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INTERNATIONAL COOPERATION

Markku Puustinen

Management of the Runoff Waters from Arable Land

Final Report of the EU/LIFE Project
(LIFE 97 ENV/FIN/335)

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Foreword

In 1996, on the initiative of the Ministry of Agriculture and Forestry, the Finnish Environment Institute conducted a survey of the situation regarding the need to treat agricultural runoff waters and means of promoting this treatment. Enshrined in the initiative was the goal of establishing a new development project. This project for management of runoff waters from arable land was designed as one in the Life series and designated VIHTA. After it had received approval from the EU Life Fund (Environment) it was launched on 1.8.1997. Later, after delays caused by inclement weather, an extension of its period was applied for. The project was concluded on 31.12.2000.

In addition to the Life Fund, the Ministry of Agriculture and Forestry and the Ministry of the Environment contributed significantly to funding. It was implemented as a national development project by the Finnish Environment Institute, the Agricultural Research Centre and the Technical Research Centre of Finland. Co-ordination was entrusted to the Finnish Environment Institute.

A steering group and a project group were appointed to run the project. The task of the former was to follow progress and approve the working plans for each reporting period. Its membership comprised Senior Inspector Ilkka Reponen from the Ministry of Agriculture & Forestry, Senior Inspector Heikki Latostenmaa from the Ministry of the Environment, Professor Markus Pyykkönen from the Agricultural Research Centre, Dr. Raimo Ihme from the Technical Research Centre of Finland and, representing various units of the Finnish Environment Institute, Mikael Hilden, Seppo Rekolainen, Ilkka Manni and Antti Lehtinen. The Finnish Environment Institute's Director of Research Juha Kämäri chaired the steering group.

VIHTA consisted of the following sub-projects (e-mail addresses of persons responsible in brackets): Constructed Wetlands VESIKOT (markku.puustinen@vyh.fi), Demonstrative Modelling and Instructions for Management of Acidity of Runoff Water HAPSU2 (sirpa.joukainen@vyh.fi), Decision Analysis and Decision Support System DADSS (sirkka.tattari@vyh.fi) and Demonstrative Instructions for Dissemination of Information in Effective Implementation of Agro-Environmental Protection Measures NETTI (helena.valve@vyh.fi). The persons in charge of the sub-projects formed the project group, the responsibility of which was to see to the progress of the sub-projects and thus to implement the project plan under the steering group's supervision. The person responsible for VIHTA overall was Markku Puustinen.

The project involved substantial co-operation with the ministries of the Environment and Agriculture & Forestry, the South-West Finland Regional Environment Centre, the Pyhäjärvi and Lestijoki Life projects, the Vantaanjoki Life project, the Life Vesijärvi project, the Helsinki University of Technology, the Finnish Game and Fisheries Research Institute, the Finnish Field Drainage Centre, the University of Helsinki and various bodies involved in agricultural extension. There was regular participation in training events arranged by the ministries of the Environment and Agriculture & Forestry in relation to implementation of environmental subsidies for agriculture as well as in drafting a new environmental support programme. Advisory and training events for farmers as well as international congresses were attended.

This report deals with the background to VIHTA, its goals and implementation, the experience gained, the central results obtained and its environmental benefits. The conclusions include an assessment of the most important research and development needs as well as recommendations for measures to promote environmental affairs in agriculture. The report is a summary of the results presented in the sub-project reports, in articles, at seminars held within the framework of the project and on the Internet.

On behalf of VIHTA I wish to express my warmest thanks to the bodies which provided funding and to all who contributed to the project or advanced its progress. Without good cooperation neither the project nor this report would have been possible.

Helsinki 30.3.2001 Markku Puustinen

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Executive summary

During the 1st phase (1995-1999) of the Finnish Agri-Environmental Programme (FAEP), the system of environmental subsidies was divided between the General Agricultural Environment Protection Scheme (GAEPS) and the Special Protection Scheme (SPS). Almost 90% of the country's farmers joined the former. Far fewer initially participated in the SPS, which provides for more efficient and extensive measures, and therefore there was a need to increase its coverage. The treatment methods for runoff waters mentioned in the SPS were constructed wetlands, sedimentation ponds, controlled drainage, lime filter drainage, surface liming of sulphate acid soils and riparian buffer zones.

The goals of VIHTA related to developing the runoff water treatment methods provided for in the special scheme and solving problems associated with their implementation. The goals related to a great variety of levels, ranging from individual techniques for treating runoff to developing a method to facilitate comprehensive decision making and experimenting with methods of promoting extension work among farmers. The project comprised four sub-projects (VESIKOT, HAPSU2, NETTI, DADSS).

The results of the sub-projects were availed of in the development of the VIHTA model. This contains data on the effects and costs of wetlands, sedimentation ponds, riparian buffer zones and controlled drainage. The method comparisons made using the model show that it pays to begin with buffer zones and wetlands when attempting to treat runoff waters from arable land. This is the best way to derive the greatest benefits from environmental investments. As measures gradually advance, controlled drainage enters the picture as a useful method. Arguments in favour of sedimentation ponds likewise present themselves. VIHTA compares treatment methods with each other on the basis of a cost-benefit analysis. However, a very important point that needs to be understood is that the implementability of treatment methods for runoff waters depends on the characteristics of the catchment in question. Given the differences that exist between various parts of the country, the most advantageous measures vary greatly from place to place.

An efficient wetland can remove as much as 70% of the suspended solids and nutrients entering it each year, and 40% of the nitrogen load. The longer the water remains in the wetland, the higher the rate of removal. However, wetlands cannot be constructed anywhere at all. Broad riparian buffer zones reduce the surface-flow load by 40-60%. The efficiency of buffer zones derives from their capacity to filter nutrients and from the load-reducing effect of the area reserved for them being excluded from cultivation. Wetlands and buffer zones enrich biodiversity and enhance scenic attractiveness.

The GIS applications developed alongside VIHTA enable suitable sites for wetlands to be identified. Thanks to this, the overall benefits of wetlands on the catchment scale can be assessed already in the planning stage.

The HAPSU model developed on the basis of the HAPSU2 sub-project material is a good tool for assessing the suitability of lime filter drains, controlled drainage and surface application of lime to acid soils as well as for comparing results. On the basis of this examination it is possible to identify the most effective method for reducing the detrimental impacts on the environment of acid sulphate soils.

Farmers need dependable information on which to base their environment-related decisions. The NETTI sub-project involved the development of cooperation between the actors with roles in the implementation of environmental policy in the agricultural sector, interpretation of the goals of this policy as well as advisory and planning methods to facilitate care of the environment on the practical level.

The information, experience and practical instruments that the project produced are conducive to more widespread adoption of the Special Protection Measures, which will bring local, regional and national benefits for the environment. The approaches and solutions adopted in the project are suitable for use throughout the European Union.

List of abbreviations

TSS	=	Total suspended solids
P	=	Phosphorus
PP	=	Particle-bound phosphorus
DP	=	Dissolved phosphorus
TP	=	Total phosphorus
N	=	Nitrogen
PN	=	Particle-bound nitrogen
DN	=	Dissolved nitrogen
TN	=	Total nitrogen
GIS	=	Geographic Information Systems
FAEP	=	Finnish Agri-Environmental Programme
GAEPS	=	General Agricultural Protection Scheme of the FAEP
SPS	=	Supplementary Protection Scheme of the FAEP
W/C-ratio	=	Wetland area divided by its catchment's area
WRT	=	Residence time of water
CW	=	Constructed wetland
SB	=	Sedimentation basin
BZ	=	Buffer zone
CD	=	Controlled drainage
LFD	=	Lime filter drainage
SL	=	Surface liming
FEI	=	Finnish Environment Institute
VIHTA	=	EU-Life project "Management of the Runoff Waters from Arable Land"
VESIKOT	=	Sub-project "Constructed Wetlands"
HAPSU2	=	Sub-project "Demonstrative Modelling and Instructions for Management of Acidity of Runoff Water"
HAPSU	=	A pre-existing simulation model for the management of acid sulphate soils
DADSS	=	Sub-project "Decision analysis and Decision Support System"
NETTI	=	Sub-project "Demonstrative Instructions for Dissemination of Information in Effective Implementation of Agro-Environmental Protection Measures"

Introduction

1.1 Agriculture and the state of the environment

The present level of agricultural loading that affects surface waters in Finland is a result of a development that has taken place over several decades. Arable land in this country is inherently very poor in plant-available phosphorus (P). Due to the acidity of the soil, most fertiliser-added P is firmly bound and leaching has been exiguous. Hence, Finnish cropland has been fertilised more than the crops would actually need. The excess P of fertiliser origin has gradually raised soil P to its present level and increased the risk of leaching (Fig. 1). One-third of the present P reserves in Finnish arable land is of fertiliser origin.

For reasons of economy, grain cultivation has been made more intensive and higher-productivity varieties have been introduced. The most essential changes have been an increase in the level of fertiliser inputs and more efficient cultivation methods. Due to the brevity of the period available, it has made most sense to plough already in autumn. This has increased erosion and thus transport of P to water bodies. Moreover, the higher level of fertiliser use has contributed to nitrogen (N) leaching, which increases substantially when the amount applied exceeds 100 kg N ha^{-1} yr^{-1} (Fig. 2). The total N load per ha of arable land varies between 8 and 20 kg ha^{-1} yr^{-1}, and the total P load between 0.9 and 1.8 kg ha^{-1} yr^{-1} [3]. In the early 1990s, the annual average total N load from field cultivation was estimated at 30,000 tonnes and total P 3,000 tonnes. Losses from manure storages was estimated to contribute a further loading of 2,900 tonnes of N and 300 tonnes of P.

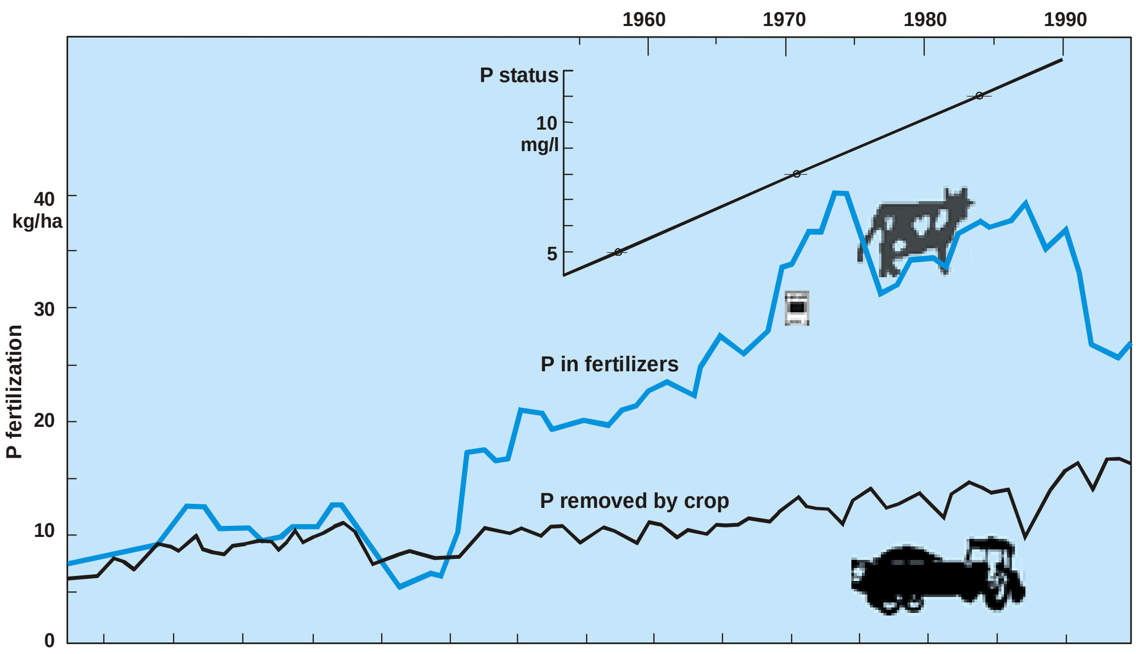

Figure 1. The use of phosphorus in commercial fertilizers and animal manure (kg ha^{-1}) and the uptake of phosphorus by yields (kg ha^{-1}) in 1950-1995 in Finland [1]. In the upper right corner: The development of the ammonium-acetate extractable phosphorus (mg l^{-1}) in surface soil layers [2].

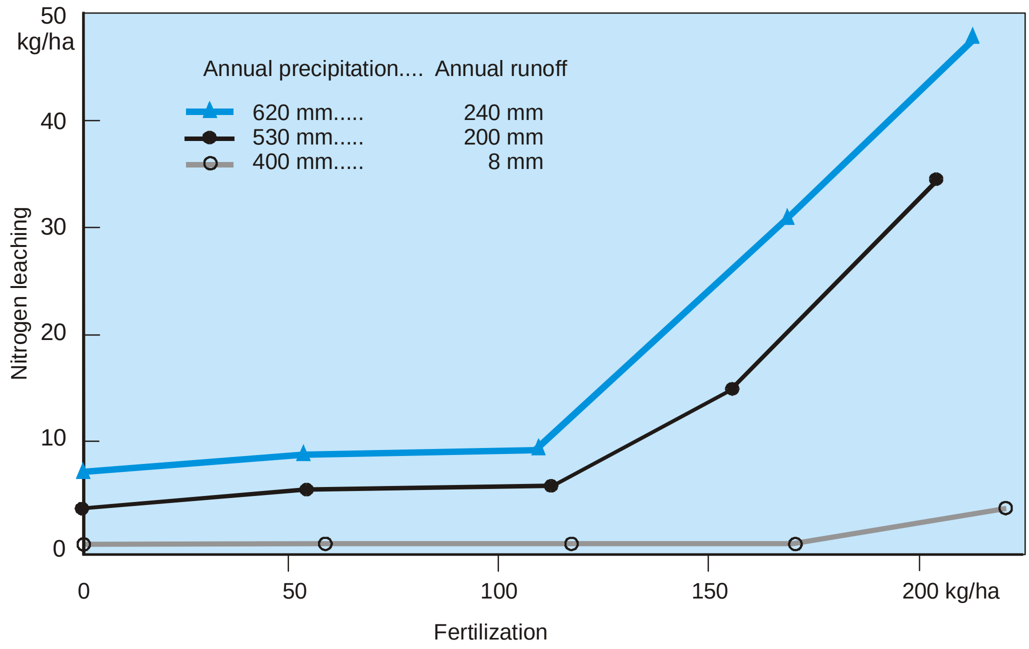

Figure 2. Nitrogen leaching as affected by different precipitation and runoff conditions and different fertilisation levels [4].

