COMMISSIE VOOR HYDROLOGISCH ONDERZOEK TNO

TNO COMMITTEE ON HYDROLOGICAL RESEARCH

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WATER MANAGEMENT IN RELATION TO NATURE, FORESTRY AND LANDSCAPE MANAGEMENT

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WATER MANAGEMENT IN RELATION TO NATURE, FORESTRY AND LANDSCAPE MANAGEMENT

PROCEEDINGS OF
TECHNICAL MEETING 43
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INTRODUCTION

G.A. Oosterbaan

In the technical meetings organized since 1946 by the TNO Committee on Hydrological Research (CHO-TNO) the relation between water management and nature conservation, forestry and landscape has not been discussed so far.

In hydrological studies in the Netherlands nature conservation has been treated mainly as a boundary condition for the protection of the areas involved. Forestry got some attention in studies on rainfall/runoff relationships and on evapotranspiration. Until recently little was known about the influence of different water management strategies on nature and forestry. Hydrologists generally did not pay much attention to these problems.

Biologists have always been fully aware of the significance of water for natural vegetations. However, it appeared to be difficult to link the knowledge developed in this discipline to the work of hydrologists. From the hydrologists' point of view the work on landscape ecology seemed to offer more points of contact. The Netherlands Society for Landscape Ecology arranged a meeting in 1979 on ecosystems in relation to the groundwater regime. Looking back at the proceedings of that meeting one gets the impression that the integration of biological and hydrological research was then arriving in its first stage. The contributions to this CHO-TNO meeting may show how far this process of integration developed in recent years.

Much work has been done in the Netherlands to improve water management conditions. In general these measures were aiming at protection of the country against inundations, improvement of the conditions for agriculture and water supply for domestic and industrial purposes. Nature conservation and forestry generally got little attention of the planning authorities until the sixties. From that time on the emphasis changed and as a consequence it became more and more important to explore fields of research that were neglected in the past.

One of the reasons why the knowledge on the relation between water management, nature and forestry is lagging behind, lies undoubtedly in the different research traditions in the various disciplines involved. In addition to this difference interdisciplinary co-operation often failed in the past. Initiatives to improve this situation have been taken since 1970 by the State Forestry Service, the Committee for the Groundwater Act on Water Companies and the Provincial Board of Gelderland. A very important step was taken in 1982 with the creation of the SWNBL Study Committee Water Management Nature-, Forest- and Landscape Management which is now supported by the most relevant ministries, provincial boards and the Union of Waterboards. SWNBL was founded with the purpose to create a synthesis of knowledge in the field of ecology, forestry, landscape and hydrology in such a way that it could be used to predict the effects of changing hydrological conditions on natural vegetation, forestry and landscape. The SWNBL-study, that has to be completed in 1987, is limited in scope to terrestrial flora and vegetation of the higher plants but includes timber production and landscape physiognomy. A review of the first results of the SWNBL-study is given in the Annex.

The programme of the technical meeting on water management and nature conservation, forestry and landscape is for a good deal based on (provisional) results of the SWNBL-project. A contribution on landscape physiognomy could not be included at this stage.

The programme of SWNBL is focussed on the relation

hydrology - site factors - plant/plantcommunity.

In this context site factors are the link between the hydrological system and the vegetation. The contributions to the technical meeting fitted in the same framework. They were introduced by a survey of problems as they are met in the practice of water management. The programme ended with a presentation of practical experiences.

The contributions in this volume were prepared by authors from different disciplines, including agricultural sciences, biology, physical geography and civil engineering. They may demonstrate how the co-operation between the various disciplines in the field of water management - nature conservation - forestry has improved in recent years.

BE WISE WITH WATER

J.M. Leemhuis-Stout

ABSTRACT

Water boards are confronted with the problem of how to cater for a wide range of interests. Besides the interests involved in the basic tasks of the water boards there are many interests of third parties which must be taken into account.

Due to conflicting requirements which are inherent in the interests concerned it is not always possible to please everyone. It is sometimes not possible to cater for all the interests which by nature are part of the basic task of the water boards, as these too often create conflicting demands. The water boards are therefore continually placed in a position in which they must evaluate the interests and weigh them up against one another. This is particularly true with regard to the interests of managers of nature, forest and landscape matters.

Two aspects of this evaluation process are of particular importance. Firstly, the constraints which prevent all interests being catering for all are often of a financial nature. Extension of the rates system in order to obtain tax income from residents in the area would help to alleviate this problem. Secondly, the extent of available knowledge as to the nature of the requirements concerned is not sufficient in order to make the necessary value judgements.
Research into such matters would also greatly improve the situation.

1 INTRODUCTION

During this symposium a number of lectures are being given on aspects of the relationship between regional water management and the management of nature, forest and landscape matters. The organizers of this event have made a good choice since these more scientific talks are preceded by more general reflections on the relationship. It is assumed in these observations that it is no longer necessary to give a fundamental lecture about the tasks, powers and structure of the water managers, being in this respect the water boards, and the position of these government bodies in the entire governmental system. It does seem useful - and that is the first part of this introduction - to say something about the interests which are involved in water management and the way in which these interests are served by the water board. Following this, more specific attention is given to the interests of the management of nature, forestry and landscape matters and the way in which they are involved in the execution of the tasks of the water board. Thirdly, some practical problems and questions which arise in this connection will be touched upon. Those are then the questions to which hopefully an answer, or at least the beginnings of an answer, will be given in the following lectures.

2 WATER CONTROL

Water boards have one task: to take care of State water matters on a local and a regional level. This duty is divided into the care of weirs and dams, water quantity, water quality and waterways. In this paper it is limited to the water quantity and the water quality, or to put it differently: the water economy. The task of the water board in this area boils down to the fact that the water board must ensure that the interests which are involved in the water economy are optimally served.

Two key words are contained in the previous sentence 'interests' and 'optimally'. As far as the first term is concerned it can be noted that there are now more interests than was previously realized.

Mention must be made of the interests of safety, habitability and the quantity of the environment, the provision of drinking water, agriculture, industry, shipping, fishery, recreation and (last but not least) the (management of) nature, forest and landscape matters. In that connection the problem occasionally arises that these interests make not only extensive, but also conflicting demands. This makes it necessary for the water board to weigh matters up; this is where the word 'optimally' comes into the picture. For weighing up implies that one, the other or even all interests may fail to get the treatment they desire. A good water board will, however, aim at optimizing the net result. The daily work of the office of the water board Hoogheemraadschap Schieland shows that a water board is continually occupied with such matters.

Apart from these introductory remarks, however, a last comment must be made about the notion "interests" in order to obtain a good understanding. That was done for the first time in a report in 1979 of the so-called Merkx Committee, which was concerned with the structure of the water board. A distinction was made in that respect between task interests on the one hand and related interests on the other hand.

Task interests are those interests for the care of which the water board was established; related interests are not those interests for which the water board was established, but for which, taking into consideration the social position of this governmental body as a public administrator, it has to have regard for when carrying out its tasks. In this connection one sometimes also speaks of the 'social function' of the water board. It is clear that related interests will be looked after by the water board if it is possible without much extra effort, for example in the case of two alternatives which are approximately equivalent from the point of view of carrying out the tasks.

If, however, substantial resources are required, especially financial resources, then they must come from outside of the water board if the related interest is to be catered for. But even task interests will

not always get all treatment they deserve. To begin with, different task interests can sometimes make physically contradicting demands. Furthermore, fulfillment of a task interest is dependent on the extent of the costs involved and the extent to which it is reasonable to impose these costs on the relevant rate-paying categories in the water board area. In this connection it can be mentioned that in the present situation only owners and others who
have rights to real estate (buildings or land) have a duty to pay these rates. It is not always reasonable to have these categories of specifically interested parties bear costs which concern the care of general task interests. A contribution from third parties can therefore be a condition in order to cater for an interest which in itself must be considered as a task interest of the water board.
The completion of the Bill on the Water Boards, on the basis of which representatives of general interests in particular can in future contribute to the water board through rates chargeable to residents, will in that respect offer more room for financing certain expenses with the aid of tax income from the board's own tax area.

3 WATER CONTROL AND THE CONTROL OF FOREST, NATURE AND LANDSCAPE

In order to place the interests of the management of forest, nature and landscape matters into the above division a distinction is made between quantity management and quality management.

As far as the management of water quantity is concerned this is a task interest in so far as it is dependent on the water economics of the water course. It is therefore particularly concerned with a management of water levels such that sufficient water is supplied or drained-off to maintain the groundwater level in the surrounding area at the desired level.

This desire can be able to be fulfilled if one can speak of seperate unequivocal forest or nature areas, managed by private or public institutions which are committed to the maintenance of that interest (for example National Forest Service or a private organization such as the Association for the Preservation of Natural Monuments). In such a case we can, after all, speak of a landholder who contributes to the water board, whose desires must be taken into account. The extent to which this is possible depends, on the evaluation process mentioned above. But even if we cannot speak of 'owners of rights in rem to real estate', who specifically stand up for the interest of nature, and forestry management, an adequate level of management remains in principle one of the tasks of the water board. The absence of income from a section which is concerned will, however, sometimes tip the scales the other way. In this connection the extension of the taxable area of the water board, among other things by means of rates for residents, is of importance. In that situation accommodation of general task interests of the water board is after all more reasonable than at present is the case.

The interest of nature, forest and landscape can, however, also be of related importance for the quantity manager. That relation is present if, for example, decorative landscaping of waterways with forest elements, the manner of maintenance of these waterways or the maintenance of Water Department works for cultural-historical reasons are concerned. These are all interests which touch upon the fulfillment of the task of the water board, but which do not primarily depend on the water-economical situation of the water course. The water board must also keep an eye on these interests, and in practice this is what happens.

An example is the so-called EBO-report, which deals among other things with the ownership, management and maintenance of forest elements alongside water courses after completion of a landscape development project. This report states that in certain circumstances care must be exercised by the water board. If we leave aside for the moment the question as to how the idea in this report will be implemented, the reaction of the water boards is in principle in agreement with this idea.

However, when related interests are concerned, an eye must always be kept on the fact that the really substantial efforts of the water board will only be able to be demanded if an external contribution is available in return.

As far as quality management is concerned it can be briefly noted in that this agreement - this can also be read in the last water-IMP - has grown from taking care of the physical nature of the water to taking care of the aquatic ecosystem, including the foreshores and river beds. It appears from this that the water quality manager has a direct task as far as the maintenance of the physical values in the water course are concerned. It must be noted, however, that this care does not extend without limit, but just so far as this maintenance can be served by an adequate draining policy or other actions in the sphere of water economy. To illustrate that with an example: the promotion of the growth of rare plants in a ditch by raising the quality of the ditch water does belong to the area of the water board, but introducing and enforcing a ban on picking does not.

4 SOME QUESTIONS AND PROBLEMS

In the last part of this lecture a few practical problems in the relationship between water management and the management of nature, forest and landscape matters are discussed. In the preceding comments the way in which the latter interests are weighed-up in principle by the regional water manager has been sketched. Both terrestic and aquatic.

For this evaluation it is important in practice that the demands which are made from within the relevant interest can be translated into parameters which the water can understand. For various interests which are connected with water control this presents few or no problems.

The demands of agriculture or drinking water supply, for example, can be relatively easily translated into quantitative and qualitative water requirements. This is often somewhat more difficult for the water board in its contacts with the managers of nature, forest or landscape matters: the latter manager is rather intent on maintaining or achieving a certain situation without being able to show specifically what that means in terms of the water economy. Naturally, this does not help the evaluation process, at least not in favour of the interest which is a central theme today. A summary is given below of the points which would be desired in the opinion of the water manager:

a As concerns the destination and the organization of the water board area questions arise:
  - of a hydrological nature: what is known about the relationship between lowering the surface water level and lowering the groundwater level, or which relationships exist between the groundwater level and physical forestry values; which requirements are set by managers of nature areas and forests for the drainage capacity of the water course system;
  - of a morphological nature: which requirements are set for the network fineness or the rectilinearity or the (over) dimensioning of the water course system;
  - of a qualitative nature: what is known about the relationship between water quality and physical and forestry values; what is the effect of desalinating on situations which are briny by nature.

b Questions also arise in respect of the daily management of a water board (assuming a certain destination and organization), such as:
  - do nature managers and foresters make demands in respect of permissible fluctuations with regard to water quality or water levels;
  - can something be said about the permissible maintenance frequencies and about the time when the maintenance should preferably take place.

Other questions which the water manager will in practice want to ask in order to deal with the relevant interest in a responsible manner can no doubt be added to these questions. More than ten wise men will

no doubt be needed in order to give the necessary answers, and much of that wisdom will still have to be obtained from research. Within the scope of the Study Committee with the long name, known under the abbreviation SWNBL, the necessary attention is being given to these matters. Hopefully, this committee will indeed have the opportunity to produce the useful results which the water manager would like to see. Even a symposium such as this can give a good impulse in this respect. At the beginning of this lecture hope is expressed that the next speakers will find the opportunity to answer, at least partially, questions which arise in practice, so that the motto of this introduction:
"be wise with water", will become and remain a reality in two ways. It remains to be seen in the following lectures whether this is to be the case.

THE RELATION BETWEEN GEOHYDROLOGY AND SITE FACTORS FOR TERRESTIC VEGETATIONS. A SURVEY OF THE FIELD OF PROBLEMS

F.A.M. Claessen

ABSTRACT

A survey is given of the main scientific problems in the Netherlands concerning the interrelationship between natural or by man induced hydrologic alterations in and around terrestic nature reservations and the site factors for spontaneous mire vegetation.
The first section generally deals with basic problems.
In the second part the results are presented of an investigation of the major problems concerning this relationship in twenty terrestic nature reservations.
A general description of the geohydrologic features of these nature reservations and their setting in a regional environment is given.

1 INTRODUCTION

The content of this article is predominantly based on results and experiences gathered during the last years by the project team 4 (SWNBL) "Water Management and Environmental factors for terrestic vegetations" (SWNBL project 4, 1986).

The goal of this project team was to define and select geohydrologic parameters, which are closely related with relevant site factors of terrestic mire vegetations.
One of the first actions in respect to this goal was a systematic investigation of the problems, which were met by studies and analyses of the relationship between hydrology and site factors in 20 terrestic nature reservations in the Netherlands.

The main topics of this investigation were:

* Physical geography, hydrogeology and topography of the reservations and their environments.
* Kind of hydrologic alterations in and around these locations.
* Kind of effects for the water related site factors.

By means of this survey knowledge is gained to which extend present scientific methods and techniques face these problems. This contributes to design an effective strategy for future research programs.

2 MAJOR PROBLEMS

2.1 The basic problem

The basic question is: how do influence alterations in the water management or water control in or nearby terrestic nature reservations site factors.

These alterations can be naturally, for instance by climatological fluctuations, or induced by man, e.g. by building water works, reclamation, reallocation of land, urbanization, withdrawal of groundwater, improved water supply and so on.
These alterations can effect the geohydrological conditions in and around terrestic nature reservations, for instance:

- the piezometric and/or pheatic head can change
- so seepage rate can change
- this can result in a different quality of surface water and of water in the rootzone of spontaneous mire vegetation also due to chemical and biological processes.

2.2 Other kind of problems

Most nature reservations in the Netherlands can be found at locations which have a marginal land use by man. Historical reasons for this extensive land use are:

- these locations are hard to reclaim (too wet or dry, too poor soil-conditions, too far away from settlements etc.);
- previous land use made further intensive use impossible (after mining of construction material and fuel);
- private landownership (latifundia) who loves nature.

Inherent to their marginal status and specific properties these locations have pronounced physiographic gradients, inhomogeneous structures and are often rather isolated from more intensive used lands and waters.
Examples of these marginal areas are the dune area Waddenzee, floodplains, marshlands, river valleys, old riverbends, river dunes, ice pushed ridges and remnants of large heather grounds.

Intensive used urban or cultivated lands have lost the original gradients and mosaic-like structures. One finds in these locations nowadays more or less homogeneous structures of land use (monocultures) separated from each other by sharp discontinuities or border lines (see figure 1).
Application of hydrologic sciences to intensive used lands is in general less complicated than to natural reservations with spontaneous vegetations and complex physiographic structures.

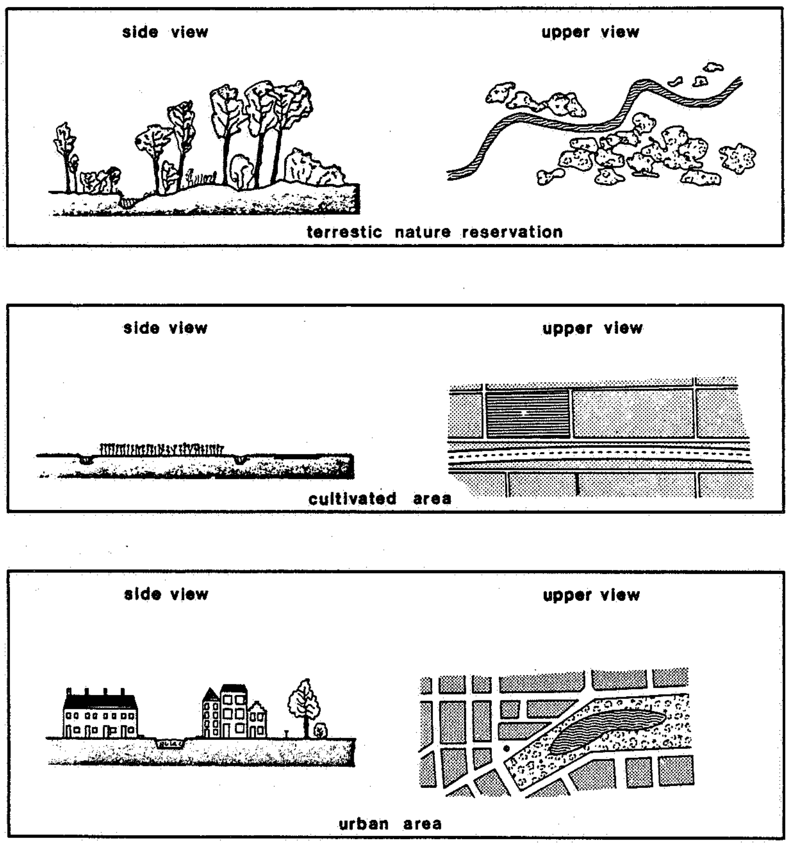


Figure 1 Difference in spatial patterns

In the last 50 years applied Hydrology was focussed upon the water flow and processes in the reclaimed conditioned, urbanised, cultivated areas (for design and engineering activities).
The hydrology of unreclaimed, uncultivated areas and their environment is rather a young branch of this science. Thence the establishment of research projects like SWNBL.

Ideas about some hydrologic alterations in nature reservations are often based upon observed modifications in the presence of so called rare guide plants and not upon geohydrologic observations in the area. So conclusions about hydrologic causes of changing site factors are not established directly from hydrologic facts but indirectly from modifications in the vegetation.

Sometimes an extra complication occur if a time lag exists between alternations in site factors and the resulting alternations in plant composition. Such a delay can be more than several years. So hydrologic boundary conditions can be changed already, it will take this long period after site factors are changed significantly.

Up till now in the interrelationship between:
Hydrology - site factors - plants/vegetation
most attention was given to the relation site factor - vegetation and only to a small extent to hydrology-site factors.

Another problem which is closely related to these interrelationships is the difference in scale at which hydrologic and biologic processes can occur.
Hydrologic processes are active at almost any scale some where in the hydrologic cycle, while processes related to site factors only occur at micro scale. Thus for insight into the relations between some specific hydrologic intervention some where at some scale and the hydrologic effects of this intervention upon certain site factors at some very local scale it is necessary to know the spatial relationship between the hydrologic processes at regional and at local scale. Therefore it is important to know the hierarchical spatial-temporal structure of hydrological systems in the area of attention.

From this general analyses of the problems concerning the relationship hydrology - site factors it can be concluded that hydrologic research in natural or uncultivated areas is more complicated than the same kind of research in intensive cultivated areas. So is modelling more complicated in natural areas as a result of their heterogeneity.

3 INVESTIGATION OF 20 TERRESTIC NATURE RESERVATIONS

3.1 Introduction

In a systematic way information was collected and analysed from 20 locations, spread all over the country. The selection of these areas was largely based on pragmatic reasons and was more or less arbitrary. Information was selected around three major topics:

- Physical geography of the reservation and its environment, especially the geohydrologic description
- nature of hydrologic alterations that prevailed during the last decennia around and within these areas;
- nature of hydrologic effects upon site factors in the nature reservations.

Figure 2 shows where these 20 areas are situated. The locations are indicated on a map of hydrologic systems of the Netherlands (Engelen, 1980). The map shows four major supra regional hydrologic systems and fifteen regional systems.

3.2 Results

3.2.1 Major physical geographic and geohydrologic features

Most locations of interest are situated in topographic depressions. Soil types and groundwater depth fluctuations indicate moist to wet conditions during a large part of the year.
Figure 3 shows the dominant vegetation types in the selected areas: e.g. poor grass lands, heather, ombrotrophic and eutrophic peat bogs, marsh woods and deciduous forest on rich mineral soils.
Data about surface water levels and the local geohydrologic conditions are mostly not available.

Based on general information the 20 areas can be characterized in geohydrologic terms. First the location in the Pleistocene part will be described, secondly those in the Holocene part of the country.

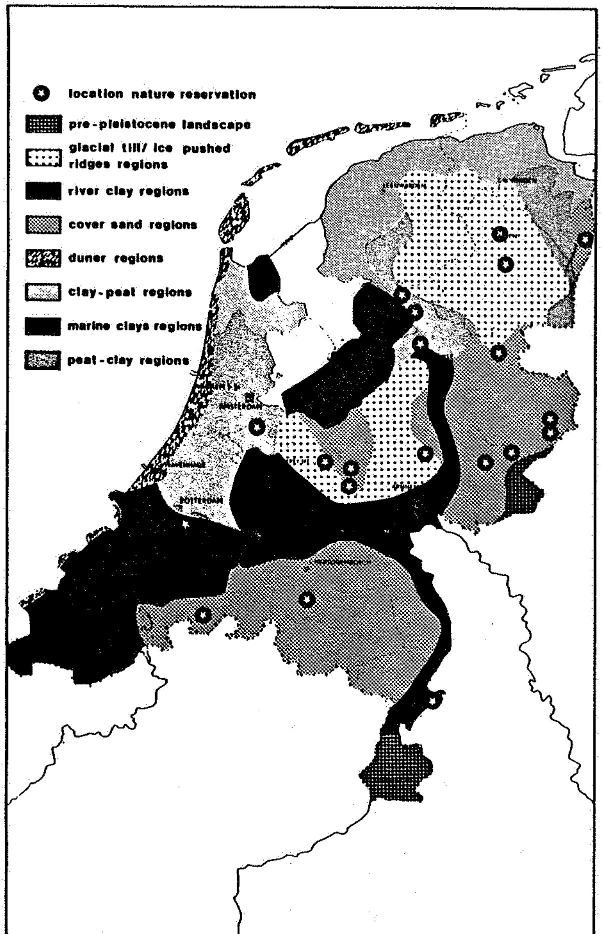


Figure 2 Location of selected areas on a map of hydrologic systems of The Netherlands (after G.B. Engelen, 1980)

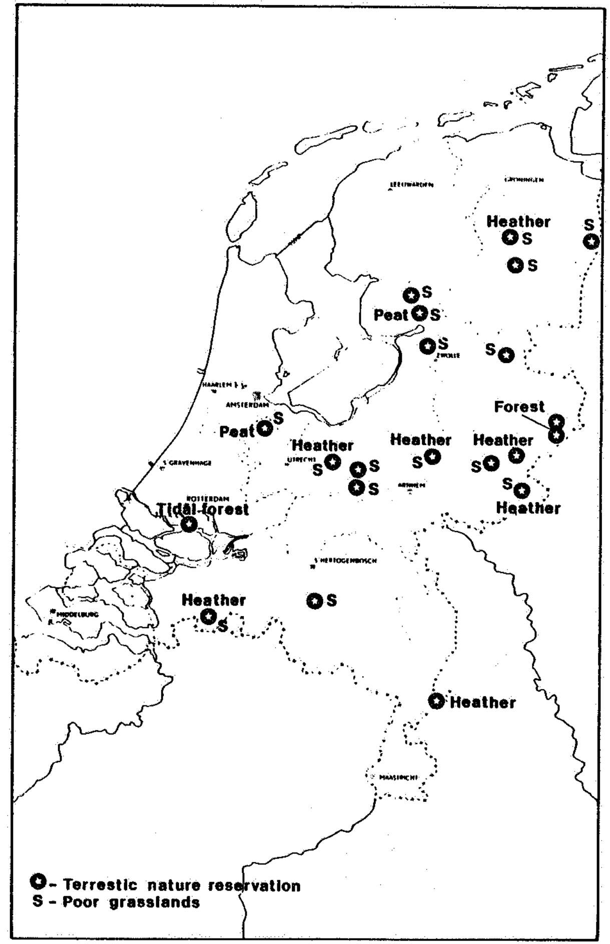


Figure 3 Dominant types of vegetations per nature reservation

Generally in the Pleistocene part nature reservations can be found at two types of locations:

- upon flat regional water divides in fluvio-glacial and cover sand regions
- in depressions in the cover sand region (e.g. small river valleys).

The first areas are remnants of extensive former peat bogs (Drenthe, Eastern Gelderland). These areas have in origin poorly drainage conditions. In the depressions of the cover sand regions the flow of groundwater of local and regional hydrologic systems prevails. These areas contain more or less permanent seepage of socalled lithocline groundwater (v. Wirdum, 1980), which is rich in minerals like calcium and has a high buffering capacity.

