DEMONSTRATION PROJECT FOR THE DEVELOPMENT OF INTEGRATED MANAGEMENT PLANS FOR CATCHMENT AREAS OF SMALL TRANS-BORDER LOWLAND RIVERS: THE RIVER DOMMEL

Universiteit Utrecht

1. Ecohydrological Modeling and Integrated Management Planning in the Catchment of the River Dommel

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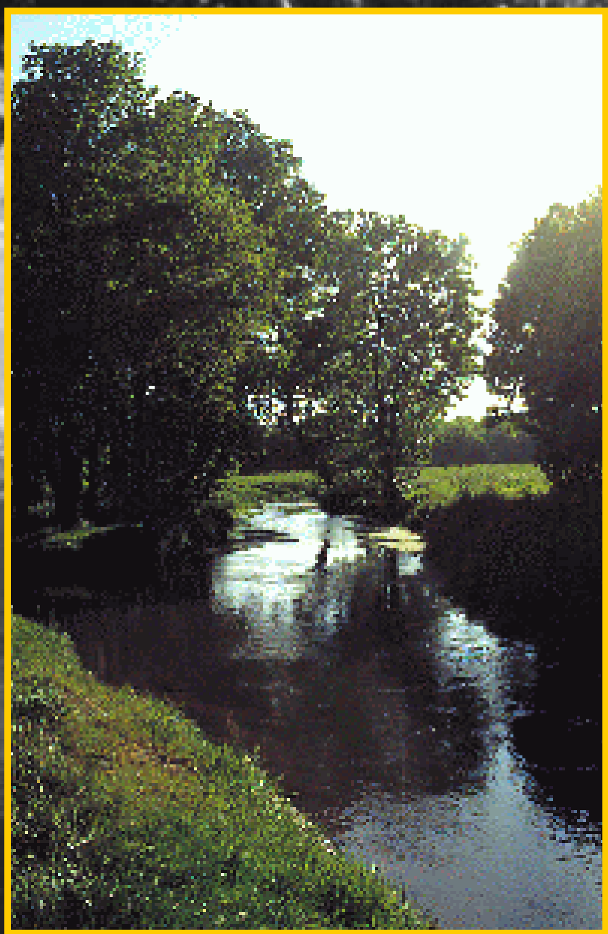

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Utrecht, 1998

Demonstration project for the Development of Integrated Management Plans for Catchment Areas of Small Trans-Border Lowland Rivers: the River Dommel

Administrative project leader: Ir. A. Span (Province of North Brabant, NL)
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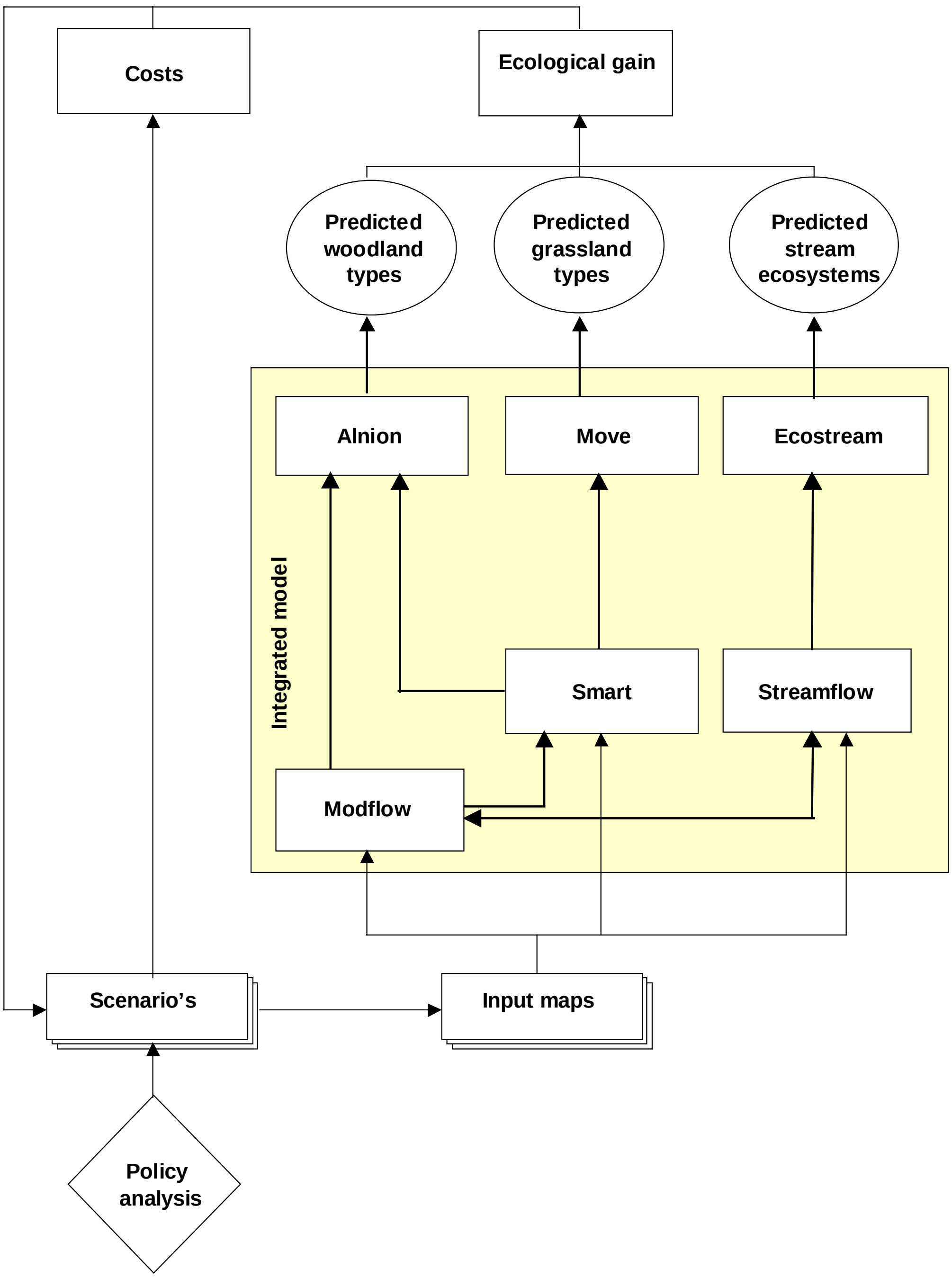
Preface

This publication is part of a series of technical reports concerning the EU-LIFE demonstration project for the development of integrated management plans for trans-border lowland river catchments. For this project the Dutch-Belgian catchment area of the river Dommel served as a case area.