Eutrophication is one of the most extensive and severe adverse environmental impacts in our country. The N and P loadings that accelerate it come from both point and diffuse sources. Point-source loading consists of industrial and municipal wastewaters and discharges from fish farms. Diffuse loading includes discharges from agriculture, forestry, and the rural population not connected to sewage systems. At present, the total N and total P loadings from agriculture are higher than the combined loading from industrial and municipal sources (Fig. 3). Agriculture's high share arises from the fact that efficient treatment plants have significantly reduced industrial and municipal discharges in recent decades, particularly for P. In the same period, however, the environmental problems relating to agriculture were not entirely recognised.

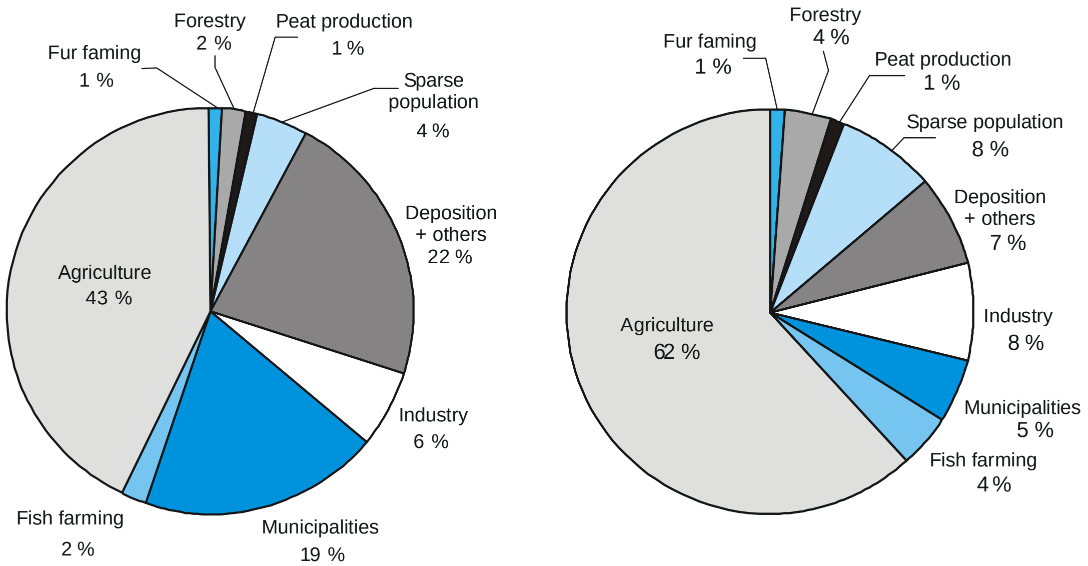

Figure 3. Nitrogen (left figure) and phosphorus (right figure) losses to surface water from main point and non-point sources [5].

The diffuse loading from agriculture mainly comes in autumn and spring. Most of the P entering water bodies finds time to settle and sediment with suspended matter before the growing season begins. Dissolved P, however, remains in the water until it is biologically depleted, e.g. by algae. According to the residence time in the particular water body, this takes place directly in the receiving lake, in the lower reaches of the waterway, or at the latest in the sea. The eutrophication caused by agriculture typically proceeds slowly, but on the other hand affects large areas of water. The impacts are seen also in water bodies where agriculture is the sole source of loading.

In Finnish conditions, P is assumed to be the limiting nutrient regulating the growth of algae in most of surface freshwater bodies. Indeed, the limnological impacts of increased P loading usually appear as eutrophication. Despite the prolonged period that they have been subjected to loading, Finnish surface waters are still regarded as being in fairly good condition. According to the general rating for usability of waters, approximately 80% of our lakes are "good" or "excellent". In general, rivers show poorer water quality than lakes. The harmful impacts of agriculture are more emphatically visible along small rivers with a high percentage of cropland in their catchments. This good overall state could, however, easily be frittered away unless extensive load reduction measures are applied in agriculture. The drawbacks in relation to water quality are already manifesting themselves as local problems.

Other agri-environmental problems are leaching of pesticides, bacteria from livestock farming, nitrate leaching into groundwater and loss of biodiversity. Agricultural specialisation has created monocultures in Finnish arable areas. Subsurface drainage has further strengthened this trend. For example, the disappearance of open ditches has dramatically reduced the nesting places available to field birds. There has been a marked transformation of rural scenery towards monotonous views of fields. Uncultivated fields becoming overgrown as a result of depopulation has emerged as another serious problem associated with the anthropogenic rural landscape in recent years.

1.2 Environmental protection schemes and their goals

Extensive measures and investment to prevent water pollution have been implemented mainly by large point-source polluters, particularly industry and municipalities. The smaller and more slowly-accumulating changes caused by the numerous actors who contribute to diffuse loading have been more difficult for the authorities to manage. For as long as research into such matters as diffuse loading by agriculture, groundwater contamination and the decreasing biodiversity of aquatic ecosystems remained incomplete, attitudes in the public debate on agri-environmental issues were typically strictly for or against.

As understanding of the importance of diffuse loading increased, the Government arrived in 1988 at a decision-in-principle on a programme of targets to be achieved in water pollution control by 1995. The P loading caused by agriculture was to be reduced by one-third from the level of the late 1980s. The programme also called for actions to bring about a significant reduction of N loading. The programme was binding on the authorities, which meant that it had to be taken into consideration in official supervision and extension (=advice or counselling) activities. At the same time, a large group of experts was formulating a set of principles for so-called 'good cultivation practices'. In this work, the latest knowledge of how cultivation practices influence load reduction was applied. Water protection targets were revised in the latest decision-in-principle (for 2005), which was adopted in 1998. The present goal is to reduce the loading in 2005 to half the mid-1990s level. This applies to both surface and ground waters and the Baltic.

When we joined the EU in 1995, we began implementing our comprehensive Finnish Agri-Environmental Programme (FAEP). Its main aim was to mitigate the harmful environmental impacts of agriculture. The assumption is that over the long term the FAEP will significantly reduce the loading from agriculture and hence eutrophication of surface waters, in addition to increasing biodiversity in agricultural areas. Other anticipated benefits are a reduction in atmospheric emissions from agriculture and preservation of the rural landscape. Now the 2nd phase of the FAEP (2000 – 2006) is being implemented in a form that is a partly-revised version of that implemented in the 1st phase (1995 – 1999).

In the days before EU membership, extension and training were the principal means of combatting agri-environmental problems. Most economic support was channelled into repairing and expanding storage facilities for manure, urine, and silage effluent. For some years, a fertiliser tax was also collected. Other policy instruments, such as financial incentives, were, however, practised on a rather small scale. The present phase of the FAEP is compatible with the EU's CAP reform and makes it possible to provide a substantially higher level of economic subsidies to aid investment to protect the environment. Thus the FAEP is one of the instruments that make it possible for the programme's targets with respect to water pollution control to be achieved.

1.3 Development, location and general regional planning of agri-environmental measures

The main issues to be borne in mind in research and development in relation to diffuse loading are: the origin of the loading, its dependence on runoff and the importance of precipitation and drainage. Efficient drainage is the basic element in successful field cultivation in Finland. The basic ditch network is dimensioned for rapid removal of snowmelt waters from the fields, and to make the growing season as long as possible. The field drainage system is mainly responsible for the diffuse loading that agriculture imposes on water bodies. Direct surface runoff accounts for part of the loading mainly in steeply-sloping fields adjacent to water bodies. The effects of field cultivation that potentially extend to water bodies concern 90% of Finland's arable area (2.1 million hectares).

Approximately half of the annual precipitation becomes runoff. The amount of agricultural diffuse loading causing eutrophication is directly related to both the total amount of runoff waters and the nutrient concentrations in it. When either of these factors is reduced, so is the level of loading. Annual runoff in southern Finland averages approximately 250 – 300 mm runoff. This corresponds to 2,500 – 3,000 m^3 of runoff water from one hectare of field. Runoff is somewhat higher in northern Finland. Since drainage is a means of conducting away from fields that portion of the water that is harmful to crop production and cultivation, the amount of runoff by field drainage can not be significantly reduced as a part of efforts to prevent pollution. By changing the distribution of runoff it is, however, possible to reduce the loading if the nutrient concentrations are reduced while the runoff is trying to find optional routes through the soil. The amount of surface runoff can be reduced through such measures as improving the texture of the soil and increasing its porosity.

The most significant reduction in agricultural diffuse loading is achieved by lowering concentrations of polluting substances in runoff. This rule concerns all potential load-reduction measures that may be implemented in various phases of the runoff route from field to water body. The first opportunity is in the field, where different cultivation practises can be applied to prevent concentrations from increasing. The next is on the fringe of fields, where concentrations may be reduced in surface runoff in particular. And after that the possibility of lowering concentrations exists all along the runoff's course until it reaches a lake or river. There is an extensive choice of measures that affect mechanisms regulating concentrations in various conditions (Fig. 4).

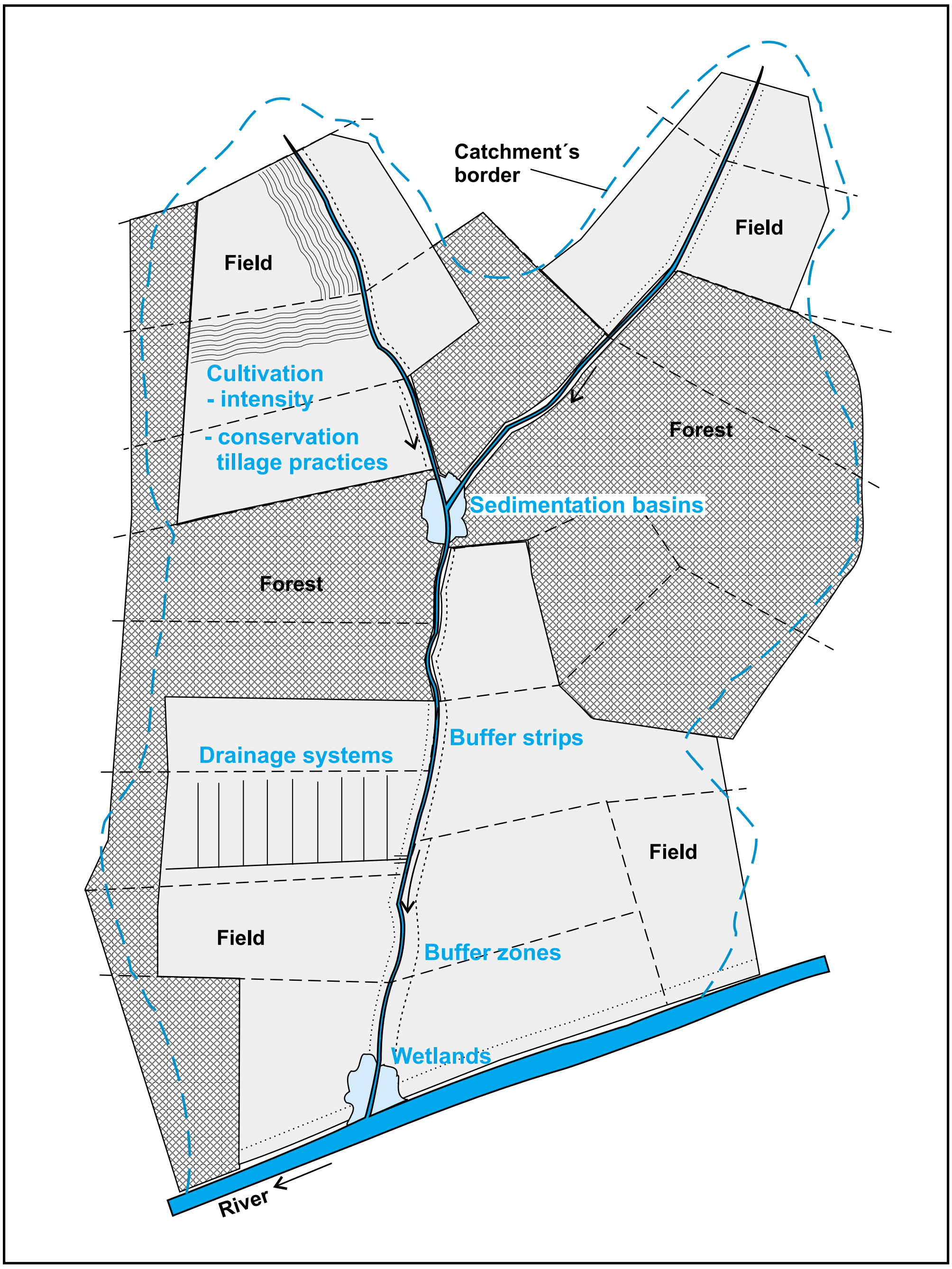

Figure 4. Schematic picture of possibilities of implementation of water protection measures along the runoff's course from fields to recipient water bodies.

