Ecohydrology

Wassen, M.J; Grootjans, A.P.

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Ecohydrology: an interdisciplinary approach for wetland management and restoration

Martin J. Wassen[1,*] & Ab P. Grootjans[2]
[1]*The Netherlands Centre for Geo-ecological Research, Functioning of Landscape Ecosystems Research Group, Department of Environmental Studies, Utrecht University, P.O.Box 80.115, 3508 TC Utrecht, the Netherlands;* [2]*Laboratory of Plant Ecology, Department of Plant Biology, University of Groningen, P.O.Box 14, 9750 AA Haren, the Netherlands (*corresponding author)*

In August 1994 the VIth International Congress of Ecology was held in Manchester, United Kingdom. Within the frame work of INTECOL a symposium on ecohydrological approaches in wetland ecology was convened by Dr Martin Wassen on behalf of the Ecohydrology working group of the Dutch Association for Landscape Ecology (WLO). Fourteen papers were presented during a two-day session on 'Consequences of Changes in the Water Cycle for Groundwater and Surface Water Fed Ecosystems' Eight of the papers presented during the symposium are published in this special issue of Vegetatio.

Ecohydrology is an application driven interdisciplin and aims at a better understanding of hydrological factors determining the natural development of wet ecosystems, especially in regard of their functional value for nature protection and restoration. Grootjans et al. (1996) defined ecohydrology as the science of the hydrological aspects of ecology; the overlap between hydrology and ecology, studied in view of ecological problems. In ecohydrology wetland ecosystems are analysed in a landscape-ecological context. The focus is on the chorological relations by water flow and the conditioning effect of water chemistry on site conditions. Topography and geology constitute differences in altitude and permeability generating piezometric gradients and groundwater flow. During its flow, water chemistry changes depending on the mineral composition of parent material. Consequently not only flow direction and fluxes change but also the macro-ionic composition of the water. Next, the controlling effect of different water sources on local nutrient cycling, base status and vegetation development is studied. In ecohydrology differences in water chemistry are frequently used to distinguish the various hydrological systems. Isotope analysis and hydrological models are less frequently used to determine the origin of the water. This is a direct effect of the fact that the scientific roots of ecohydrology are in ecology. Hydrologists joined the debate later (since the end of the eighties) and there are still relatively few hydrologists who actually cooperate with ecologists in inter-disciplinary ecohydrological research projects. Recent publications on ecohydrological approaches can be found in Bakker et al. 1990; Wassen 1990; Schot 1991; Van Wirdum 1991, 1993; Verhoeven 1992; Wheeler et al. 1995; De Mars 1996; Grootjans et al. 1996.

Ecohydrology in The Netherlands has its roots in three lines of scientific research: vegetation science, hydrology of mire ecosystems and agro-ecological research on soil fertility. Some twenty years ago very descriptive techniques were used in vegetation science to assess the deleterious impacts of human interferences with the hydrology. Lateron more mature approaches were developed in order to assess restoration prospects of damaged wetlands. These approaches benefitted considerably from developments in geohydrology (Engelen & Jones 1986; Schot 1991; Stuyfzand 1993; Komor 1994) and soil chemistry (Patrick & Khalid 1974; Richardson & Marshall 1986; Caraco et al. 1989). Ecohydrology in The Netherlands first moved from the analysis of landscapes and wetland ecosystems to water and wetland management and is presently shifting to the field of restoration ecology where more attention is given to, for instance, experimental research on plant adaptations (Wheeler et al. 1985; Roelofs 1991) and diaspores dispersal (Van der Valk & Pederson 1989; Maas & Schop-Guth 1995).

Ecohydrological research usually does not claim to unraffel all hydrological and ecological mechanisms responsible for the observed changes in the species composition of damaged or restored wetlands, but it may contribute to the understanding of how to properly manage these ecosystems. We have tried to illustrate this in this special issue.