The project aimed at the development of scientifically sound environmental impact-assessment tools on the one hand, and the construction of viable plans on the other. Administrative project coordination was carried out by the Province of North Brabant, scientific project coordination by Utrecht University. The methodological structure of the project is shown in the next figure.



Construction of the groundwater model (based on MODFLOW), the development of the models STREAMFLOW, ALNION, and ECOSTREAM, and integration of all models in a Geographical Information System, were carried out by Utrecht University. MOVE originates from the National Institute of Public Health and Environment (RIVM), and SMART from the Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO). MOVE and SMART were adjusted to a regional scale, rewritten in ARC-INFO, and calibrated for this project by Utrecht University. The model ECOSTREAM is primarily based on the Aquatic Ecotope System as developed by the Institute for Forestry and Nature Research (IBN-DLO) and the University of Leiden. Policy scenarios were developed by SC- DLO and the University of Nijmegen, in cooperation with Dutch and Belgian policy actors of the Dommel catchment. Evaluation of the costs and ecological gains of the scenarios was carried out by SC-DLO. For further information about the project one is referred to the first report in this series: Ecohydrological Modelling and Integrated Management Planning in the Catchment Area of the River Dommel. A list of all reports in this series is shown at the last page of this report.

To reach the project objectives, a good cooperation between policy makers from both sides of the Dutch-Belgian border, and scientists was very important. Due to the enthusiastic contribution of all participants to this large and complicated project, it was completed successfully. The following persons participated in the supervising committee of this project:

The project was supervised by a committee in which the following persons participated ;

A.S.W. Span	(chairwoman)	Province of North Brabant,The Netherlands
J.S. ten Veldhuis	(Secretary)	Province of North Brabant, The Netherlands
A.W.M. Mol		Province of North Brabant, The Netherlands
J. Hemelraad		Water board the Dommel,The Netherlands
Y. Ronse		Flemish Environmental Company (VMM), Belgium
M. Lambrichts		Administration for Environment, Nature and Land use (AMINAL), Belgium.
G. Lambrechts		Administration for Environment, Nature and Land use (AMINAL), Belgium.
G. Vanderwaeren		Administration for Environment, Nature and Land use (AMINAL), Belgium.
H. Awouters		Province of Limburg, Belgium
J. van Rijen		Ministry of Agriculture, Nature conservation and Fisheries (LNV), The Netherlands

Summary

The EU-LIFE Dommel project aims at the development of methods for the combined use of landscape ecological models and socio-economic knowledge in the drawing up of integrated management plans for catchment areas of small trans-border rivers. These methods were developed and tested in the catchment area of the river Dommel.

The river Dommel is one of the important tributaries of the river Meuse. It crosses the border between Belgium and the Netherlands. Because there exist strong conflicts between the ecology and socio-economic developments within the catchment, many ecosystems have deteriorated during the last decades and the remains are threatened by future socio-economic developments.

The short-term objective of the project was to lay the foundation for an integrated management plan to abate these problems in the study area. The project was executed in collaboration between scientists and regional policy actors. The project consisted of three phases. In the first phase an analysis was made of interrelated socio-economic and environmental developments. In the second phase a number of landscape-ecological models were developed to be able to predict environmental effects of different land use and water management scenarios. In the third phase a number of these scenarios were drawn up and compared with regard to ecological gains, societal acceptability and costs. This led to a final scenario which offered good perspectives for nature restoration and which was considered feasible by the relevant authorities in the catchment area.

To comply with the long-term objective of the project, methods were developed which are applicable in other catchment areas. These methods concern organizational aspects (project phasing, co-operation in the project) and aspects with respect to scientific content (landscape-ecological models, determination of ecological gains).

Samenvatting

Het LIFE-Dommel project had als doel om methoden te ontwikkelen voor de gecombineerde inzet van landschapsecologische modellen en sociaal-economische kennis bij het opstellen van integrale beheersplannen voor stroomgebieden van kleinere grensoverschrijdende rivieren en beken. Hiertoe is een pilot project uitgevoerd binnen het stroomgebied van de Dommel.

De Dommel is een van de belangrijke zijrivieren van de Maas. Het stroomgebied ligt deels in Belgie, deels in Nederland. In de afgelopen decennia zijn in dit gebied door sociaal-economische ontwikkelingen veel waardevolle ecosystemen verdwenen. Het resterende deel wordt bedreigd door te verwachten verdere sociaal-economische ontwikkelingen.

Het korte termijn doel van het project was het leggen van een basis voor een integraal beheersplan om de problemen in het studiegebied aan te pakken. Het project is uitgevoerd in samenwerking tussen wetenschappers en regionale beleidsinstanties. Het is in drie fasen uitgewerkt. In de eerste fase is een analyse gemaakt van de interrelaties tussen sociaal-economische ontwikkelingen en milieuontwikkelingen in het studiegebied. In de tweede fase zijn een reeks landschapsecologische modellen opgesteld die het mogelijk maakten om voor verschillende landgebruiks- en waterbeheerscenario's de milieu-effecten te voorspellen. In de derde fase zijn een aantal van dergelijke scenario's opgesteld en onderling vergeleken wat betreft ecologisch rendement, maatschappelijk draagvlak en kosten. Aan de hand van deze vergelijking is vervolgens een eindscenario opgesteld, dat goede perspectieven biedt voor natuurherstel en haalbaar wordt geacht door de regionale beleidsinstanties.

Conform het lange termijn doel van het project zijn methoden ontwikkeld die kunnen worden toegepast in andere stroomgebieden. De methoden betreffen organisatorische aspecten (project fasering, samenwerking) en wetenschappelijke aspecten (landschapsecologische modellen, bepaling van milieurendement).

1. Introduction

Background of the project

The catchments of small-trans border rivers, crossing the boundaries of Belgium and Germany with the Netherlands, occupy areas of several tens of thousand square kilometer. From an ecological point of view the catchment areas of these rivers are important because they have strong potentials for the occurrence of valuable aquatic and terrestrial ecosystems. However, many of these ecosystems have deteriorated during the last decades and the remaining part is threatened by further socio-economic developments. To find solutions for these problems integrated land use and water management plans have to be developed for the entire catchment area. On catchment level causes and effects with regard to water quality and water quantity problems can be related to each other.

For the development of these integrated management plans a process of close cooperation is needed between regional authorities at both sides of the border. Furthermore, to make the plans well-founded, sufficient scientific information has to be incorporated in the plan devising activities. In order to formulate possible solutions for the ecological problems landscape ecological information is needed about natural processes and their disturbances by human activities. To weigh the ecological effects of these possible solutions against other societal interests socio-economic information is needed. All information must be closely attuned to the policy process and must become available within the time limits of the plan devising activities.