When designing agri-environmental protection measures, planners and decision makers have to consider aspects of ecology, economy, agricultural policy, sociology and landscape. Due to a dearth of information on the actual effects of the measures, an assessment of the total benefits that different combinations of them would yield on the catchment scale could not have been made. Thus the overall effects of agri-environmental measures have been difficult to piece together. On the one hand, the problems are general, but on the other they are very local in nature. One good example of a culmination of local problems is the harm caused by acid sulphate soils the runoff waters from which have caused serious deterioration of water quality in coastal areas of western and south-western Finland. As a consequence of drainage, the sulphides are oxidised into sulphuric acid at a rate exceeding the soil's buffering and neutralising capacity. A sharp rise in acidity, low pH and high concentrations of toxic metal cations, especially during the spring and autumn floods, cause fish kills and seriously damage their reproduction. It has been estimated that about 30 major rivers on the west coast of Finland have severe acidity problems.

Halving the nutrient loading caused by field cultivation is a realistic goal, but it will not be achieved through any or randomly-targeted measures. The need for intensive research and development is quite acute. Innovations also require freedom from prejudice. Development of basic solutions on which to base agri-environmental measures is a matter of very topical importance. On the other hand, targeting and implementation of measures presuppose fundamental development work. The attitudes of farmers is likewise a challenge.

2 Project goals

The goals of the VIHTA project were derived from the problematic conflicts of interest between farmers and society generally that could be identified. There were many levels of aims, from increasing knowledge of individual measures to treat runoff waters all the way to the development of a comprehensive decision-support system and experimental demonstrations of new methods in farmer extension activities. The scope of the project was limited to measures for treating runoff waters from arable land, which accorded with the most fundamental needs of development.

2.1 Need for knowledge of treatment measures for runoff waters from arable land

The following treatment measures for runoff waters were referred to in the Supplementary Protection Scheme (SPS) in the first period of the FAEP:

- Constructed wetlands
- Sedimentation ponds
- Riparian buffer zones
- Controlled drainage
- Lime filter drainage
- Surface liming of soil

The latter three measures are mostly intended for treatment of runoff from acid sulphate soils.

A common task of the project was to collect the latest, detailed information on the environmental impacts of measures, partly within the sub-projects and partly from external sources. An essential aim was to obtain some degree of certainty on the question: How efficient are the measures actually when they are used to clean cold, diluted runoff waters from arable land?

Wetlands can be defined according to use: e.g. as waterfowl habitats, to improve the landscape, or to trap nutrients. In the SPS, a **constructed wetland** (CW) for water protection is defined as "A part of a ditch, brook, river, or other element of a water body together with its adjacent littoral zone, which is waterlogged for long periods and remains wet at all times. A CW is usually established by damming". Although the definition is general, the foremost aim with CWs is to reduce agricultural diffuse loading. Ancillary benefits that may be obtained include improvement of the rural landscape, increased biodiversity, and various possibilities for recreation (hunting, bird-watching, etc.). In the SPS, a **sedimentation basin** (SB) is defined as "a basin excavated or dammed within a ditch or brook, the main purpose of which is to prevent the soil particles detached from the fields and ditch network from being transported with runoff to water bodies".

During the 1st period of the FAEP a little under 100 CWs and almost 300 SBs were constructed. Since little experience of the design and dimensioning of CWs existed, a guideline (non-compulsory) ratio of wetland area to the area of its catchment (W/C ratio) was applied. The compulsory minimum ratio was the same for both CWs and SBs. Therefore, the majority of the present CWs in Finland are rather small in relation to their catchments. Moreover, the lack of knowledge about the actual efficiency of CWs led to competing opinions about their real benefit for water protection. As for SBs, a detailed study done before the VIHTA project suggested that their water-purification benefit is confined to removal of the coarsest particles of suspended solids and that removal of nutrients is not very efficient.

Within the 'Constructed Wetlands' (VESIKOT) sub-project, a demonstration wetland was designed and constructed as an example for future CWs. The intention with the VESIKOT sub-project was to find out how efficient CWs are in reducing agricultural diffuse loading, and to illustrate their impacts on the rural landscape and biodiversity. The results will form the basis for revising design guidelines for CWs.

The aim with respect to **riparian buffer zones** (BZs) was to ascertain their significance as measures to protect water and increase biodiversity. **Controlled drainage** (CD), as well as **lime filter ditching** (LFD) and **surface liming** (SL) were dealt with by collecting existing knowledge and utilising it simultaneously with the results obtained in the sub-project called 'Demonstrative Modelling and Instructions for Management of Acidity of Runoff Water' (HAPSU2). The available information on treatment methods was contradictory. Due to the severe nature of the acidity problems, it was necessary to gather very detailed information on practicable solutions and their effects. An additional aim with the HAPSU2 sub-project was to further develop a pre-existing simulation system for detecting and comparing the long-term impacts of optional measures.

2.2 Planning and controlling treatment measures for runoff waters from arable land

The FAEP is based on farm-scale planning and solutions. However, it would be at least equally important to examine the issue on the catchment scale. Indeed, the runoff waters cascading to a water body come from the catchment as a whole irrespective of the number of farms or field percentage. The properties of a catchment greatly determine the total loading imposed on the water body. Especially with regard to the measures included in the SPS, a comprehensive catchment-scale planning approach would be necessary. A side-by-side examination of all potential measures would help critical sources of loading (hot spots) to be recognised and, conversely, reveal the less-polluting areas. In this regard, there are big differences between field plots. A comparison of potential measures should be combined with an examination of their economics, since cost-effectiveness – along with optimal allocation of the measures – is the key consideration.

Comprehensive environmental planning requires reliable information on loading, the long-term impacts of protective measures and the costs of implementation. It is difficult to use fragmented knowledge in an actual planning situation. On the catchment scale, complex phenomena and the effects relating to protective measures are almost impossible to grasp without sophisticated facilities. Where implementation is concerned, it is essential to strive for a methodical approach in a regional context rather than randomness.

One essential aim of the VIHTA project was to develop a method that would enable pollution-control measures to be more accurately and economically located. The complexity and diversity of agri-environmental issues accentuates the need for such a tool; besides environmental protection, attention must be paid also to such aspects as socio-economic and environment-policy-related questions. Significant improvements with regard to water quality, biodiversity, and landscape are achievable, provided comprehensive planning, new solutions and improved decision-making are conducive to protective measures being widely adopted. Parallel to this, the authorities become more likely to take account of the environment in land-use planning and allocate economic resources efficiently. Adopting and exploiting the principles of decision analysis in order to outline the phenomena with complex cause-and-effect relations was included in the project goals. These issues were dealt with in the sub-project 'Decision Analysis and Decision Support System' (DADSS).

Planning and decision-making systems require ample regional information on catchment properties and their distribution. Field studies – as time-consuming as they may be – are unavoidable. There are also reliable sample-average-based distributions of field properties on hand in Finland. However, efficient regional inspection calls for utilisation of Geographic Information Systems (GIS). A sophisticated GIS application may be used for various computations and assessments. One aim in the VIHTA project was to develop a GIS system for exploration of locations suitable for CWs.

2.3 Farmers and the environment

The FAEP is the most significant agri-environmental policy instrument in Finland. During its 1st phase, almost 90% of the country's farmers joined the General Agricultural Environment Protection Scheme (GAEPS). Far fewer participated in the SPS, which includes more efficient and extensive measures than those included in the GAEPS. Therefore, the coverage of the SPS should be increased.

Executive responsibility for agri-environmental policy and subsidy systems is divided between several actors. In the final instance, financing decisions are made at the level of the regional administration or municipality, mostly by agricultural authorities. The regional environmental authorities, however, also play an important role in planning and allocating measures and in setting goals. The extensionists specialised in environmental issues are usually responsible for the practical guidance and activation of farmers. The most demanding challenges facing those who execute agri-environmental policy are dispersed expertise, the as-yet unclear nature of information on how measures function in different conditions as well as farmers' motivation to implement measures systematically and efficiently.

To find answers to these questions, obstacles to widespread adoption of protective measures and ways of promoting implementation of these measures were examined. The approach was based particularly on the farmers' values and objectives. Since the final power of decision, and also the responsibility, as to whether or not to implement the measures resides with farmers, they are entitled to reliable information on which to base their individual decisions. These issues were dealt with in the sub-project 'Methods for Extension and Dissemination of Information' (NETTI). The objective was to enhance co-operation between the actors involved in implementation of the agri-environmental policy, to clarify interpretation of the goals of the policy, and to develop extension and planning methods that facilitate care for the environment on a practical level.

3 Implementation of the project

VIHTA was a national demonstration project, for the co-ordination of which the Finnish Environment Institute (FEI) was responsible. The project was implemented between 1st Aug 1997 and 31st Dec 2000 in collaboration with the Agricultural Research Centre of Finland/Agricultural Engineering Research (MTT/VAKOLA) and the Technical Research Centre of Finland (VTT). A steering group with the task of following the progress of the project and approving the working plans for each reporting period was formed. It also approved the plan for provision of information on the project and supervised its fulfilment. The group represented the Ministry of the Environment, the Ministry of Agriculture and Forestry, MTT, VTT, and those divisions of the FEI that were involved with the project. It had six meetings during the project. Minutes were kept on all occasions.

One person was appointed to head each of the four sub-projects, which comprised totalities of different subject matters. The persons in charge of the sub-projects formed the project group, the responsibility of which was to see to the progress of the sub-projects and thus to implement the project plan under the steering group's supervision. The project group prepared the agenda for the steering group. Minutes of its meetings were kept. The project manager was responsible for the progress, finalisation and financial follow-up of the project. The sub-projects with their different goals formed a comprehensive totality dealing with treatment of runoff waters from arable land. Co-operation between the sub-projects was close, regular and mutually-supportive.

During the VIHTA project there was co-operation with the ministries of the Environment and Agriculture & Forestry, the South-West Finland Regional Environment Centre, the Pyhäjärvi, Lestijoki, Vantaanjoki, and Vesijärvi Life projects, the Helsinki University of Technology, the Finnish Game and Fisheries Research Institute, the Finnish Field Drainage Centre, the University of Helsinki, and with organisations involved in agricultural extension. Educational meetings arranged by the ministries to discuss implementation of the FAEP, as well as gatherings to advise farmers drew regular attendances. Work to revise the FAEP was also participated in. Co-operation and fruitful discussion on issues greatly benefited the VIHTA project. The feedback obtained served as a basis for revising assessments of information needs and for directing the project in the light of the most relevant questions.

Experiment sites and other areas of operation of the VIHTA-project are presented in the map of Fig. 5.

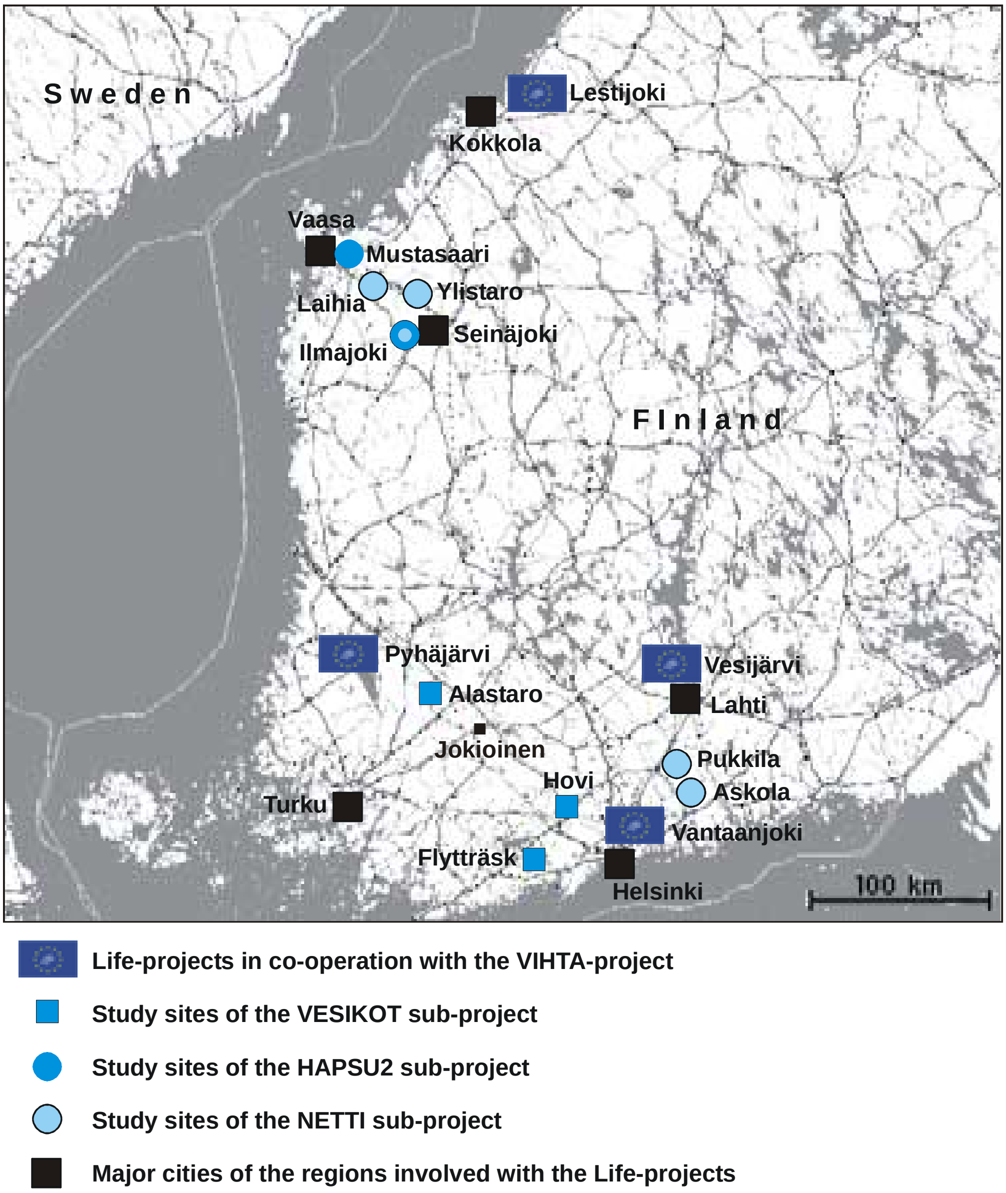

Figure 5. Experiment sites and other areas of operation of the VIHTA-project.