Groundwaterflow is induced by infiltration of net precipitation in elevated recharge areas. The groundwater discharge occurs in topographic depressions. This flow is nested in regional and local hydrologic systems with a spatio-temporal character (Engelen, 1981). Figure 4 shows for the cover sand region some times of residence along average streamlines within flow systems (de Vries, 1974). The time of residence depends on the depth of the streamlines and seems to vary between less than 50 to more than 150 years.

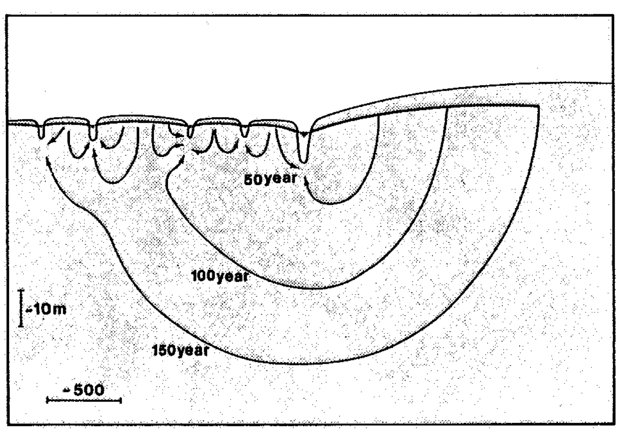


Figure 4 Schematic groundwater flow pattern in a coversand region

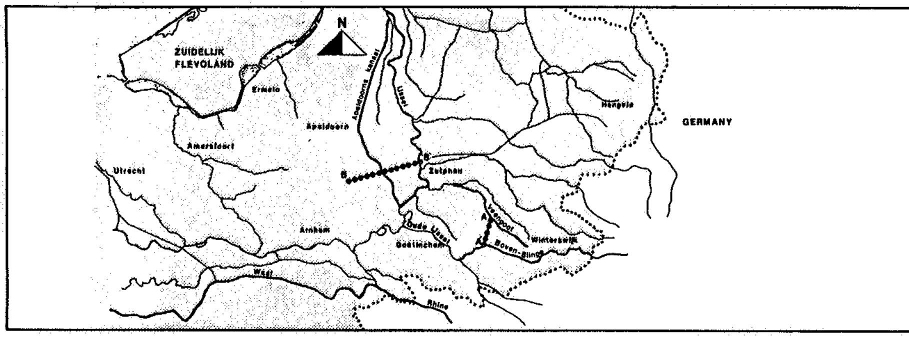
Next two figures show schematic cross-sections of topography, groundwater table (fig. 5) and the schematic groundwater flow pattern (fig.6) during summer and winter at different locations in the cover sand regions in the province of Gelderland.
According to a dense groundwater drainage system in winter and a much less dense system in summer is the groundwater flow pattern in winter is more complex than in summer.
From the figure it can be inferred that the groundwater table is continuously more or less parallel to the landsurface topography. The groundwater table is in winter about 0,5 meter and in summer 1,0 to 1,5 meter below groundsurface.

Generally in the Holocene part nature reservations can be found at two types of locations:
- in the lower peat(bogs) areas;
- in the socalled "Boezem" lands.

In both areas the groundwater level is controlled artificially by drainage e.g. by pumping. The canal systems between the polder drainage systems are flushed regularly with fresh river water for pollution control purposes. The groundwater table in these polder regions will be in general at depths less than 0,5 meter.

The lower peat areas can geohydrologically be divided up into two sub regions:
- areas bordering the Pleistocene sand regions;
- areas bordering the deep polders (reclaimed lakes);

The peat areas bordering the Pleistocene collect deep lithocline seepage water from the adjacent high grounds.
The areas next to deep reclamations predominantly have groundwater recharge conditions, so surface water supply is necessary in summer from adjacent water systems. If this imported water has a poor quality, eutrophication or other damage to mire vegetation can occur in the nature reservations.
Peatlands are vulnerable to landsubsidence as a result of a decrease of surface water- and piezometric levels and a process of oxidation.



Location map of cross sections A-A' and B-B' (figure 6).

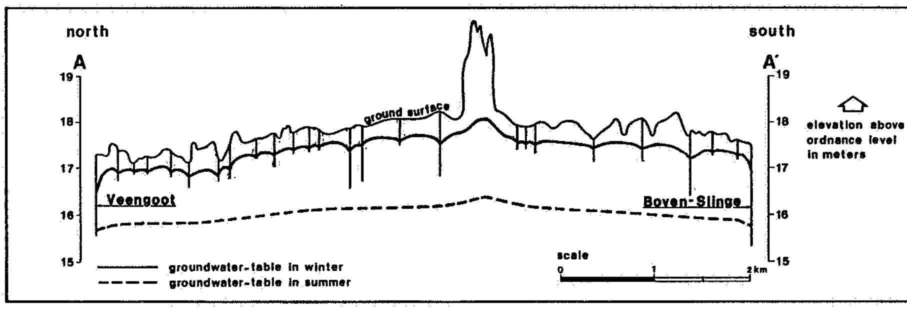


Figure 5 Average winter and summer groundwater table between Veengoot and Boven-Slinge (province of Gelderland)

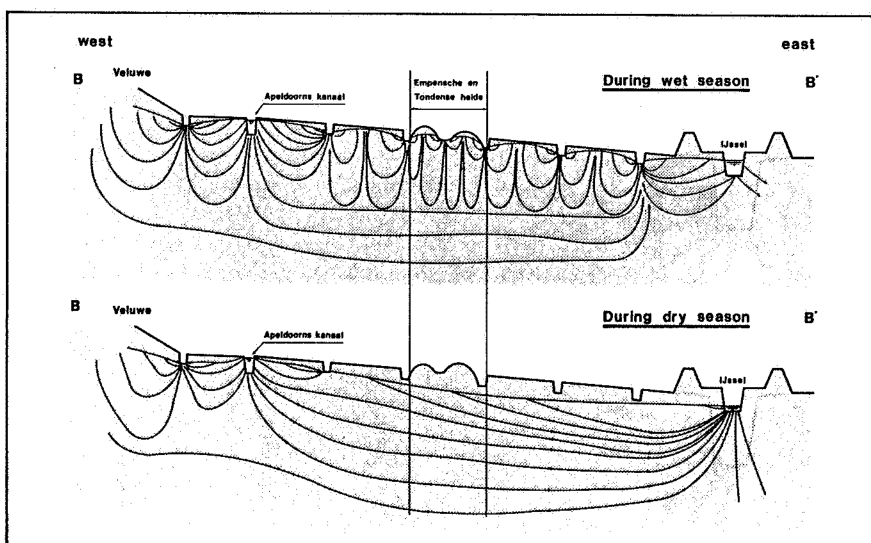


Figure 6 Schematic groundwater flow pattern in the Brummen-Voorst area (see figure 5)

"Boezem"lands are located outside the very polder systems or outside the lands protected by river- canal- or lake dikes.
This land is used for storage of superfluous drainage water during wet periods; in dry periods water supply for the polder areas occurs by inlet of water from this "boezem"water systems. Boezem waters are interlinked and connected with the hydrologic head systems of the country (fig. 1), and can be described as the secondary system.
In wet periods the boezem lands can inundate for some time. The altitude of these lands is relative high in respect to the adjacent polderland. Thus infiltration of surface- and rainwater into the pleistocene aquifer prevails. So the water quality of the root zone will not be influenced by deep groundwater here.
Eutrophication and damage to mire vegetation possibly occur, if -in dry periods- the imported surface water has a poor quality.
The groundwater table will vary only little at these locations because of the influence of the surface water system with a controlled water level. The depth of the groundwater table is in general less than 0,5 meter.

Groundwater flow patterns in the Holocene areas change from season to season. In the shallow subsurface the alterations are the largest. In the wet periods shallow groundwater flow directly to the drains and ditches of the polder drainage system, in the dry season the direction of flow can be reverse: from the ditches towards the soil. Only in deep polders groundwater flows continuously.

3.2.3 Most important hydrologic alterations

Groundwater withdrawal for drinking and industry water purposes happens in about 50 percent of all areas, at distances between 1000 and 3000 meter to the reservations. Irrigation with use of groundwater is applied at a small scale and during dry summers only.
Improvement on a broad scale of dewatering, drainage and watersupply facilities in the urbanized and cultivated areas occured in the last decades. This enhanced alterations in the water management of large parts of the country. In some areas the quality of surface water has been decreased by increased pollution in the last decades.

Recently in some nature reservations the water management is modified in favour of the vegetations. This has been done for instance in the Reitma area (Zeeman, 1986).

3.2.4 Hydrologic effects for site factors

As a result of the hydrologic alterations mentioned in the previous paragraph one can expect some effects upon site factors of the vegetations in the nature reservations. From the data available in many cases it is not clear which effects dominate. In most cases a gradual decrease of the average and minimum groundwater level per year are proved. There is in most cases some evidence that during last decades there has been a gradual decrease of the average and minimum groundwater level per year. In some areas there's a strong evidence that groundwater withdrawal forms the head cause. Other possible causes are:
- measurements to improve dewatering and drainage facilities;
- climatologic fluctuations in the year to year net precipitation.

Also in many areas is known about effects upon the availability of plant nutrients and about the chemical quality of the water in the rootzone. Although in some areas data about these alterations in site factors still exist (e.g. peat areas in the provinces of Utrecht and Overijssel).

4 CONCLUSIONS AND RECOMMENDATIONS

- In most areas of considerations, detailed geohydrologic knowledge is limited, atmost in respect to the effects of hydrologic alterations upon site factors and in respect to the geohydrologic setting of the nature reservations in the geohydrologic systems (scale problem).

- It is important to stress the geohydrologic relationship of the nature reservations and their environment. So for the relative low areas the geohydrologic regime of the bordering high grounds is important; for the relative high Holocene areas most important seems to be the quality of the imported surface water which is necessary for water supply in dry periods.

- Most important hydrologic alterations for site factors are:
  - withdrawal of groundwater (industry and drinking water)
  - improvement of dewatering, drainage and watersupply facilities (agriculture)
  - decrease of surface water quality (industry, urbanisation, agriculture)
  - climatic fluctuations in net precipitations.

- Most important hydrologic effects are:
  - drop of the groundwater table during growing season
  - increase of groundwater recharge or decrease of the seepage
  - alteration of the water quality in the root zone.

- Further research should be more focused upon data aquisition to get more insight into the spatio-temporal patterns of hydrological systems and their relations with the site factors of spontaneous mire vegetations.

- For an answer upon the question: is present knowledge sufficient to solve adequately the many problems being described above is given in the contribution of Kemmers.

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WATER RELATED IMPACTS ON NATURE PROTECTION SITES

G. van Wirdum

ABSTRACT

Models for the prediction of impacts of water-related projects on nature protection areas are often based on the assumption that the involved sites are homogeneous with respect to the operational environment of spontaneously settled plant species. This is shown to be a false assumption. As a consequence, the site requirements for nature protection cannot be immediately derived from autecological records, as it is done in agricultural impact models. Both types of impact models are compared. In this contribution, the nature site is conceived as an ecological device, which itself requires a singular environment in order to safeguard the requisite internal variety. Impact models for nature protection should be based on the environmental requirements of such ecodevices, rather than those of the individual species. Current Dutch models are compared with regard to the description and the role of the sites.

1 INTRODUCTION

Some statistical figures about the development of The Netherlands (Table 1, Centraal Bureau voor de Statistiek, 1979, 1985) can illustrate how much the Dutch must have modified their land to relieve the needs of the human society. Most of the surface area, 96% of 41473 km^2 in 1983, is directly used for this purpose, and the total land area is even continuously being enlarged by land reclamations. Much of the remaining 'waste land' is reserved for nature protection: 2.9% of The Netherlands. The society needs include drinking and industrial water use, and these have disproportionally grown because of the increasing standard of living. The industrial use of water is estimated to be about twice as large as the public water use. Several hundreds of land-improvement plans for large areas were realized after 1950, including an often radical revision of the water management. Especially the animal productivity grew enormously.

Table 1 Statistics of the population density, the drinking water withdrawal, the production of milk, meat, and dung, and the use of fertilizers in The Netherlands

Year	1950	1983
Population density (people per km^2)	309	423
Public drinking water supply (x 10^6 m^3)	317	1072
viz., groundwater	239	738
surface water	78	334
Milk production (x 10^6 l)	5771	13207
Meat production (x 10^6 kg)	400	2468
Dung production (x 10^6 kg)	ca 20000	51682
i.e., P as P_2O_5	70	179
N	117	290
K as K_2O	124	277
Use of fertilizers (x 10^6 kg):		
P as P_2O_5	120	87
N	156	478
K as K_2O	155	117

These numbers tell how important water-related engineering projects in The Netherlands are, and how severely they almost must interfere with nature protection, both in the 'waste land' area, including the nature reserves, and in the corners of the cultivated land area.

In order to take account of the needs of nature protection in forthcoming water-related projects, and to possibly stop the harmful effects of historical and ongoing projects, it is desired to state these needs in a formal and quantitative way which should also allow for impact assessment. The SWNBL study (Oosterbaan, 1986) sped up studies in this field in order to make a general impact model available.

This contribution focuses on the impact on the spontaneous vegetation, since the vegetation is often used to determine the value of an area for nature protection, and since the impact on the vegetation seems to be somewhat more straightforward than it is on the fauna. A comparison is made with current approaches in agriculture to show the large differences. Mentioning of less representative cases, such as reed cropping as an agricultural item, or salt marshes for nature protection, is avoided. These are not the main problem areas for the present study. The discussion is extended to some of the logic which is being used in nature protection models. A general scheme which covers both types of applied ecological models serves as a starting point. Individual parts of the present reasoning have been presented in earlier publications (van Wirdum, 1979, 1981, 1982a,b, 1985a).

2 THE PROBLEM

In order to state the impacts of water-related projects on nature protection it is tried to answer the question:

What relates the objets d'art of the water engineers to wild plants?

An analogous problem has been solved for agriculture by primarily considering the physiological **requirements of the species** (crops) involved. Here, a rationale will be developed which highlights the requirements for the processes in the various environments of nature, i.e., the **requirements of the sites** of the species. Although crops and wild plants all belong to the Regnum Vegetabile, it will be seen that the models which are profitably being used in agriculture are not readily applicable to the impact problems of nature protection. The reasons for this point are:

Table 2 Comparison of features of water-impact models for agriculture and for nature protection, respectively. Critical requirements have been printed in bold face

	Agriculture	Nature protection
1. Object features		
1a. Site	homogeneous operational environment	various operational environments
1b. Vegetation	few species of plants	many species of plants
1c. Description	site average	frequency distribution
2. Criterion	productivity of crop	capacity to fit spontaneously settled threatened species
3. Water quantity parameters		
3a. Water use by the vegetation	**minimum groundwater level (critical)**	minimal groundwater level (mostly not critical)
3b. Soil aeration	maximum groundwater level to prevent anoxia (rarely critical in impact studies)	**minimum groundwater level to prevent change of redox conditions and decomposition of organic soil components (highly critical)**
3c. Accessibility for cattle and vehicles	maximum groundwater level (rarely critical in impact studies)	of secundary importance (not critical)
4. Water quality parameters		
4a. Salt damage	fresh water required	**various requirements**
4b. Ionic composition	rarely considered	**especially litho-atmocline gradient critical**
5. Adjustment time	years	centuries
6. Relation with nutrient status via 3b and 4b		
	only weak, since external supply to excess status	**strong, since maximum tolerated nutrient status low**

- The objects are different: the Dutch meadows and arable fields are different from natural sites;
- Nature protection has different criteria for the evaluation of sites, i.e., the variate to be explained is different;
- The critical causative parameters appear to be different for conservational land use as compared to agriculture, and as far as the same parameters play a key role, they are often critical in a different range.

Some of the arguments for these statements are summarized in Table 2. Of course this detracts nothing from the usefulness of the results of agricultural science, even for the present purpose.

3 THE MODEL: GENERAL CHARACTERISTICS AND A FIRST APPROXIMATION

3.1 The model set-up

The following compartments are distinguished in the causal chain between a water-related project and plant performance (Fig. 1):

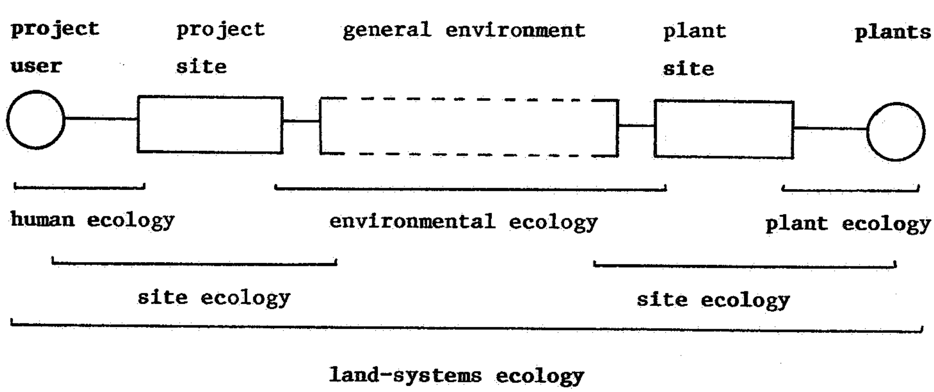

Figure 1 The causal chain of impacts; the relevant branches of applied ecology have been indicated

The **project user** has requirements, e.g., **p** m^3 of drinking and industrial water per year, or a water table not more than a cm below the soil surface in the summer, and not less than **b** cm in the winter. The **project site** is used to meet these requirements, e.g., by groundwater withdrawal, or water supply and drainage. The **general environment** dynamically sustains both the project and the plant site. Ideally, it should not be considerably changed by the work involved: the inexhaustible-resources scenario. It has appeared, however, that the general environment is most often changed a lot near the project site, though the effect decreases as the distance from the project site increases. In a model, this is formally represented by some transfer logic, including loss functions. In the case of water-related projects such logic is often based on the Darcy and continuity equations for water flow. The relevant aspects of the state of the general environment near the **plant site** can thus be determined. The latter may be an arable field, or a nature reserve, etc. It should fulfil the requirements of the **plants.**

Sites, in turn, transfer the information from the general environment to the **operational environment** of the plants, especially to the root zone. The properties of the site determine how this information is modified during transfer and thus constitute **conditional factors.** Since the site is the last compartment through which the information is passed to the plant it is imperative to have a reliable model for site processes. Details which may be neglected in the model of the general environment must often be considered in the model of the site. This will be shown to be the bottleneck in studies of the causal chain of impacts on spontaneous vegetation.

The aim of nature protection is commonly related to the protection of threatened species, the threats being caused by human impacts on the environment of wild organisms. One must be aware, however, that the interest is not the individual species, but the construct 'nature', which enables the spontaneous coexistence of so many different forms of life. The threatened species are indicators of the state of nature, they indicate the Achilles' heel of the natural construct. According to this concept of nature protection, the threatened organisms in a nature reserve might themselves be regarded the end users of the plant site. We still need people to formulate their requirements, however, using **criteria** and **targets** for the value of the site. Both are related to the presence of specified organisms, the indicator organisms and goal organisms of nature protection, respectively. The goal organisms are the threatened organisms themselves. The indicator organisms inform about the goodness of the protection that the goal organisms receive, and about the chance that they will appear or disappear. In agriculture, humans are obviously the end users of the site, and they also have criteria and target values, e.g., crop, milk, or meat production in kg/ha (2 in Table 2). Note that the present author is convinced that there are objective criteria for the comparison of the value of sites for nature protection. When such criteria are properly derived from the general aim stated above, there should be no objection against incorporating them in a model. The weighting of the interest of nature protection, as compared to, e.g., agriculture, in contrast, is a matter of concern at the social and political level of decision. At that level, humans consider themselves the end users of the whole of all sites, and nature protection is recognized at human will.

3.2 The varying model entities: ecological field, ecodevices, and operational environment

The sites as conceived in the above-mentioned fashion are called **ecodevices:** devices that process inputs from the general environment into the required products. **Humecs** (human ecodevices) are ecodevices which are installed to relieve immediate needs of humans. They may be related to urban and industrial functions (urban ecodvices, or **urbecs**), such as a groundwater-withdrawal station, or to rural, especially agrarian functions (agrarian ecodevices, or **agrecs**), such as an arable field. **Natecs** (natural ecodevices) are ecodevices which should safeguard the spontaneous occurrence of wild organisms. They may be deliberately installed and used for this purpose by humans: nature reserves. Ecodevices may also be used to undo or diminish the effects of other ecodevices on the general environment. Such **envecs** (environmental ecodevices: water-purification plants, buffer zones, etc.) thus limit or nullify the transfer in the general environment.

The general environment as conceived here is called **ecological field**: **An ecological field is an area within which the ecological properties orderly depend on space, and possibly time, coordinates.** Consequently, those ecological properties which do not do so are excluded from the field description and have to be coped with in the ecodevice one. The field factors are called **positional factors** since they explain the capacity of the ecological field to sustain ecodevices according to the place in the field.

An ecodevice is the conceptual aggregate of land components which is capable of in situ processing the ecological field properties into a user-required operational environment. The preservation of natecs thus signifies that nature protection preserves natural processes in support of the existence of wild organisms, rather than artificially preserving their operational environments, as in pot cultivation. Wild organisms are indicators of the state of health of nature, rather than themselves individually being the motives for nature protection. The main types of ecodevices are listed with their shorthand names in Table 3.

Table 3 The main types of ecodevices

ECODEVICES	- for humans:	- as to urban functions:	**URBECS**
in situ processing	**HUMECS**	- as to agrarian functions:	**AGRECS**
of ecological	- for nature:		**NATECS**
field properties	- for field stability:		**ENVECS**

Individual plants respond to their immediate environment. The immediate environment which comprises the **operational** factors is called the **operational environment** or **milieu sensu stricto**:
The operational environment of organisms is the part of their environment which immediately determines their biological performance. This notion covers the range from physiology to population dynamics. Strictly spoken the response is solely determined by the biological properties of the plants (their **biological program**).

The rightmost part of the general scheme of Fig. 1 is dealt with here, including, (1), the plants (crops or wild ones), (2), the plant sites (agrecs or natecs), and, (3), the varying properties of the ecological field at the location of agrecs and natecs, i.e., where these devices happen to be 'plugged in'.

3.3 Modelling conventions

The distinction between the ecodevices and the ecological field is a starting point for further formal restrictions in the modelling process. By way of agreement, the general environment is only capable of direct transfer of information: when the input is water, the output is not heat or birds. This is different from ecodevices. In the present systems concept, ecodevices may process a volume of water and yield a concentration of phosphate, or, indeed, even plants, birds, and humans, and anything which can have a part in the composition of the environment which the goal organisms will meet. It will be shown that even the current agricultural models formally let biomass be produced out of water. This allowance may bring about great difficulties for a physically realistic description of even only some of the complex transfers within an ecodevice. It is therefore compulsory to arrest that troublesome 'virus' within the ecodevices. The ecological field is used to derive the values of the variables which explain the possible excitation of the virus.

Accordingly, the ecological field may mostly be described by a deterministic model, while one often must resort to more or less stochastic models in order to capture what is going on in ecodevices, especially in complex natecs. In the model representation by Kemmers (1986, Figure 1), the same increase in complexity can be recognized from the ecological field towards the operational environment. It may be noted, however, that Kemmers still pinpoints the deterministically explainable functions of supposedly homogeneous ecodevices in this first-level approach.

3.4 A model for agricultural ecodevices

Several models for agrarian ecodevices which have been developed in the last decade start with the hydraulic head in the ecological field as a positional factor, measured below the lowest groundwater level observed at the plant site, i.e., in the ecodevice. The unsaturated water flow and evapotranspiration problem in the conditionally active ecodevice is then simultaneously solved to determine the flow of water through the crop (operational factor). To arrive at the end result, an empirical formula is implemented which relates this water use to biomass production and compares it to a target value for similar weather conditions (de Laat et al., 1981). This is a model of applied ecology, rather than a scientific model, since many ecodevice processes which are controlled by the same positional factor, and which have an impact on biomass production, are not being taken into account. Since J.B. van Helmont (1577-1644, cited from Russell, 1973) concluded from experiments that plant production was entirely determined by water use, agricultural science has been able to reveal the shortcomings of such a simple model. Because the other aspects of plant nutrition, especially soil fertility, are separately controlled in modern agriculture, however, the modern version of the facts which van Helmont found is sufficient in the applied agricultural model of the impact of water-related projects (3a in Table 2). In this case it is therefore not necessary for the impact model to let the ecodevice transfer anything else than water. Such a **direct-chain model** (only water transfer) is conceptually simple and can be realized on the basis of physics, although the very making is still quite an achievement (de Laat, 1980). As a device, the agrec is only weakly developed or **open** in the sense of van Leeuwen (1966). It is taken apart in this model, (1), to enable a more detailed description of vertical water transfer, and, (2), to let the water be processed into biomass.

Another point to be stressed is that the ecodevice in this model may be considered homogeneous (1a,b,c in Table 2). Although there may exist differences in water use at different places within the ecodevice, the average value is enough to know, provided that the differences are not extreme. This is characteristic of open devices. The operational environment is everywhere the same within such an ecodevice. Of course this is partially the effect of such human device functions as tillage measures and land improvement. In modern agriculture, agrarian ecodevices in gradients of the ecological field are designed so as to break the gradient up in discrete homogeneous parts. Such agrecs are therefore **convergent** (van Leeuwen, 1966) ecodevices.

A third reason for the relative simplicity of this agricultural model is that the relation between the hydraulic head and water use mostly shows a relatively wide optimum range: as the hydraulic head rises above a critical level, the water use is increased until it is at the maximum. A further increase of the hydraulic head has no further effects until the root zone becomes anoxic and production drops sharply. Most agricultural ecodevices in The Netherlands are provided with a drainage system which is able of preventing such a situation. This is therefore not a critical part of the range for impact models (3b,c in Table 2).