Taking these preconditions into consideration, it is clear that it is not easy to obtain the required information and process it in a suitable form. The interrelations within a catchment are generally very complex. Ecological effects of human activities can be at a far distance from places where these activities occur. In view of these difficulties there is a need to develop methods to support the plan devising activities with adequate scientific information. For this reason a project was started in the catchment area of the Belgium-Dutch river Dommel to develop and test such methods.

The Dommel water system is one of the important tributaries of the Meuse (see figure 1). The river catchment area occupies 1700 square kilometer. This area is characterized by a large diversity of habitats and has high potential ecological values. However strong conflicts exist between these ecological potentials and socio-economic developments. A short time before the start of the project a basin committee was formed to strengthen the Flemish/Dutch water management co-operation in the Dommel area. The development of an integrated management plan was their first priority.

Objectives of the project

The long term object of the project was formulated as the development of methods for the combined use of landscape ecological and socio-economic knowledge in plan devising activities, leading to integrated management plans for nature conservation and restoration. These management plans concern catchment areas of small trans-border rivers. The methods were developed and tested in the catchment area of the river Dommel, leading to a number of scenarios aimed at the attainment of higher ecological quality. These scenarios formed the short-term objective of the project.

Project partners

The project was executed in collaboration between the Utrecht University and the (for the project) most relevant policy actors, which are represented in the basin committee of the river Dommel. From the Netherlands: Province of North Brabant, Water board of the Dommel; from Flanders: Province of Limburg, "Vlaamse Milieu Maatschappij" (Flemish Environmental Company), Administratie Milieu, Natuur en Landinrichting" (Administration for Environment, Nature and Land use).

The main task of the Utrecht University was the development of methods to support the plan devising activities of the policy actors with scientific information. The main task of the policy actors was to formulate different feasible scenarios. The actual scenario building and consequence analysis was a joint responsibility.

Figure 1. *Catchment area of the river Dommel*

2. General outline of the project

Phases of the project

The project consisted of three phases. In figure 2 an overview is presented of the different activities during the three phases.

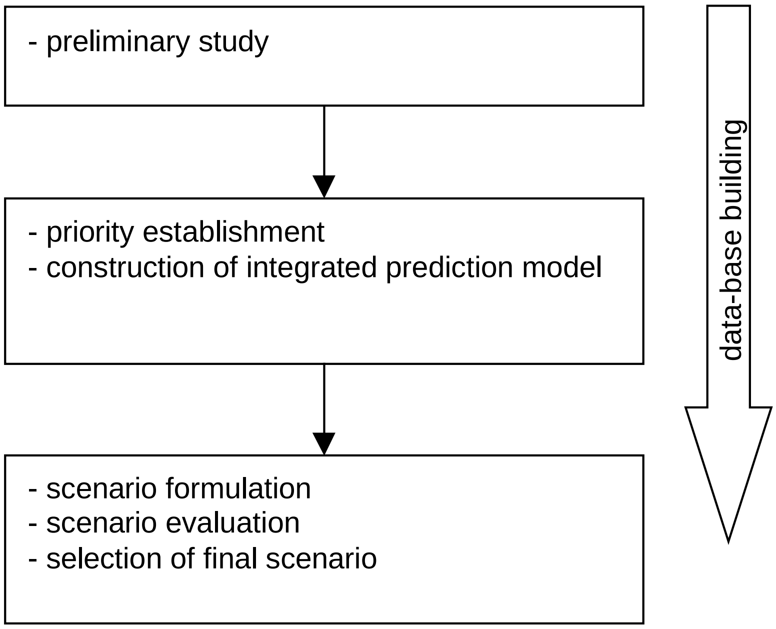


Figure 2. *Overview of activities during the three phases of the project*

Phase 1

In the first phase (1 year) a preliminary study was carried out to get a clear insight in the major environmental problems, their relations to human impacts and bottlenecks for attaining a higher ecological quality. Relations between socio-economic developments and their impacts on nature were analyzed (past, actual, prospective). Furthermore, an analysis was made of the goals, organization and instruments of policy. Finally a start was made with the construction of a database. Landscape ecological information and information concerning socio-economic activities which interfere in the landscape ecological processes were stored in a geographical information system (GIS) of the study area.

The results of the preliminary study were used to make choices for a further demarcation of the project in phase 2.

Phase 2

The aim of the second phase (3 years) was the construction of an integrated prediction model for the Dommel area, with which the spatial environmental effects of different land use and water management scenarios could be determined. At the start of this phase priorities were established concerning the environmental impacts and ecological responses, which should be included in this prediction model. These priorities were based on the results of phase 1, policy preferences and technical possibilities of model construction. Related to these priorities a number of hydrological and ecological models were developed, which were subsequently linked to each other. Simultaneously the construction of the GIS database, which was started in phase 1, was completed. This database was connected to the different models.

Phase 3

During the third phase (0.5 year) a number of realistic scenarios were formulated to attain higher ecological quality in the Dommel area. These scenarios included different measures concerning future land use, treatment of pollution sources, ground water extractions and management of river topology. Furthermore two reference scenarios were used. The first of these scenarios was a nature scenario, in which almost all human interferences in the landscape are banished. In the second of these scenarios a continuation of the present situation was assumed.

Using the integrated prediction model developed in phase 2, ecological potentials of the scenarios were determined. Some model adjustments were made to get a better match between the prediction possibilities of the model and the proposed measures in the scenarios. Subsequently ecological gains of the realistic scenarios were evaluated in relation to their costs (investments, loss of capital in socio-economic functioning). A sensitivity analysis was carried out to determine the relative importance of separate measures in the scenarios for nature restoration. Based on the outcomes of these activities a final scenario was formulated.

Project organization

The province of North-Brabant was appointed as administrative project leader. She beared the financial and administrative responsibility for the project. Utrecht University was appointed as scientific project leader.

The progress and results of the project were regularly evaluated by a technical supervising committee, consisting of expert representatives of the policy partners. The general project leader was chairwoman of this committee. The technical supervising committee reported to the basin committee of the river Dommel, which is the Flemish/Dutch consultative body for integrated water management in the Dommel area. Important decisions about the project were made by this committee. Activities in phase 1 and 2 and modeling activities in phase 3 were executed by the Utrecht University. Activities connected to scenario construction and evaluation in phase 3 were executed by the Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO) and Nijmegen University in collaboration with the project partners from policy, coordinated by the province of North-Brabant.