Technical actions

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4.1 VIHTA model for management of runoff waters from arable land

The VIHTA model is a decision-making system that incorporates the agricultural loading status, the efficiency and costs of protective measures and the target level of water protection (Fig. 6). The present loading status was considered as being expressed in absolute numerical values for loading substances. The model was based on the information obtained from both the VIHTA project and research work done elsewhere. The approach on which it is based looks at the relation between conditions and loading and the effects of protective measures in different circumstances. The model was not designed to calculate physical dependencies between different variables, but rather to process the available information. The number of variables is limited, facilitating transparency and openness in decision making.

The choice of the most important variables that influence loading (Fig. 7) was based on experts' assessments. The correlations between the variables and loading were found from existing results of several measurements [6], [7], [8], [9], [10], [11] and [12] from modelling exercises [13], [14] and [15], and from experts' assessments.

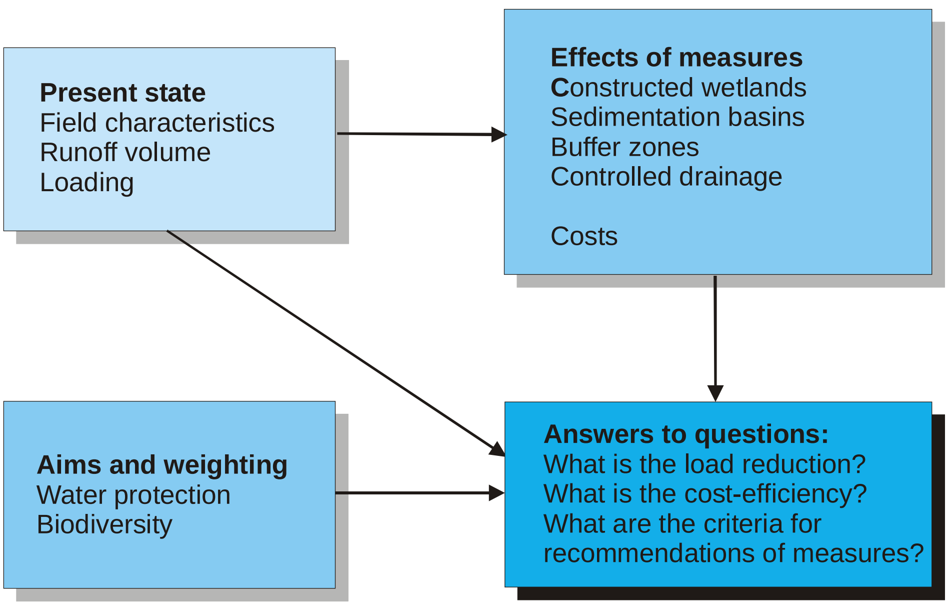

Figure 6. Principle of the VIHTA-model.

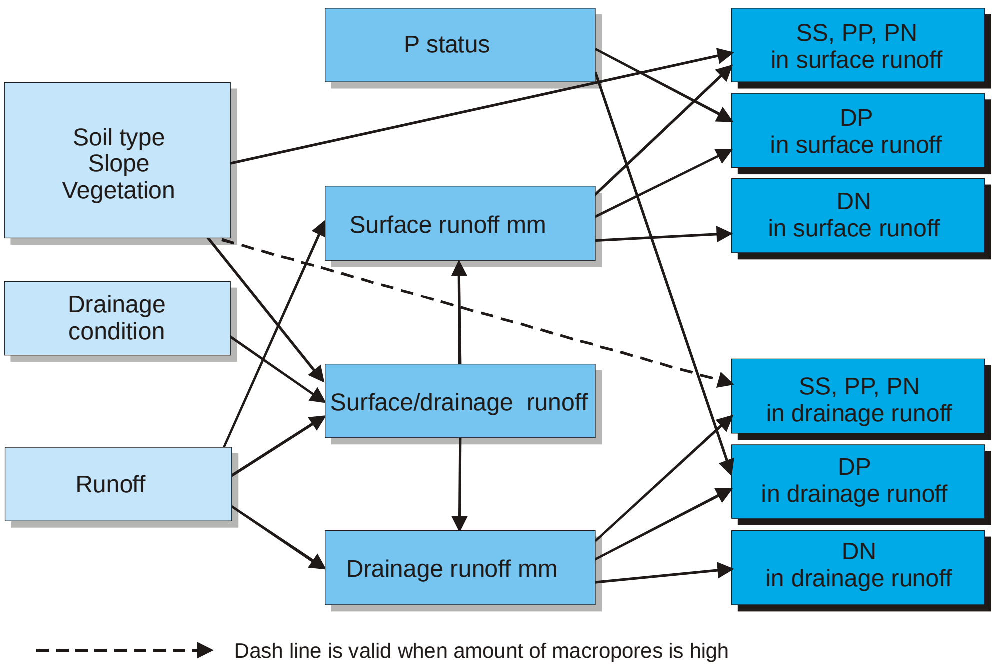

Figure 7. Effect of different variables when the present state of the loading from arable land is being assessed.

In the model, the following loading substances transported from fields to water bodies were examined:

- Total suspended solids (TSS)
- Particle-bound phosphorus (PP)
- Dissolved phosphorus (DP)
- Total phosphorus (TP)
- Particle-bound nitrogen (PN)
- Dissolved nitrogen (DN)
- Total nitrogen (TN)

The model is based on an MS Excel™ spreadsheet, which makes its initialisation simple for most users. The load reductions achievable through each measure are easily readable and can be modified by the user. Any desired weightings of different objectives as well as calculation of the total benefit obtained will also be possible. When the benefit is divided by the costs, a benefit-cost-ratio for various measures in various conditions with various weighting is obtained.

The sources of information regarding water-protection measures include the results of the VESIKOT sub-project [16], [17] and [18] the results of studies on runoff treatment methods [11], [12], [19], [20] and [21], and the expert evaluations of the effects of protective measures on the quality of runoff waters. With respect to BZs, the significance of different factors for TSS loading was examined using a mathematical model [18]. The model can be applied on various scales from a field plot to a catchment. Indeed, assessments covering the whole country are possible.

The model is useful, when e.g.:

- The level of loading in a target area is assessed
- The effects of treatment methods for runoff waters are evaluated
- Treatment methods are compared
- The cost-effectiveness of treatment methods is calculated
- The criteria for choosing treatment methods is assessed
- Treatment methods are prioritised for implementation

The model's user can choose between a drier-than-normal year, a normal year or a wetter-than-normal one. According to the catchment characteristics, implementation of optional treatment methods can be simulated. The model recommends the most cost-effective method for as many locations of the catchment as possible, then the next-best, and so on. The process is continued for as long as the target level of load reduction is achieved.

The field-property variables that have affect loading are classified in the model as follows:

- P content of soil (2 classes)
- Soil type (3 classes)
- Slope (2 classes)
- Vegetation (2 classes)
- Ditching (2 classes)
- Macropores (2 classes)

This classification yields $2 \cdot 3 \cdot 2 \cdot 2 \cdot 2 \cdot 2 = 96$ different field categories (Table 1). The model gives an estimate of the amount of TSS, PP, DRP, PN and DN transported by runoff waters for each category. The estimate distinguishes between surface runoff and drainage flow. The category-specific load estimates form a basis of the model, but they can be changed when needed.

With the present assumptions and sources of information entered, the model prefers CWs to SBs, BZs, or CD with regard to cost-effectiveness. CWs are able to retain nutrients both bound in suspended matter and in dissolved forms. However, the appropriate sites for CWs are often hard to find in agricultural areas. The SBs are most appropriate at locations where the TSS transported by runoff water is coarse. In addition to protecting water, CWs and BZs often add biodiversity as well.

Table 1. Description of field classes and an example of estimation of suspended solids loss.

Class	P-status	Slope	Macro-pores	Soil type	Vegetation	Ditching	Su/Dr	Susp. solids loss Su	Dr	(kg/ha) Total
1	low	low	high	class1	covering	good	0.19	129	182	311
2	low	low	high	class1	covering	poor	0.32	272	153	425
3	low	low	high	class1	not covering	good	0.32	535	370	904
4	low	low	high	class1	not covering	poor	0.44	1105	300	1405
5	low	low	high	class2	covering	good	0.14	104	285	388
6	low	low	high	class2	covering	poor	0.27	259	242	501
7	low	low	high	class2	not covering	good	0.26	462	475	937
8	low	low	high	class2	not covering	poor	0.39	1053	392	1445
...	...	...	...	...	...	...	...	...	...	...
96	high	high	low	class3	covering	poor	0.56	3165	13	3179

Su = Surface runoff
Dr = Drainage flow

As part of the catchment-scale approach, a GIS (Geographic Information Systems) application was developed. Its functioning is based on the ditch network, the elevation model and land use within a single catchment. It recognises the most appropriate locations for CWs according to the preconditions set by the user. The locations recommended by the application serve as a part of the baseline data for planning protective measures. The GIS application is based on the ArcView/Spatial AnalystJ tools of ESRI Inc. The most important initial data consist of the topographical model and the land-use classification of the catchment. The user of the application first chooses a single channel (e.g. a ditch or brook) and then sets the preconditions for the area and the field percentage of the above catchment, for the W/C-ratio, and for the distance between examination points. The user obtains the maximum runoff for the examined area from a theoretical nomogram and enters it. The application then compares the entered data with the real properties of the catchment, assesses the topography near the point under examination, and finally either approves or rejects the point. By going through the whole channel network, the user will obtain all potential locations for CWs within the examined area.

The GIS application can be used to assess the regional feasibility of CWs and the field area that will be within the range of intended measures, as well as the regional distributions of the field areas that will, or will not, belong to the appropriate areas. In practice, this assessment method can be used when local GIS data, nation-wide databases and empirical research data are available. The accuracy and reliability of the GIS tool primarily depend on the precision of the available elevation model. A crucial shortcoming of the national elevation data is that the information on the elevation of the channel bottom in relation to the elevation of the surrounding terrain is missing. Therefore, if more precise data are not available, the effect of channel profile and channel depth on topography remain unknown in regional assessments. The lack of accuracy also prevents recognition of small areas, as well as volume assessments as a part of the process.

4.2 Methods for treating runoff waters from arable land

4.2.1 Constructed wetlands

Technical planning of the demonstration wetland

Technical planning of the demonstration wetland was based on the hydrology of the upstream catchment. Our objective was to implement a CW with controllable hydrology. The CW was also intended to fit well into the local scenery. Planning of the excavation work was combined with overall planning, which was based on a wide range of experts' opinions and the relevant information in the literature. A belief-network approach including interviews with seven experts was applied as part of the planning. The aim of the belief-network examination was to highlight uncertainty relating to the functioning of CWs and thus point to the major need for research and development. Although the belief-network examination indicated a high degree of uncertainty, the demonstration wetland was planned, according to the best-available knowledge, for efficient removal of all polluting substances.

The demonstration wetland was designed to consist of three parts: a gently meandering ditch, a deep open-water pond, and a shallow vegetated area. As for nutrient removal, the deep part was primarily intended for N, and the shallow part primarily for P. The course of water through all three phases is controlled by two spits of land made from the excavated soil. The shape of the wetland resembles a mirror-image of the letter "S". The spits of land, the tops of which remain dry even during the highest floods, also provide access to the different parts of the wetland (Fig. 8). The geotechnical bearing capacity of the demonstration wetland was ascertained by means of soil samples and laboratory experiments. The P content of the wetland soil was also determined. The uppermost soil layer was found to be rich in P and removed in order to avoid leaching of this nutrient from the wetland.

Landscape design of the demonstration wetland

The landscape design of the demonstration wetland was an essential part of its technical planning and implementation. Our intention was to create a CW that would be an enlivening element in the field scenery and serve as a representative example of good planning and implementation. As already noted, different objectives called for various elements in the wetland, such as an area where suspended particles could settle, a deeper part for reactions that favour low-oxygen conditions and a shallow part for vegetation and reactions that take place in aerobic conditions (Fig. 8)

That the excavation work should be economic was a general principle followed in the design of the demonstration wetland. The deepest part was excavated in the area where the land elevation was at its lowest. The dense bottom clay removed was used in the surrounding embankments. Only the amount of bottom clay needed for the spits of land was removed from the shallow part. Some of the surface soil (containing humus and P) removed was used to cover the topmost parts of the embankments. The rest was spread in the surrounding fields.