3.5 Further reflections on the agricultural model

Model parameters adapt the model to a singular case: crop parameters, soil parameters, and weather parameters. The crop parameters follow from the species and variety of crop. For some crops, additional research must be done in order to get precise results. The soil parameters can be determined by physical analysis of the soil, or they are estimated from the soil type represented on soil maps (Bouma et al., 1981). For any historical period, the recorded weather parameters can be used; otherwise they have to be inferred from the known climate. It is an important feature of the model that the soil parameters are supposed to form a rigid structure of fixed properties, i.e., properties which do not change in the long run. In other words: the device as such is invariable. This is often only justified because of tillage measures: the state of the device is frequently redressed by sawing, planting, ploughing, manuring, etc.

According to the Relations Theory by van Leeuwen (1966) it appears anomalous that open and convergent devices exhibit a deterministic behaviour. This is largely due to the choice of the variate to be explained: crop production. The crop species, however, can only grow in such devices as a result of the intensive human care. With regard to the spontaneous vegetation, open and convergent devices are characterized by a small number of species which may or may not occur, and even become dominant weeds, according to coincidences which are difficult to predict. None of them has a fixed long-term niche in the ecodevices under discussion. The pair 'large natural uncertainty - small agricultural uncertainty' symbolizes the dominance of human control functions over natural ones in agriculture. Where the human control fails, the natural uncertainty can take over, and even become a lethal factor for the users under the form of droughts and plagues. The stochastic approach of complex natecs, on the other hand, is a consequence of the processes in such natecs being determined to such a degree of precision as is beyond the human faculties of independent measuring and modelling.

Shortly, in an agricultural water-impact model for The Netherlands:
- the ecodevice may be considered homogeneous and invariable;
- a direct causal chain of water is considered;
- the model may be largely deterministic;
- the range of sensitivity should be the range of variation of crop water use under the influence of a varying suction head in the root zone.

3.6 Existing natec models

Until recently, natec water-impact reasoning was not really different from the main lines of the agricultural model. Londo (1975) uses 'groundwater influence in the root zone' as an explaining variable, which suggests that a calculation of vertical water transfer in the ecodevice might be a useful component of a natec impact model. The natec hydraulic head is mostly translated into groundwater levels, and, instead of the calculation of water use, informal knowledge or look-up tables are used to check which of the species might probably be able to survive. With this input, a formula for the evaluation usually accounts

Table 4 Summary of current water-impact models for natecs. Legend: (A) highly demanding, (B) trained personnel required, (C) formal desk study, (D) current hydrological models, (0) no prescribed procedures, expert judgment acceptable, (*) computer procedures provided

ICHORS	
Learning phase	
Field assessment of species composition of sites	(B)
Field and laboratory assessment of site characteristics	(A)
Derivation of response model for each species separately	(*)
Application phase	
Definition of site characteristics	(0)
Computation of probability of occurrence of each species separately	(*)
VEDES	
Learning phase (not always necessary?)	
Field assessment of site characteristics, inclusive of the vegetation	(B)
Classification of ecotopes	(*)
Definition of ongoing activities	(0)
Derivation of transition matrices for ecotope classes	(0)
Application phase	
Field assessment of site characteristics, inclusive of the vegetation	(B)
Classification of ecotopes	(*)
Definition of proposed activities which may have an impact	(0)
Derivation of predicted ecotope class (via transition matrix)	(*)
Evaluation of ecotope for nature protection (look-up table)	(*)
WAFLO	
No learning phase needed	
Application phase	
Field assessment of species composition	(B)
Assessment of site characteristics (from existing Dutch soil maps)	(C)
Definition of new average groundwater table in spring	(D)
Derivation of new site state (fixed models and rules)	(*)
Matching with old species list (look-up tables)	(*)
Evaluation for nature protection (formula)	(*)

Table 5 Description and use of site properties in impact models for natecs. In brackets: units of expression, or number of classes

ICHORS	VEDES	WAFLO
initial state **a-c** nearest open water level; summer, winter, and difference (cm) **d** difference of hydraulic head, summer-winter (cm) **e-f** upward or downward groundwater flow; summer and winter (+/-) **g-t** open water composition (pH, Cl, Na, Mg, Ca, K, HCO_3, NO_3, NH_4, PO_4, P-tot, S-tot, Fe-tot, Si-tot) (mg/l) **u-x** principal soil component; 0-30 cm, 30-60 cm, 60-120 cm; secundary component 0-30 cm (7)	**initial state** **a** vegetation structure (8) **b** succession stage (2) **c** substratum (2) **d** stability of substratum when pioneer stage (3) **e** soil moisture (4) **f** salinity (3) **g** nutrient level (4) **h** chalk/pH (2) **i** facultative additional quality indication (3) (all derived from a vegetation description in the standard procedure; at least a species list)	**initial state** **a** species list **b** soil type **c** ASG = average spring groundwater level (a can be derived from vegetation maps; **b** and **c** from standard Dutch soil maps)
cause of change (similarly defined new state)	**cause of change** **j** activity names, such as groundwater-withdrawal, grazing, manuring, eutrophication, etc.	**cause of change** **d** change of ASG (cm) **e** expected new ASG (cm)
		intermediate result **1** watersupply according to agricultural model (9) **2** increase of instability of environment (+/-) **3** nitrogen mobilization (empirical formula)(+/-) **4** degree of aeration (empirical formula) (10) **5** depth of ditches (3)
result probability of occurrence of 209 species according to response model from general statistics	**result** new ecotope type according to transition matrix (empirical, literature, or expert judgment) (ca 100)	**result** new species list = initial list minus species whose milieu will disappear (chance 0, 0.5, or 1) according to formalized correspondence of new state to Ellenberg and Londo milieus
evaluation suggested procedure: percentage change of probability per species respective to computed probability in initial state; weighting optional	**evaluation** attached value of ecotope type (under development)	**evaluation** according to rareness of species in The Netherlands

for species diversity and rareness of individual species. In order to cope with the many-species problem, variants of this type of model condense the species information into phytosociological groups. Others have extended such procedures to the classification of **ecotopes** (see 4.1) on the basis of both phytosociological and general ecological information. Van Gijsen (1979) discussed five then existing methods for the assessment of impacts. Her conclusion with regard to these methods is that the probably best ones yield results which are difficult to be reproduced, since they include a lot of informal 'best professional judgment'.

The formalization of water-impact models for natecs has since followed three slightly diverging lines of development in The Netherlands, yielding the models ICHORS, WAFLO, and VEDES, summarized in Tables 4 and 5.

1) The ICHORS model (Barendregt et al., 1985, 1986) consists of an entirely statistical correlative approach. Strictly, ICHORS is a matching model, rather than an impact model. Values of several parameters are measured in sites and used to derive a multidimensional response model for individual species. The 24 input parameter values for the new state, including a complete chemical analysis of the water, are derived from external sources. In the present state, the model 'knows' the response of 135 phreatophytes (see 4.3) and includes a less reliable model for a further 75 species, which are too rare to allow for an accurate calculation of the probability of their occurrence. In the sample applications provided, only the occurrence of few, more common species reaches an appreciable probability at the 95% level of significance, even in the environments that fit them best.

2) The WAFLO model (Gremmen et al., 1985) was developed to be linked with current hydrological models for the ecological field. The strict modular construction of WAFLO enables the replacement of individual modules when better alternatives become available. The input is the new groundwater level and the draw-down. It contains some logic to derive the availability of water and nutrients, the degree of aeration in land sites, and the depth of open-water sites, and uses these parameters to

predict which of the presently occurring species will formally disappear. The species are matched to the site parameters by means of the Ellenberg indicator lists (see 4.3). An additional feature is the formal reaction of 'midy-haters' according to Londo (mostly threatened species, see 4.3) to a slight change of the average depth of the water table. Kemmers (1986) explains the present efforts to improve the non-biological parts of this type of models. In the present form, the model has been calibrated and tested for the Pleistocene part of The Netherlands. The evaluation for nature protection is separately carried out. A validation has been attempted, but was not very successful. The simulation was correct for about one half of the species involved.

3) The VEDES model (Udo de Haes et al., 1985) is based on a typology of 'ecotopes'. The major, and most mature, part of the model concerns the classification of ecotopes. The assessment of impacts is realized on the basis of empirical transition matrices which are provided for some activities and ecotope types. The activities are only weakly quantified. Each ecotope type has been given a fixed base value in order to evaluate the impacts. This base value can be supplemented with a quality indication for each individual ecotope. In the present state, 78 ecotopes have been defined, of which 28 unsufficiently (Runhaar et al., 1985, p.41). Several threatened species are unknown to the model, e.g., 8 of the 20 species which are listed in Table 7. The method includes a great amount of expert judgment. Hence, the reproducibility of results is uncertain. A related model at a further level of abstraction has been presented by Canters & Udo de Haes (1986).

Stimulated by contract research and marketing perspectives the different lines of development each go their own way, and a clear comparison of the pros and cons, of the similarities and dissimilarities, and of the actual stage of development and testing is not available at present. As far as the present author knows, the WAFLO model is the only one for which all fundamental information has been published until now, inclusive of a sensitivity analysis and validity testing. In the following an attempt is made to discuss some of the different elements of the models.

4 SITES IN THE CURRENT MODELS

4.1 Milieu, ecotope, and ecodevice: different ways to look at a site

Although it may be possible to study the operational environment of a free-floating alga in nature, it is unpracticable to separate the operational environment of a rooting plant at a natural site. In order to gain information on this point, the **site which contains the operational environment** is sampled:

Depending on the study objectives, a site in ecology is the smallest separately considered environmental envelope comprising and sustaining the operational environment of the organisms of interest. A dynamic relation exists between the milieu, the plant of interest, and the other components of the site.

In planning and impact studies to a mapping scale of, e.g., 1:50 000 the lower limit for site size is approximately 250 x 250 m^2. Such large sites may obviously accomodate several different operational environments at once. The ecodevice concept stresses the possible non-equivalence of sites to operational environments.

The following situations can occur:
1) the site is rather homogeneous: the same operational environment and one plant species are dominant all-over, as in many agrarian ecodevices;
2) the site is slightly inhomogeneous. Yet the different operational environments have much in common, and the different plant species may be considered as one ecological group. Their distribution over the site is more or less random;
3) the site is definitely inhomogeneous. The average value for any of the operational factors in the different milieus is not representative of what the goal organisms of nature protection require.

All three natec models summarized in Table 4 are based on a case-2 site concept. The actual sites investigated meet several requirements of which the ecotope concept in the VEDES model may be considered representative (Runhaar et al., 1985). Udo de Haes et al. (1985)

specify:

'An ecotope is an area which is homogeneous with respect to its vegetation structure, its succession stage, and a number of abiotic factors', and list the homogeneity criteria used. The authors of the ICHORS and WAFLO models used similar criteria to define the reacting sites in an equally reproducible fashion, but they do not require them to be classed under discrete types of supposedly universal validity. In WAFLO, the initial state of a site may well be derived from maps which represent classed sites, however (Gremmen et al., 1983). Ecotopes are visible real-world sites, primarily distinguished on the basis of morphological characteristics. VEDES ecotopes are just classed sites. The morphological homogeneity is different from functional homogeneity with regard to plant species, however. Opposite the claim by Runhaar et al. (1985), ecotopes, like other sites, may comprise different operational environments (cases 1-3 above). In advance of checking the possible importance of case-3 sites, the role of the sites in the different models is exposed below. Attention has been given to the reasons why different authors preferred different concepts. A thorough discussion on these choices is really needed. The following is just a first attempt, based on the published information.

4.2 The role of sites in the current models

In all three models under discussion, sites have characteristic properties (Table 5). In the ICHORS model, most of the abiotic properties have to be specified precisely according to a continuous cardinal scale of expression, e.g., 'p mg Cl^- per dm^3 of water'. VEDES uses a smaller amount of abiotic parameters, and these are classified according to a low-resolution ordinal scale, e.g., 'eutrophic'. WAFLO uses soil and groundwater information as available on standard Dutch soil maps. The cause of change is also formulated differently in the three models. It is very uncertain whether the ICHORS input requirements can be reliably met in real-world applications. Yet, they make the model a potentially useful instrument for the answering of 'what, if' questions, i.e., to check the variance which remains uncovered after the application of less accurate models. The importance of the water-quality parameters (see below) is being given attention in the WAFLO and SWNBL studies too (Kemmers, 1986, Waterloopkundig Laboratorium, 1985).

VEDES and WAFLO require a description of the vegetation, which is rather similar in both cases. The models differ, however, in the way these descriptions are used. In VEDES, this is to derive the abiotic properties of the site and some general characteristics of the vegetation (structure, succession stage), in order to class it as an ecotope. The properties of the ecotope which react in the model, are average properties assigned to the type of ecotope. The original species lists are preserved for the purpose of attaching an additional quality indication to individual ecotopes. When this is not desired, a less precise description of the vegetation in the field work stage will suffice. Udo de Haes et al. (1985) even reject the species level as it is used in WAFLO for reasons which are hard to accept. The ecotope system is itself largely based on the species level of indication. The loss of resolution, which is caused by the removal of detailed information with regard to species leads to trivial impact statements, such as 'drainage, manuring, and grazing of bogs will change them into manured grasslands, which are less rare, and less unique, and need a shorter time of development than bogs'. Runhaar et al. (1985) reveal an increased interest in the species level in order to, (1), improve the ecotope classification, and, (2), enable a more useful impact evaluation. As emerging properties of ecodevices, species are especially indicative of the functioning and the overall value of such devices.

ICHORS, and less strictly VEDES, are different from WAFLO in requiring freshly derived matching logic, prompted by the desire (Barendregt et al., 1986) for continuous response curves, rather than indications of the optimum. Runhaar et al. (1985) also stress the need to take account of the range of tolerance of species, but they overlook (p. 38) the possible occurrence of case-3 sites, and use phytosociological criteria to derive the required information (see 4.4). Apart from conceptual errors, it must be doubted whether it is still possible in The Netherlands to find enough steady-state sites for the fresh development of response models, especially with regard to rare species (van Wirdum &

van Dam, 1984). In the framework of the WAFLO model, and of the SWNBL study, statistical response models have been thoroughly tried out (Looman, 1985, van Wirdum, 1985b). It was decided to prefer the compiled experience of earlier workers, such as Ellenberg (1978) and Londo (1975). There data were proven to be consistent with records by Kruijne et al. (1967), who did a statistical survey under more favourable circumstances than the natural environment presently provides. Dijkema et al. (1985) attempted to correlate the characteristics of the most threatened operational environments in nature reserves to requirements of the relevant natecs. In the long run, a combination of such investigations with more advanced statistical techniques may yield interesting results. For the time being, however, the approaches of the environment in ICHORS and in VEDES will probably decrease the precision of predictions to a level which is appropriate to case-2 sites (4.1). They certainly do not enable good explanations of the occurrence of many rare species, such as those bound to the 'gradient belts' mapped by van Leeuwen (1966, 1967).

An interesting point of difference between the models is that WAFLO uses the matching logic to predict which of the initial state species **will not** be able to survive, while ICHORS predicts the probability of species to **be able** to occur in the new state, disregarding the possibility that some of the factors are out of their required range. Likewise, VEDES implicitly stresses the positive probability of occurrence attached to the new ecotope. Both WAFLO and VEDES recognize the importance of initial state information. The WAFLO procedure comes in the place of the notably difficult prediction of circumstances which are supposedly not influenced by the change which causes an impact on the site. The neglect of possible new species to appear is accepted by reasoning that the experience has taught that most newly appearing species, in the cases for which the model was made, are not indicative of an increased protective value of the ecodevices. In the present form, the model is therefore unsuited for predicting the course of development of natecs as a result of purposeful management. It remains to be seen whether the procedures used in VEDES and ICHORS render these models any better for that situations, however. The missing of the initial state, and thus of change as such, in ICHORS is at least a very severe drawback here.

4.3 A survey of the milieu of threatened phreatophytes

Especially valuable natecs may loose some of their value. Since this study emphasizes situations which might be threatened by becoming dryer, the presentation is restricted to hydrophytes and phreatophytes according to Londo (1975):

Hydrophytes are species with submerged or floating vegetative parts.

Phreatophytes are species which are mainly confined to the sphere of influence of the phreatic surface in the area considered. Hydrophytes are also phreatophytes. The latter collective name will be used here.

Table 6 The number of threatened phreatophytes and hydrophytes in each Ellenberg milieu (bold face), comparative to the sum total of Dutch species. Species which have not been assigned to any singular milieu by Ellenberg (1978) have been omitted from the counts. The Ellenberg moisture (F), nitrogen (N), and acidity (A) figures appropriate to each milieu have been indicated

Nutrient status	**Acidity**		**Dry** F1-3		**Moist** F4-6		**Wet** F7-9		**Very wet** F10-12	
Rich	**Alkaline**	**R7-9**	3	**0**	54	**6**	29	**8**	19	**5**
N7-9	**Intermediate**	**R4-6**	0	**0**	13	**0**	4	**1**	3	**2**
	Acid	**R1-3**	0	**0**	2	**0**	0	**0**	0	0
Intermediate	**Alkaline**	**R7-9**	14	**0**	69	**7**	29	**7**	19	**4**
N4-6	**Intermediate**	**R4-6**	4	0	32	**4**	27	12	8	1
	Acid	**R1-3**	0	**0**	13	**2**	3	**1**	0	0
Poor	**Alkaline**	**R7-9**	51	**0**	36	**2**	17	**16**	4	**4**
N1-3	**Intermediate**	**R4-6**	10	**0**	16	**3**	15	**12**	2	**2**
	Acid	**R1-3**	11	**0**	31	**3**	35	**23**	9	**6**

Table 7 Some threatened phreatophytes of the poor & wet Ellenberg milieus and the appropriate F, R, and N figures according to Ellenberg (1978). English and Dutch names are provided

	F	R	N
Species of acid milieu			
Drosera rotundifolia L. - Sundew (ronde zonnedauw)	9	1	1
Carex echinata Murray - Star Sedge (sterzegge)	8	3	2
Cirsium dissectum (L.) Hill - Marsh Plume Thistle (spaanse ruiter)	8	3	2
Myrica gale L. - Bog Myrtle (gagel)	9	3	2
Species of intermediate milieu			
Carex lasiocarpa Ehrh. - Slender Sedge (draadzegge)	9	4	3
Eriophorum gracile Roth - Slender Cotton-grass (slank wollegras)	9	5	2
Carex diandra Schrank - Lesser Tussock Sedge (ronde zegge)	9	6	3
Carex hostiana DC. - Tawny Sedge (blonde zegge)	9	6	2
Species of alkaline milieu			
Dactylorhiza incarnata (L.) Soó - Meadow Orchid (vleeskleurige orchis)	8	7	2
Parnassia palustris L. - Grass of Parnassus (parnassia)	8	7	2
Epipactis palustris (L.) Crantz - Marsh Helleborine (moeraswespenorchis)	8	8	2
Liparis loeselii (L.) Rich. - Fen Orchid (sturmia)	9	9	2
Species which have been classified indifferent with regard to acidity			
Carex dioica L. - Dioecious Sedge (tweehuizige zegge)	9	x	2
Calamagrostis stricta (Timm) Koeler - Narrow Smallreed (stijf struisgras)	9	x	2
Sanguisorba officinalis L. - Salad Burnet (grote pimpernel)	7	x	3
Oxycoccus palustris L. - Cranberry (veenbes)	9	x	2
Menyanthes trifoliata L. - Buckbean (waterdrieblad)	9	x	2
Valeriana dioica L. - Marsh Valerian (kleine valeriaan)	8	x	2
Succisa pratensis Moench - Devil's-bit Scabious (blauwe knoop)	7	x	2
Pedicularis palustris L. - Red-rattle (moeraskartelblad)	9	x	2

As a first approximation, Ellenberg's ranking of species for the water, nutrient, and acidity factors has been analysed (van Wirdum & van Dam 1984, Looman, unpublished). The resolution of this ranking (Ellenberg, 1978) is diminished here to a 4x3x3 matrix of 'scaled-down Ellenberg milieus', as in Table 6. Londo lists which phreatophytes 'are characteristic of the relatively constant (less dynamic) and/or relatively oligotrophic and/or vulnerable habitats, or are (relatively) rare species of more dynamic and/or eutrophic habitats'. This phrase obviously signifies threatened species, which are indicative of highly protective ecodevices, i.e., very valuable natecs. They are called 'midy-haters' for reasons which are not explained here. Table 6 presents the numbers of Dutch midy-haters according to Londo in the 4x3x3 matrix of Ellenberg milieus, together with the sum total of Dutch species in each class. Species which Ellenberg has not classed under any singular milieu have been disregarded, however. Thus, one third of the Dutch flora is covered.

There is an obvious clustering of midy-haters in the 'poor & wet' classes. When it would be possible to classify any real site (of ca 250 x 250 m^2) in any singular one of these classes, there would at least be a basis for a physically realistic impact model for natecs according to a case-1 or case-2 approach (4.1). In such a model, one could treat all species which are classed under the same Ellenberg milieu as one biologically homogeneous group, as in the WAFLO model.

Checking the list of midy-haters for each of the three 'poor & wet' classes, it appears that this is correct for the water and nutrient factors, but not for the acidity factor. A more or less representative sample of the species involved is given in Table 7, which includes some species that are considered indifferent with regard to the acidity factor. These species can be found together at 30 x 30 m^2 sites! They are even more often found together than alone: 'Rare species never come singly'. As far as such sites have not yet gone lost, they belong to the most valuable ones for nature protection in The Netherlands. The involved species are indicative of species-rich sites which exhibit a great variety of operational environments with respect to acidity.

Meanwhile, Tables 6 and 7 confirm the statements under items 3 and 4 in Table 2 with regard to nature protection. The wet and very wet milieus are all characteristic of an excess water supply. Table 7 reveals a dominance of F9 species, which is also reported for actual nature reserves by Dijkema et al. (1985). According to Ellenberg, F9 species are 'wetness indicators, especially on badly aerated soils'. The water use by the vegetation is apparently not a critical factor here. With regard to the N figure, N2 species are most frequent in Table 6, forming a category in between N1 ('only on soils, very poor in mineral nitrogen'), and N3 ('mostly on poor soils'). Since the majority of the involved soils in natecs are rich in humus or peat, i.e., organic nitrogen compounds, the poor aeration apparently controls the mobilization of nitrogen, as acknowledged in item 3b of Table 2. The recognition of such indirect controls is formalized in the WAFLO model. In VEDES, it relies on the contents of the transition matrices, which are rather informally derived.

With regard to water-quantity parameters, it may be concluded that a case-2 approach (4.1) is probably allowed, justifying the treatment of these parameters in the WAFLO model, and the ongoing modelling efforts discussed by Kemmers (1986). A body of knowledge, acquired by the agricultural sciences can thus be profitably used. The wide span of the acidity figure, F1 ('only on very acid soils') to F9 ('alkalinity and chalk indicators'), reflected by item 4b (Table 2), will be a subject of further discussion here (see 5).

4.4 Phytosociological homogeneity is different from milieu homogeneity

With regard to the sites in the current models, the homogeneity concept, as relevant to the operational environment of plants, will now be compared with the homogeneity concept in phytosociology, which is used to limit sites, especially in the VEDES ecotope system. Most of the species in Table 7 can be met with in, or are even characteristic of, syntaxa which belong to the Parvocaricetea class of rich-fen communities and the Molinietalia order of species-rich meadow communities, respectively (Westhoff & den Held, 1969, Oberdorfer, 1979, van der

Meijden, 1983). The involved syntaxa (classes which comprise all more or less similar arrangements of species found in nature) are in fact nodums in a phytosociological continuum, as is expressed by Westhoff & den Held (1969, p. 178). As far as the species show a syntaxonomically different range, stands of the relevant syntaxa are often found together in a fine-grained pattern. Accordingly, it is often possible to select such a level of phytosociological classification that sites appear homogeneous with respect to the vegetation, as is in fact done in the VEDES ecotope classification system. Several problems are attached to the implementation of this idea, however, of which two are mentioned here:

1) The syntaxon is not always easy to assess and the environmental data with respect to its preferred environment include several individual stands which may especially differ with regard to the presence or absence of threatened, but phytosociologically often **characteristic** species. It has thus been falsely suggested (see van Gijsen, 1979) that the value of a site for nature protection would not change if the environmental state would only stay within the range of tolerance of the relevant syntaxon as a whole, or of its **dominant** species. This point still plays a role in the VEDES ecotope system.
2) Opposite to what most standard texts (e.g. Westhoff & den Held, 1969, p. 25) suggest, the milieu of a syntaxon is fundamentally different from the milieu of a taxon (i.c., a species). The well-developed presence of a syntaxon is indicative of a particular spatial pattern of different species-milieus. The extreme milieus represent requirements, rather than being indicative of tolerance. This is especially well demonstrated by the natural association of slightly acid hummocks and alkaline hollows in several base-rich fen sites with covers of the mentioned Parvocaricetea vegetation.

It is obvious that the best solution to both problems is to take account of each individual species, or of ecological species groups, and to describe the sites by characteristic frequency distributions, rather than average values (Table 2, item 1c). This would acknowledge the awareness of the **requisite variety** of a site in order to have rare species.

5 THE ECODEVICE AS A VARIETY GUARD

Any species which is bound to a narrow range of states of the environmental complex can only exist there in the long run, when this range is guaranteed for a long time. Allthough it can not be concluded that threatened phreatophytes are bound to sites which belong to any singular Ellenberg milieu, it appears that many of them require 'poor & wet' sites with an internal variety of alkaline to acid types of operational environments. The impact problem for such a site is thus moved to the problem of safeguarding the dynamic equilibrium which controls the inhomogeneity of the site, rather than only safeguarding the operational environment of any of the individual species.