3. Description of the different phases

Phase 1: *preliminary study*

In the preliminary study the following water related environmental problems were distinguished:
- Acidification (verzuring)
- Dispersion of toxic substances (verspreiding)
- Eutrophication (vermesting)
- Dessication (verdroging)

Based on literature and expert judgments these environmental problems were related to the originating human activities in the catchment area and to their impacts on nature. The spatial variation and intensity of the environmental problems was analyzed, using physical and biotic environmental indicators. The physical indicators were primarily based on land use data and data on the quality of air, groundwater and surface water. The biotic indicators were based on changes between a historical and the current distribution of ecosystems. To be able to show regional variation, the catchment area was divided into 16 sub water systems. These sub water systems were subsequently divided in impact areas (mostly nature reserves) and origin areas (the areas in which human activities influence the ground- and surface water of the impact areas). It appeared to be very difficult to compare the results of the analysis using physical and biotic indicators. Physical indicators were based on the present situation (no adequate historic data were available), whilst the biotic indicators described changes in time. For the explanation of the occurring ecological problems the biotic indicators were most suited. From these indicators it was concluded that dessication is the main problem. Eutrophication and dispersion of toxic substances are also important. These problems are mainly caused by agricultural activities, urbanization, groundwater extractions and water management activities.

Two socio-economic studies were carried out. The first study concerned environmental policy in the Dommel region. Based on literature and interviews the policy related to the different environmental problems was described and evaluated. For each of the participants in the policy process an inventory was made of their strategic and operational goals, their instruments and their use of instruments. Subsequently this policy was evaluated. This was executed using environmental and administrative criteria. Environmental criteria concerned the environmental policy goals. Administrative criteria concerned the policy organization. It was concluded that the formulation of clearer goals and the further organization of broad and efficient cooperation in the Dommel area are priorities for future policy. The second study concerned socio-economic developments. Developments in the past were analyzed and expectations were formulated for the future. For the future it was concluded that decreases are to be expected in eutrophication, acidification and dispersion of toxic substances. Concerning eutrophication and acidification this is caused by less manure production in agriculture and a decline in the number of farmers. Concerning dispersion of toxic substances this is caused by technical pollution abatement measures.

Finally landscape ecological and socio-economic information of the Dommel area was stored in a Geographical Information System (GIS). Data were entered on geomorphology, relief, soil, groundwater, surface water, vegetation, land use, water use (passive and active) and sources of pollution (point and diffuse).

The results of the preliminary study are published in two reports: Bos et al, 1995; Overbeek, 1995.

Phase 2*: *construction of models

At the start of phase 2 priorities were established concerning the construction of the integrated prediction model. Valuable ecosystems were distinguished for which ecological effect models should be developed, i.e. brook valley woodlands, brook valley meadows and ecosystems in the brooks.

From the preliminary study it became clear that the groundwater and surface water related ecological problems are primarily caused by dessication, eutrophication and dispersion of toxic substances. The group of toxic substances shows a large variety. For instance heavy metals, pesticides and organic micro pollutants are included in this group. Modeling of the dispersion of this variety of substances was not feasible. Moreover knowledge about the ecological effects of these substances is scarce. For these reasons it was decided to exclude dispersion of toxic substances from the modeling activities.

After the establishment of these priorities the integrated prediction model was constructed. A technical description of the construction of this model and the hydrological and ecological sub-models is given in chapter 4. In the next paragraphs the main features of these models are discussed.

The integrated model consists of a set of hydrological and ecological models which are linked to each other (see figure 3). This model is used to predict the effects of different land use and water management scenarios on the selected ecosystems. So the ecological models form the heart of the integrated model. Hydrological models, connected to land use and water management, were developed in such a way that they provided the necessary input parameters for the ecological response models. Therefore the ecological models are discussed first.

Ecological models

First a preliminary study was carried out on model concepts (Olde Venterink & Wassen, 1997). Next ecological response models were constructed for grasslands (MOVE), for woodlands (ALNION) and for aquatic ecosystems (ECOSTREAM).

MOVE is an existing model, developed at the Dutch National Institute of Public Health and Environment (RIVM). To improve this model for meadows along lowland rivers field observations and experiments were carried out. First MOVE was used to predict probabilities of occurrence of grassland species. The obtained information was subsequently aggregated to get predictions for vegetation types.

The models ALNION and ECOSTREAM were based on literature and expert judgement. Major types of brook valley woodlands and aquatic stream ecosystem types were distinguished. In addition differentiating environmental variables were determined, based on existing data and statistical treatment of these data.

In tables 1 and 2 overviews are presented of the predicted nature types and of the differentiating environmental parameters, which are used as input for the models.

MOVE predictions are expressed in probabilities of occurrence of a vegetation type, given environmental conditions. ALNION and ECOSTREAM are based on classification and decision rules at given environmental conditions. A nature type can occur or it can’t.

Table 1. *Nature types predicted by the ecological models.*

model	nature type	predicted nature type
ALNION	brook valley woodlands	birch wood 2 types of alder woods 2 types of spring woods 2 types wet woodlands on mineral soil wet ruderal woodland drained woodland
MOVE	meadows and fens in brook valleys	*Phragmition* *Filipendulion* *Caricion gracilis/C. elatae* *Caricion nigrae* *Calthion palustris* *Junco-Molinion* *Nardo-Galion saxatilis* *Cynosurion cristati* *Arrhenatherion elatioris*
ECOSTREAM	aquatic ecosystems in lowland streams and small rivers	29 types of aquatic ecosystems (aquatic invertebrates, fish and plants)

Table 2. *Input parameters for the ecological models.*

model	input parameter
ALNION	mean groundwater level (year) soil type acidity of the root zone flooding
MOVE	moisture content of the rootzone (derived from spring groundwater level) acidity of the root zone nitrogen mineralization (year)
ECOSTREAM	stream dimensions (upper, middle, lower course) intermittance current velocity saprobic state

An example of a brook valley woodland: *Normal Alder Swamp*

Oosterikker Broek (Twente, The Netherlands)

An example of a brook valley meadow: *Junco-Molinion*

Urkhovense Zeggen (N-Brabant, The Netherlands)

An example of a natural lowland stream ecosystem:

Zwarte Beek (Limburg, Belgium)

Hydrological models

On the base of the preliminary study it was decided that the main problems, which should be taken into account in the model construction, were dessication and eutrophication. However field observations and outcomes of the ecological modeling gave course for further considerations. From field observations it became clear that nutrients, which leach to the groundwater from agricultural areas, do not reach the terrestrial vegetation in the brook valleys. So for these ecosystems there was no need to include a nutrient transport component in the groundwater modeling. Concerning surface water the outcomes of the ecological modeling with ECOSTREAM showed that organic load is a more differentiating factor for the occurrence of aquatic ecosystems than nutrient load. So organic load was included in the surface water modeling instead of nutrients. Finally the results of the ecological modeling with MOVE and ALNION showed that acidity is an important differentiating factor for the terrestrial vegetation. Therefore, though no serious acidification problems were recognized in the preliminary study, also acidity was incorporated in the hydrological models.