Wassen et al. demonstrate that flooding by stream water, discharge of groundwater from aquifers and infiltration of precipitation water, each have specific impact on the site characteristics of wet ecosystems since they contribute differently to the specific ionic composition of a wetland site. Diversity in ionic composition in the wetlands, therefore, mainly depends on the origin of the water. Interferences in the hydrological cycle affect both the fluxes and the ionic composition of water flows. This in turn triggers changes in site conditions which leads to succession. A comparison between relatively pristine fens and flood plains in the Biebrza catchment in Northeast Poland with fens in heavily impacted plains in the Netherlands (Vecht and Gorecht areas), showed that the water sources feeding the different vegetation types are similar in both areas, leading to comparable hydrochemical conditions, although both the hydrological pattern and the vegetation pattern have changed enormous in the Dutch areas.

In the second paper Grootjans et al. show that seasonal flooding of a small dune slack on the Dutch Waddensea Island Schiermonnikoog is essential for the maintenance of low productive basiphilous vegetation types, which are characteristic for young calcareous wet dune slacks. When flooded the slack functions as a flow through lake and captures calcareous groundwater in a small discharge zone. The water then proceeds as surface water and infiltrates again at the opposite infiltration zone. Integration of hydrochemical analysis, simulated groundwater flow paths and isotope analysis led to a clear understanding of the hydrology and the chemical processes in the slack.

In the next paper Sival & Grootjans discuss the nutrient and organic matter accumulation in the same dune slack in more detail. The decalcification depth appeared to reflect the hydrological regime quite well: shallow in the discharge zone and deeper in the infiltration belt. The low productive dune slack vegetation with endangered 'Red List' species was restricted to sites with low amounts of organic matter and nitrogen in the top soil. It was hypothesized that a regular supply of acid buffering components from the calcareous soil buffers the pH at a circum neutral level and slows down the accumulation of organic matter thus creating opportunities for the rare basiphilous plant species. The information gathered in both studies was used to make a reconstruction of the hydrological and vegetation history of the slack.

Boeye et al. studied a local rich fen which is fed by calcareous groundwater from an artificial river water infiltration system. The fen is situated in a region with poor soils and acid substratum. The fens receive acid groundwater and are therefore typically poor fens. The fen studied in this paper is a notable exception and has a distinct basiphilous vegetation. For its alkaline condition this rich fen depends entirely on an artificial river water system which has existed for more than one century now. This example shows that the threatened *Caricion davallianae* fen vegetation type can be created out of poor fen precursors. The possibilities for restoration and the difficulties with use of allochtonous water for nature conservation are discussed.

De Mars et al. studied the effects of drainage on peat chemistry and fen vegetation in the vast fen areas in the Biebrza catchment in NE-Poland. Several fen meadows have been affected by drainage here due to the construction of large canals, but these meadows have never been reclaimed for intensive agricultural use and may be suitable for mire restoration by rewetting. A complete restoration aimed at the regeneration of the original fen vegetation, however, may not be accomplished by just restoring the original water level. The irreversable changes in physical and chemical properties of the peat will prevent successful restoration of the low productive fen vegetation. The paper discusses the species composition of both drained and undrained fens in the Middle Basin of the Biebrza. A comparison of soil chemistry and groundwater composition showed that drainage strongly affects the soil moisture dynamics which irreversibly affects the soil redox status. The phosphate availability in particular was low under high redox conditions and this appeared to shift the nutrient limitation from N to P. In the more intensively drained sites leaching and mowing had also caused a pronounced K limitation. A conceptual scheme is presented for the expected succession after rewetting.