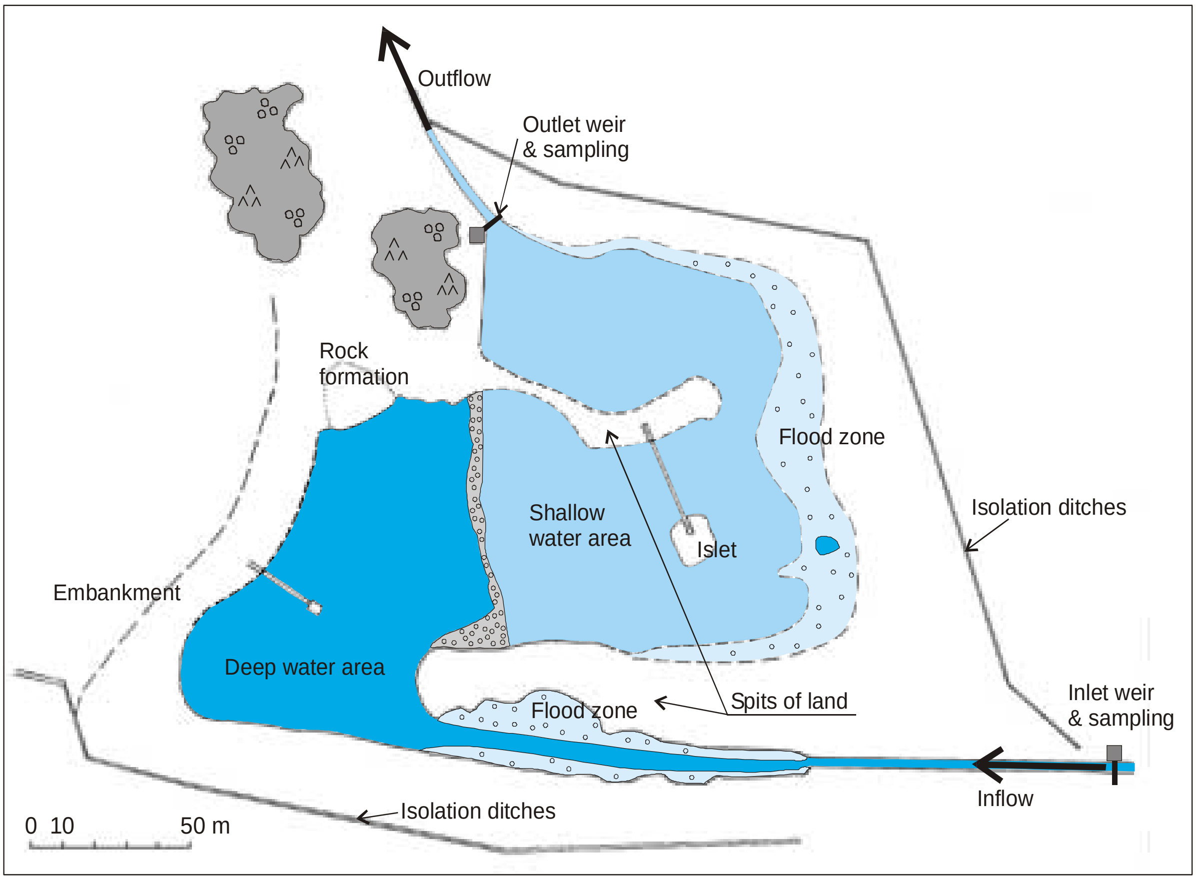

Figure 8. Schematic picture of the Hovi demonstration wetland.

Variations in land elevation and outlining of littoral zones were designed to blend smoothly with each other. Straight shorelines and steep, evenly-banked slopes were avoided. In the topographical design of the littoral zones; the objective was to create a CW that readily adapts to a fluctuating water level. Therefore a lot of the total area was reserved for the shallow part of the wetland in order to provide room to accommodate flood water. This flood reservoir is smoothly connected to a permanently dry meadow area. The overall aim was to achieve a shape imitating the forms existing in nature and suiting the initial landscape (Fig. 9).

Vegetation is an important part of wetland scenery. A distinctive element of the demonstration wetland was a rock formation with a stand of scrub and deciduous trees. Aquatic vegetation was enhanced according to a separate experiment scheme that included, e.g., colourfully flowering plants like yellow flag (*Iris pseudacorus*) and purple loosestrife (*Lythrum salicaria*) in the vicinity of the rock formation. The vegetation will be cut away from the central areas of the view according to the principles observed in the management of BZs.

Construction of the demonstration wetland

Construction of the demonstration wetland (the Hovi CW in the municipality of Vihti) was timed and planned to ensure that the River Vihtijoki downstream from it would suffer as little loading as possible. Carrying out the excavation work in early summer would allow the vegetation to have rooted and formed a buffer against erosion before the autumn rains. The excavation plan was based on the topography of the area, on the existing ditches and subsurface drains and on the economies of both excavation and earth moving.

Construction was originally planned for June 1998, but that summer was exceptionally rainy and the work had to be suspended after several attempts. A tractor excavator of a type used on farms proved unsuitable due to the inability of the ground to bear its weight. The deep part of the wetland and the surrounding embankments were finally completed using a tracked excavator in late June 1998.

Figure 9. The Hovi demonstration wetland in summer 2000. Photo Maarit Puumala.

The plan was still to do the shallow part with the tractor excavator, but this too proved futile and the wetland was finally completed using tracked equipment between 10 Oct and 1 Nov 1998. One of the two tracked excavators was equipped with a reclining bucket. The soil removed from the area was heaped up near the wetland and, later in the winter when the land was frozen, applied to the neighbouring fields.

Monitoring of the wetlands

The catchment area of the Hovi wetland is entirely arable land with runoff fluctuating within a wide range. A relatively sharp-angled (30 º) V-notch weir was chosen for the outlet. Measured from the bottom of the V-notch, the water level may fluctuate within the range 0 - 30 cm (the V-part). Above 30 cm (the flat part), the weir is widened to permit discharge of the highest floods. In a dry summer – such as 1999 – the water level may drop so much below the V-notch that the total fluctuation range is 70 cm. The large capacity of the Hovi wetland means that occasional summer rains are not always able to fill it up to the V-notch, so that the outflow might not begin until the next autumn. Thus the Hovi wetland is a very efficient leveller of runoff fluctuations.

In addition to the Hovi demonstration wetland, we monitored two others as well (the Alastaro and Flytträsk CWs in the municipalities of Alastaro and Inkoo, respectively). The monitored wetlands differed from each other with regard to dimensioning and catchment characteristics. The monitoring provided data for assessments of the effects of wetlands on load reductions as well as on landscape and biodiversity. The development of wetland vegetation and possibilities of artificially enhancing it were likewise studied.

The load reduction achieved by constructed wetlands

The VIHTA model assumes that CWs are appropriately constructed and maintained, and that there is enough vegetation for denitrification. The most significant factors effecting TSS and nutrient-load reductions are the residence time of water (WRT) and concentrations in runoff waters (Fig. 10). As for DP and DN, the characteristics of the wetland soil also play a role. According to the experience gained in the VIHTA project, the maximum total benefit from CWs is obtained when the following matters are kept in mind when designing and dimensioning them:

- As large area of CW as possible in order to facilitate long WRT
- High input concentrations, high field percentage
- Even flow through whole CW, no short-circuiting
- Flood zone for levelling runoff peaks
- Bypass channel for extreme floods, when needed
- Natural locations for CWs
- Minimisation of excavation work
- Construction of CWs on former cropland should be avoided
- If part of a field remains under a CW, the surface soil should be first removed
- Multiform CWs with both deep open-water parts and shallow regions should be favoured

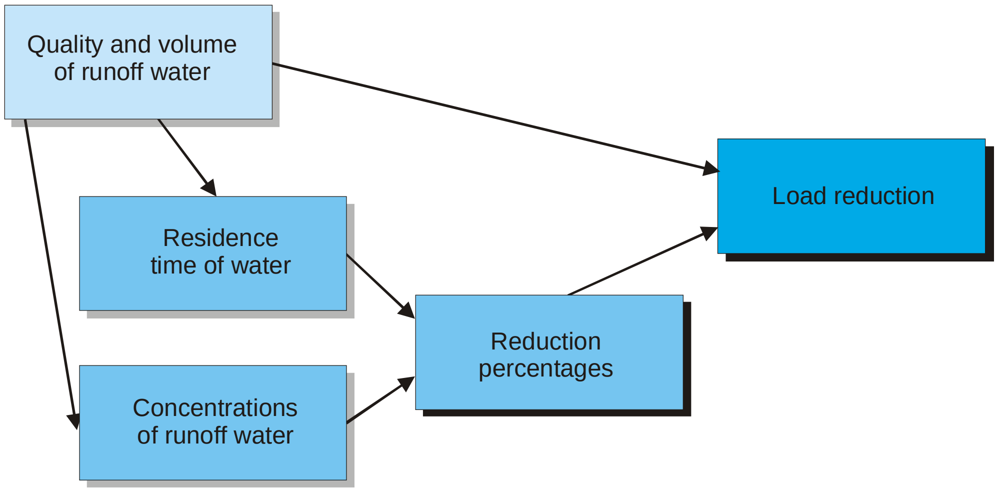

Figure 10. Variables regulating the retention of suspended solids and nutrients in CWs

In the VIHTA model, the assessments of percentage load reductions achieved are based on monitoring of the demonstration wetland and the two other CWs. Because all three were constructed on clay soil, the assessments of reductions when the soil is coarser are based on a study of SBs [19]. The load reductions for PP and PN are presumed to be equal to those for SS. Load-reduction percentages increase with lengthening WRT, i.e. with increasing W/C-ratio (see Fig. 11). Also input concentrations are supposed to correlate positively with load reductions. Moreover, TSS load reduction is presumed to strongly depend on the soil coarseness of the fields in the catchment.

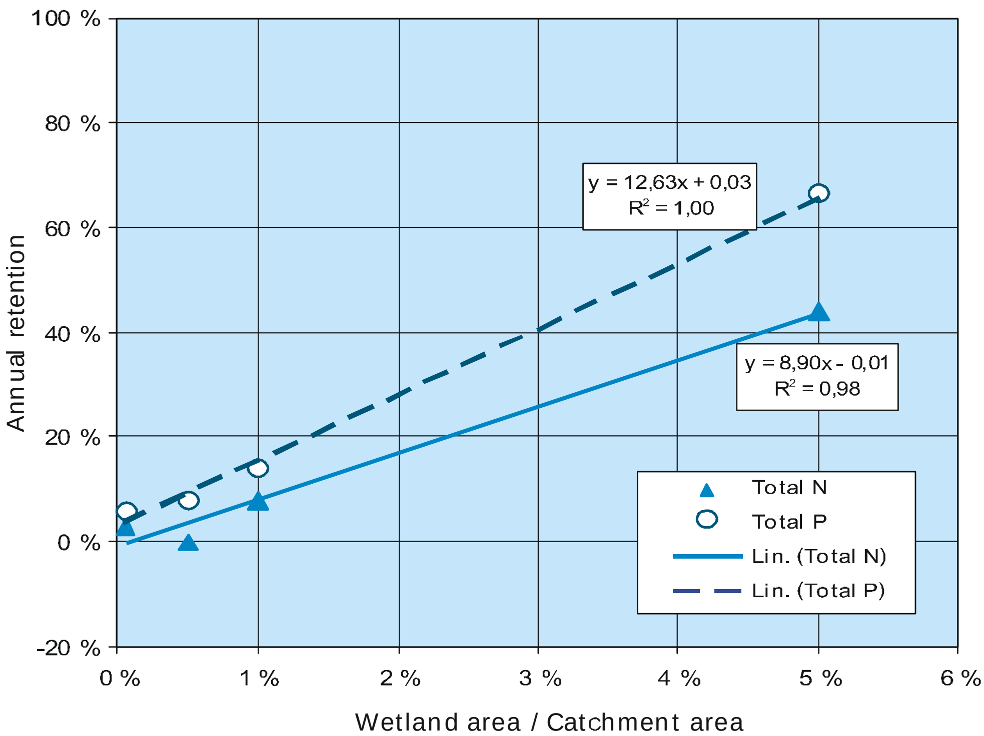

Figure 11. Annual retention of nutrients in CWs and SBs as affected by dimensioning (CW or SB area / Catchment area).

In the model, the typical annual maximum runoff (MHq) is supposed to depend on the field-% of the catchment. The equation is based on Dr. Seuna's diagram presented in a publication of the National Board of Waters [23]. The WRT in a CW can be calculated when both MHq and the dimensions of the CW are known. For example, for a CW with 0.5 ha area, 1.5 m mean depth, 30 ha catchment, and 60% field percentage of the catchment the WRT at MHq is 1.8 days. In practice, WRT at MHq seldom exceeds 2 days in CWs in Finland.

In the model, the input concentrations in the water entering a CW are obtained by dividing the annual amounts transported from both arable and forested areas by the annual runoff. The pre-known unit amounts from both arable and forested areas are multiplied by the corresponding acreages. The unit amounts from arable areas vary according to the field classes.

4.2.2 Sedimentation basins

Sedimentation basin (SB) here means a basin that is excavated in connection with a ditch or a brook. The purpose is to retain the soil particles detached from the fields and ditch networks, and thus to prevent their transport into water bodies. An SB should be deep enough to be able to slow the flow velocity and allow soil particles to settle. An excavated SB does not weaken the drainage status of the neighbouring fields, unless it causes damming of water.