In connection to the ecological models for grasslands and woodlands a groundwater model was constructed, using an existing program code (MODFLOW). In combination with an existing soil model (SMART) this model is used to predict the effects of land use and water management on the input parameters of the terrestrial ecological models. In connection to the ecological model for aquatic ecosystems a distributed surface water balance and transport model was developed. Subsequently this model was extended to simulate organic load transport. The resulting model (STREAMFLOW) is used to predict the effects of land use and water management on the input parameters of the aquatic ecological model.

In table 3 an overview is presented of the input parameters of the different hydrological models.

Table 3. *Input parameters for the abiotic models. Bold printed parameters are changeable in the scenarios.*

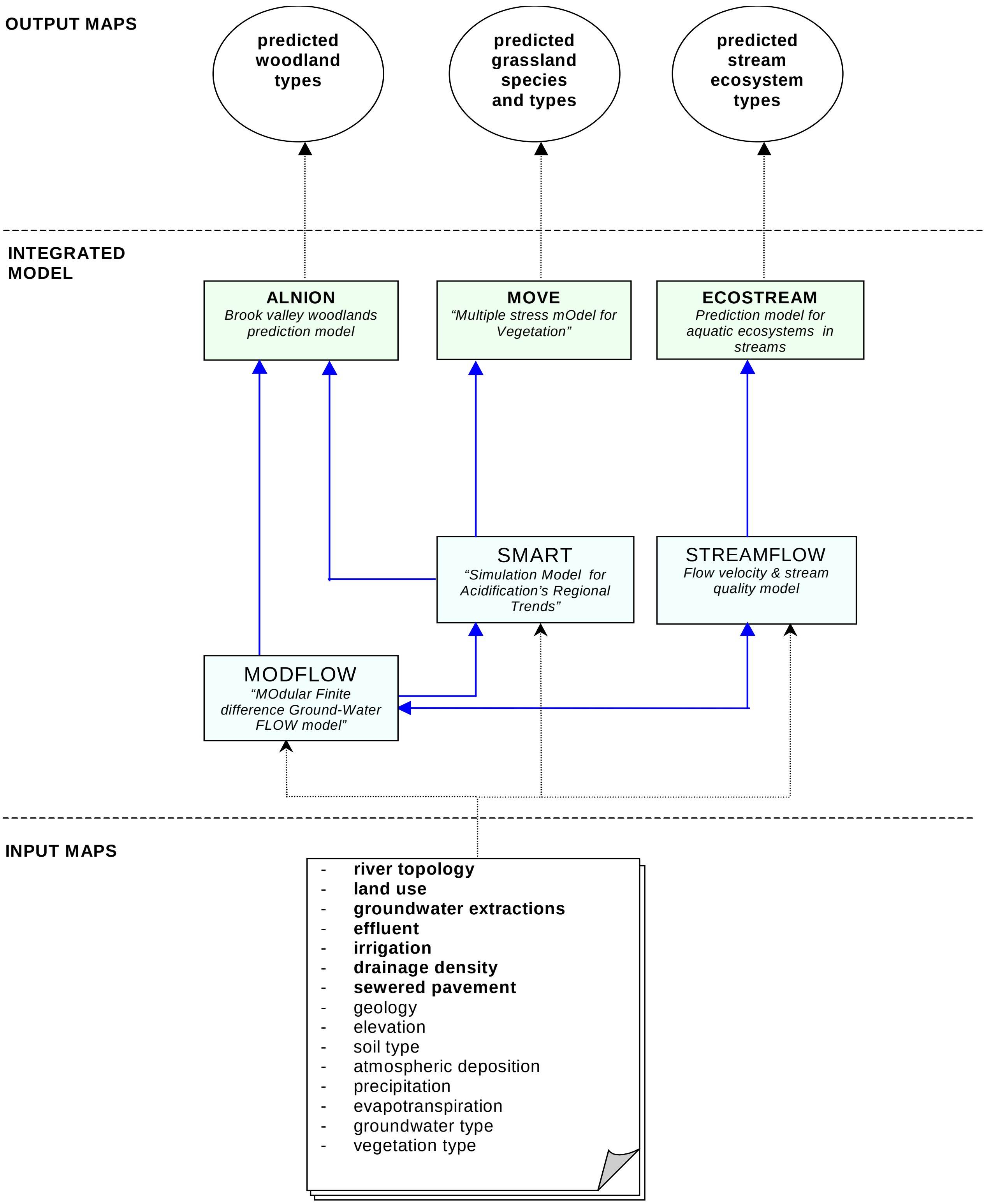
model	input parameter
MODFLOW	geology soil type elevation precipitation and evaporation **surface water head** **drainage density** **depth of groundwater extractions** **discharge of groundwater extractions** **yearly average irrigation** **land use** **area of sewered pavement**
STREAMFLOW	soil type elevation precipitation and evaporation waterstorage capacity of the root zone surfacewater head groundwater levels seepage **landuse** **area of sewered pavement** **transfer of water between streams** **drainage density** **weirs** **meander factor** **locations of effluent disposal** **connections of households to wastewater plants** **connections of households to sewers**
SMART	soil type cation and anion concentrations in groundwater atmospheric deposition of cations, anions and water vegetation type groundwater levels seepage flux

Integrated model

The integrated model consists of the previously constructed GIS database linked to the different hydrological and ecological models (see figure 3). The GIS is used for data storage, data processing, and data conversion to- and from the sub models. The input of the model is in the form of maps. These maps contain data about the landscape and human interferences in the landscape. The output, in terms of ecological predictions, is also in the form of maps, discriminating between cells of 100x100 meter. The ecological predictions for these cells concern probabilities of occurrence of the different nature types, given the environmental conditions, which are calculated using the hydrological models. However, land use in these cells can prevent the development of the predicted nature types. For this reason the ecological predictions must be interpreted as ecological potentials.

The results of phase 2 are published in five reports: Olde Venterink et al, 1998 a,b ; Pieterse et al, 1998 a,b,c.