The stable, fine-grained gradient-zone between acid and alkaline circumstances within an ecodevice is basically supported by microrelief, and possibly reinforced by the response of the vegetation, as discussed for mires by van Wirdum (1979). In order to solve the impact problem, it is necessary to find out which of the hydrology-related ecological field properties is a necessity for the ecodevice to guard the existence of this so-called **poikilotrophic** (variegated) zone. When the soil, the relief, and the vegetation may be considered fixed initial state characteristics of the natec, the remaining causative variates are the amount and chemical composition of the rainwater, the hydraulic head and composition of the groundwater, and the composition and level of the surface water. From several investigations (Dijkema et al., 1985, Grootjans, 1985, Kemmers, 1985, van Wirdum, 1979, 1981), it has appeared that the frequency distribution of the hydraulic head of a singular type of alkaline, **lithotrophic** groundwater (van Wirdum, 1980, 1982a), and of surface water are controllable positional factors which determine the distribution of chemical types of water within the ecodevice. A change of these parameters will, after some time, cause the vegetation, and even the soil, to be altered. This is preliminary recognized in WAFLO by the 'instability of the environment' (Table 5), and by inferences from an 'ecohydrological map' (Reijnen et al., 1981).

The internal drainage structure of the ecodevice is a conditional factor in the variety control mechanism. It is sometimes possible to partially compensate the change of positional factors by an adjustment of the drainage system.

Several device properties, such as the relief, the soil type, and the vegetation structure are regarded fixed properties in the equilibrium state of an ecodevice. These properties play an important role, both physically and chemically, unless the device is of an open type (3.4). If the ecological-field 'tension' is changed, however, the fixed properties may also become altered. This is often a slow process. Initially, it may even appear that the ecodevice continues to work normally. The apparent stability of an ecodevice, as judged from the stable vegetation pattern, is caused by the same protective capacity which enables complex ecodevices to bridge natural periods of less favourable ecological-field properties.

The time needed to acquire a new steady state, in equilibrium with a changed positional environment, is probably of the order of magnitude of several centuries in many natecs (5 in Table 2). The disappearance of certain rare plant species may consequently lag behind a long time. It must be emphasized that the protective power which is responsible for the occurrence of such species is also responsible for their very slow reaction. The ecodevice, as it were, has a memory of the original equilibrium state. This is a major reason why validity testing of impact models which do not emphasize the kinetics of the change process is a very delicate matter, especially while several other influences may interfere during the equilibration phase. Such influences may comprise the atmospheric pollution and the presently severe problems of eutrophication and dung disposal in The Netherlands (cf. Table 1).

Many of the most important natecs in The Netherlands are rich in species which indicate that the ecodevice is in part fed with lithotrophic water, which is supposed to be derived from groundwater inflow, as in seepage areas (Dijkema et al., 1985). It is indeed uncertain whether these natecs still exist in a steady state.

6 CONCLUSIONS AND RECOMMENDATIONS

1) Impact modelling for nature conservation is more difficult than it is for agriculture. The ecodevice concept facilitates a separation of deterministic and stochastic aspects of the involved models. This has only been done in the WAFLO model.

2) The impact models WAFLO, VEDES, and ICHORS differ with respect to modular structure, accuracy, completeness, stage of development, and documentation. They are similar in the site concept. Further differences are not backed by convincing arguments. In the cases of ICHORS and VEDES sensitivity analyses are badly missed. The further stage of development of WAFLO is balanced by a pragmatic incorporation of modules which are possibly not very precise. The other models can hardly be judged at this point.

3) Natecs can be characterized by a requisite variety, which is partially supported by the water quality in the ecological field. It is recommended that systems for the description and classification of sites are checked with regard to their possible incorporation in models which emphasize these points. The development of such models requires more, and more cooperative, efforts than have apparently been given to the currently available models.

4) Validation of natec impact models is very difficult. In all conclusions, one must check for possible lagging of the ecodevice characteristics.

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DISTRIBUTION OF NUTRIENT POOR PLANT COMMUNITIES IN RELATION TO THE GROUNDWATER REGIME AND NUTRIENT AVAILABILITY

B. Beltman and A.P. Grootjans

ABSTRACT

Two approaches of organising the research with regard to the study of the conditional and positional relationships between plants, plant communities and hydrology are discussed briefly. The latter, the landscape ecological approach, is illustrated with examples from research in the Drentse Aa and the Vechtplassen area. Results from the distribution pattern research give directions to follow-up studies to habitat characteristics of plants (Calcium-richness, mineralization, availability of nitrogen and phosphorus etc.) and also to hydrological studies. Both directions of follow-up studies are illustrated with examples. Two hypotheses about the characteristics of the contact zone between water types, the poikilotrophic zone are postulated.

1 INTRODUCTION

In the Netherlands two approaches can be distinguished with regard to the study of the relationship between vegetation and hydrology.

A- One approach is focussed on the (conditional) aspects of the habitat characteristics such as the availability of soil moisture, nutrients or influence of toxins (Fresco 1983,

Verhoeven 1983, Vermeer 1985, Grootjans 1985, Kemmers 1985).
B- The other approach is focussed on the (positional) relationships of plant species distribution patterns and the hydrological systems (van Wirdum 1980, Both & van Wirdum 1979, Vermeer 1985, Grootjans 1985, Verhoeven et al. 1985 ,Everts & de Vries 1986 and Beltman et al. 1986) .

The first approach has led to hypotheses about plant/habitat relationships which were further tested by experiments under controlled conditions (Berendse 1981, Berendse & Aerts 1984, Pegtel 1983). This type of plant ecological research has been succesfully applied in heathlands and salt marshes which are relatively simple ecosystems, poor in species and occuring on mineral soils. For these types of habitats sophisticated computer models have been developed that are able to predict species composition, given habitat characteristics and management (Berendse 1985, Fresco 1986).

For research at the individual plant level many factors have to be studied in much detail e.g. the competition between two plants for light, space , different nutrients and their combinations, groundwater level and moisture conditions of the soil and rooting depth. For all these parameters the relationships between plants of the same species and of different species have to be studied as well as the combinations of the different parameters and for plants of different ages This is because seedlings might require different conditions than adult plants. It is clear that this is a long way to go and that results might be expected in relatively species-poor vegetation because there are so many factors and interactions to be considered. For a species-poor vegetation type like the heathlands with Erica tetralix and Molinia caerulea Berendse (1985) has built a sophisticated model in which factors such as nutrient availability, water conditions, competition between plants, mineralisation and decomposition and grazing by sheep are incorporated amongst others. This model predicts the development of the vegetation during 50-100 years under different sets of parameters or variations in them. Fresco (1986) built a similar model for salt marshes in which the vegetation response to desalinisation and grazing are simulated.

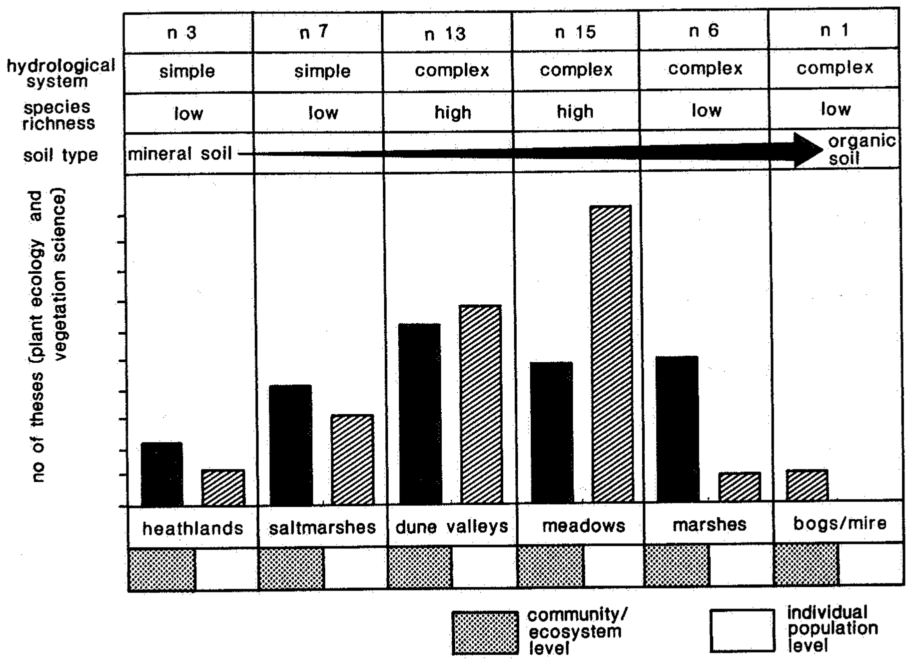


Figure 1 Plant ecological research on some Dutch terrestrial ecosystems measured by the output of theses from universities in the Netherlands.

To illustrate the lac of information on complex ecosystems on organic soils we classified about 40 ecological thesis, published in the Netherlands during the last 40 years, according to the habitat studied(fig.1). We distinguished between studies on individual or population level and the level of community or ecosystem and counted them for the different landscape units. We are aware that the number of theses is a pragmatic choice and that much research is published by other means, the figure makes clear however that a lot of research has been done during the last decades. Although a few more theses on mire ecosystems will appear within the next two years, we are far from simulating the complex interactions between, for exam-

ple groundwater quality and nutrient availability in organic soils of species-rich grasslands and mire systems. Since 1970 much plant ecological research has been focussed on these types of ecosystems, but most of the work on individual species has been carried out with annual plants (Rhinanthus sp.) or biennials (Cirsium palustre, Senecio aquaticus, Centaurea sp.) although the majority of the species of these ecosystems are perennials. The small number of perennials that have been studied represent a species group which is less relevant from a nature conservancy point of view (Festuca rubra, Anthoxantum, Lolium perenne, Plantago sp.).
At the vegetation level correlative research on habitat characteristics of species has been published, not only for the Netherlands (Kruyne et al. 1967, de Lange 1972) but also in other countries (Ellenberg 1974, Pietch 1976). This has led to rough estimations of indicator values of plant species for soil moisture, nutrient status etc.
Any approach that merely focusses on species performance in relation to habitat characteristics will fail to reveal the controling factors of species distribution in a landscape in which complex hydrological features are present. This is why plant ecologists studying mire systems or brook valley gradients, for example, have applied the system approach on a landscape level (van Wirdum 1982, Kemmers 1986, Vermeer 1985, Grootjans 1985).This way approach to research will be illustrated with a few examples.

2 RESEARCH CONCERNING DISTRIBUTION PATTERNS OF PLANTS AND HYDROLOGICAL FACTORS

For this approach as example from the pleistocene part the Drentse Aa catchment and as example from the holocene part of the Netherlands the Vecht area will be presented.
The brook valleys of the Drenthian Plateau receive most of their water from aquifers in the subsoil nourished by groundwater. Many of the hydrological systems and subsystems still exist (Engelen 1984) and in the brook valleys their influence is still

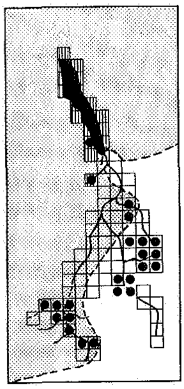


Figure 2

Map of study area, showing cells influenced by flooding (■) and those severely affected by amelioration works (▣). The water quality measured in the deep aquifer is indicated by the total hardness (▦ = $\geq$ 6D) and by chloride (▥ = $Cl^- \geq 20$ mg/l). From Grootjans (1985) .

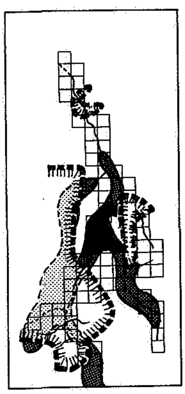
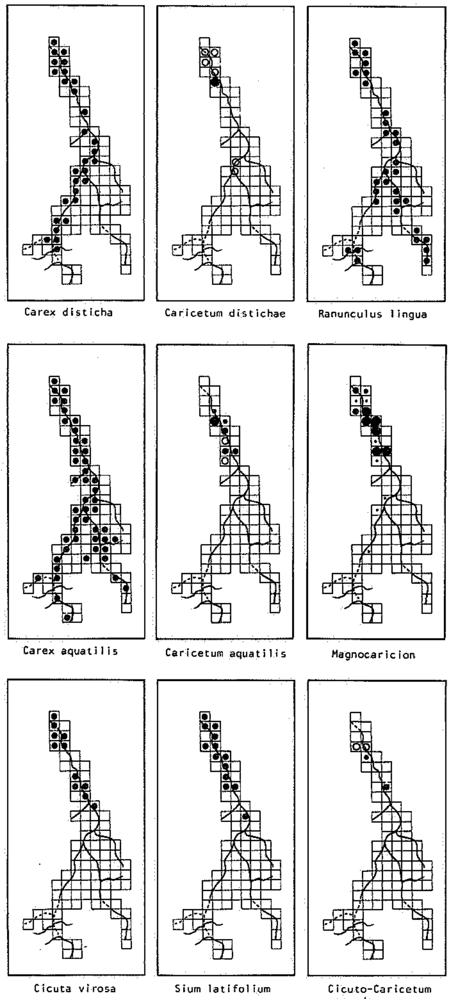


Figure 3

Map of the study area showing seepage and infiltration areas (■ = $\Delta\psi \geq 1$ m, ▦ = $0 < \Delta\psi < 1$, □ = $\Delta\psi \leq 0$).
$\Delta\psi$ = difference in hydraulic head .
Also depicted is a clay layer , covering the main aquifer . From Grootjans (1985) .



Symbols used in the distribution patterns of plant communities ,are as follows:

○ : the vegetation type is recorded only a few times within the km^2 investigated and covers at least 25 m²

• : the vegetation type is present in either many small patches (larger than 25 m²) or in some large ones.

● : the vegetation type is frequent

● ■ : the vegetation type is abundant

Figure 4 Distribution patterns of plant species and plant communities in the Drentse Aa valley .

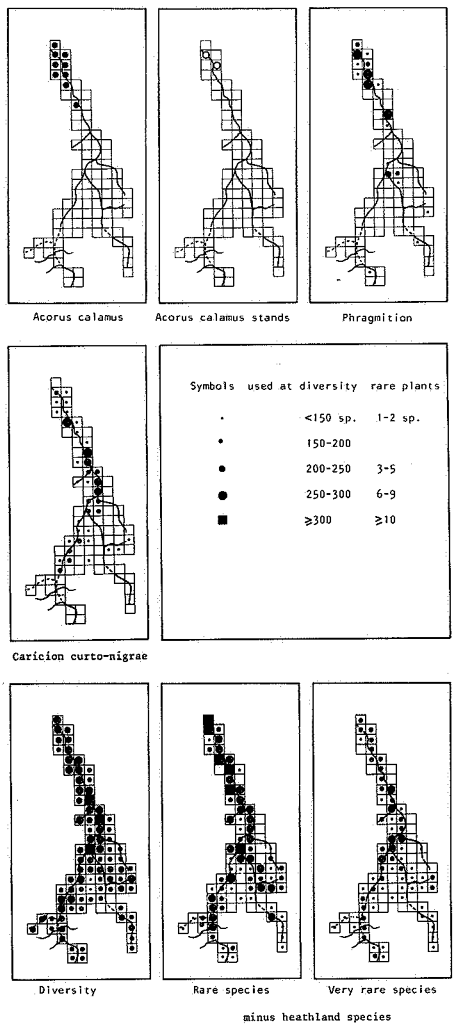


Figure 5 Distribution patterns of plant species , plant communities and some parameters in the Drentse Aa valley .

expressed in the distribution patterns of groundwater dependant plant species (phreatophytes). The sources of the different types of groundwater (deep-shallow) can be characterized with the composition of the groundwater (van Wirdum 1980). Most of the samples were taken in nature reserves because elsewhere the situation was too disturbed by human activities. Grootjans (1985) working in the the brook valley of the Drentse Aa characterized every square km of the area by hydrological parameters such as regularly flooding, seepage or infiltration(based on differences in the water table contour maps for deep and shallow groundwater), chemical analyses of the deep groundwater and human activities (amelioration works, groundwater abstraction). Some results are shown in fig. 2 + 3. Also the parameters of the vegetation were calculated at that large scale. Presented were rare plants/sq.km, distribution of oligo- , meso- and eutrophic vegetation types and their characteristic species /sq.km . Fig. 4 + 5 show that the distribution patterns are not random and that several plant species are restricted to special locations. One of the results of this research is, that the distribution pattern of the phreatophytes (and combination of these) can be used to give information about the distribution of different types of shallow groundwater. This long-term research over several years in the brookvalley of the Drentse Aa (Everts et al 1984 Grootjans 1985) can be used as a reference or guide to understanding the distribution patterns of vegetation types and hydrology in other , more disturbed brook valley systems. A second study that we will discuss here, was carried out in the holocene part of the Netherlands is situated North of the city of Utrecht. This area is mainly used for dairy production but in some nature reserves there are still examples of the natural peat forming vegetation. These nature reserves lay scattered between the fertilized meadows. The botanical research in this area (Vermeer 1985, Vermeer & Verhoeven 1985) can be explained from a distribution pattern point of view (see fig. 6). In the research area of 20 sq.km about 125 piezometers (filters between 2-8 m below surface) were placed and recorded every fortnight. Recording

		I.A.1	I.A.2	I.B.1	I.B.2	I.B.3	II.A	II.B	II.C
	Juncus subnodulosus	3 2.8	4 9.5	5 17.1	5 8.5	5 3.1		5 0.4	5 5.5
	Potentilla palustris	3 0.5	5 0.5	5 2.3	3 7.0	5 2.5	3 0.3	3 0.3	3 0.3
	Stellaria palustris	3 0.3	4 0.5	5 1.6	4 1.1	5 0.5	5 1.2		
	Galium palustre	5 0.7	4 1.1	5 1.4	5 0.8	5 1.5	5 5.0		
	Cardamine pratensis	5 0.5	5 0.6	5 0.7	5 0.9	5 0.7	3 0.5		
a	*Calamagrostis canescens*	1 0.1	4 17.0	5 3.1	3 0.8	3 1.5			5 3.0
	Betula pubescens	2 0.2	4 0.5	3 0.3	2 0.1	2 0.2			5 1.0
	Lythrum salicaria		2 0.1	3 0.4	2 0.1	2 0.2	2 0.3	2 0.2	
	Lycopus europaeus	2 0.2	3 0.3	4 0.3	3 0.3	2 0.3	3 0.5		
	Holcus lanatus	1 0.1	4 0.4	4 2.6		4 0.5	3 2.0		5 0.5
	Lysimachia vulgaris	1 0.1		4 0.5	2 0.3	5 4.0	2 0.3		3 0.3
	Menyanthes trifoliata	5 1.7	4 3.0	5 7.8	4 0.5	5 4.3			
b	*Equisetum fluviatile*	5 0.8	4 9.6	5 13.1	5 13.5	4 0.5			
	Peucedanum palustre	2 0.2	3 0.3	5 0.7		2 2.0	2 0.3		
	Iris pseudacorus	1 0.2	4 0.5	4 0.7	5 1.4	1 0.1	2 0.2		
c	*Carex acutiformis*	5 81.8	5 11.6	3 0.9	3 5.5	5 2.3			
	Equisetum palustre	5 2.0	5 5.0	3 3.4		1 0.1			
	Lemna minor	3 0.3	3 0.5	1 0.1		3 0.3			
	Poa trivialis	2 0.2	5 4.2	4 0.7	3 0.4	1 0.1			
	Ranunculus flammula	1 0.1	4 0.5	3 0.4	2 0.1	2 0.2			
	Glyceria maxima		5 4.5	1 0.4	2 0.3	1 0.1			
d	*Carex disticha*		4 1.0	2 0.4					
	Carex pseudocyperus		4 13.3	2 0.5					
	Filipendula ulmaria		3 3.0						
	Lathyrus palustris		4 0.9						
	Hierochloe odorata		3 4.0	1 0.1					
	Galium aparine		3 0.5						
	Carex curta		2 2.7	3 0.8	3 0.3	1 0.1		2 0.2	
	Caltha palustris	1 0.1		4 1.2	3 1.5			2 0.2	
	Mentha aquatica	2 0.2		5 0.7	2 0.1	1 0.1			
	Eleocharis acicularis			1 0.1	3 7.5	3 0.3	2 0.2		
	Lysimachia thyrsiflora		4 2.8	3 1.0	3 0.6	2 0.5			
	Carex diandra	1 0.1		5 10.0	3 3.0	1 0.1	2 0.2		
e	*Pedicularis palustris*	1 0.1		5 4.3	5 5.8	4 12.5			
	Carex rostrata		2 0.7	3 0.6	5 12.5	3 0.3			
	Ranunculus lingua		2 0.3	3 0.3	4 0.5	2 0.1			
	Valeriana officinalis	1 0.1		3 0.5					
	Myosotis palustris			2 0.3	2 0.1	1 0.1			
	Alisma plantago-aquatica			1 0.1					
	Cicuta virosa			1 0.2					
f	*Phragmites australis*	5 1.7	4 1.3	1 0.1		4 8.0	5 14.	5 0.5	5 0.4
	Sphagnum			1 0.1		2 0.3	5 18.	3 12.0	5 84.
	Agrostis stolonifera	3 0.2	2 2.8	2 0.2	2 0.3	5 2.0	5 36.		
	Thelypteris palustris	1 0.1				2 1.0	5 3.0		
g	*Typha latifolia*					2 0.3	3 5.3		
	Sparganium erectum						3 6.3		
	Rumex hydrolapathum		2 0.2	2 0.2		2 0.6	3 0.3		
	Carex lasiocarpa	1 0.1		2 1.0		3 1.5		3 15.	
	Juncus articulatus			1 0.1				5 2.0	
	Carex demissa	1 0.1						5 2.2	
	Molinia caerulea							5 9.0	
h	*Myrica gale*							5 4.2	
	Drosera rotundifolia							5 2.8	
	Hydrocotyle vulgaris	1 0.1						3 0.3	
	Carex riparia							2 2.0	
	Erica tetralix			1 0.1				2 1.3	
i	*Anthoxanthum odoratum*								5 0.5
	Carex paniculata								5 0.5
	Sample number	6	4	12	4	7	3	3	2

Figure 6 Synoptic table of types of mesotrophic fen communities in the "Vechtplassen" area . The first number is the frequency in which a species occurs in each type ; the second number is the mean biomass contribution (%) of each species . In the table the fen plots are divided into two main groups , sections I and II. The main difference in the species composition of the two sections is the absence in section II of the species groups b, c, d and e characteristic for section I and its subsections .

Section II is characterized by the dominance of peat-moss (Sphagnum sp.)and reed (Phragmites australis) . Most conspicious is a large group of species-rich fens(IB) characterized by low productive small sedges . A second group (IA) consists of fens poorer in species : they are dominated by highly productive species such as Carex acutiformis and are poor in in mosses. To the third group (section II) belong those fens which are poor in species and dominated by peat-moss (Sphagnum sp.). These fens are situated in infiltration areas . From Vermeer (1985).

the heads and carrying out chemical analyses of the ground- and surface water gave information at the "biological level" (Verhoeven et al. 1985, Beltman et al. 1986). The seepage and infiltration areas were assessed with the help of water table contour lines and differences in piezometric heads between deep and shallow groundwater. Even at the local scale the seepage water discharged mostly in ditches and under floating fens (Beltman 1986, Beltman et al. 1986b). The peat layer is very shallow here, due to peat digging. The resistence for upwelling groundwater therefore, was low. The STIFF-diagrams (see fig 7), the ionic ratio (sensu van Wirdum 1980) or the relative calcium quotient clearly show the differences between infiltration and seepage and the groundwater welling up from deep or shallow layers. Similar results were obtained by Kemmers (1985) studying Ca-enrichment processes in the Peel area.We also found that the discharging deep groundwater was less polluted than the shallow groundwater. The seepage isolates areas from others that are influenced by water inlet etc. in summer. The species rich fens are situated in areas where the seepage reaches the surface whereas the species poor (section II in fig.6) highly productive (a high production of above ground biomass each year) or Sphagnum fens (acid rain!) occur in infiltration areas. In our research area we discovered, as van Wirdum did in N.W.Overijsel, a distinct contact zone between water that can be characterised as "groundwater-like" (lithocline sensu van Wirdum 1980) and a "rainwater-like" (atmocline" sensu van Wirdum), which van Wirdum described as the poikilotrophic zone of a mire system. In this

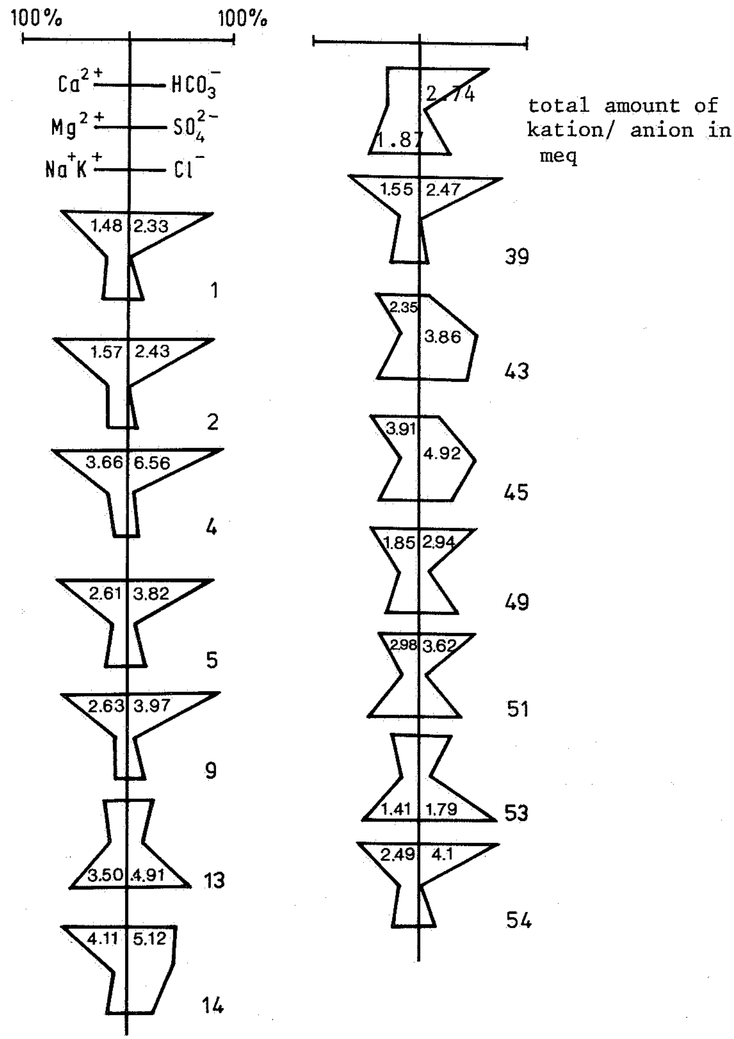


Figure 7

Stiff-diagrams , drawn from the yearly averages of 12 samples from the shallow groundwater in the "Vechtplassen" area. The diagrams for the groundwater from the seepage areas differ clearly from those for the infiltration areas . The latter can be subdivided in a type with infiltration of surface water (nr 13 and 53) and a type strongly influenced by infiltration of acid rain (nr 43 and 45).

contact zone the less productive vegetation types with rare species were found. Also in the Stobbe Ribben (N.W.Overijsel) the "natural" species composition and less productive vegetation type was found in this contact zone, the poikilotrophic zone (Kooyman, Verhoeven & van Wirdum 1985).