The load reduction obtained with SBs is restricted to the coarser fractions of TSS. Thus, the environmental benefit achieved is rather low [19]. At most, SBs constructed to protect water have an area of a few hundred square meters and a depth of a couple of meters. As with CWs, load reductions in SBs depend on both WRT (Fig. 11) and input concentrations and, in addition, on the particle-size distribution of the input TSS.

4.2.3 Buffer zones

The importance of BZs for water protection and biodiversity was assessed using both a model (FcBeNe) based on decision-analysis theory [24] and [25], and the VIHTA model. The aim was to find out how eight experts perceive the functioning of stabilised (10-year-old) BZs. In the modelling, BZs had two different meanings: (1) *traditional BZs* established between an arable field and a water body, and (2) *dry meadows* established in the upper part of a field. It was supposed in the modelling that BZs are established as continuous entities in areas where they produce maximal benefit. The experts' opinions formed a basis for assessment of the uncertainty included in the correlations. The modelling revealed the weak spots in knowledge and thus the questions most urgently-needing further research.

Existing knowledge of the effects of BZs on water protection and biodiversity was collected in a descriptive model (25 variables). The effects of field and BZ properties, the effects that actions done in BZs have on erosion, nutrient (PP, DP) leaching and biodiversity (total numbers of plant, insect and bird species) and also the impacts on the landscape were estimated. The differences between the models created by different experts were, in places, quite big. This reflects the contradictory character of knowledge relating to the functioning of BZs.

In the assessment of biodiversity experts, BZs lead to a greater richness of plant, insect, and bird species. The strongest improvement was predicted for plant and insect species. Almost all experts were of the view that heterogeneity of nutrients increases the number of plant species, whereas tall vegetation and high soil nutrient content reduce it. Openness (which declines as the vegetation's covering power and the height of tree stands increases) was seen conflictingly; some of the experts regarded it as an increasing factor, whilst others took the opposite view. As for insects, there was less of a consensus on affecting factors than in the case of plants. It was, however, believed that diversity of plant species increased that of insects. The amount of pesticides and the covering power and height of vegetation were assessed as detrimental to insect diversity. The diversity of bird species was thought to remain constant (30% likelihood) or to slightly increase (66% likelihood). The increasing diversity of plant and insect species would, according to the experts, increase the diversity of bird species.

According to the FcBeNe examination, the effect of BZs on DP was not unequivocal. Experts predict that there is a 48%-likelihood of a slight or moderate DP load reduction, whereas the likelihood of its being unaffected or even slightly increased is 52% likelihood. The most important variables were the P-status of a field, the nutrient content of the soil, grazing, mowing and vegetation cover.

In the VIHTA model, the load reductions achieved by BZs are based on field experiments conducted by the Agricultural Research Centre of Finland [21] and [26], and the Finnish Environment Institute [20]. As for BZs, the load reductions comprise two elements: (1) the reduction in the field acreage that is changed to BZs and (2) retention of TSS and nutrients in BZs (Fig.12). The more steep and erodible the fields converted to BZs, the more significant the former element becomes.

The load reduction percentages for BZs vary, according to slope, between 30 and 60 for TSS and between 5 and 20 for dissolved nutrients. Gently-sloping BZs retain TSS and nutrients more efficiently than steeper ones, although the total efficiency of the latter increases significantly because they remain uncultivated. The assumption in the VIHTA model is that the type of soil in a field does not affect retention performance. In addition, concentrations in surface runoff are not supposed to influence load-reduction percentages, but rather only retentions in absolute figures.

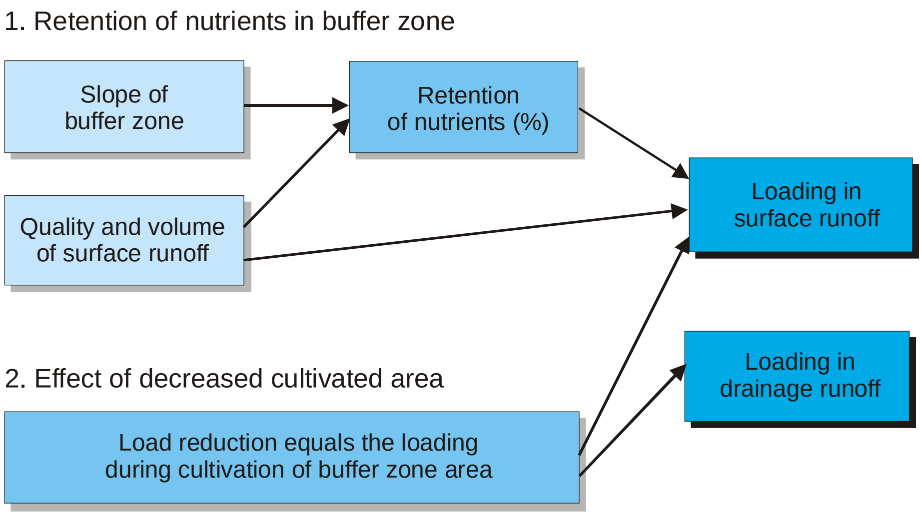

Figure 12. Variables regulating the retention of suspended solids and nutrients in BZs.

4.2.4 Controlled drainage

The effectiveness of traditional subsurface drainage can be improved, with regard to both environmental aspects and crop growth, by means of CD, which makes it possible both to reduce the amount of drainage flow – and thus nutrient leaching – and to store water for use by crops. CD is usually applied in fields that already have subsurface pipes [11].

Soil type, slope and the depth of impermeable soil are the most essential factors affecting the appropriateness of CD. The FAEP conditions concerning CD require that the slope of the field may not exceed 2% and that the soil type should be mainly sand, fine sand, or muddy clay. It is estimated that there is 800,000 ha of field fulfilling these requirements in Finland [27]. Effects similar to those obtained with CD can also be achieved by controlling the water flow in open ditches.

When compared with fields without any subsurface drainage, both CD and traditional subsurface drainage usually reduce the proportion of surface runoff whereupon P leaching usually decreases, whereas N leaching tends to increase. CD directly affects neither P nor N concentrations. The closer to each other and, in particular, the deeper drainage pipes are laid, the more N is leached. CD also affects the nutrient uptake of crops and the processes of nitrate-N [11].

It is assumed in the VIHTA model that CD is applied only in fields with a slope not exceeding 2% and where water permeability is high, and also that the groundwater level is high enough (1.5 – 2 m). Moreover, it is assumed that control (damming) measures are performed properly. For example, when heavy rains are forecast, the storage capacity of the soil should be increased by reducing the damming effect. Unless this is done, surface runoff may increase to an even higher level than with traditional subsurface drainage.

According to the model, CD is not as efficient at load reduction as CWs or BZs. It should, however, be noted that CD is usually not a 'competing' method and that it can be applied only in fields meeting its requirements. In general, the surface runoff and hence the loads of TSS and particle-bound substances from such fields is rather low, whereas N loading via subsurface drainage can be remarkably high. Because CD increases the crop yield in dry years, farmers have been more willing to implement it than to establish CWs or BZs.

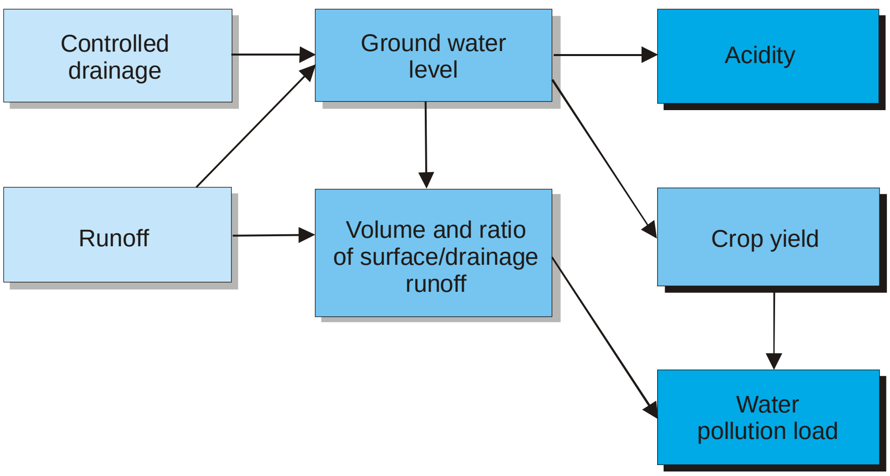

Figure 13. Variables regulating acidity, crop yield, and water pollution load when CD is applied.

The most significant factors affecting the load reductions achieved by CD are the groundwater level and the amounts of surface runoff and drainage flow (Fig. 13). These factors are highly variable from year to year, which made their incorporation into the model complicated. Because, on the other hand, only long-term effects are examined, these factors were ignored in the model and the reduction rate for TSS and nutrients was estimated at 15%. This includes the load reduction due to both the decrease in total runoff and the increase in crop yield.

4.2.5 Solutions for problems caused by acid sulphate soils

In the sub-project 'Demonstrative modelling and instructions for management of acidity of runoff water' (HAPSU2) the efficiency of LFD, CD and SL was evaluated both in the light of empirical field data and modelling exercises. Data was collected at two experimental sites in 1998-2000. This data was used in the further development and calibration of the pre-existing model HAPSU, which can be used for comparing the long-term efficiency and usability of different water protection measures in different conditions. During this project the model development included incorporation of components for estimating impacts of LFD and CD on hydrology and drainage water quality.

The results from the Ilmajoki experiment site suggested that acidity and aluminium concentrations of runoff waters can be reduced by controlling the groundwater level. It was noted during field studies that, in addition to recently drained acid sulphate soils, also those acid sulphate soil fields that have been pipe-drained for several decades can significantly contribute to acidification of watercourses. The management of these old and partly leached acid sulphate soils is best done using CD. The efficiency of CD increased towards the end of the study period.

LFD was studied at Ilmajoki with and without combination with CD. It was noted that LFD increases pH of drainage water but LFD can occasionally cause very high metal concentrations in the drainage water. These metals are mainly not in the toxic dissolved form but in acidic environment they may dissolve cause harm to the water ecosystem. LFD functions best during snow melt in the spring and other periods when groundwater level is high and significant part of the drainage waters flow via lime filter. Therefore the efficiency of LFD can be increased by combining LFD with CD. As CD is used together with LFD, also producion of acidity in the soil is decreased and LFD function a longer time period. Efficiency of LFD solely decreased during the study period but LFD-CD combination functioned better than either of these measures alone. In 2000, the average pH of drainage water was 4.0 in conventionally subsurface drained plot, 4.3 in LFD plot, 4.4 in CD plot and 4.8 in LFD-CD combination plot at Ilmajoki.

Extensive soil surface liming was tested at Mustasaari experiment site. Different kind of liming products, including also slurry lime, were studied. However, none of these products, not even when used in large amounts, had significant impact on the drainage water quality during the study period of 1999-2000.

The HAPSU model proved to be a useful tool for estimating impacts of different water management practices. Based on the modelling studies, it seems that LFD are efficient for about 5 years. When combined with CD, LFD functions few years longer. After the functional period aluminium in the lime filter starts to dissolve. As a consequence, acidity and metal concentrations of the drainage waters increase heavily. During ten years period, controlled drainage is the most efficient measure. It may decrease acidity about 25 %. According to the modelling studies, extensive soil surface liming does not have practically any impact on the drainage water quality. The HAPSU model could now be used for e.g. estimating acid load from different areas inside the watershed and choosing the most appropriate water protection measures for each area.

4.3 Decisions at farm level and farmers' commitment to environmental measures

Farmers have a central role when agri-environmental measures are implemented. Without their willingness and final decisions, agri-environmental protection gets nowhere. Their environmental awareness must be seen as a coherent part of national and local planning and of extension work in environmental protection.

Closer networking and working together in group extension provide a co-ordinated contact amongst extensionists and between extensionists and farmers. This is especially useful in Finland, where the rigid sector division into environmental and agricultural administration complicates the implementation of agri-environmental policy. The threshold for contacting especially the environment officials is brought down by the establishment of mutual trust through face-to-face meetings. Particularly so in the contact between regional environment officials and the local level actors - both parties perceived new possibilities for co-operation as a result of the project.

With the approach applied in the NETTI sub-project it is possible to

- increase dialogue and trust between the actors involved
- support co-operation with farms and villages
- make allocation of measures to protect the environment more effective
- utilise knowledge of local conditions and practical experience
- support comprehensive consideration of financing sources
- encourage the long-term commitment of farmers to implemented measures
- produce new information on the practical problems encountered in implementing measures

In the sub-project 'Methods for Extension and Dissemination of Information' (NETTI) farmers were interviewed in the Lake Pyhäjärvi region in south-west Finland and in the River Porvoonjoki catchment in the south. Four different strategies of commitment to good cultivation practices were examined. These were (1) "forced", (2) "buckled under", (3) "power producers", and (4) "bearers of environmental responsibility". In addition, the farmers' views and proposals concerning improvement of implementation practices were examined.

As already noted, almost 90% of Finnish farms had joined the GAEPS by 1999. Because the terms for receiving subsidies do not require major changes in farming practices, the farmers' commitment has required little effort. The high number of farms receiving subsidies may also have a positive effect on the cultivation practices accepted in the farming community and motivate individual farmers to develop their environmental protection. According to the interviews, the farmers are themselves committed to producing environmental benefits, which accords with the objectives of the FAEP. Few, however, are willing to pay the costs that follow from environmental protection. Many regard their farming as pro-environment enough and believe participation in the GAEPS justifies this stance. They have seen environmental measures as complementary to their existing farming practices rather than as something that essentially changes them. The subsidy system has also proved rather inflexible with regard to different production customs and consideration of local conditions.