Jansen et al. focus on the restoration of minerotrophic species-rich heathland communities in the Netherlands. Many of them have become severely acidified and eutrophicated during the last decades as a result of changes in the local or regional hydrology. In their study the effects of sodcutting and hydrological measures on vegetation and soil chemistry was monitored in two nature reserves where characteristic heathland species (*Ericetum tetralicis*) and litter fen species (*Cirsio-Molinietum*) disappeared decades ago. Sod cutting was successful for the regeneration of the former community, but restoration of the *Cirsio-*

Molinietum required both sod cutting and hydrological measures that countered prolonged inundation and reinforced the discharge of base-rich groundwater. The possible influence of calcium- and iron-rich groundwater on the availability of nutrients is discussed for each case study.

Galatowitsch & Van der Valk report on wetland restoration in the prairie pothole region of North-America. In this intensively used agricultural region with an intensive network of surface ditches and subsurface tile drains nearly 90% of the wetlands in the region had been drained, which even caused a lowering of the regional water table. During the last 10 years a large number of wetland restorations have been attempted, but many fail to resemble natural wetlands. The authors compared the vegetation and abiotic conditions of 10 restored and 10 natural wetlands three years after reflooding. They found that soils of restored wetlands had a lower organic carbon content compared to natural wetlands, although the fluctuation in water storage was comparable. The ionic composition of the surface water and the vegetation of restored wetlands differed from that of natural wetlands, the latter having more emergent and meadow species, but less submergent aquatics. The authors suggest that for sedges and wet meadow species the dispersal of propagules to restored wetlands is slow and may pose a serious problem for the re-establishment of these species. Low organic carbon contents and a high bulk density of the soil may also prevent the establishment of such species, even when the dispersal is not limiting.

Pfadenhauer & Klötzli give an overview of regeneration experiments in Middle European wet terrestrial ecosystems. They focus on a number of regeneration experiments which are in progress and discuss the effects of rewetting and nutrient depletion on the re-establishment of typical wetland plant communities. They conclude that reconstruction of the former state is in most cases impossible within reasonable time spans. In severely drained and industrially exploited bogs, the primary aim is to restore efficient peat formation, even when it leads to the development of eutraphent fen and bog species. In cultivated fens the aim is to reduce peat loss. A first step is to convert arable fields into permanent grassland. If possible the fertility of the soil should be reduced, prior to permanent rewetting. Well tested techniques are now available to reduce the soil fertility and to even introduce typical fen species. This introduction of typical fen species is often necessary because seed banks are usually depleted after intensive cultivation and the natural dispersal of fen species is very slow. The total prevention of peat loss is, however, only possible when the peats are permanently rewetted. Only then can fens function as nutrient sinks in the landscape.

In our opinion this ecohydrological special issue shows how different ecohydrological approaches contribute to our understanding of the hydrological functioning of wetland ecosystems in various landscapes. Wetlands may be pristine, heavily influenced or even created artificially. Yet they may have much in common with respect to their hydrological control. Wassen et al., Boeye et al. and De Mars et al. focused on physical and chemical dynamics of fen ecohydrology. Grootjans et al. and Sival & Grootjans focused on dune slacks, which vegetation shows similarities to fen vegetation. When flooded their hydrological functioning is comparable to that of some polder areas in the reclaimed Vecht river plain and that of prairie potholes: they all have groundwater inflow at one side, lateral throughflow by surface water and infiltration at the other side. This water flux maintains a certain base saturation and mineral input which prevents acidification. Furthermore various contributions demonstrated the differentiating effect of water sources on the site conditions and the vegetation composition in the wetlands. Pfadenhauer & Klötzli, Jansen et al. and Galatowitsch & Van der Valk pay particular attention to possibilities and constraints in wetland restoration, but also the other authors try to use the outcomes of their ecohydrological studies as a basis for designing regeneration measures. This special issue also shows a shortcoming in ecohydrology: Uncertainty about the exact hydrological mechanisms. This is due to unsufficient participation of hydrologists in most studies. A more narrow cooperation with hydrologists is important for the future development of ecohydrology. More specific challenges for the future are: hysteresis in restoration ecohydrology; processes in the unsaturated zone; catchment modelling in which hydrological and ecological process knowledge is coupled in a GIS.

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