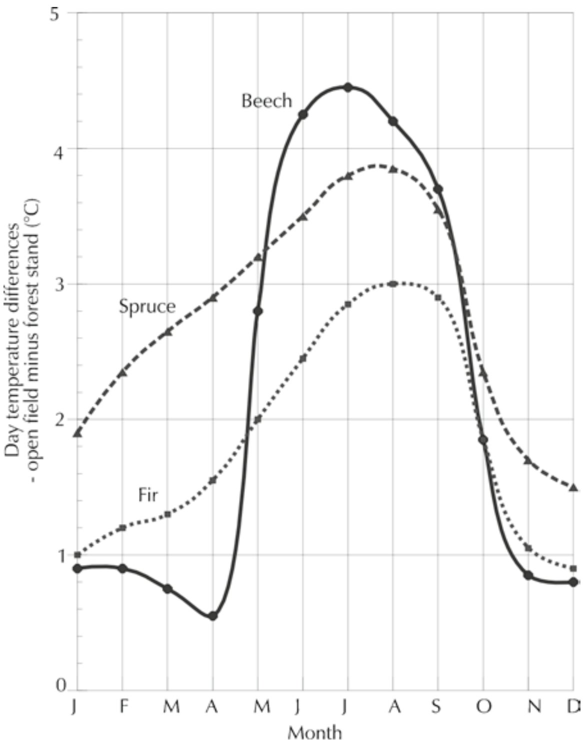

Fig. 1.5 Daily temperature reductions in three forest types compared to open field (based on data from Müttrich 1890)

1.3 The Stör River Catchment as an Example of Human Interference with Natural Processes

1.3.1 Site Description and Monitoring Programme

An intensive monitoring programme was set up during 1991–1994 in the Stör River catchment (an area of 1,155 km^2, in Schleswig-Holstein, NW Germany) in order to gain a detailed understanding of the processes responsible for the very high matter losses from this predominantly agricultural catchment. The land (at an altitude of 6–90 m asl) is dominated by agriculture (72%, 50% of which is arable and 22% covered by meadows and pastures) with some forestry (15%). The parameters measured at various points throughout the catchment included: total runoff (discharge) and dissolved chemical load (using both chemical analysis and conductivity measured in streams) from catchment and sub-catchments; and temperature measurements (both at a micro-habitat level and with the use of satellite information). The data from high time-resolution (every 20 min) ground measurements