Figure 3. *Structure of the integrated model. Bold printed input maps can be varied in the scenario studies.*



Phase 3*: *scenario building and evaluation

Phase 3 consisted of three steps. In the first step a number of land use and water management scenarios were formulated. In the second step the consequences of these scenarios were evaluated. Based on the outcomes of this evaluation a final scenario was formulated in the third step. Activities concerning model calculations and alterations were executed by Utrecht University. Activities concerning the formulation and evaluation of scenarios were executed by the Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO) in cooperation with Nijmegen University, by order of the Province of North-Brabant. These activities were conducted in close cooperation with the project policy partners.

Formulation of scenarios

A workshop for policy actors from Flanders and the Netherlands was organized. In this workshop the general outline and aims of the Life-Dommel project were explained. Special attention was paid to the need to attain a higher ecological quality in the Dommel area. To reach this aim a close cooperation was requested in the process of scenario building. Next the performance of the integrated model was demonstrated. For a number of policy measures their calculated hydrological and ecological effects were shown. After these presentations the feasibility of a number of policy measures, which could be incorporated in the scenarios, was discussed.

Following on the policy study executed by the Utrecht University in phase 1, a more detailed study was carried out by SC-DLO in cooperation with Nijmegen University. This study concerned policy aims and proposed policy measures, which are applied in areas with different societal functions. The following types of areas were distinguished.

- Forest and nature areas
- Agricultural areas with additional nature values
- Agricultural areas
- Existing urban areas
- Newly planned urban areas
- Groundwater extractions

Based on the results of the workshop and the additional policy study, two policy scenarios were formulated. The first scenario was based on a high priority to nature restoration in policy plans (optimistic-realistic scenario). The second scenario represented a standstill situation with only some additional measures in nature areas (pessimistic-realistic scenario). Furthermore two reference scenarios were distinguished. In the first of these scenarios almost all human interferences in the landscape were banished (nature scenario). In the second scenario a continuation of the present situation was assumed (zero-scenario).
A number of policy measures were incorporated in the scenarios, which differed between the above-mentioned types of areas.

Evaluation of scenarios

The ecological potentials of the scenarios were determined, using the integrated prediction model. Some model adjustments were necessary to get a better match between the prediction possibilities of the model and the proposed measures in the scenarios. As previously shown in table 1, ecological predictions can be made for a variety of grassland types, woodland types and aquatic ecosystem types. For evaluation purposes a number of these types were selected, among other things based on rarity, vulnerability and species richness. This resulted in the following selection:

- *Calthion palustris* and *Caricion gracilis/elatae* (grasslands)
- Normal Alder Swamp/Alder Spring Wood and Birdcherry Ash Wood (woodlands)
- Oligo-mesosaprobe types (aquatic ecosystems)

Next, for each scenario the determined ecological potentials of the selected nature types were translated into ecological gains. The ecological potentials of the zero-scenario were defined as ecological gains of 0 %. The ecological potentials of the nature scenario were defined as ecological gains of 100 %. Subsequently the ecological gains of the realistic scenarios were determined by comparing their ecological potentials to the ecological potentials of the reference scenarios. The results of this last step are shown in figure 4.

Based on former studies and expert judgement, the costs of the realistic scenarios were calculated. Only costs of measures, which are additional to existing policy plans were taken into account. Costs concerned management investments (single, yearly) and losses in yields in agriculture (caused by changes in water levels). The calculated investment costs related to the optimistic and pessimistic scenario are shown in table 5.

Finally separate measures, incorporated in the scenarios, were compared with regard to their relative environmental effects. These effects were calculated with the hydrological models.

Formulation of final scenario

A second workshop for policy actors in the Netherlands and Flanders was organized. In this workshop the results of scenario formulation and evaluation were presented and discussed. Next policy measures were evaluated with respect to their costs and their effectiveness for nature restoration. Based on policy practice experience, an assessment was made of the most obvious measures to be taken in the time span till 2020. In this way a first outline of the final scenario was constructed.

This outline was further worked out in a number of meetings of the technical supervising committee. The resulting final scenario is shown in table 4.

Table 4. *Measures in the final scenario (Kwakernaak et al, 1998).* * existing policy

Forest and nature areas
- removal of drain pipes
- filling in of ditches
- replacement of 35 % of coniferous forests by deciduous forests *
- remeandering of brooks
- removal of weirs
- extension of brook maintenance

Agricultural areas with additional nature values
- storage of drainage water during winter periods
- termination of sprinkling from groundwater sources
- re-meandering of brooks
- extending of brook maintenance
- shallowness of ditches 20 cm below ground level
- removal of drain pipes

Agricultural areas
- shallowness of ditches 20 cm below ground level
- removal of drain pipes
- 20 % reduction of sprinkling from groundwater sources

Existing urban areas
- purification of effluent from isolated houses
- 40% disconnection of rainwater discharge from the sewer systems *
- extension of connections to sewage mains (90% Belgium, 98% NL) *

Newly planned urban areas
- groundwater neutral building of new houses *

Groundwater extractions
- termination of industrial groundwater extractions for low-quality purposes
- 20 % reductions of the other extractions

The investment costs of this final scenario, additional to costs of existing policy, are 117 million ECU (table 5). Changes in groundwater levels in the final scenario cause no damage for agricultural production if regarded on the level of the catchment scale. On the contrary, a yearly profit of 0.5 million ECU was calculated.

The ecological potentials of this scenario were determined, using the integrated prediction model. The results show a considerable increased area of wet brookvalley woodlands, length of oligo- and mesosaprobic aquatic ecosystems and area with increased probability of occurrence of currently rare grassland ecosystems. An overview is given in table 6 and table 7. In figure 4 the ecological gains of the final scenario are presented.

The results of phase 3 are published in Kwakernaak et al, 1998 and De Jong, 1998.