The interviews revealed that farmers respond to agri-environmental problems as a part of the social transition of Finnish rural areas. The uncertain future of the countryside is closely linked to the environmental benefits and drawbacks caused by agriculture. The farmers' views on the seriousness of environmental problems are influenced by their opinions of the nature of scientific information and of the actions and trustworthiness of the environmental authorities. The farmers' way of interpreting environmental information depends on their possibility of using it and taking action in practice. Farmers should be offered knowledge which increases their capability to understand and manage environmental impact on their farm as opposed to just given information on how to implement and manage particular measures. The preoccupation with achieving as many scheme contracts as possible may obscure the purpose of environmental knowledge in extension.

In the light of the experience gained in the NETTI sub-project it can be stated that the planning of extension work calls for particular attention. It pays to gather together farmers with similar information needs and holdings. This may mean, for example, a group of farmers with similar environmental-protection needs or a group interested in more extensive environmental projects. 5 – 10 farmers at a time should be called together. With a view to successful co-operation, it is very important to determine aims, means and responsibilities for actions right at the beginning. The participants must have a clear conception of what discussions are aimed to achieve and what matters they can influence. In order to focus the discussion, it would be beneficial to find a consensus on what the problems to be solved are and to ascertain what kinds of financial sources are available.

Group extension does not necessarily promote the type of learning which will lead to more sincere commitment to environmental goals and measures on farm level. At it's best it can provide prerequisites for the confrontation of different values and negotiation of normative perceptions. This is more likely to happen with funding, which does not set rigid conditions for the practical implementation of environmental measures. A positive example of this from the demonstration is the negotiations about specific sites on the field during the buffer-zone planning.

The negotiating and interactive approach to extension calls for a new kind of role for both extensionists and authorities. The former have to support the farmers' ability to recognise the environmental impacts of their practices and to embrace measures to control problems. Interactivity also means equality.

Conclusions and environmental benefits

5

The Life-VIHTA project was involved with an influence network comprising the actors dealing with agri-environmental problems. The involvement was carried out in the form of four sub-projects, each with individual objectives and solutions to problems (Fig. 14). Thus the scope of the project was comprehensive. When we look at the results and conclusions of the VIHTA project in the context of the influence network, they form an interesting totality. The results help in piecing together the problematic nature of agri-environmental issues in a broad context. Such a comprehensive approach likewise underscores that agri-environmental measures are needed on many different levels and that all actors play a significant role.

Mitigation of agri-environmental problems requires an abundance of new information on alternative measures as well as concrete, appropriately-implemented actions. The sub-projects that dealt with CWs (VESIKOT) and acid sulphate soils (HAPSU2) both produced fresh knowledge concerning the sources feeding the influence network presented in Fig. 14.

However, the distance between new information and practical actions of the SPS is long. Active extension and guidance methods are needed in directing measures. At the national level, agri-environmental goals are determined in the programme of targets for water protection. The goals set by the EU and defined in, for example, the Nitrate Directive and the Water Framework Directive are already reflected in the present objectives and will be emphasised in the future. The key question is how well practical measures implemented by farmers match the environmental goals set by society. Ultimately, this depends solely on the farmers' decisions on the implementation of the measures of the SPS. These decisions are influenced by the latest information on protective measures and by the economics of these measures with respect to the farmers' individual holdings.

Research results have traditionally been regarded as sets of non-alternative facts to be presented to people in need of information. By studying the problems of extension and experimenting with a new approach, the NETTI sub-project operated in the middle ground between extension and farmers and sought to gather the two parties into a common forum. Doing this replaces the conflict that often develops in the interface between new information and those needing it with a fruitful discussion within the group involved in extension. Individual farmers' distrust of information that is handed down from above, and much of which seems odd to them, can be dispelled through a collective, group-oriented extension process, in the course of which local environmental problems are concretely adduced. This makes it more likely that local needs and the most efficient measures will find each other.

With regard to the subject matter, new extension approaches require an objective and comprehensive examination before local-level solutions can be referred to farmers for their subjective decisions. Even though individual items may be of a high utility value, the usability and benefits of information are elevated to an altogether higher level when it is processed in a wider context.

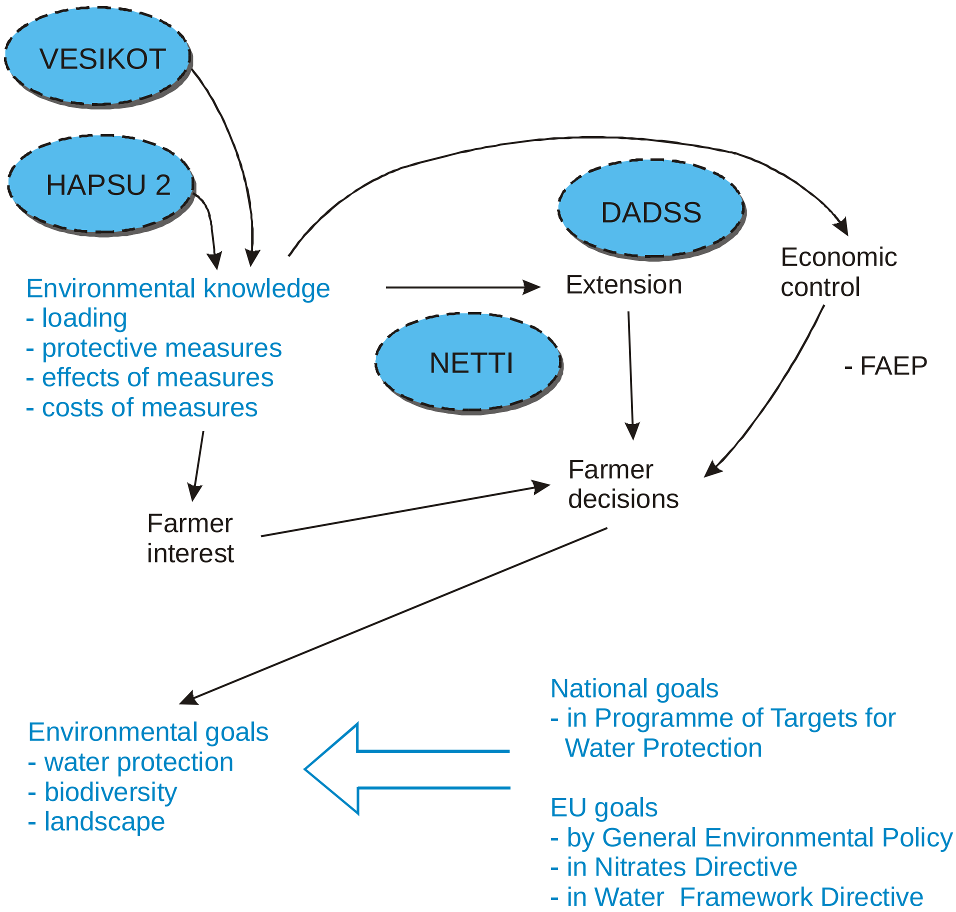

Figure 14. Influence network formed by environmental goals and the interest groups within the environmental care of agriculture.

In particular, these issues emerge when the environmental benefits of different protective measures or less-polluting production practices are compared with each other, or when the total benefits of different combinations of measures are evaluated. At catchment-level, such an approach is a central basis for regional environmental planning. Information on local conditions and loading and, in particular, on the long-term impacts of optional measures is an essential prerequisite for appropriate allocation and implementation of measures.

When public resources are used for environmental protection, financial oversight becomes an essential part of the total approach. Clearly, limited resources should be used as efficiently as possible. Randomly locating measures without systematic planning causes major waste (Fig. 15). With the objective being to reduce the loading by a certain amount over a certain period, accurate allocation of measures is of paramount importance. Thus also farmers' decisions should be the right ones from society's point of view. Their decision making can be guided in the desired direction by means of economic policy instruments and by introducing all relevant information that they may need on, e.g., the state of the environment or the goals that society has set.

The DADSS sub-project was in the middle ground between the extension and economic policy instruments. The VIHTA model as part of the project can be applied also as a planning aid for economic steering. It is particularly useful when a conflict arises between a farmer's private economic interests and the objectives of society.

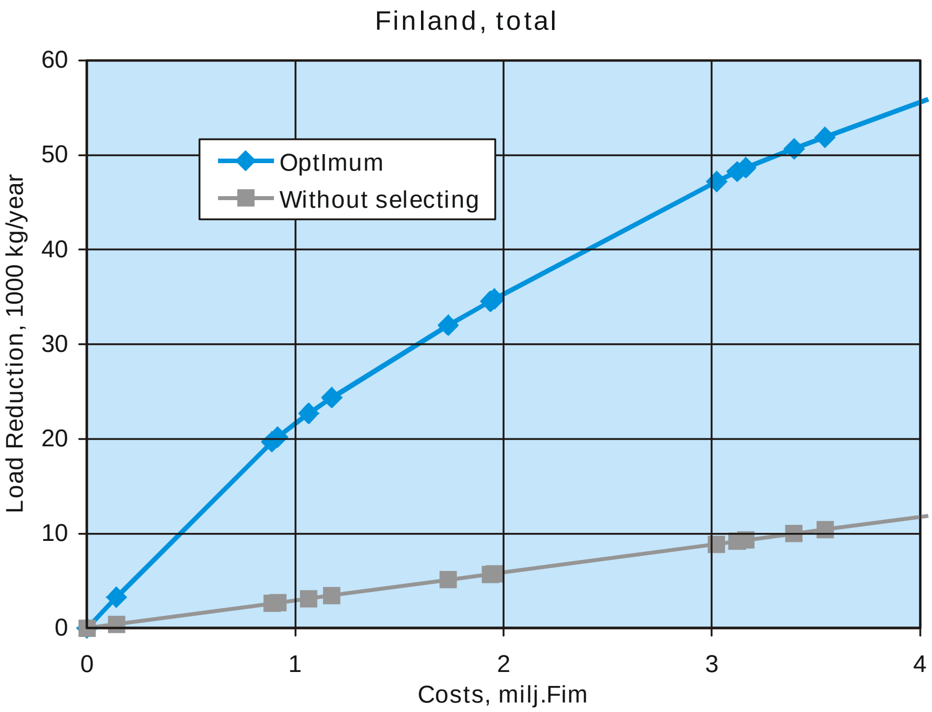

Figure 15. VIHTA-model predictions of TP load reductions achieved by CWs with different environmental investment levels in different parts of Finland.

5.1 Main conclusions

The main results and conclusions are presented in greater detail in the reports for each sub-project as listed in the ANNEX I.

The need for load reduction and environmental care

- The state of the environment is by and large a societal matter. Regulations and limitations concerning it are enshrined in laws, decrees and directives. As a general rule, national goals with respect to environmental protection are defined as environmental-policy decisions.
- One of the most important areas of operation with regard to environmental protection is combatting water pollution. The present, fairly good, status of Finnish water bodies will not remain unchanged without effective environmental measures.
- Our national goals with respect to reducing agricultural loading are determined in the programme of targets for water protection. The levels of agricultural N and P loading in 2005 are planned to be half what they were in the early 1990s. The means of implementation in the agricultural sector are the FAEP, the EU Nitrate Directive and national legislation. The programme applies to all polluters of waters.
- Most of the anthropogenic N and P loading imposed on water bodies comes from agriculture. Mitigating it will require constant and visible agri-environmental measures.

- In addition to preventing water pollution, other activities to protect the environment and landscape are also needed. Biodiversity of both flora and fauna and landscape aspects can be assessed together with water protection. There is a strong link between measures to protect water and the environment generally, on the one hand, and river engineering and restoration, on the other. Farmers who implement agri-environmental measures can be regarded as custodians of the environment and rural landscape.

Treatment methods for runoff waters and their effects

- Several practical measures are appropriate for the treatment of agricultural runoff. The total effect is achieved through the combined impact of a variety of measures; the problems of agricultural diffuse loading can not be solved through a single measure.
- Methods for treating runoff water from cropland are an essential part of the wider choice of measures appropriate for mitigating agricultural diffuse loading. Other important environmental aspects, such as biodiversity and landscape, can easily be linked with treatment methods.
- Successful implementation and efficient functioning of a treatment method depends on its planning, dimensioning and spatial focus. If concentrations of TSS and nutrients are low, it is difficult to reduce loading. Hence, measures should be applied as near as possible to the source of loading, e.g., a field under cultivation. Implementing treatment methods without appropriate planning and dimensioning is pointless, and possibly even counterproductive.
- CWs should be planned and dimensioned according to the hydrology of the catchment. A CW with adequate dimensioning is able to retain a significant part of the TSS, TP and TN loading entering it. Purification effects are negligible in CWs with short WRTs. SBs are useful only for retaining coarse soil.
- Dissolved P, which accelerates eutrophication of surface waters in particular, is readily retained in the soil of a CW, provided the water there is evenly spread, its WRT is long and the P content of the soil is low.
- Spontaneous propagation of vegetation in a CW during one growing season is successful if suitable species are left there and the water level is suitable. Transplantation is the most effective means of artificial propagation and it is essential if the development of vegetation needs to take place quickly or be steered in a particular direction. It is advisable to choose locally-found species.
- N is removed in CWs by denitrification, macrophytes and sedimentation. Vegetation plays an important role in N load reduction in a newly-established CW. During the later phases of the life span of a CW, the importance of denitrification increases.
- With regard to landscape improvement, the most significant benefit of establishing CWs is that open-water elements are added to otherwise-monotonous field sceneries. As they become more common, they will help to achieve the goal of restoring rural environments. Moreover, a CW constructed to maintain a varying area of water is able to even out flow peaks and therefore reduce the risk of flooding downstream.
- The high waterfowl densities observed in CWs indicate that their establishment on a large scale will significantly increase local and regional populations of these birds, especially in arable catchments with few lakes.