The above mentioned landscape ecological approach to study the relationship between plant species distribution and regional hydrological cycles will not only lead to hypothesis on habitat characteristics of species which are relevant from a nature conservancy point of view. The results of these studies can be useful for both biological and hydrological "follow up" research.

- If one is interested in why certain rare species are restricted to undisturbed seepage areas, one should study in more detail the vegetation response in relation to changes in habitat characteristics. The distribution patterns of species may give a clue where precisely the study sites should be selected in the field or which experiments should be carried out in the glass house under controled conditions.
- If one is interested in the hydrological factors controling the above mentioned habitat characteristics, distribution patterns of species may indicate where additional hydrological information can best be sampled.

Studies of the first category dealing with the vegetation response to changed habitat characteristics were presented by for instance Both & van Wirdum 1979, Vermeer 1985, Kemmers & Jansen 1985, Grootjans 1985 e.o.. Some results will be discussed briefly. In the Drentse Aa area, for instance,it was found that plant species restricted to locations with high Ca and HCO3 contents reacted strongly to even a slight change of the groundwater level. Mostly they disappeared within two and eight years. The replacement of lithocline water by atmocline water appeared to be significant here (Grootjans 1985). The studies of Kemmers, working in a nutrient poor fen vegetation (Circio Molinetum) near Amersfoort (Grootzandbrink) shed some light on this phenomenon. There appeared to be a very complex interaction between the Ca-content in the soil(solubility of Ca-P, Fe-P and Al-P salts), the discharge of lithotrophic groundwater and the availability of phosphate (Kemmers 1984,1986).

A second effect of drainage is the increased mineralisation of the dryer peat layer leading to a very high availability of mineral nitrogen up to 150-450 kgN/ha y Grootjans et al. (1985). This type of "fertilizition" is not uncommon in agricultural pastures, but in nature reserves it has devastating effects (see also Vermeer 1985 e.o.). The response of the vegetation appeared to be dependent on the nutrient conditions of the soil before the changing of the water table. In a wet meadow of the Circio-Molinietum type (nutrient poor litter fen) the production of above ground biomass decreased, whereas in a nutrient rich Calthion palustre meadow the biomass productivity increased (Grootjans et all 1985,1986). Kemmers (1985) suggested that acidiphication due to the stronger influence of acid rain results in an increasing release of phosphorus in these soils. In soils with a high amount of total phosphorus, therefore, the effects of increased N mineralisation may be more pronounced than in soils with a very low amount of total phosphorus. In both types of wet meadows the characteristic species disappeared In the Calthion meadow the species richness decreased considerably.

Experimental and field research on nutrient availability in floating fens (Caricion lasiocarpae) and litter fens (Junco Molinion) were in good agreement with the above mentioned field observations. Verhoeven(1986) and Vermeer (1985) showed for the floating fens and wet meadows of the Circio-Molinietum type that the species-poor, high productivity plots have a high amount of total N,K and P in the soil. This is in contrast to the species-rich but low productivity fens where the availability of K or P was low. The contents of total P&K differed significantly whereas total N did not. The experiments of Pegtel (1983), Vermeer (1985)and Berendse & Aerts(1983) showed that the amount and type of fertilizer as well as water table manipulations had distinct influence on the species composition and biomass production of the plots. A follow up study of the mineralisation of peat showed

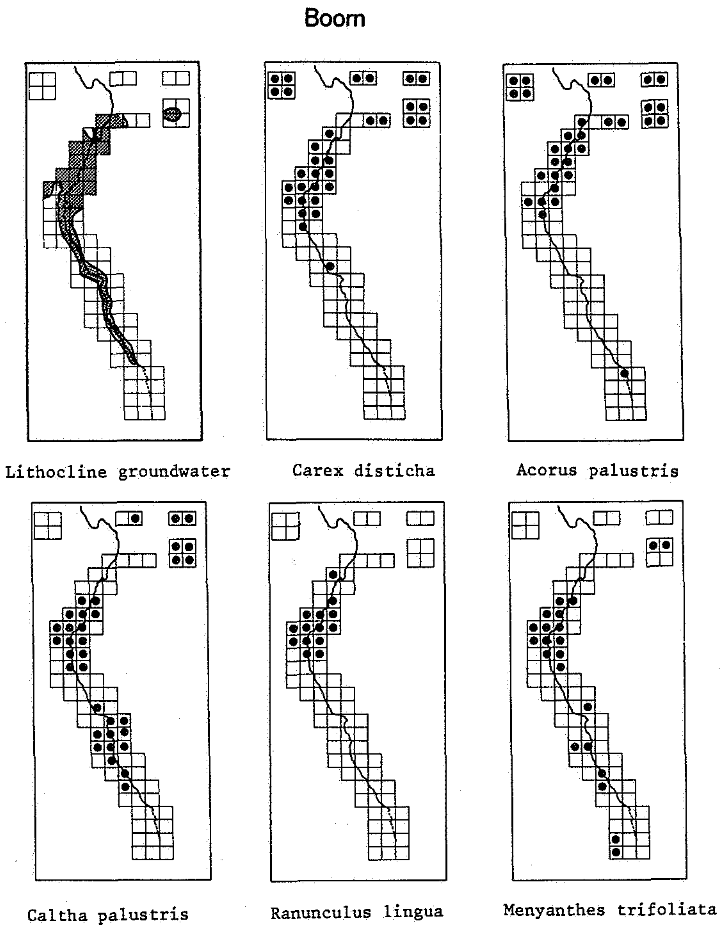


Figure 8 Distribution patterns of six phreatophytes in the Boorn valley in relation to the distribution of lithocline groundwater (0-120 cm below surface) . From Grootjans (1985) .

(Verhoeven 1985) that phosphorus and/or potassium were scarce. The limiting phosphorus factor appeared to take place in fens where seepage had been measured The upwelling water with high Fe and Ca contents resulted in formation of complexes with phosphate, which precipitate or remain floating as colloid particals. This is a very important second effect of seepage, which appear to regulate the growth conditions of the plants.

Many rare and protected marsh plants are found under such conditions namely: very wet, Calcium-rich and with a low availability of nitrogen, potassium and phosphorus in particular. These results may shed some further light on the characteristics of the poikilotrophic zone, the contact zone of water types. Possibly a special mechanisms is operating in this zone fulfilling the conditions of the location for the growth of many rare plants. If we look at the distribution of the plant species in the Boorne valley (see fig. 8) it is clear that the eutraphent Acorus is restricted to the lower course, whereas Ranunculus and Menyantes are restricted to the seepage zone. These distribution patterns that can also be found in many places near Utrecht, and it is possible to postulate another hypothesis on the poikilotrophic zone and the appearence of the rare plant species. If we look at some of the characteristics of this zone: very wet, Ca-rich, not acid and nutrient poor , then it is clear that in the peaty areas in the lower course of the valleys in the last decades the drainage has altered the wet conditions and mostly also the higher availability of N + P and the lower availability of Ca, whereas in the upper course the acidiphication (both rain and drainage) influences overruled fine gradients. Concerning these two events it can be postulated that the poikilotrophic zone might be the last zone where the "normal" succession of peat forming vegetation takes place. The plants do not have their optimum growth conditions there, but this is the only area where they still find their Ca-rich, clean groundwater. Support for this hypothesis is the distribution of Menyanthes trifoliata.

This is not a species indicating seepage but a species that requires clean water and the seepage is still bringing up clean (mineral rich but not eutrophic) water. It is obvious that this zone is very susceptable to changes and can be easily destroyed. It has to be protected and treated with the best possible means if we want to keep many threatened phreatophytes preserved for the Netherlands.

Distribution patterns of species may also be directing for further hydrological research in an area with many wet nature reserves. Everts & de Vries(1986), working in a brook valley system in Drenthe (Roden/Norg) have related distribution patterns of phreatophytic species with the geohydrological condition of the research area. Distribution patterns of some 20 species were used to formulate hypothesis on discharging groundwater flows. These hypothesis were compared with existing geohydrological data and tested at certain key sites by analizing the macro-ionic composition of the shallow groundwater. The distribution of 8 species is shown in fig. 9 in relation to the geohydrology of a part of the area. The distribution of the plant species is clearly different on the left and right bank of the stream. The STIFF-diagrams in fig. 9 show, that the source of the groundwater originates from different geological formations. This is an example that relevant information on the water household (relevant from a nature conservancy point of view) can be gathered with the help of plant/water relationships.

3 EVALUATION RESEARCH

To make results from research available for decisions made in policy two examples will be given.

-WAFLO (Reijnen & Wierts 1984) is a model that generates the knowledge from different research and field experience. For different parameters in the water-vegetation relation they postulate some quantitative relations based on literature and best professional judgement. Doing this they accepted a width for each parameter so that small fluctuations in these parameters

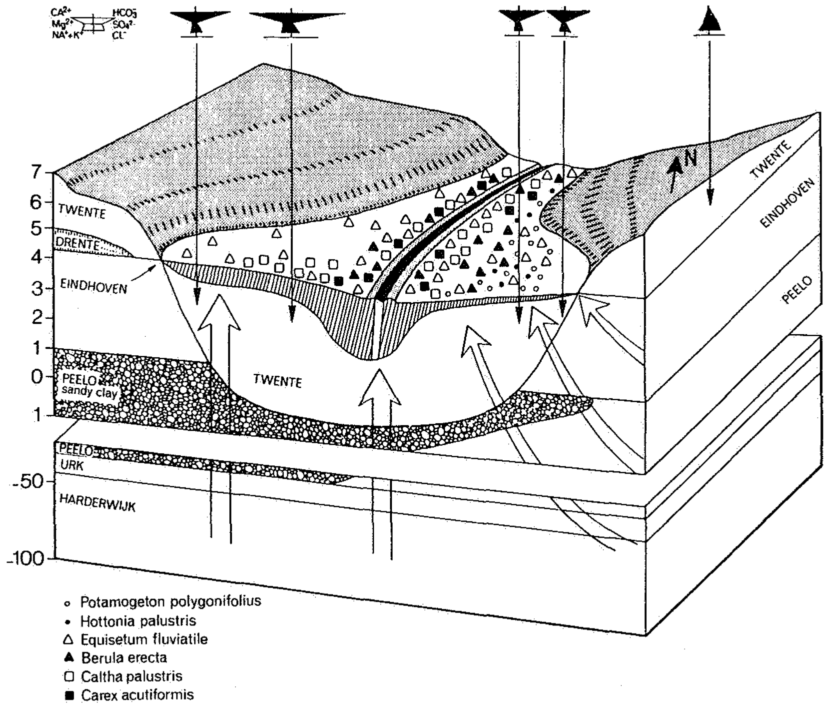


Figure 9 Distribution of eight plant species in relation to the geohydrology of a part of the brook valley system near Roden/Norg . The distribution of the plant species and the Stiff-diagrams show clearly the differences between the two banks of the stream . This figure was placed by permition of van der Wal & Langbroek . The research was carried out for the Government Service for Land and Water Use .

during the year or between years are incorporated. This model predicts the disappearence of plant species by different intensities of water table drawdawn.

- ICHORS (Barendregt et al. 1985) This model gives the possibility of encountering plant species in different water management obtions in regard to water quality. This model has been developed for a small area (75 sq km) and is based on correlations of 24 parameters and 200 plant species measured at 800 lokations (1/2-3 ha each). This type of model might only be

applied within the boundaries of the measured parameters. It can only give correlations with parameters measured.
As mentioned above the two ways of organising the research have already given a lot of useful information about the relationship between vegetation and water and nutrient conditions. Much has still to be done but in the mean time a direct contact and interaction of research, management and policy is needed to manage and conserve our wet plant communities.

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WATER IN RELATION TO FORESTS - A REVIEW OF RESEARCH AND KNOWLEDGE IN THE NETHERLANDS

J. van den Burg

ABSTRACT

In The Netherlands, relationships between forests and availability of soil water are imperfectly understood, as is the impact of forest on water management. Current research is reviewed and the state of knowledge is presented, based mainly on recent work done by SWNBL.

1 INTRODUCTION: Definition of the subject

"Forest" is defined as "a community of plants, its aspect being determined by trees". Forests grow on soils where water is never a limiting factor, but they also grow on soils where shortage of sufficient water affects their growth to a greater or lesser degree. This article is mainly concerned with the latter forests. Because forests usually have a considerable vertical demension compared with short vegetation and shrubs, the air above forests is turbulent, and this reduces resistance to water vapour transport, and hence alters the water balance. Advective heat is also an important factor enhancing transpiration from forests in The Netherlands, because although there are many forests, they are small, and scattered.

To measure all the terms of the water balance of forests is much more difficult than to measure the terms for short vegetations. However, increased knowledge of relationships between forests and water are more important than increased knowledge of relationships between short vegetation and water, if one is to understand the impacts of water management measures on forest growth and forest health. Therefore, researchers have concentrated on forests, rather then on forest vegetation.

It must by stressed that the aim of a forest does not play a role in these investigations. Forest policy in The Netherlands places high values on timber production, recreation and nature conservation. Relationships between forests and water are not influenced by these aims.

Water influences forest growth and health, and, conversely, forests influence the water balance. The influence on the water balance of an area is presumed to be different as regards the magnitude of terms in the balance equation, compared with agricultural crops and short vegetation (11).

The relationship between forest and water is too complex to be dealt with adequately. Therefore, as the starting point of this lecture I have chosen the research initiated by the SWNBL in 1983, which consisted of a review of the literature on water management and the water relations of forests. This involved summarizing the information already compiled in two internal reports. I shall also briefly discuss other related topics, and the present state of knowledge.

2 PRESENT STATE OF RESEARCH

2.1 Literature survey

The literature survey on water management of forests, done in 1983-1984, followed two themes: a study of the transpiration and water interception of forests (the ICW contribution) and a study on the influence of water on the growth and health of forests (the Dorschkamp contribution). Both studies have been published as SWNBL reports (14, 19).

The main conclusions of the authors are:

- Models describing transpiration and interception of water by forests have been developed in some countries. These models will be useful for forests in The Netherlands, but first their parameters must be re-determined because the original parameters were derived under conditions that differ substantially from those in The Netherlands (climate, forest pattern). This requires technically complicated, time-consuming and expensive measurements.
- Models that describe the transpiration of forests must take into account both physical and physiological processes. Models mainly or completely based on physical processes, such as the Penman model, are less suitable. A very important factor is the crop resistance, r_c, which depends both on stomatic resistance (r_s) and on Leaf Area Index (LAI) ($r_c = \frac{\bar{r}_s}{LAI}$). Crop resistance is influenced by physiological processes. Ways of estimating LAI reliably are currently being investigated in many studies dealing with relationships between water consumption, leaf area, photosynthesis and biomass production.
- Knowledge in The Netherlands about rate of root growth, final rooting depth and rooting intensity of trees is very limited. However, a factor such as rooting depth is very important. Models describing transpiration of forests are very sensitive to variation of this factor.
- Little is known about relationships between forest growth and water management. The only results (3, 4, 8, 9, 10, 12) are from empirical studies. Data based on studies in forests in which the water table has been lowered provide information about extreme cases only (18).

2.2 Water table research

This type of research is being carried out by "De Dorschkamp" in a field trial in which water tables are being manipulated. Two trials with poplars and certain other hardwoods were completed during the periods 1970-1972, and 1973-1979. The results have been analysed in internal reports, but have not yet been published (6, 7). Results of research with apple trees have been done by the IJsselmeerpolders Development Authority (22).

2.3 Falling water table, and forest growth

An inventory of stands threatened by falling water tables was made during the early 1970^s, but only one forest area was considered to be suitable for further research on the effect of falling water table and forest growth: the "Oldenzaalse Veen" estate, which has Scots pine as dominating species. Growth data about changes in the water table were collected during the period 1975-1981. Two stands of Scots pine, where the water table was not influenced by abstraction of drinking water, were selected for further research.

Annual basal area increment was deduced, taking into account competition between individual trees. A model called LAMOS was used for the computation of the water stress. Water stress was computed as the annual difference $E_{pot} - N$ (E_{pot} = potential evapotranspiration; N = precipitation). E_{pot} was formulated as "f". E_0, in which "f" includes interception as well as transpiration. The correlation between water stress during the vegetation period and annual basal area increment was ascertained. A good correlation ($r = -0.68$) was found for one stand. The basal area increment of the second stand was not influenced by water stress, but an inspection of the rooting system revealed that the roots had penetrated to a depth of nearly three metres (26).

2.4 Growth and site factors

Relationships between soil water availability, soil fertility, and site index have been collected in a handbook for stand establishment and stand treatment for forests in The Netherlands (1). Soil water availability is computed as the amount of water supplied from the rooted zone, plus the subsequent delivery from the water table. Current research is being done on growth-site relationships of Euramerican poplar, beech and pedunculate oak. One of the aims of these investigations is to ascertain what amounts of soil water have a significant effect on tree growth.

2.5 Research on interception

Trees intercept 15-40% of the annual precipitation, but the exact amount intercepted is difficult to forecast. The present tendency is to develop models that describe interception - mainly of conifer stands - as a function of a few parameters only. In The Netherlands, this problem is being tackled by analysing data from the lysimeter in Castricum. The tree species being studied are black pine and oak (16, 20).

2.6 Impact of forest on water management

Only one study has been done in The Netherlands. It is reported in an ICW publication from 1969 (5). Furthermore, the effect of afforestation of heathlands, (including the repercussions for water management) in the Veluwe was analysed in 1960 (24). Current research is being carried out by the IJsselmeerpolders Development Authority. Additional knowledge has become available through the literature studies for SWNBL project 7 (14, 19).

3 CURRENT KNOWLEDGE ON WATER MANAGEMENT OF FORESTS IN THE NETHERLANDS

Our knowledge of the various aspects involved varies enormously. It may be summarized as follows:

- Existing knowledge and educated guesses about water management in forests have been analysed, and collected in a system for soil suitability classification for forestry, developed by The Netherlands Soil Survey Institute (13). This system permits rough forecasts to be made about the influence on forests on lowering the soil water table, if soil water table classes before and after intervention in the water table are known. However, this system uses only three crude classes of yield: "good", "medium" and "poor". A draw-back is that changes in rooting depth, and the reaction of a standing forest under various meteorological conditions are not well known, and must be guessed.

- Little is known about the relationship between tree growth and availability of soil water. Interaction between soil fertility and soil moisture supply in their combined impact on tree growth cannot be ruled out.
- Both water management and forest growth need to be quantified. Models to describe the water management of trees have recently been developed, but it is not yet possible to apply them, because parameters must be re-established for the meteorological conditions, in The Netherlands, and for the pattern of Dutch forests (i.e. many small forests, which raises the problem of advection). More attention must be paid to the study of factors that determine and limit rooting depth. Measurement of growth and production is not always simple, because in many old stands height growth cannot be used as a parameter, and therefore in such cases basal area increment must be estimated.
- Until more parameters of forest hydrology are known, only rough guesses can be made about the differences in quantity and in time between the water consumption of forests and that of arable land and pasture (5, 15, 17, 21, 23).

These conclusions may be sound disappointing to many partical foresters and water managers. Matters seem to have reached an impasse. This is why a working group on "Forest damage caused by pumping soil water" recently concluded that an interim method must be developed, to estimate the permanent damage that will result from lowering the soil water table, the impact this fall in water table will have on soil suitability for forestry, and its financial repercussions (2, 25).
It might therefore be worth collecting all scattered data about relationships between tree growth and soil moisture supply to ascertain whether there are some general relationships. If relationships are found, it might be possible te make crude forecasts about the major effects of changing the water supply of forests. Like the SWNBL studies of the literature on the water management of forests, this might be a starting-point for further research.

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PERSPECTIVES IN MODELING OF PROCESSES IN THE ROOT ZONE OF SPONTANEOUS VEGETATION AT WET AND DAMP SITES IN RELATION TO REGIONAL WATER MANAGEMENT

R.H. Kemmers

SUMMARY

On a regional scale topography can be considered as the most important state factor in the development of soil and vegetation. Topographical differences in altitude underlie flow patterns, recharge and discharge of regional groundwater. A sustainable pattern of hydrological and hydrochemical conditions occurs in the landscape. Through their influence on the main site factors as soil moisture supply and nutrient-availability these conditions cause the regional differentiation of vegetation.

Three-dimensional hydrological models simulating the regional water management are available to predict changes of local hydrological and hydrochemical conditions as groundwater levels and ion contents. The effect of these changes on site factors can be forecasted with local one-dimensional models. These models deal with moisture content and nutrient availability in the unsaturated zone.

By fitting the local models to the regional models the impact of regional water management on the main site factors can be predicted.

1 INTRODUCTION

The insistent call of waterpolicy making authorities for methods to evaluate impacts of changed regional water management on nature performance stimulated thinking about an acceptable approach to the development of models simulating the influence of water management on site factors.

Recent eco-hydrological research (Van Wirdum, 1981; Kemmers and Jansen, 1985a; Grootjans, 1985; Beltman, 1986) stresses the importance of both quantitative and qualitative hydrology on the master site factors: soil moisture, oxygen, nitrogen and phosphorus. The conceptual framework of this eco-hydrological approach, relating hydrology and site factors is shown in Fig. 1.

It is of practical advantage to restrict the problem in the first place

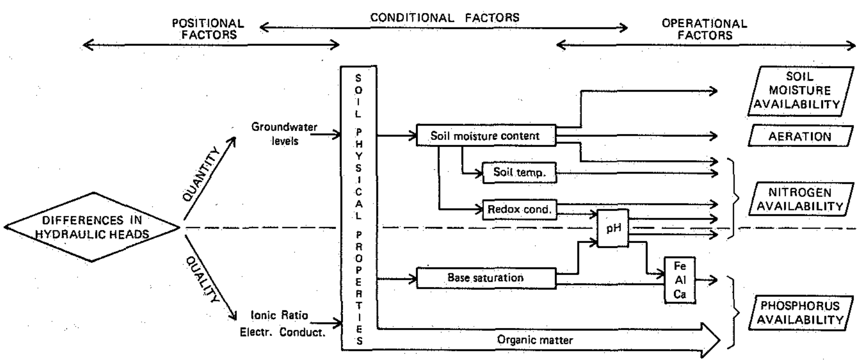

Figure 1 Conceptual framework of the eco-hydrological approach. Groundwater levels and hydrochemical composition (Ionic Ratio, Electric Conductivity) of any particular site mainly are determined by its topographical position in the landscape. They both have a distinct influence on conditions in the root zone. These conditions on their turn affect the processes that control the fluxes of the main site factors in the plant's operational environment

to master site factors. With the experience from agricultural sciences models can be developed that simulate these site factors in relation with water management in a global directive way. In the second stage more advanced models may be composed with additional knowledge still to gather.

In chapter 2 the important hydrological and hydrochemical conditions and their role in the vegetational differentiation of the landscape are reviewed. Chapter 3 shows the perspectives of modeling the influence of regional water management on those site factors that are of main importance to vegetational differentiation. Concluding remarks are given in chapter 4.

2 THE HYDROLOGICAL FACTOR AND MACRO-ECOLOGICAL PATTERNS

2.1 Theoretical considerations

In his classical vision of the landscape Jenny (1946, 1958) distinguished between dependent and independent factors. The genesis of soil, vegetation and landscape is mainly controlled by the independent state factors climate, biology, topography, parent material, and time.
On a regional scale climate, biology and parent material are supposed not to have any spatial variation in a first approach (Kemmers, 1985). Consequently only topography and time are responsible for differences in the development of soil and vegetation. Via differences in altitude the topographical factor causes groundwater flow from subregions with high hydraulic heads to subregions with low hydraulic heads. As a result hydrological differentiation occurs, which is fundamental to distribution of soil types and to macro-ecological patterning in the landscape (Grootjans, 1985).

On a local scale heterogeneity of soil texture, micro-climate, ground levels etc. can add some extra variation and refine the hydrological base pattern. This sublocal variability does not fit the scale of water management in practice and, being noise, must be neglected firstly for modeling purposes.

Spatial extrapolation of hydrological point observations within any soil type to uniform planes belonging to that soil type is acceptable. By bordering the subregions according to distribution of soil types in modeling the regional water management, each subregion can be considered as a fysiotoop with uniformity of the soil and hydrological factor. This will be reflected by a homogeneous composition of the vegetation to a certain degree. The fysiotoop can be treated as the site of any vegetation. The soil and the hydrological factor of the site are conditional to the site factors.