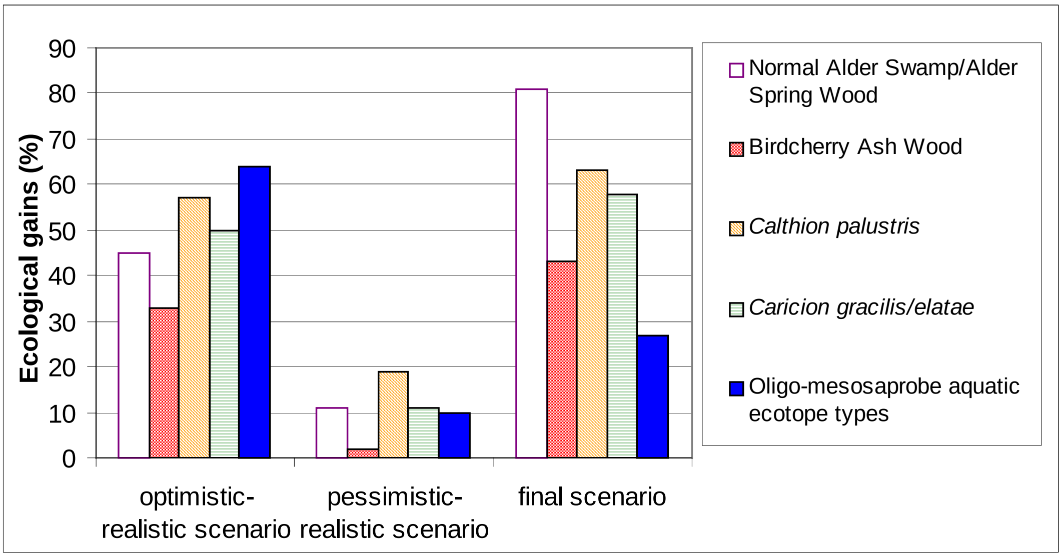


Figure 4. *Ecological gains of the three scenarios (Kwakernaak et al, 1998).*

Table 5. *Investment costs of the three scenarios pertaining to a plan period of 20 years (after Kwakernaak et al, 1998). Only the costs of measures, additional to existing policy, are taken into account.*

scenario	costs (x 10^6 ECU)
optimistic-realistic	141
pessimistic-realistic	13
final	159

Table 6. *Ecological potentials of the final scenario. The increased area and stream length of several ecosystem types compared to the current situation. Total area of brook valleys is 42850 ha, total length of streams is 473 km.*

ecosystem type	increased area or length
	area (ha):
Normal Alder Swamp/Alder Spring Wood	199
Birdcherry Ash Wood	1700
	stream length (km):
oligo-mesosaprobe aquatic ecosystems	79

Table 7. *Ecological potentials of the final scenario. The net area with increased probability of occurrence (> 1%) of grassland ecosystems compared to the current situation. Total area of brook valleys is 42850 ha.*

ecosystem type	area with increased probability of occurrence (ha)
Calthion palustris	10250
Caricion gracilis / elatae	7750

4. Technical description of models

Ecological models

Two ecological response models are used for terrestrial ecosystems in brook valleys; MOVE for meadows, and ALNION for woodlands.

MOVE is used to predict the effects of changes in environmental conditions—moisture availability, acidity, and nutrient availability—on the probability of plant species occurrence (e.g. Latour & Reiling, 1993). MOVE has been developed at the Dutch National Institute of Public Health and Environment (RIVM) and contains response curves of most western European terrestrial plant species. The response curves were determined by logistic regression of mean Ellenberg indication values of 17000 vegetation relevées. The Ellenberg values for moisture availability and acidity have been calibrated with measured environmental variables. For this LIFE-project additional calibration of the Ellenberg indication values for nutrient availability was carried out to improve MOVE for meadows along lowland rivers. Comprehensive field observations and experiments were carried out during 18 months at 8 locations along the river Dommel (Belgium & The Netherlands) and at 3 locations along the Zwarte Beek (Belgium). These 11 locations contain 100 sites in total. Data were collected on ground water levels, groundwater quality, soil moisture quality, soil parameters, N,P & K mineralization, nutrient uptake of the vegetation, nutrient limitation, and vegetation composition. This study resulted in a significant relationship between Ellenberg-N indication values and net annual N-mineralization (Pieterse et al, 1998a).

For brook valley woodlands of lowland rivers the model ALNION was developed (Olde Venterink et al, 1998a). Based on a literature study the 9 major woodland types of western Europe were distinguished (Birch Wood, Acid Alder Swamp, Normal Alder Swamp, Alder Spring Wood, Ash Spring Wood, Birdcherry Ash Wood, Hornbeam Oak Forest, Drained Ruderal Alder, and Wet Ruderal Alder). Differentiating environmental variables were selected by means of statistical analysis. Based on characteristic differences in environmental variables between the major woodland types, decision rules were constructed and incorporated in ALNION in order to enable predictions on brook valley woodlands following changes in environmental conditions. The variables: soil type, mean annual water level, flooding, top soil acidity, and water level dynamics were incorporated in the ALNION model. Predictions can be made for almost all woodland types. The wet ruderal alder was omitted from ALNION because knowledge is lacking about the type- and concentrations of nutrients at which nitrophilous species are going to dominate the vegetation. The dataset on which the ALNION decision rules are based were compared to other datasets. It was concluded that the decisions, for which a comparison was possible, are appropriately underpinned by data.

For aquatic ecosystems in streams predictions are made by means of the model ECOSTREAM (Olde Venterink et al, 1998b). Basic entities of this model are the aquatic ecotope types (AET) developed by the DLO-Institute for Forestry and Nature Management (IBN-DLO) and the Centre for Environmental Science (CML), University of Leiden (Verdonschot et al, 1992). The occurrence of aquatic ecotope types is predicted by means of decision rules, which are based on data from literature and expert knowledge. The construction of ECOSTREAM is primarily based on aquatic invertebrates of lowland streams. The major input variables are; stream dimensions (position in the catchment, and whether or not dry periods in summer), current velocity, and saprobic state of the surface water. The aquatic ecotope types were arranged in a 3D-matrix with these variables along the axes. The decision rules of ECOSTREAM relate to these environmental variables.

Hydrological models

The major input variables of the ecological models for meadows and woodlands are moisture availability, acidity, and N-mineralization.

Moisture availability is considered as depending on phreatic ground-water levels and is modeled with the finite element ground-water flow model MODFLOW (Pieterse et al, 1998c). The program code for this model has been developed by the United States Geological Survey (McDonald & Harbaugh, 1984). MODFLOW is used to predict effects of socio-economic activities like ground-water extraction on phreatic ground-water levels and ground-water discharge rates. The ground-water model of the Dommel catchment is schematized by 140 x 80 cells of 500 x 500 m and 9 model layers. Calibration of MODFLOW has been performed with measured ground-water levels from 700 piezometers in the Dommel region and ground-water discharge to streams using hydrograph information of the river Dommel.

The variables acidity and nutrient availability are predicted by the model SMART-2. SMART-2 has been developed by the DLO-Winand Staring Centre (Kros et al, 1995). Predictions are based upon atmospheric deposition, soil type, seepage, ground-water level, and mineralization (Kros et al, 1995). Groundwater levels are obtained from MODFLOW calculations. SMART-2 simulations of acidity and nutrient availability were compared with field data which had been collected in the above mentioned comprehensive field study. Simulations of acidity were comparable with measured acidity. N-mineralization simulations did not match with field observations. Moreover, these simulations did not differentiate between various sites, although these sites have different soil properties and different hydrological regimes. For these reasons calculations of N-mineralization with SMART-2, needed as an input parameter for MOVE, were considered unreliable. It was decided to exclude the MOVE variable N-mineralization from the MOVE equations. Because the multiple regression equations of MOVE cannot be altered, the optimum N for each plant species was used instead (e.g. Pieterse et al, 1998a).