Theoretically each subregion can be treated now as a site of a vegetation, characterized by uniformity of the soil-water-plant system.

2.2 Environmental conditions

In several parts of the Netherlands detailed eco-hydrological research has been carried out in the last decade. Fig. 2 shows the distribution of the study areas. From these studies both a general concept of the positional relationship between the different sites in the hydrological system and the common denominators of the relevant hydrological and hydrochemical conditions of those sites can be derived. This concept is presented in Fig. 3.

In the Pleistocenic part elevated sandy soils alternate with brook-valleys constituting drainage basins of different hierarchical levels. Both recharge (downward seepage) and discharge (upward seepage) areas (Eriksson, 1984) with hydro soils are present. Hydro soils are constituting a suborder level in the system of soil classification for the Netherlands (De Bakker and Schelling, 1966). These soils are permanently or periodically saturated with water.

Several hydro soils on the subgroup level are widely distributed and are belonging to the common soils of the Netherlands: 'Veld'podzol soils, 'beek'earth soils, 'polder'vague soils, 'koop'peat soils, 'made' peat soils and 'vliet'peat soils. The distribution of these common soil types throughout the landscape is strictly bonded to the geo-hydrolog-

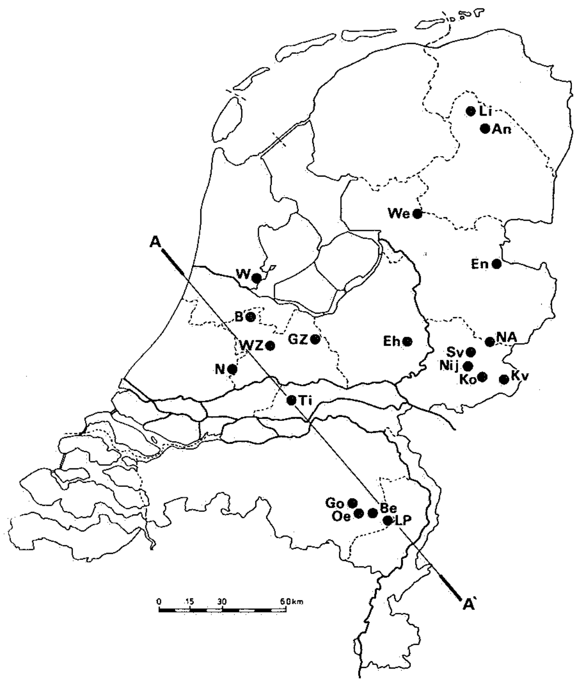

Figure 2 Map of locations of eco-hydrological research in the Netherlands. Ti: Kemmers and Jansen (1979); LP: Ludwig (1980); En: Van Wirdum (1980); Eh, Nij, Ko: Both and Van Wirdum (1981); GZ: Jansen and Kemmers (1982); An: Altenburg and Wildschut (1983); Oe, Go, Be: Jansen (1984); NA, We, Sv, W, B, N: Dijkema et al. (1985); Li: Grootjans (1985); WZ: Beltman et al. (1986); KV: Mankor (pers. comm.)

ical system (Fig. 3a).

Hydrological conditions

The prevailing hydrological conditions of the sites of the different soils can best be shown in making cumulative frequency analyses of groundwater levels and by plotting them as depth-duration-frequency curves. The picture of the generalized duration curves in Fig. 3b is derived from detailed hydrological studies (Kemmers and Jansen, 1979; Grootjans and Ten Klooster, 1980; Jansen and Kemmers, 1982; Jansen, 1984;

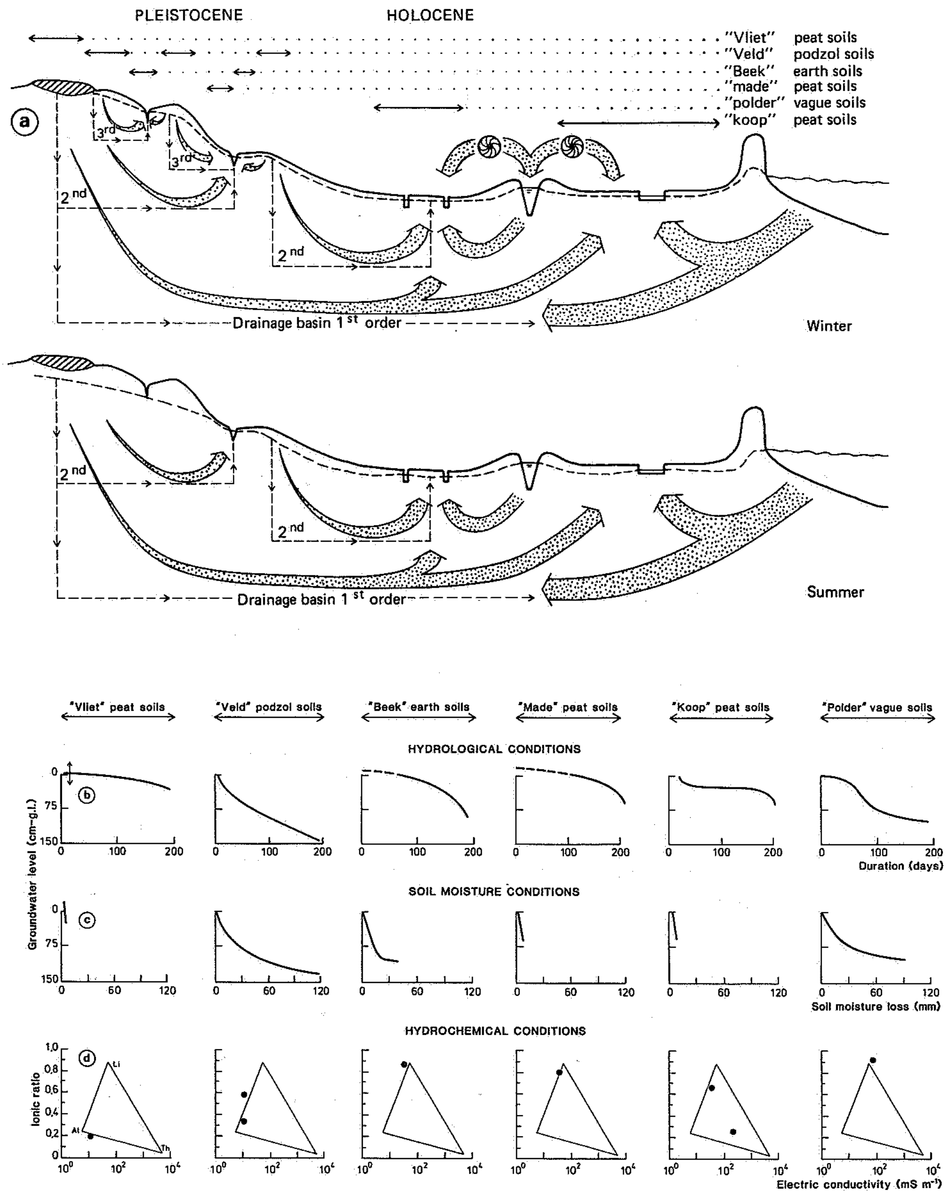

Figure 3 Flow patterns of groundwater in an idealized SE-NW transsect of the Netherlands (A-A', Fig. 2). Groundwater discharge to drainage areas has a permanent character but may be periodically in catchments of a lower order. Soil and vegetation development is strongly dependent on regional hydrology. Soil

types are positioned in the landscape according to hydrological conditions (a).
Main environmental conditions of some common soil types are presented in b-d. b: Hydrological conditions as depth-duration-frequency curves of groundwater levels; c: Soil moisture conditions as soil moisture loss related to groundwater levels; d: Hydrochemical conditions as the Ionic Ratio versus Electric Conductivity. The vertices (At, Li, Th) represent reference values of atmotrophic, lithotrophic and thalassotrophic groundwater types

Beltman et al. (1986); Mankor (pers. comm.)). It is obvious that sites in discharge areas have longer periods of high groundwater levels than sites in recharge areas.

Sites of 'beek'earth soils differ from other sites in discharge areas by the ceasing of the discharge in dry periods and an occurrence of low groundwater levels only during short periods.

Although their duration curves are nearly identical, sites of 'vliet' peat soils (bog type) derive their wet conditions from a very low infiltration capacity of the subsoil to rainwater, whereas the sites of 'made'peat - and 'koop'peat soils (fen type) render their wetness to discharging groundwater.

Often being located in polders the sites of 'polder'vague soils show a marked influence of the artificial lowering of the surface water levels in springtime and a rapid fall of groundwater levels. During summer the groundwater levels are maintained by subsurface infiltration from the ditches. The ditches can be supplied by river water.

In the Holocenic western part of the Netherlands 'koop'peat soils are typical to reclaimed fen type peatland. The influence of superficial drainage can be detected by the very short period of high groundwater levels as shown in the corresponding duration curve.

Soil moisture conditions

Soil moisture conditions in the unsaturated zone of the sites can be characterized by totalizing soil moisture loss from the unsaturated zone and relating this loss to groundwater levels (Jansen and Kemmers, 1979, 1982; Jansen, 1984). From the general picture in Fig. 3c it can be deduced that the storage capacity of sites in discharge areas generally is very small (2-5%). In sites with mineral soils the storage capacity will increase exponentially if they are drained. This will result not only in changed aeration of the root zone but also in an increased dilution of the soil solution as will be shown later.

Hydrochemical conditions

Not only quantitative hydrological conditions are responsible for soil and vegetation development and patterning. By ion exchange, dissolution of calcite or weathering of calcium bearing minerals in the parent material the groundwater will be enriched predominantly by Ca- and HCO_3-ions during its flow from recharge to discharge areas. Differentiation of hydrochemical conditions in the landscape is the result.

In recharge areas the groundwater can be characterized by a low Electric Conduvtivity and a low Ionic Ratio (Ca/(Ca+Cl), Van Wirdum, 1980). Discharge areas are supplied by groundwater with a high Electric Conductivity (EC) and a high Ionic Ratio (IR), which generally will increase the proton neutralization capacity of the topsoil (Kemmers and Jansen, 1985a). Consequently soil development is affected by different hydrochemical conditions that are shown for the several sites in Fig. 3d using IR-EC diagrams.

The IR-EC diagrams show mean values of samples from the phreatic groundwater of sites with different soil types. Data are derived from: Kemmers and Jansen, 1980; Ludwig, 1980; Van Wirdum, 1980; Both and Van Wirdum, 1981; Altenburg and Wildschut, 1983; Dijkema et al., 1985; Grootjans, 1985; Beltman et al., 1986; Mankor, pers comm.; Kemmers, unpubl. results.

It can be deduced that groundwater of recharge areas has a strong affinity to the atmosphere, whereas the atmospheric influence in discharge areas is of no importance. It must be concluded that the low storage capacity of discharge areas prohibits infiltration of rainwater and hence dilution of the local lithotrophic groundwater in wet periods. As a result surplus of rainwater has to be discharged via surface runoff or interflow. Conservation of this rainwater surplus and subsequent infiltration may dilute and finally substitute the original lithotrophic groundwater in the root zone (Zeeman, 1986).

Due to superficial drainage of 'koop'peat soils the rainwater influence becomes more manifest at those sites, reflected by a lowered Ionic Ratio compared with the sites of 'made'peat soils near the brook valleys. At sites of 'koop'peat soils near the coast the influence of seepage of seawater can be detected in the IR-EC diagrams. So both lithotrophic and thalassotrophic waters can occur there, as is shown in Fig. 3d. Van Wirdum (1979) points to the importance of transition zones in the landscape where the different spheres contact each other and very specific plant species can be met.

2.3 Site factors

The differentiation of hydrological and hydrochemical conditions in the landscape do have more consequences than affecting soil moisture supply annex soil aeration and amount of minerals only.

Nitrogen supply

The yearly course of the groundwater level determines the fluctuations of soil moisture content and soil temperature (Feddes, 1971). The hydrochemical composition of the groundwater determines the base saturation of the cation exchange complex and affects soil acidity consequently (Kemmers, 1985). Soil moisture, temperature and acidity are supposed to be the main variables controlling the mineralization and humification of organic matter in the soil. The net result of these two

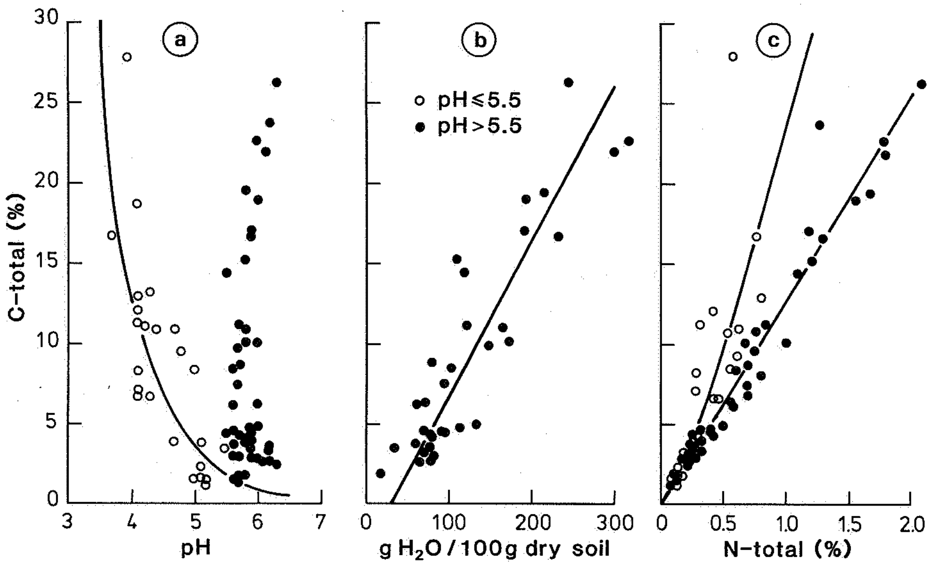

Figure 4 Carbon and nitrogen contents of the top layer of some hydro soils in relation to hydrological and hydrochemical conditions. a: Total carbon content related to soil acidity; b: Total carbon content of near neutral soils (pH > 5.5) related to soil moisture content; c: Relation between carbon and nitrogen contents of acid soils (pH < 5.5) and near neutral soils (pH > 5,5). Nitrogen release is blocked under acid conditions due to accumulation of raw humus and under near neutral, wet conditions as cause of accumulation of mild humus. Nitrogen release from the organic matter is favoured under moist and near neutral conditions

processes is the main source of the essential nutrients nitrogen and phosphorus.

Fig. 4 shows carbon and nitrogen contents of the top layer of different soils in relation with soil acidity and soil moisture (Kemmers and Jansen, 1985b). High contents of carbon are found under both acid and near neutral conditions (Fig. 4a). If conditions are becoming more acid, as is the case in acid 'beek'earth and 'veld'podzol soils (pH < 5,5), accumulation of raw humus occurs. This can be derived from the increase of the C/N ratio of these soils, due to a decreased humification of plant litter (Fig. 4c). If conditions of soil acidity are near neutral, as is the case in 'made'peat and 'beek'earth soils the relatively high base saturation (pH > 5.5) favours an intense humification of plant litter. This can be derived from the low and constant C/N ratio, of about 12.5.

If conditions are getting wetter in these near neutral soils (Fig. 4b) the mild humus cannot be mineralized and will accumulate.

It can be derived from Fig. 4 that the nitrogen release from the organic matter is strongest under near neutral and not too wet conditions. Under acid and very wet conditions on the other hand the release of nitrogen to the vegetation is blocked.

Phosphorus supply

Soil acidity and the metal ions Ca, Al and Fe are supposed to play an important role in the precipitation of inorganic phosphorus after its release from the organic matter by mineralization. Orthophosphate concentrations from the topsoil of different sites are plotted against soil acidity and related to the solubility of some important phosphate salts (Fig. 5).

Under acid conditions phosphate contents do not obey to the expected theoretical solubility of salts. From about pH > 4.5 concentrations seem to follow the theoretical solubility of Al-P, Fe-P and Ca-P salts. It might be concluded that the phosphate availability to the vegetation of 'beek'earth and 'made'peat soils with lime potentials >4.5, due to the discharge of lithotrophic groundwater (Kemmers, 1984) are controlled by the calcium ion. The maintenance of regional groundwater flow to these discharge areas is of conditional importance to the phosphorus supply of the vegetation.

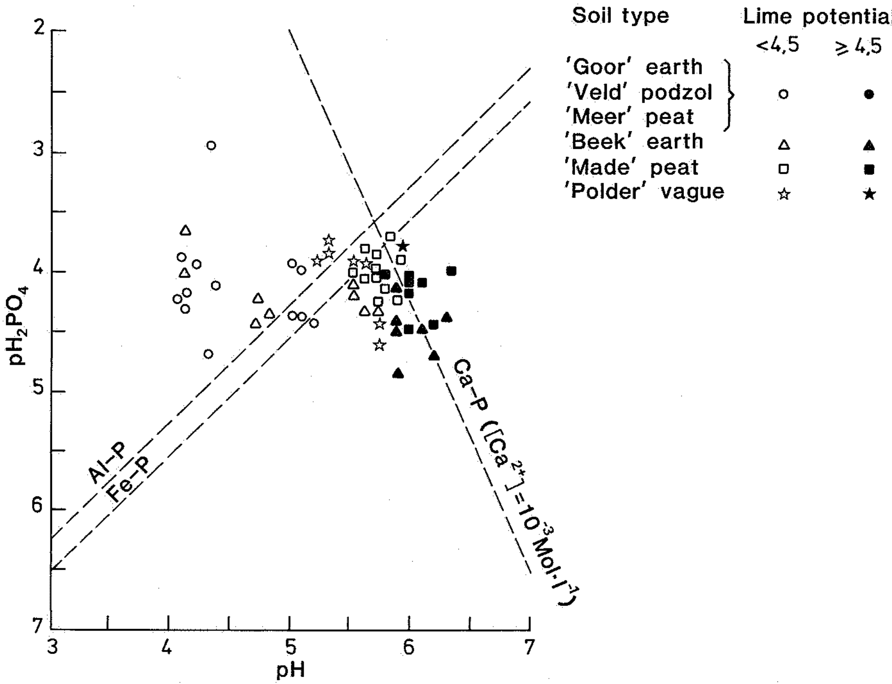

Figure 5 Solubility lines of phosphates of aluminum, iron and calcium in relation with soil acidity. Samples are collected from the topsoil of different sites. A distinction was made between the lime potential (pH - 0.5pCa) of the sites, being high (>4.5) if the site is supplied with lithotrophic groundwater. Lime potentials of sites supplied with rainwater are low (<4.5)

3 PERSPECTIVES IN MODELING

An outline of activities involved in the regional water management (Claessen, 1986) and of the type of models needed to predict the local impacts of these activities is depicted in Fig. 6.

Two categories of models can be distinguished. Firstly we need three-dimensional regional models simulating the regional hydrological system. Their point of application is the saturated zone of the hydrological

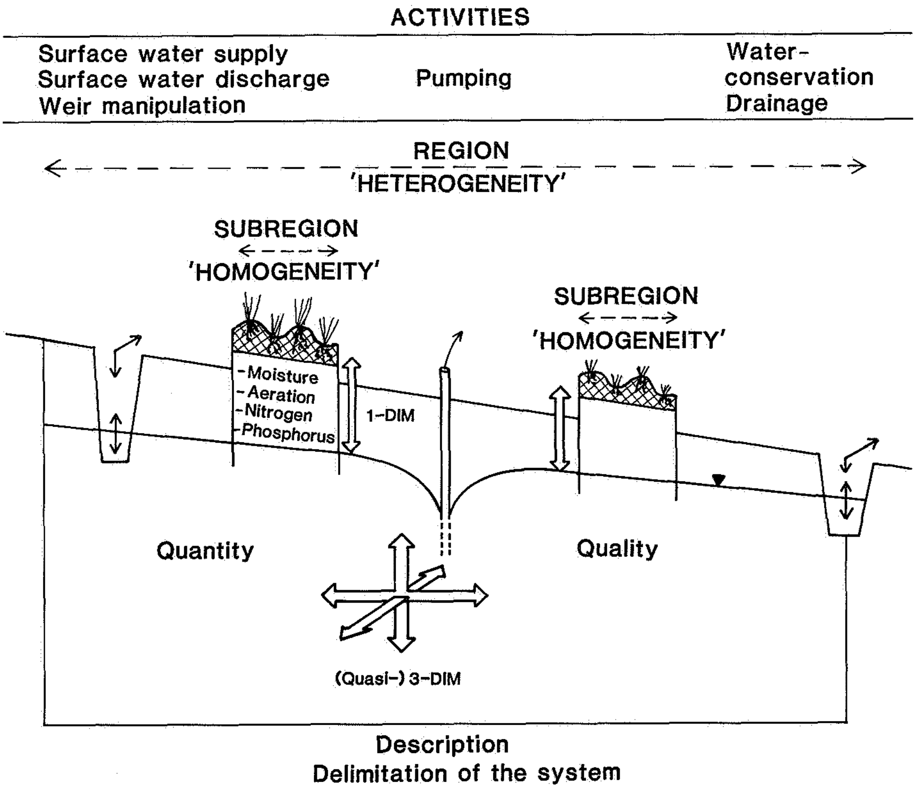

Figure 6 Outline of human activities to be included in models that simulate water management of a regional hydrological system. Three-dimensional water quantity and water quality models are necessary for the simulation of interlocal communication within a heterogeneous region. One-dimensional models being a communication channel between the groundwater level and the root zone of a subregion, are needed to simulate soil moisture, oxygen, nitrogen and phosphorus supply to the vegetation. Subregions are considered homogeneous both in soil properties and vegetational composition firstly

system. They have to describe both quantitative and qualitative processes.

The second category consists of one-dimensional local models. These models have to simulate the processes in the unsaturated zone dealing with the availability of water, oxygen and nutrients on the site. For practical application the local models must be limited in their resolution. They are supposed to consider subregions as sites which are homogeneous in soil properties and in the hydrological factor. Sublocal diversity, suggested with the undulating ground level in Fig. 6, has to be neglected firstly.

3.1 Regional models

To run regional models for the water management it is a prerequisite to describe the geohydrological system correctly. With the present knowledge and available methods no problems are to be expected in this stage.

Quantitative models

If the geohydrological system is known it is possible to select regional drainage basins within supra-regional basins by formulating lower and side boundary conditions (Fig. 7). Delimitation of the system is a practical requirement in modeling.

Further simplification can be obtained by supposing that vertical hydraulic gradients in aquifers do not exist. Consequently a quasi-3-dimensional system with only horizontal flow in aquifers and vertical flow in aquitards is created.

Subregions (sites) have to be selected based on the homogeneity of the hydrological factor and soil properties. Within each subregion drainage channels of different hierarchical order can be distinguished. A network of nodal points fitted to the pattern of subregions is needed as a framework to calculate the fluxes in the regional model. If initial conditions of groundwater levels or fluxes from the atmospheric system and all system parameters (transmissivity, resistance, etc.) are known all required input data are present.

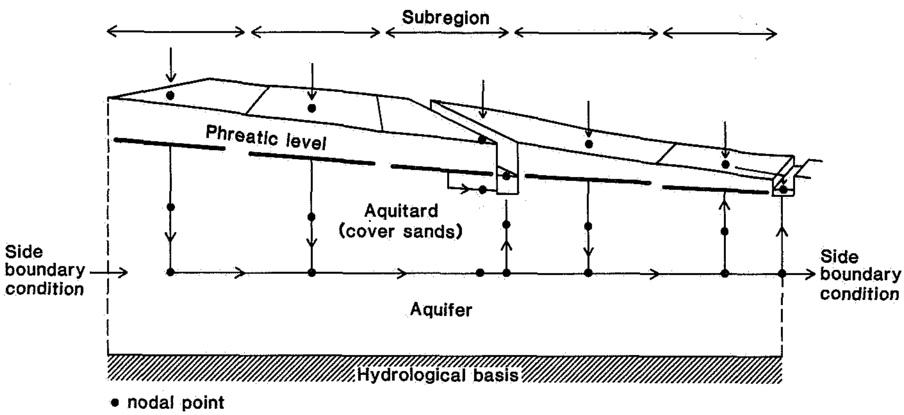

Figure 7 The regional geohydrology diagrammed for quantitative hydrological models. The area is divided in homogeneous subregions with a fitted network of nodal points. Boundary conditions are formulated and distinction is made between vertical groundwater flow in aquitards and horizontal flow in aquifers

Application of numerical solutions of the flow problem resulted in the development of several models simulating the regional groundwater flow, using the finite element or finite difference approach. These models calculate fluxes to and from nodal points in the saturated zone.

By the linkage of the unsaturated zone regional models also can simulate fluxes through the phreatic level to the root zone of subregions (GELGAM, De Laat et al., 1981; SHE, Refsgaard and Hansen, 1982; FEMSATP, Querner and Van Bakel, 1984). The output of model calculations can be presented as hydraulic heads or fluxes of water in place and time.

By linking the regional hydrological models of the saturated/unsaturated zone with an hydraulic model for channel networks, the influence of pattern, size and flow resistance of the drainage system on the discharge rate and the drainage capacity can be evaluated too (PREDIS, Crebus and Wesseling, 1983; SIMPRO, Querner, 1986). With criteria for minimum and maximum water levels during the year, ditch density and an assumed maintenance program, it then will be possible to calculate whether water levels are high enough to satisfy the required hydrological conditions of specified nature areas (Leemhuis-Stout, 1986).

Quality models

In contrary to the quantitative models the groundwater flow pattern has to be described in models for the water quality. The real pathway and the real velocity instead of the apparent velocity of the water particles has to be described which is a complicated problem.

Special attention has been asked for the development of models simulating the transport of calcium ions (Ch. 2.2). Calcium easily reacts with other components. So next to the flow problem these models should describe chemical interactions too (Fig. 8). Dispersion and diffusion of chemical compounds during transport through the aquifer is another problem to be solved.

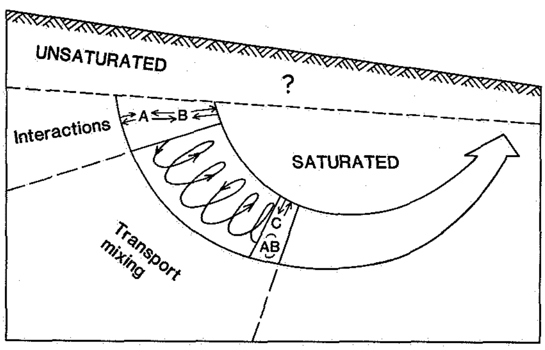

Figure 8 Regional models for water quality simulate real pathways of groundwater flow and interactions between chemical compounds. They are constructed to predict changes in ion concentrations after human interference with the hydrological system. Two-dimensional models describing the water quality of the saturated zone have been developed. Models linking the saturated and the unsaturated zone fail until now

A desk-study has been carried out to simulate the Ca-ion behaviour in a vertical cross section through the saturated zone of a drainage basin (Waterloopkundig Laboratorium, 1986). It turned out that new equilibria of the calcium ion after perturbation of the hydrological system settled only after long periods (tens to hundreds of years). Further elaboration of this model is going on and has to involve the third dimension and the linkage of the unsaturated zone as is not yet the case.

Main problem of water quality models is the verification of model simulations due to the slow progress of transport phenomena in the soil-water system.

3.2 Local models

Regional models are of importance in providing the lower boundary conditions of the 1-dimensional local models, which have to describe transport and processes in the unsaturated zone of the site.

Although the subregions are preferably supposed to be homogeneous firstly in order to develop global directive models, the resolution might be increased to any desired level. If the resolution is raised, however, one will be confronted with less important site factors that are responsible to minor vegetational differentiation, which was neglected in a first stage.

Moisture and oxygen supply

Main aim of the 1-dimensional models for the moisture supply is to calculate whether any shortage of water for evapotranspiration will result after changed groundwater levels or not. Both simple and laborious models can be applied (Fig. 9).

Simple 1-dimensional local models of the saturated/unsaturated zone can be used if the subregions are supposed to be homogeneous in order to evaluate the impacts of water management in a global directive way (e.g.

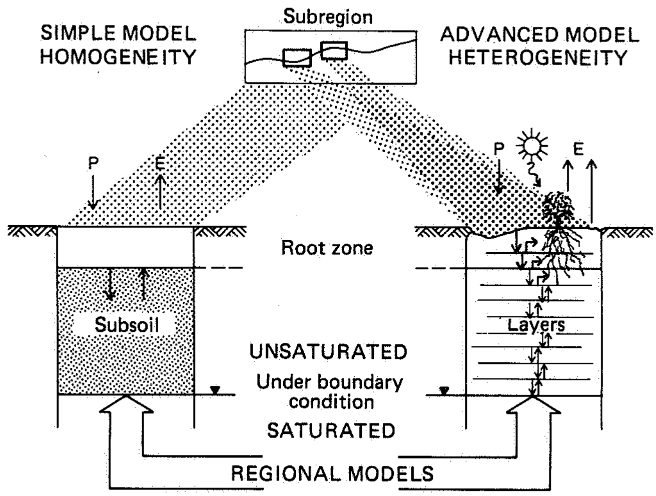

Figure 9 Local water supply in relation to hydrological conditions is simulated with 1-dimensional models. These models need the output of regional models as a lower boundary condition. Simple models can be used if subregions are considered homogeneous. Sublocal differences can be evaluated by application of the model to a restricted area within the subregion, by means of sublocal input data. P, precipitation; E, evapotranspiration

WATBAL, Berghuys-Van Dijk, 1985). These simple models distinguish between the root zone and a layer below the root zone at least as deep as the lowest occurring groundwater level. Water is considered to be stored in the root zone until a certain equilibrium is reached. If the equilibrium is exceeded, excess water will percolate to the unsaturated zone. If the water content in the root zone is below its equilibrium, capillary flux from the phreatic surface will take place. Precipitation and open water evapotranspiration can be used as input data to calculate actual evapotranspiration.

The more sophisticated models for the unsaturated zone (non-stationary: SWATRE, Belmans et al., 1983; quasi-stationary: MUST, De Laat, 1985) are describing the soil water-plant system in a more detailed way. These models can be applied to soils with vertical heterogeneity and

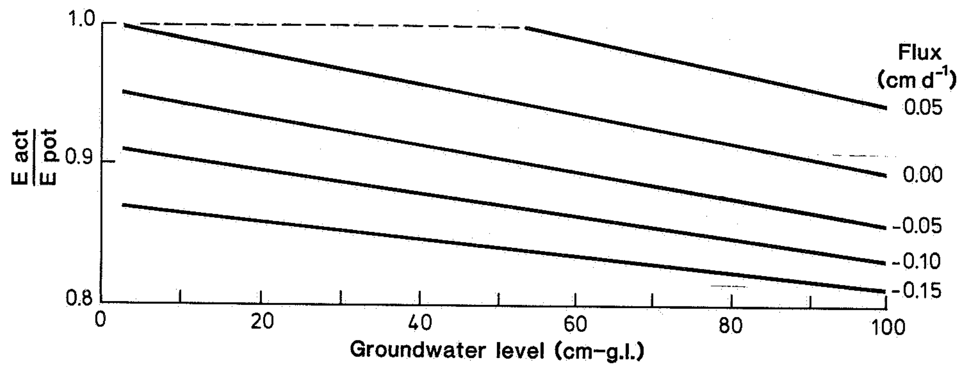

Figure 10 Reduction of evapotranspiration (E_{act}/E_{pot}) in dependency of different fluxes to the root zone and different initial groundwater levels at the first of April on a 'beek' earth soil with loamy fine sand

calculate actual transpiration from meteorological data, crop and soil properties on a daily base. Water uptake by roots can be described by a sink term depending on soil moisture pressure head, rooting depth and potential transpiration (Belmans et al., 1983). The advanced models can be used to verify and refine the output of the simple models.

Jansen (1983) calculated the reduction of evapotranspiration in dependency of different fluxes through the phreatic level starting with different spring levels of groundwater with SWATRE (Fig. 10).

Oxygen supply can be involved in these models simply by considering oxygen contents complementary to soil moisture content. In more advanced models the diffusion of oxygen in the soil-water system can be taken into account (Berghuys-Van Dijk et al., 1985).

Nitrogen supply

A simple 1-dimensional model to calculate mineral nitrogen supply to the vegetation is described by Kemmers and Jansen (1985b). The nitrogen processes are considered as a black-box, with soil moisture, soil tem-

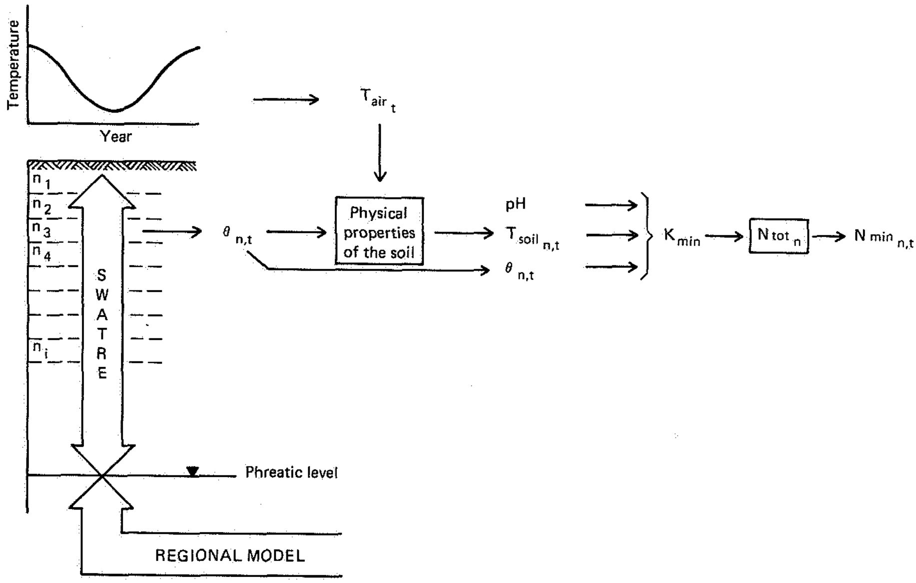

Figure 11 Concept of a simple 1-dimensional model to calculate mineral nitrogen release (N_{min}) from organic nitrogen (N_{tot}) on a short term. Soil moisture contents (θ) are calculated with the SWATRE-model. Regional models can be used to supply the SWATRE-model with lower boundary conditions. Soil moisture data are also used as input to calculate soil temperature (T_{soil}) with a physical submodel. This physical submodel calculates soil temperature in place and time, supposing a sinus wave of the air temperature (T_{air}) at the soil surface, in dependency of physical soil properties. T_{soil}, θ and pH are control variables of the mineralization constant (K_{min}); n, depth of a soil layer; t, time

perature and soil acidity as control variables of the nitrogen mineralization process. The mineralization rate was derived from empirical research. Fig. 11 represents the model concept. With this simple approach it is possible to calculate mineral nitrogen supply on the short term related to the hydrological factor and soil properties. An example of the mineral nitrogen supply of three sites (Table 1) calculated with the simple model is presented in Table 2.

Table 1 Site characteristics of the soil types of which the mineral nitrogen supply was calculated. Nomenclature of vegetation types according to Westhoff and Den Held (1969)

Site characteristics	'Made'peat	'Beek'earth	'Meer'earth
Groundwater levels (cm - g.l.)	0-40	0-90	20-80
C-total (%)	22.75	2.63	8.44
N-total (%)	1.70	0.21	0.40
pH-H_2O	6.0	6.1	5.0
Vegetation type	Calthion palustris	Cirsio-Molinietum	Juncetum acutiflori

Table 2 Mineral nitrogen supply to the vegetation in different layers of three sites on different soil types according to simple model calculations

Soil layer (cm - g.l.)	Mineral N-supply (kg.ha^{-1})		
	'Made'peat	'Beek'earth	'Meer'peat
0- 5	69.7	27.1	24.0
5-10	70.2	27.0	22.3
10-15	73.7	26.9	21.2
15-20	76.0	26.5	20.2

To evaluate impacts on the long term more advanced models are needed. These models need to include interacting system parameters as total organic carbon and nitrogen contents and to calculate balances of compounds to fulfil the law of continuity. Berghuys-Van Dijk et al. (1985) developed ANIMO (Agricultural NItrogen MOdel), a model that simulates the behaviour of nitrogen in a soil-water-plant system influenced by soil type, soil use, water management, weather conditions, fertilizer use and cropping history.

Phosphorus supply

In ecological sciences one is interested in the availability of phosphorus to spontaneous vegetation in dependency of natural soil processes. In our context the role of water quantity and -quality parameters in controlling the phosphorus availability is of importance.

As described in Ch. 2.2 the mineralization process, being the main source of phosphorus also, is influenced by soil moisture conditions. As frequently is referred to the calcium ion in its ability to fix the phosphates by precipitation of Ca-P salts (Ulrich, 1961), hydrochemistry cannot be neglected in models of phosphorus behaviour. As the calcium ion on its turn is influenced by partial CO_2 pressure, the organic carbon decomposition has to be involved too.

Exercises in modeling P in relation to water quantity and -quality parameters has been started only recently.

4 CONCLUSION

As soil types are units of homogeneous hydrological and hydrochemical conditions, they can be considered to represent uniform sites. Common denominators exist to characterize the prevailing hydrological and hydrochemical conditions of the sites. Those conditions cannot be discoupled from the regional hydrological system. The conditions are controlling the main site factors moisture, oxygen, nitrogen and phosphorus supply to the vegetation. As these site factors are of prime importance to vegetational development the regional geohydrological system is fundamental to the macro-ecological pattern in a landscape.

With regional three-dimensional models the effects of measures of regional water management throughout the drainage basin or even from outside can be translated to changes of local hydrological conditions in terms of recharge/discharge or groundwater levels.

With respect to water quality a pilot model is developed to predict

Ca-ion contents in a vertical cross section through the saturated zone after perturbations of the hydrological system. Connections between the saturated and the unsaturated zone are not yet included. The model provides the possibility of a first approximation to simulate local hydrochemical conditions in a regional hydrological system.

Fluxes to the subregions calculated with the regional models can be used as input data to the local models. Local 1-dimensional models simulating soil moisture and nitrogen supply of the site in relation to water management are available. Local models to describe the phosphorus supply and the water quality are currently developed.

The simple local models can be used in practice by policy making authorities to evaluate the impact of changed water management in a global directive way. Advanced models generally will have a more scientific significance and are not of practical interest. Advanced local models can be used to refine and verify the output of the simple models.

The available regional and local models provide a framework to develop a method for the evaluation of the impact of measures of water management on site factors that control growth and development of spontaneous vegetation.

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APPLICATION IN LAND, NATURE AND WATER MANAGEMENT: THE REITMA A CASE STUDY

W.P.C. Zeeman

ABSTRACT

The importance of the relations of the hydrological system-site-vegetation is evident. To describe these relations complicated models are/have been developped. In this lecture it is shown that a good field experience and understanding of these relations can compensate a relatively small data set and modelling techniques.

1 INTRODUCTION

In the previous lectures a lot was learned about the interim results of the study. The question of application in practice comes up for discussion at the end.

The managers of water, as well as nature, forest and landscape always end up with the same questions:
"What demands do nature, forest and landscape make on water management in terms of quantity and quality or both" (Leemhuis-Stout, 1986).

To answer this questions the first thing to do is to characterise the (geo) hydrological situation on the site. Various kinds of situations can be met (Claessen, 1986).

Thereafter we have to focus on the site itself, linking the vegetation and the hydrology. The 4 main site factors, soil moisture supply, nutrient availability, aeration and last but not least the buffer capacity, characterised by the Calcium-ratio and the electric conductivity, should be dealt with. The importance of these factors is stressed by van Wirdum ('86).

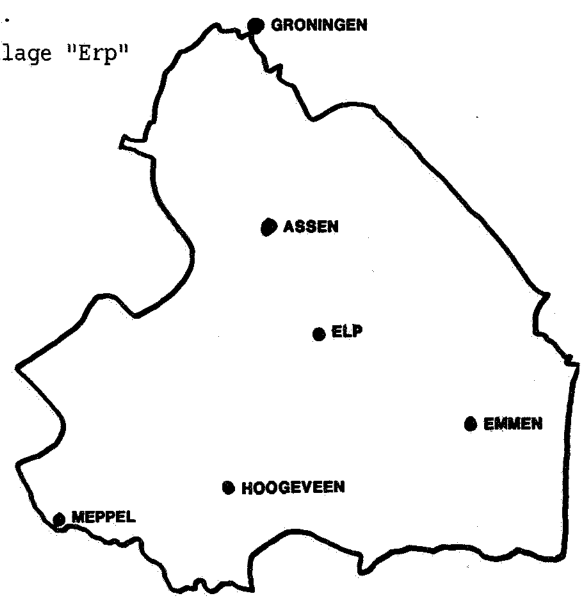
At this point it has to be decided how to continue the survey. Firstly one can solve the problem using modelling techniques as Beltman ('86) and Kemmers ('86) have shown. Thus the relations of the hydrological system-site-vegetation/plant can be described. However application of these techniques requires collection of a great deal of data which would require a long period of time. Therefore, in the next part, it is shown how to handle these problems on the basis of common sense and field experience. For that data collecting is minimal and no complicated computer models are required.
In principle, however, this approach does not differ from the above-mentioned modelling techniques, since the underlying theory is the same.

2 THE EXAMPLE

2.1 Description of the problems

The example area is known as the "Reitma". It is a nature-reserve of 2,5 hectares. It is located in the centre of the province of Drenthe, near the village called "Erp" (fig. 1).

figure 1 Province of Drenthe.
Location of the village "Erp"

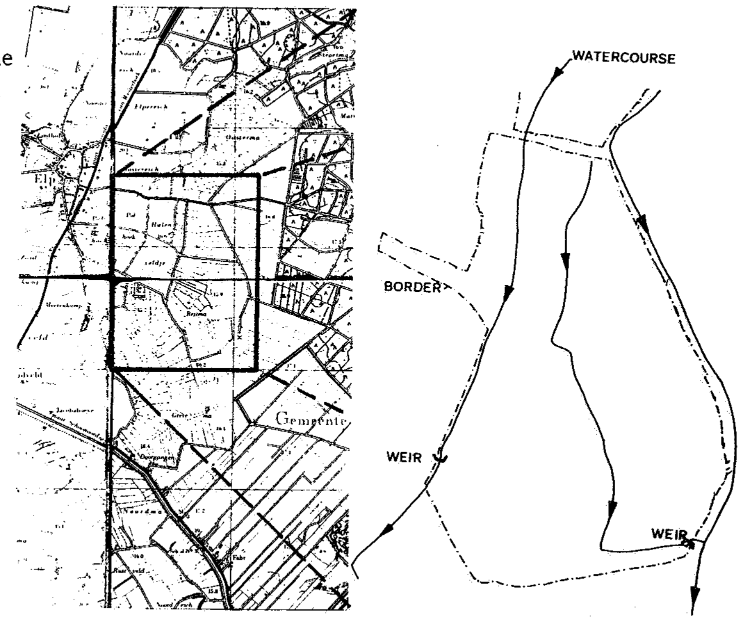


It is a small-scaled area with hedgerows, wet graslands and wet, nutrient-poor hayfields situated in the upper part of the catchment area of a brook called the "Elperstroom".
The following picture gives an impression of this special type of landscape (fig. 2).

figure 2 The example area
Photo by A.W. van Beusekom

During the 1970's water management measurements were planned in the surrounding area. Initially these plans were intended to improve the drainage and discharge capacities of the streams, brooks and ditches in the adjacent agricultural fields. In several places (fig. 3) dams and weirs were built to prevent losses of surfacewater from the terrain. For the same purpose an underground loamy vertical dam was additionally constructed.

figure 3
Location of the
nature reserve
the "Reitma"

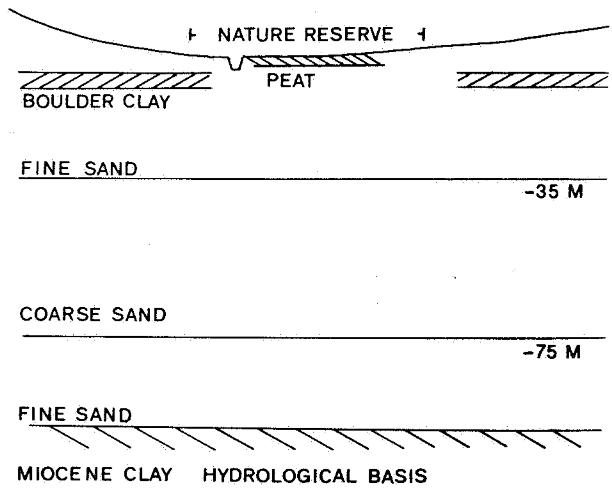


It is obvious that the main objective was to preserve as much water as possible in the terrain. The measurements that were taken to reach this goal seemed to be a success in winter, spring and wet summer seasons. The duration of inundation however, was prolonged in wet periods, while the groundwater level dropped much too deeply in dry summer seasons. The vegetation development was in accordance with this phenomenon. While rare and valued plant species were relatively common in the past, in the period since the changes in water management ruderal species have come to dominate. Knowing as we now do, the importance of the major site factors mentioned above, this situation can easily be understood, as follows.

2.2 Analysis afterwards

At first the problem has to be analysed by typifying the areal characteristics and their changes. Considering the cross section of the valley (fig. 4) the most important geohydrological characters are shown.

figure 4
Geohydrological
cross section
of the valley



The permeable and impervious layers alternate from top to bottom. At more than 100 m below ground level a very thick clay-layer occurs, which was formed in the miocene. It is considered as the basis of the hydrological system. On top of the clay-layer is an aquifer consisting of loose fine sands, calcium rich marine sediments in the lower part. At 75 m below ground level these fine sands are covered with coarse sands of 30 à 40 m thickness, on top of which a fine sand formation is found. The upperlayers consist of boulder-clay and peat; in the valley, however these layers are eroded.
In more recent times peat has been formed in the lower parts of the valley.
This geohydrological stratification determines the original groundwater flow-pattern. The vertical seepage of infiltrated rainwater at the flanking hills through the aquitards has built up a considerable hydraulic head in the deeper aquifers. In the valley the difference between the phreatic groundwater level and the deeper groundwater table causes a considerable recharge, especially where the impervious boulder-clay has been eroded. This recharge is enriched with calcium-ions and supplies together with the precipitation the brooksystem. Subsurface flow from the hillsides over the boulder-clay accounts for a large contribution to the system in winter and springtime. Shallow trenches

and ditches provide the drainage of superfluous water to the main stream, the "Elperstroom". In the past the phreatic head varied between ground level in winter and 30 à 40 cm below it in summer as a consequence of this constant recharge.

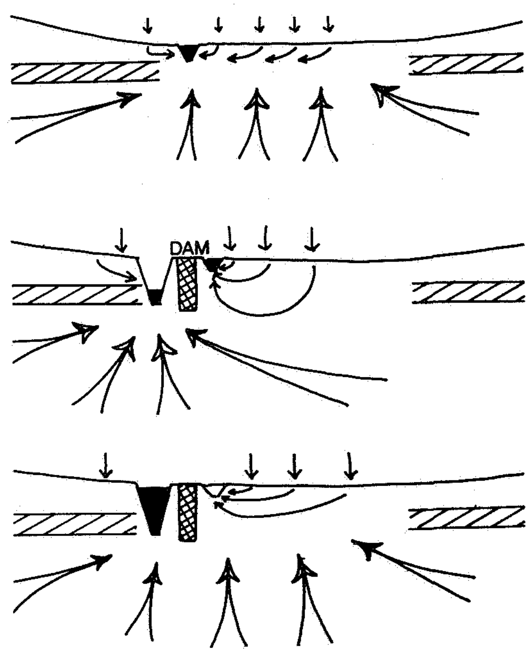
The influence of the above-mentioned hydrological system on the site is now considered, where to all 4 site factors have to be taken into account: soil moisture supply, nutrient availability, aeration and buffer capacity. With the knowledge of the demands of the specific plant species that occur in this location, this assumption is verified.
In particular the buffer capacity depends on the constant supply of groundwater recharge, enriched by calcium-ions. For this reason it can easily be understood why a number of original typical and valued species declined or even disappeared in spite of all the measures taken.
This process is explained in figure 5.

figure 5 Changes in hydrological situation

situation before 1970

situation from 1970 - 1981

situation after 1981



In the upper part of the diagram a detailed outline of the original hydrological situation is shown. The regional groundwater recharge dominates the groundwater regime in all parts of the nature reserve. The middle part of the diagram clearly shows the drainage effect of the newly-built watercourse. The enlarged dimension together with the lowered surface water table caused an effect on the extent of the recharge on that site. Additionally precipitation water diluted or even substituted the original lithotrophic groundwater in the root zone. This phenomenon was intensified by the conservation measurements mentioned above. Nevertheless at the end of the summer season groundwater levels were still too deep. Observations of both groundwater levels and vegetation showed the same trends; an average lower groundwater table with more fluctations corresponding with an increasing number of ruderal species characteristic of more acid conditions.

2.4 Improvement of the situation

Some years after the measurements described here were taken, problems were again analysed in the context of the planning of the water management in the nature reserve. For the first time the supposition was made that the influence of groundwater quality could also be important in addition to the above-mentioned quantitative effects. However, proof was not yet available due to the lack of data on the groundwater quality in the root zone.
Changes in the hydrological system corresponding with those in the vegetation were analysed as far as possible, and concomitant measurements of water management and the adjusting infrastructure were made. The same measures were made for a more detailed management on the water levels as well as to restrict the draining of the main watercourse located in the western part of the reserve and for this purpose a movable weir was built downstream (fig. 6).

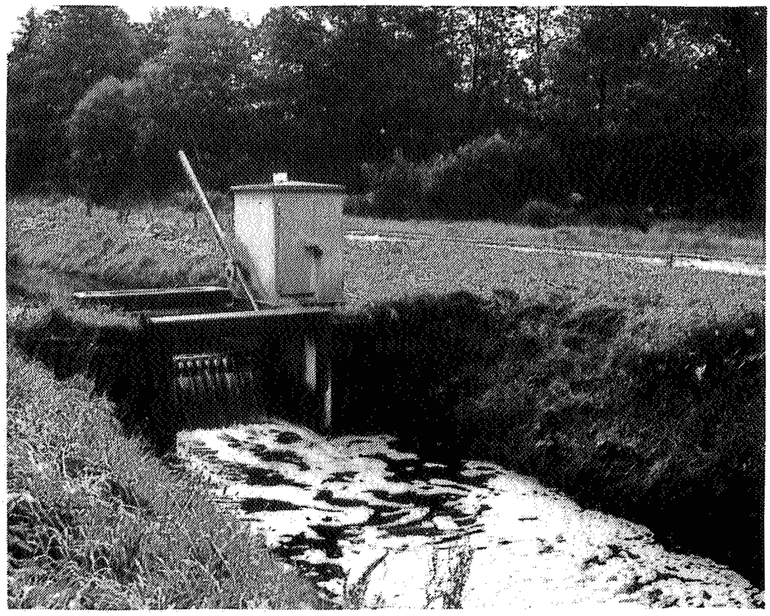


figure 6 Movable weir to maintain the water levels

Initially an agreement was made with the local waterboard to maintain a high level in the summer season, later on the same high water level could be reached in wintertime since adjoining low-lying agricultural land was acquired and included in the nature reserve (fig. 7).

figure 7 High water level in the main watercourse

The first positive results of this measure can be recognised already: an increasing percentage of calcium-ions in the groundwater, a more lithotrophic groundwater is establishing and the deep regional groundwater recharge seems to have been restored and the vegetation is recovering too. Valued species, such as various orchids, Cirsium dissectum and Carex pulicaris, which have been disappearing since the 1970's, can be found once again. Other phenomena such as agglutination of Fe_2O_3 and the presence of iron-bacteria in ditches can also be observed again.