The major input variables of the ecological model for aquatic ecosystems are flow velocity, saprobic state, stream dimensions and subdivision between continuous and intermittent streams. These variables are predicted by the model STREAMFLOW (Pieterse et al, 1998b). STREAMFLOW is a distributed conceptual water balance model and calculates the contribution of run off and base flow to river discharge. STREAMFLOW is build with cells of 500 by 500 meter wide. The model is constructed with the PCRASTER GIS program developed by the faculty of Geography of Utrecht University (Wesseling et al, 1996). Climatic influences (dry- and wet periods), the influence of soil moisture content on runoff mechanisms and seepage and infiltration between streams and groundwater are taken into account. An assessment is made of flow velocity with the Manning formula. Discharge simulations were compared with field observations and found reliable. The calculated stream discharge and flow velocity are subsequently used for assessment of the saprobic state. One way to define saprobic state is by means of the concentration of organic-N in streams. In STREAMFLOW, organic-N is approximated by Kjeldahl-N. The major sources of Kjeldahl-N are households and industry, disposal of effluent to waste water plants, to untreated sewers and direct to the stream. Degradation of Kjeldahl-N is accounted for as a function of the Kjeldahl-N load and residence time in a cell. After comparison with observations at several locations in the Netherlands it could be concluded that the pattern of saprobic state is adequately simulated.

Integrated model

Simulations of the connected hydrological and ecological models were compared with observations.

MODFLOW-SMART-MOVE simulations are in agreement with expectations of potentials for nature development, based on fieldwork. The simulations show that in the larger part of the catchment, the probability of occurrence of species-rich grasslands is very low. Indeed hardly of these grasslands are left in the catchment area (Pieterse et al, 1998a).

MODFLOW-SMART-ALNION simulations were compared with observed woodland types in the catchment area. From the inventory of actual occurring woodland types it is concluded that only very small parts of the brook valleys (still) contain woodlands. Moreover, the larger parts of the observed woodlands are dry and drained. This observation is in agreement with the results of the simulations (Olde Venterink et al, 1998a).

STREAMFLOW-ECOSTREAM simulations were compared with the distribution of a measured biotic index in the catchment area. This biotic index is determined by means of the indication value of aquatic invertebrates for especially organic pollution of the surface water. The simulated ecotope types corresponded well with the observed distribution of the biotic index in the field. It was concluded that the saprobic state part of ECOSTREAM functions appropriately (Olde Venterink et al, 1998b).

5. Conclusions and recommendations

The short-term objective of the project was the formulation of scenarios to attain a higher ecological quality in the Dommel area. At the end of the project it can be concluded that the collaboration between policy actors and scientists, needed to reach this aim, was organized successfully. Furthermore a landscape ecological and socio-economic knowledge base was developed which proved to be suitable to formulate and evaluate a number of scenarios to attain a higher ecological quality. This has resulted in a final scenario, which is considered feasible by authorities from Belgium and the Netherlands. This ambitious scenario offers good perspectives for nature restoration. In the near future the results of the project will be used by the basin committee of the river Dommel to formulate an integrated management plan.

The long-term objective of the project was the development of methods, which should be applicable in other catchment areas (The Dommel catchment project is a case study). In the next paragraphs some main conclusions concerning these methods are discussed. These concern organizational aspects (project phasing, co-operation in the project) and aspects with respect to scientific content (construction of models, determination of ecological gains)

Project phasing

The project phasing appeared suitable and can be used in similar projects. One aspect deserves special attention. The construction and integration of appropriate models at the level of a catchment is very complicated. Therefore, at an early stage it is necessary to establish priorities concerning the environmental impacts and ecological responses, which should be included in the different prediction models. This is not an easy task, due to two reasons. The first reason concerns communication problems between policy actors and scientists. Policy actors are schooled in practical policy and have little knowledge about technical possibilities of model construction. Concerning scientists, the situation is the other way around. From experiences in the Dommel project it can be concluded that it is important to invest much time in the gaining of mutual understanding. The second reason concerns information on which priorities can be based. Insight is needed in the major environmental problems, their relations to human impacts and bottlenecks for attaining a higher ecological quality. At the start of a project, this insight is often not clear. In the Dommel project this insight was gained by conducting a thorough preliminary study. A similar approach is recommended for future projects.

Cooperation

As stated above, the organization of cooperation in the project has resulted in a final scenario, which is supported by the authorities in the Dommel area. This organization was shaped in two ways. Firstly by consultations in the technical supervising committee and basin committee (which members also consulted the organizations which they represent). Secondly by organizing two workshops for a broad audience of policy actors. These workshops have been crucial for the success of the process of scenario building. In these workshops the information gap was bridged between the policy actors directly involved in the project and other policy actors, which could contribute to the success of the project. Furthermore, these meetings functioned as a platform for the generation of ideas, concerning feasible policy measures, which could be incorporated in the scenarios.

Model construction

In this paragraph the applicability of the newly developed models is discussed.

The general way of construction of the integrated model, using a GIS database for the coupling of sub models, can be used in other projects. The different sub models also have a wide application range. The model (STREAMFLOW) offers a new approach in surface water modeling, enabling calculation of stream discharges (and related transport of substances) for every location in a catchment. The prediction model for grasslands is based on an existing model (MOVE). The application possibilities of MOVE have been extended by calibration of the nutrient availability component. It appeared to be difficult to couple this component of the MOVE model to predictions of nutrient availability using the soil model (SMART-2). These predictions did not differentiate between various sites, although these sites had different soil properties and different hydrological regimes. Further research on the applicability of SMART-2 on a local scale is recommended.

The newly developed prediction models for brook valley woodlands (ALNION) and lowland stream ecosystems (ECOSTREAM) are based on data from North Western Europe. This implies that the predictions generated by these models are valid for North Western European brook valleys.

Determination of ecological gains

In the project a method was developed to translate ecological effects into ecological gains. This method has been very useful for the evaluation of the different scenarios. It was used for five nature types, which are typical for the Dommel area. For application purposes in other areas also other nature types can be selected, using the wide variety of prediction possibilities of the integrated model. The method is not suitable to compare ecological gains in different areas in an absolute way. In this respect the method can be improved.

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