This example may prove that a relatively small data set can be compensated and complemented by a good field experience and understanding of the relation between vegetation and water management, even without recourse to complicated computer models.
On the other hand the impression must not be gained that the results of the SWNBL-study are alienated from practice; it is shown below near future.

3 RESULTS OF THE SWNBL-STUDY

Firstly the WAFLO-model must be mentioned. This model has been described by the other lecturers and it deals with prediction of the maintenance and disappearance of plant species as a consequence of certain measures taken. It is based upon the indicator values of Ellenberg, which indicate the demands plants make on their environment.
In the context of the SWNBL this model must be improved and applied to enable the prediction of appearence of specific species.

The importance of the main site factors is described above. Those factors can be expressed by the key-variables: electrical conductivity, calcium-percentage and acidity. Quantifying the indicator values of Ellenberg is now an object for study. It is expected that statistical estimations of those site factors can be made on the basis of presence of plant species.

A special form is developed in order to describe the dependance of the nature-value of the water regime and changes in it on an uniformed and ecohydrological basis. In combination with a standardisation of the description of the hydrological systems (local, regional or national) this form will certainly be a good appliance to solve a number of policy and management problems for nature reserves.

An overall predictive model in which all the relations between water management and site factors are included in the shape of partial and interconnected models, is not yet formulated. The development of this model is being carried out. When the model is completed and tested for its applicability, it can be made operational.

Forestry models for predicting effects of changes in water management on growth and vitality of trees or the influence of forests and trees on the water regime have been developed abroad. To apply these models to our system the necessary input parameters have to be measured under the circumstances in the Netherlands. This project will start in 1986.

As far as landscape is concerned it must be mentioned that a global classification according to visual characteristics of water elements has been designed and will be reproduced in a national map. This will be an excellent starting point for the policy makers and managers, especially after tests of its applicability in a number of example areas, and adapting it afterwards. It must be stressed that a general method for landscape planning in relation to water management will be developed.

4 CONCLUSION

Although the completion of this study will result in a set of recommendations for application in practice, the complexity of the problem will still necessitate the continuation of the various surveys. Certain gaps in our knowledge of the relation between water management and nature-, forest- and landscape management will be made up in comparison with other interests in relation to water management. However we cannot expect to complete this scheme and so it is good to be able to present the intermediate results to a wide audience. Hopefully these results will stimulate an awakening to these special problems and increase the chances of implimentation of the final results of this study.

ANNEX

RESULTS OF THE SURVEY OF THE STUDY COMMITTEE WATER MANAGEMENT NATURE-, FOREST- AND LANDSCAPE MANAGEMENT (SWNBL)

J.G. Vermeer

1 INTRODUCTION

Water is fundamental to the survival of plant, animal and mankind alike. Every living creature makes its own demands on the quality and quantity of water in its environment. The demands made by man have increased enormously through the last decades, because economical and technical development has progressed so rapidly and prosperity increased exponentially with the concomitant increase in water usage.
At the same time a significant deterioration in the quality and characteristics of nature, forest and landscape is apparent, especially in the wet, nutrient-poor parts of the Netherlands. The cause of this process is obvious. Due to changes in water management, carried out in order to meet man's various demands for water, water quality has changed and water quantity deminished. In these circumstances, the primary interest of man and the demands of nature, forest and landscape are in conflict. It is therefore necessary that a balance be established between these two conflicting demands in order to prevent the further deterioration of nature and natural resources.

It is important that the balance struck between the various interests is based upon realistic standards. On the one hand, it is relatively easy to transform the various economic demands made on water management. The arguments for these measures can be simply expressed in monetary terms. On the other hand, there are large gaps in our knowledge of the characteristics of nature, forest and landscape. Thus arguments on behalf of the interests of nature can hardly be quantified solely in monetary terms. Therefore it is almost impossible to take these interests into account when decisions have to be made in landscape-planning and water management. The final result is that the economic interests of man and the demands of prosperity prevail over those of nature, forest and landscape. Clearly it is vital that mankind be confronted with the fundamental importance of nature and of natural resources and that he is made aware of its immense value for the survival of mankind.

In order to improve our knowledge of the relationship between water management and nature, forest and landscape, a committee was installed in October 1982; the Study Committee Water Management Nature-, Forest- and Landscape Management. The aim of the study was at first to compile an inventory of all available information on the subjects. This inventory was completed in the first period of the study.
In the second period the objective was to suggest and illustrate the possible applications of this knowledge in landscape-planning, nature-, forest- and water management.

2 RESULTS 1983 - 1985

The study has been divided into three parts Nature, Forest and Landscape in order to make the results more accessible. It is also important to realize that research on nature in the Netherlands is more advanced than on forest and landscape. Diverging results can be expected in the end due of the differences in time required for the various parts of the study to reach their goals.
The proposed aims for the various parts of the study are given at the beginning of each chapter.

2.1 NATURE

Within the scope of this study nature is restricted to include terrestrial only plant communities composed of Phanerogamae. The reason being that the relations between plant communities and water in aquatic conditions are already reasonably understood and have been studied to a greater extent than other types. Because animals are depedent on the vegetation for completing their life cycles they have also been excluded from this study. The scope of the study on nature is not only its conservation and recovery but also included its development.

That nature depends on the quality and quantity of water is beyond question. Plants, however, are not only directly affected by water as it is supplied from elsewhere, but also indirectly influenced by the various processes which are initiated by the water supply. These processes occur in that part of the soil that is used by the plants for the uptake of nutrients and water necessary for growth and reproduction. Therefore, this interaction between the plant and the hydrology must be carefully studied: the site (standplaats; fig. 1).

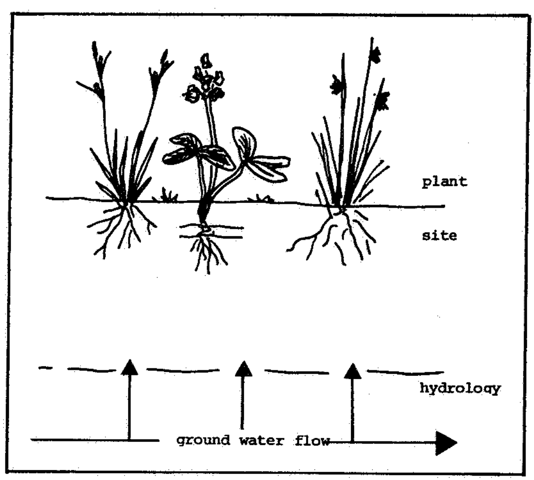
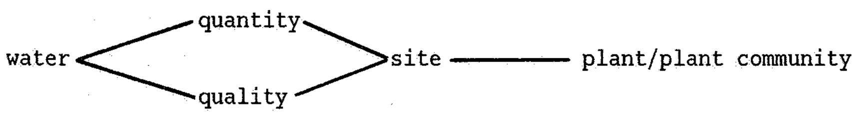


figure 1 Situation of the "site" ("standplaats") between plant and hydrology

In summary we can illustrate the relationships studied by the SWNBL in a diagram:



Changes in both water quality and quantity are responsible for changes in characteristics of the site and therefore of the plant community as well.

WATER QUANTITY

Water quantity can be characterized by the two variables; ground-water level and surface water level. Changes in these water levels, especially lowering the level, can initiate all kinds of processes in the upper soil layer. The lowering of the water table causes a decrease of the water content in the topsoil in wet areas. As a result, the oxygen concentration in this topsoil increases as well as the temperature (fig. 2).

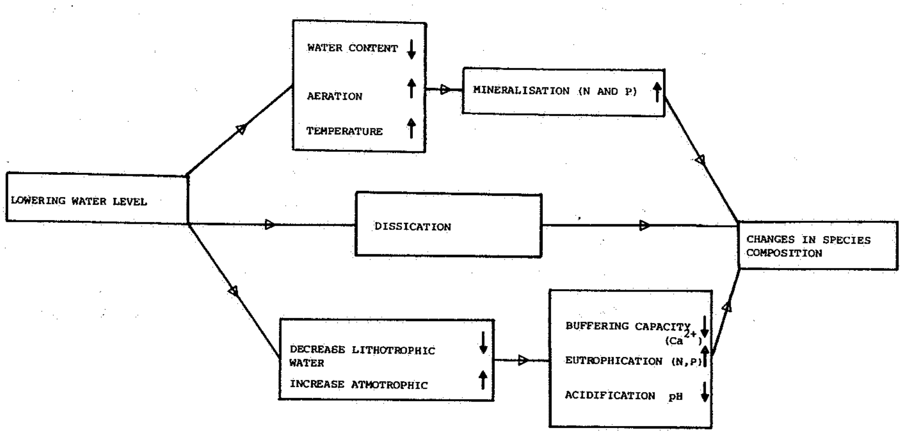


figure 2 Effects of changes in water level; relationships between hydrology, site and plant community

These changes in the micro-site cause an accelaration of the mineralisation of organic matter in the topsoil. This process leads to an increase in the availability of nutrients such as nitrogen, phosphorus and potassium. Due to the enrichment of the site, a shift in the species composition of the plant community may occur, particularly in wet, nutrient-poor conditions. Species characteristic of these situations will be replaced by species common to drier, nutrient-rich conditions. In the end lowering of the ground-water level can lead to water deficiency with all the associated consequences for the moisture content of the soil.

WATER QUALITY

Lowering the water level also affects water quality. In the Netherlands, many threatened and rare plant communities and biotopes are found in wet and moist areas in which ground-water has a lithotroof character. Due to the long period during which it is present in the subsoil, this lithotroof water gaines a relatively high calcium concentration. This high calcium concentration is very important in the processes of neutralizing acid rain water and of fixing soluble phosphate in the soil. When the water level is lowered, the influence of the upwelling ground-water in the root zone will diminish. The lithotroof water will be replaced by acid, nitrate-rich water from precipitation. The result is a change in pH, nitrate enrichment and a decrease in calcium concentration. The latter effect particularly influences the buffering capacity of the soil.
It is obvious that if we consider the quality aspects of water, the preservation of rain water in order to eliminate the effects lowering the water level is useless. The process initiated by the characteristic chemical composition of that precipitation will cause comparable negative changes in the species composition of the original plant communities.
The changes in the water quality of a certain area can, however, also be the result of changes in the quality of water flowing in from elsewhere.

SITE CHARACTERISTICS

From the above-mentioned processes as result of changes in water management we can conclude that there are five processes affecting the relationship between plant and hydrology. The following site characteristics are an expression of these:

- availability of water;
- aeration of the top soil;
- availability of nitrogen;
- availability of phosphorus;
- buffering capacity, which may be specified by such variables as pH, Ca-concentration, HCO_3 -concentration.

The next major question is how these factors behave as a result of changes in water-management and what are the effects of these changes on plant composition in wet, nutrient-poor conditions? The aim of this study is to formulate a model, in which the main processes get a key position in determining the effects of changes in water management. The perspective is that on the basis of this model predictions can be made about the conservation and disappearance of plant species as well as on the appearance of new ones.

MODELLING

An inventory was made of the availability and applicability of models for all the parameters mentioned. This inventory shows that there are plenty of models available to calculate the changes in water quantity and water level. As far as water quality is concerned the development of models has not yet reached the same level of sophistication.
This simplification of the processes need to be made for the time being. Some variables that can be easily determined and are available at short notice are electric conductivity, the ionic ratio (Ca/(Ca + Cl)) and pH. These factors characterize to great extent the total availability of soluble elements in the soil, as well as nutrient availability, therefore they may be important in determining the presence or absence of plant

species and communities.
The description of the processes as a consequence of the changes in water management has already been completed and the mathematical formulation of the submodels is now in hand. The next question to be answered is, what is the relationship between these sitefactors and the plant species? Therefore, it is necessary to have an idea of the demands which plants make on these factors. An indication of these demands may be found in lists of indicator values (Ellenberg, 1979) in which a rough division is made in classes of the possible values a certain site-factor can have.
For each species an indication is given of its optimal demands for this factor.
These values were tested on their possible use in practic. Species with the same demands are combined in species groups, which are given a place in the model (fig. 3). Together with the submodels for the various site-factors this system would complete the model, though that synthesis is not yet completed.

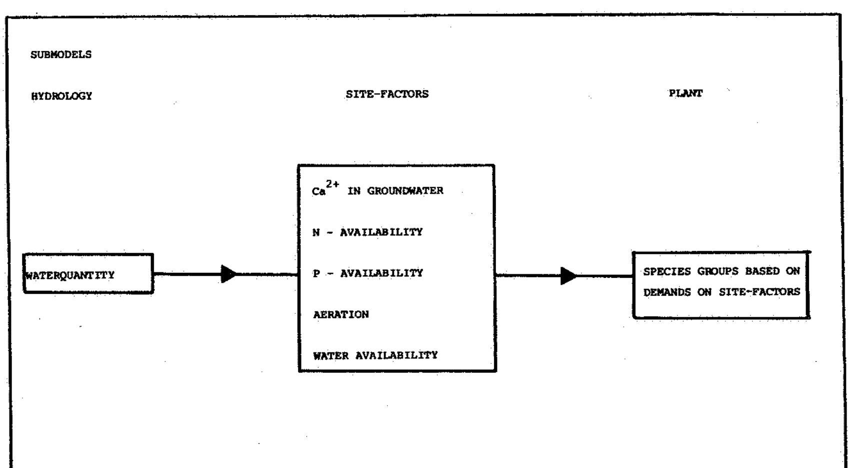
WAFLO-MODEL

A model that can be used as a basis for the development of the SWNBL-model is the WAter-FLOra-model of the RIN (WAFLO). This model is based on change-effect relationships in the same site-factors as the ones that are mentioned in the SWNBL-study: changes in availability of water, nutrients and oxygen and in the site dynamics. The model makes predictions possible on the conservation and disappearance of plant species as a result of changes in water management; in particular lowering the water level. The demands plant species make on nutrient conditions were estimated from the indicator values of Ellenberg. Each site-factor is described by a submodel, in which the response of plant species is given to the changes in the site-factor. Interpretation of the interaction between the submodels is very important, but has not been completed yet.

SWNBL-MODEL

The model in the SWNBL-survey will be yet more complex. The whole sequence of the relation hydrology-site-plant will be included as well as changes in water quantity and quality. The object is not only that the conservation and disappearance of plant species may be predicted but also the appearance of new species. Basis of this prediction will be the possible changes in water management in general and in particular those affecting the conservation, recovery and development of natural plant communities.
In order to determine accurately the conditions which plant species demand for optimal growth another method was tested in this study. On the base of many field data it was possible to calculate the response curve of each species.
This curve shows the chance of finding a species at different values of the site-factor concerned. At this moment, however, there is only a small dataset available for most species. Therefore the field investigations must be greatly expanded in order to develop a more detailed and accurate biological indicator system on basis of these response curves.

figure 3 The various compartments of the SWNBL-model. Predictions can be made on the effects changes in water management have on the species composition of terrestrial plant communities



SWNBL-MODEL

As a result of the survey we can look forward to a submodel for each site-factor containing a system of species groups in which species are grouped together with the same demands for the relevant site-factor. In the next period of study parts of the model must be completed and combined in one overall model (fig. 3) by which predictions may be possible as to the effects of changes in water-management on the species composition of terrestrial plant communities.

NATURE MANAGEMENT

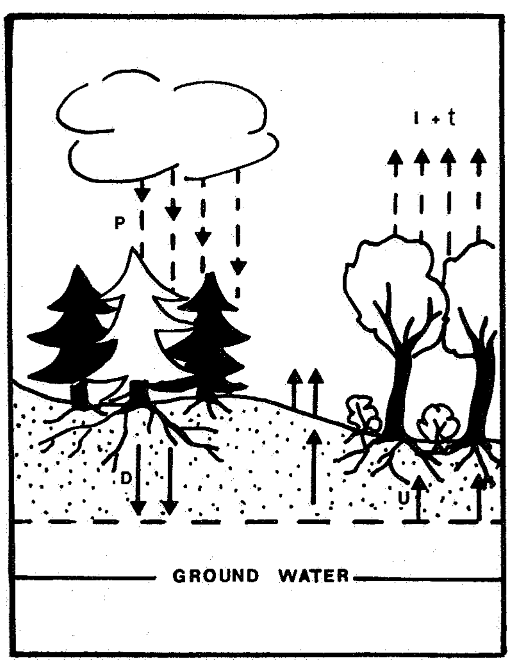
For the most efficient and practical use of a model like the one we are presently working on it is essential that the data are conveniently arranged. Nature management may also profit from such accesible system. In order to collect and standardize hydrological and ecological data a special form was developed. Data concerning soil characteristics, geomorphology, vegetation, fauna, hydrology as well as information concerning ownership, management and situation in the landscape are given in a so-called ecohydrological description form.
A description of how the area is situated in the local, regional and national hydrological system can complete the overall view. In this way comparison of various areas is much easier to deal. It is also possible to determine the potential of the site and to make decisions about the disappearance, conservation and development of threatened plant communities or biotopes.
The study also provides a survey on the methods used in vegetation mapping.

2.2 FOREST

The object of this part of the study was to clarify the effects which changes in water management have on the growth, production and vitality of forests. The influence of forests on the hydrology of the area will also be approached. The function of forests as part of nature is considered in previous chapters.
In figure 4 the various processes of the hydrological cycle in a forest are shown. Much is already known about the processes involved, especially transpiration of the trees and the undergrowing plant species and the

evaporation of the leafsurface (interception) and the soil surface. To complete the hydrological cycle, factors must be added such as precipitation, water uptake by plants and drainage to the groundwater. Literature on foreign research reveals many models to calculate and quantify the main factors in this water cycle. These models must be tested for Dutch forests. Therefore a large monitoring program must be carried out in which transpiration and interception in particular are determined. Within the scope of this study this program has begun for two tree species (Pseudotsuga menziesii and Quercus robur).
It can be expected that a relatively accurate estimation of the necessary parameters will be made based on the observations of one year, in combination with the results from the literature. The research will continue for eight years after the end of the study period.
The root system is an important factor also easily affected by lowering the water table. The roots also interfere with transpiration and vaporation. A study is being carried out to investigate the extensiveness and stratification of the rootsystem of these two species.

figure 4 hydrological cycle in a forest
P - precipitation; I - interception; t - transpiration;
D - drainage; U - uptake by rootsystem



2.3 LANDSCAPE

This part of the study aims to develope a method with which the landscape planning and management can be accurately tuned into water management and planning. A mutual understanding of both parties is therefore a neccessity. So far, the study has provided us with a system in which all landscapes in the Netherlands are divided in types based on the visual aspects and the contribution of water elements in the landscape (scale 1:1.000.000).
This system and the adjoining map can be used in management and planning policies. The accuracy of this system may be increased by testing it in various example-areas and using the results to provide the basis of amendments and improvements.
To improve the dialogue between landscape-managers and water-managers an inventory of the problems both parties have dealing with each other has been drawn up. This inventory is a basis for the elaboration of the general aims of this study.

3 THE FUTURE

The period which the Study Committee has been granted expires in 1988. Until then there is much work to be done. As far as nature is concerned the last stage of the study will be employed for the development of the submodels for the various site-factors. The integration of these submodels in the overall model, forms the end-point of the study. The division of all plant species into species groups based on the demands made on the relevant site-factors is also essential and under completion. It is expected that the results will eventually comprise a model which allows predictions of the effects which changes in water management may have on the disappearance, presence and appearance of plant species.
The results in terms of Forest and Landscape are more restricted. The field study on the transpiration and interception of tree species will take at least ten years to complete. Within the period of this study only preliminary estimations can be made of the various parameters required. These estimations can, with due reservation, contribute to the prediction of the effects that changes in water quantity have on forest ecosystems. The research on the stratification and extensiveness of the rootsystems for two tree species.

The landscape part of the study will result in a detailed landscape division based on the visual characteristics of the water elements in the landscape and on the adjoining map. In addition reasoned directions will be given to improve the cooperation and integration between landscape planning and water management in the context of policy and decision making.

Notes

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TNO COMMITTEE ON HYDROLOGICAL RESEARCH

PROCEEDINGS AND INFORMATION

No. 1 Proceedings of Technical Meetings 1-6 (with summaries in English), 1952.

1. Investigations into the water balance of the Rottegatspolder
2. The water supply for crops I
3. Observations of groundwater levels
4. Investigations by drain gauges in The Netherlands
5. The water supply for crops II
6. The problem of the increasing salinity of ground and surface water in The Netherlands

No. 2 Proceedings of Technical Meetings 7-10, and
Report on the evaporation research in the Rottegatspolder 1947-1952 (with summaries in English), 1955.

7. The study of precipitation data
8. Model research on groundwater flows
9. Measurements and improvement works in basin of brooks
10. Geo-electrical research

No. 3 Proceedings of Technical Meetings 11-12 (with summaries in English), and
Report on the Lysimeters in The Netherlands I (in English), 1958.

11. The water supply of sandy soils
12. Quality requirements for surface waters

No. 4 Evaporation Symposium and
Report on the Lysimeters in The Netherlands II (with summaries in English), 1959.

No. 5 Proceedings of Technical Meetings 13-14 (with summaries in English), 1960.

13. Groundwater levels and groundwater movement in the sandy areas of The Netherlands
14. Water in unsaturated soil

No. 6 Proceedings of Technical Meeting 15 (with summaries in English and French), 1961.
The regime of the Rhine, the Ysselmeer and Zeeland Lake

No. 7 Proceedings of Technical Meeting 16 (with summaries in English), 1962.
The dry year 1959

No. 8 Proceedings of Technical Meeting 17 (with summaries in English), 1963.
The laws of groundwater flow and their application in practice

No. 9 Proceedings of TechnicalMeeting 18 (with summaries in English), 1963.
Water nuisance

No. 10 Steady flow of groundwater towards wells; compiled by the Hydrologisch Colloquium (in English), 1964.

No. 11 Proceedings of Technical Meeting 19 (with summaries in French and German), 1964.
Geohydrological cartography

No. 12 Proceedings of Technical Meeting 20 (in English), 1966.
Water balance studies

No. 13 Proceedings of Technical Meeting 21 (in English), 1966.
Recent trends in hydrograph synthesis

No. 14 Proceedings of Technical Meeting 22, 1968.
Precipitation data (II) and
Report on the Lysimeters in The Netherlands (III) (both with summaries in English)

No. 15 Proceedings and Information no. 15 (in English), 1969.
Soil - water - plant

Proceedings of Technical Meeting 23, 1968.
Seepage
(Will not be published).

Proceedings of Technical Meeting 24, 1970.
Flow in the unsaturated zone
(Will not be published).

No. 16 Proceedings of Technical Meeting 29 (with summaries in English), 1975.
Hydrological investigations for masterplan for the future watersupply in The Netherlands

No. 17 Proceedings of Technical Meeting 25 (in English), 1973.
Automatic processing of hydrological data

No. 18 Proceedings of Technical Meeting 26 (in English), 1974.
Hydraulic research for water management

No. 19 Proceedings of Technical Meeting 27 (in English), 1974.
The hydrological investigation programme in Salland (The Netherlands)

Proceedings of Technical Meeting 28, 1973.
Water quality of Dutch rivers with respect to water management
(Will not be published)

No. 20 Proceedings of Technical Meeting 30 (in English), 1976.
Salt distribution in estuaries

No. 21 Proceedings of Technical Meeting 31 (in English), 1976.
Groundwater pollution

No. 22 Proceedings of Technical Meeting 32 (with summaries in English), 1976.
Systems approach to the management of water resources

No. 23 Proceedings of Technical Meeting 33 (in English), 1977
Precipitation and measurements of precipitation

No. 24 Proceedings of Technical Meeting 34 (in English), 1978.
Urbanization and water management

No. 25 Proceedings of Technical Meeting 35 (in English), 1979.
The relation between water quantity and water quality in studies of surface waters

No. 26 Proceedings of Technical Meeting 36 (in English), 1980.
Research on possible changes in the distribution of saline seepage in The Netherlands

No. 27 Proceedings of technical Meeting 37 (in English), 1981.
Water resources management on a regional scale

No. 28 Proceedings of Technical Meeting 38 (in English), 1981.
Evaporation in relation to hydrology

No. 29a Background papers for Technical Meeting 39 (in English), 1982.
(Netherlands contributions, related to the PAWN-study, for the ECE-seminar-1980).
Policy analysis for the national water management of The Netherlands

No. 29b Netherlands contributions, not related to the PAWN-study, for the ECE-seminar-1982 (in English), 1982.
Economic instruments for rational utilization of water resources

No. 30 Proceedings of Technical Meeting 40 (in English), 1983.
The role of hydrology in the United Nations Water Decade

No. 31 Proceedings of International Symposium (in English, with summaries in French), 1983.
Methods and instrumentation for the investigation of groundwater systems

No. 32 Proceedings of Technical Meeting 41 (with Preface in English), 1985.
Planning of Water Resources Management on a Regional Scale

No. 33 Proceedings of Technical Meeting 42 (in English), 1985.
Water in urban areas

No. 34 Proceedings of Technical Meeting 43 (in English), 1986.
Water management in relation to nature, forestry and landscape management

No. 35 Design aspects of hydrological networks (in English), 1986.
Published with support of the World Meteorological Organization

No. 36 Proceedings of International Conference (in English), 1986.
Urban storm water quality and effects upon receiving waters

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