- Problems caused by acid sulphate soils can be efficiently prevented by means of LFD, CD and combinations of these. The measures should be applied both in acid sulphate areas and where ditches have existed for long periods. CD is also an efficient way of reducing the agricultural N load.
- BZs established in raked sections of fields reduce the loading caused by cultivation by, on the one hand, filtering runoff from higher up and, on the other, eliminating cultivation in the area of the BZ itself.
- Moreover, BZs significantly increase biodiversity in arable areas dominated by monocultures.

Selecting and locating measures

- Since catchment properties are highly variable, the amount of loading from them varies. Runoff waters from 88% of Finnish fields flow through a ditch network or straight along the surface into water bodies. The median distance, measured along main ditches, between an outlet of local field runoff and the nearest water body is 1.65 km. The median area and the median field percentage of the catchment above the outlet are 36 ha and 24%, respectively.
- In most cases, a single method does not suffice to solve the problems of a catchment. Depending on its properties, a variety of optional measures can be taken. The most efficient criterion for the choice of measures is cost-efficiency. A judicious choice of where to apply them is of paramount importance. Catchment-scale environmental protection planning should be incorporated into the drafting and implementation of EU-funded rural development schemes.
- A useful principle is to locate the measures in the most appropriate places in order of cost-efficiency, as long as the desired level of load reduction is achieved. Biodiversity and landscape should also be considered.
- The application of GIS in planning and siting measures presents considerable possibilities. GIS-based tools are especially useful with CWs, SBs and BZs. Assessed according to catchment size and field percentage, one-third of Finnish runoff waters from arable land could be treated in CWs. In practice, however, the availability of appropriate locations for CWs reduces the field area that could benefit from them.
- BZs are most beneficial when they are located in the steepest parts of fields. The median slope of Finnish fields is slightly less than 1%. Slopes of over 3% and 10% are found in 17% and 2% of fields, respectively.
- A large proportion of the acid sulphate soils in Finland are under cultivation. Depending on the various criteria of acidity (shown in brackets), the field area is 336,000 ha (pH < 5), 130,000 ha (pH < 4), or 61,000 – 67 000 (pH < 3.5). Detrimental amounts of acidity are leached also from some of the less-acid field areas (pH 4 – 5). Hence, water protection measures should also be applied to soils that are already partly leached and to those with lesser acidity. Approximately 770,000 ha of the Finnish field area is suitable for CD.

Activation of farmers

- Local decisions quickly impact on the local environment, and the reliability and credibility of the information provided are the key factors influencing them. Distrust is a big obstacle to evaluation of information. This can be reduced by creating farmer networks through which to disseminate information.

- Negotiation-based, interactive extension calls for a new kind of role for extensionists and authorities. Above all, extensionists have to support farmers' ability to recognise the environmental impacts of their actions and encourage them to embrace agri-environmental measures.
- Care has to be taken in the selection of participants so that all relevant forms of expertise are represented - the selection of participants can also influence the focus of the extension undertaken. Constraints set by official roles and resources should be taken into consideration and each participant should define their role clearly in the network.
- In order to make sure that all participants have similar expectations of what help interactive extension will provide, it is important to clearly agree on the goals and purposes at the start of co-operation. The participants need to agree on or at least define what is the need for environmental measures, what is the discussed funding framework, what problems in particular need to be solved.
- Targeting of extension is crucial to ensure farmer participation and motivation to contribute. Targeting should be done according to the goals and financial framework agreed at the start of extension. Farmers with potential land and similar need for information and measures should be involved in the more intensive extension practices. At this point additional participants, whose expertise may be of use, may be identified as well.

Economic steering

- When it comes to implementation of agri-environmental measures, a farmer's private economic interests and the objectives of society may clash. Economic steering should be implemented in a way that allows farmers' decisions to harmonise with the environmental goals that society sets.
- Economic steering is most easily implemented through the existing environmental support scheme (FAEP). Financial support is being allocated to methods that are *per se* effective, but under-exploited. This suggests that the support system should be more flexible.
- Farmers will implement methods only if they are not only environmentally, but also economically on a sound basis. Profit can be seen as a reward for taking care of the environment.

5.2 Environmental benefits

In general, the environmental benefits of projects like VIHTA can be assessed in many ways. A distinction can be made between direct and potential benefits. The direct benefits are increased knowledge in relation to problem-solving methods and the main themes of projects, whereas either efficient after-care of projects or even extra investment to fund follow-up development are required before potential benefits can be realised. Dissemination of information on the results of projects, publications and extension, which all Life projects require, are also the central actions needed to realise environmental benefits. The need for follow-up development typically arises when a prototype method or a solution has been developed, but fixed-period project has failed to complete a practical tool. The proper after-care in such situations is to launch a follow-up project. Otherwise, the potential environmental benefits remain unrealised and partly vitiate the results of the primary project. In this respect, a great responsibility continues to be associated with projects even after their completion dates.

Perhaps the most fruitful way of examining the environmental benefits of the VIHTA project is to assess them locally, regionally, nationally and at the EU level. The most important benefits according to this categorisation are presented in the following paragraphs.

Local benefits

The most important local benefits are obtained when local environmental needs and agri-environmental measures are brought into better harmony with each other. This can be promoted by creating a better flow of information through farmer networks. Although these networks were not formed in the VIHTA project as well as planned, because farmers took a stance in defence of their established interests, it is probable that the networks will eventually take shape in the desired form as group extension activities continue. This can be expected because farmers must individually make decisions on agri-environmental issues that are closely linked to agricultural production itself. When farmers embrace this basic idea, agri-environmental protection will proceed in a completely new way.

When extension is based on dialogue, a multi-directional flow of information takes place between researchers, extensionists authorities and farmers. This tends to dispel prejudices, allowing topics to be handled as important factual issues. For example, local special features and problems are seldom raised without thorough discussion and reasoning. Neither planners of agri-environmental programmes nor extensionists often adequately comprehend local problems. In such cases, the presence of local experts, i.e. farmers, is a great advantage.

When methods for treating runoff waters are implemented, a local improvement in water quality can be anticipated. Immediate benefits include landscape improvement and increased biodiversity.

A CW was planned in the catchment of Lake Tuusulanjärvi near Helsinki to treat agricultural runoff there. Its design was based on the results and experience gained from the VIHTA project and construction began in early 2001. Since the lake has an exceptionally high value as a recreational amenity, the CW will be locally significant.

Regional benefits

The central regional benefit obtained from the VIHTA project are related to a regional (catchment-scale) examination of the total effects of agri-environmental measures. A prioritisation based on cost-efficiency is the bedrock on which efficient allocation of regional environmental resources must stand. A comprehensive approach highlights the special features of regional problems and their solutions, e.g. recognising acid sulphate soils and locating appropriate measures properly. Catchment-scale planning of environmental protection straightforwardly responds to the local status of waters and to needs for improvement. The VIHTA model is a useful planning aid for local environmental authorities. Experimental calculations made using it revealed that, depending on local catchment characteristics, different measures tend to yield the distinctively best benefit. Regional benefits also include the improved co-operation of authorities.

National benefits

Nationally, the benefits of the VIHTA project relate to revision of the FAEP in its current phase and, with respect to the previous phase, on evaluating the effects of treatment methods for runoff water. Participation in the revision work was regular and extensive. The model was used not only for local assessments, but also for pre-evaluation of the total effects of the measures included in the revised FAEP. The effects were simulated using different levels of subsidies and various choices of methods. The results will enable financial steering instruments to be honed.

As regards individual methods, the benefits take the form of revised national design and dimensioning guidelines and application regulations. Based on the results of the VIHTA project, a manual explaining CWs and SBs was prepared for farmers. VIHTA personnel also contributed to brochures on other methods. The Hovi demonstration wetland will serve as a good example for CWs to be established in the future.

Two-day seminars on treatment methods for runoff waters were arranged within the VIHTA project in late 1999 and within the VIHTA and Life-Pyhäjärvi projects jointly in late 2000. Both attracted large numbers of participants (appr. 100 and 150). Since those present at both were mostly extensionists and environmental authorities, the information yielded by the project was efficiently passed on for practical use throughout the country.

EU-level benefits

VIHTA was a completely national project and its benefits mainly correspond to national needs. However, it did have elements and approaches applicable elsewhere in the EU as well.

The use of a systems-analysis-based decision-making approach is becoming increasingly common in solving complicated problems. In the VIHTA project, it was employed already during the planning of the Hovi demonstration wetland. Moreover, it was used as a part of the decision-making tool. The approach is universal, and can be used for various assessments of complex cause-effect relationships on different levels and of their effects.

A system like the VIHTA model can be applied when the phenomena being examined are complex and the data from neither empirical research nor modelling exercises are sufficient to describe the entire complex of problems. With VIHTA, existing data are handled systematically and used to aid decision making and planning. It is impossible to deal with the intricate combined effects of several measures properly without an appropriate tool. The approach employed in VIHTA can be used to assess any broad problem.

Locally-oriented group extension is a useful approach when human factors are involved with the inconvenient issues relating to extension. Group-centred discussion directs attention to the problem itself and its solution, treating extensionists and farmers as equal partners.

6 Dissemination of information

Generally, dissemination of information took place by the means of newspapers, electronic media, seminars, and meetings. General reports concentrated on presentations of the project's backgrounds and aims. A leaflet brochure was made in the beginning of the project, and a layman's report about the central results at the final stage of the project.

Project's results were presented regularly in domestic seminars, in international seminars and congresses, in scientific articles and reports, and in related trade magazines. The most important results are also presented in the project's www-pages:

http://www.vyh.fi/eng/research/euproj/vihta/vihta.htm (in English)
http://www.vyh.fi/tutkimus/yhthanke/life/vihta/vihta.htm (in Finnish)

The results were utilised in preparation of the 2nd phase of the FAEP. Moreover, VIHTA project was involved with environmental impact assessments of the first phase of the FAEP. VIHTA personnel also participated regularly in the agri-environmental negotiation days arranged semiyearly by the Ministry of Environment and the Ministry of Agriculture and Forestry. VIHTA project arranged three salient seminars, the first of which (in Vaasa on 30 Sep. 1998) was entirely concentrated on the problems of acid sulphate soils. The second one (in Helsinki on 9 and 10 Nov. 1999) covered whole scope of the project. The final seminar was arranged by the VIHTA and Life-Pyhäjärvi projects jointly in Turku on 25 and 27 Oct. 2000.

The publications, articles, seminars, etc. produced as part of the VIHTA project are listed in the ANNEX I.

7 Recommendations and needs for further development

Observable decrease of detrimental effects of agricultural diffuse loading usually takes quite a long time. However, the more extensively agri-environmental measures are implemented, the more quickly the desired responses in recipient water bodies become apparent. Indeed, the agri-environmental measures should not be considered as one-off actions, but rather as permanent part of annual agricultural production activities. This is, in particular, in concordance with the goals of society. Although the primary goal of the measures is water protection, their importance and objectives should be viewed in a wider perspective.

CWs have effect on hydrological balances of catchments as retention areas against floods. On the other hand, they increase the proportion of low flow. The CWs that are established for water protection should be located in their 'original,' natural places. In that case, deceleration of flood waters will be maximised. In fact, properly located CWs can also be seen as means for restoration of once disappeared flood areas and wetlands. The more the acreages of flood areas and wetlands are increased, the more suspended matter and nutrients are retained, and less transported to water bodies. Regardless of the viewpoint, this kind of activity alters fundamentally the landscape and diversity of watercourses and agricultural environment. Increased number of wetlands, as well as their beneficial environmental impacts, is in harmony with the goals of the EU Water Framework Directive.

More detailed unsolved questions include e.g. (1) what is the actual importance of restoration of canalised brooks and (2) to what extent is it possible to develop the maintenance principles of main ditches so that improved water quality and biodiversity, and decreased maintenance costs, could be achieved. Development needs are also directed towards planning of dams of CWs which enable migration of fish and macrozoobenthos, but do not simultaneously cause harm for continuity of watercourses.

Agri-environmental measures should be developed for local problems and needs as a part of comprehensive developing of countryside. National environmental schemes do not adequately cater for local needs and lack flexibility. Local knowledge of farmers and other local actors involved should be utilised more in targeting and developing of the measures. Social starting points and anticipations should be considered together with environmental goals. Due to the societal significance of environmental issues, it is necessary to link economic policy instruments with environmental protection. Adequate level and well-balanced, maximal efficiency seeking allocation of subsidies are of particular importance. Assessments of the most cost-efficient measures are needed in all stages of decision-making.

Most pronounced needs for further research and development after the VIHTA project are targeted towards (1) the planning of implementation of the EU Water Framework Directive and (2) some still unsolved questions related to the agri-environmental measures. In part, these questions will be approached in the three following projects that will deal with the issues similar to those worked with in the VIHTA project. EU 5th framework programme has granted funding for the PRIMROSE-project for the research and development of CW processes and mechanisms in purification of waste (and runoff) waters in cold (boreal and alpine) conditions. The same source granted funding also for the AgriBMPWater-project that will deal with the problems of acid sulphate soils. The VIHTA model will be further developed in a nationally funded project called VIHMA. The aim is to add cultivation practices and cost effects into the model.

8 Cost Summary

The total budgeted and eligible costs and estimated final costs are presented in Table 2. The total budget of the EU/LIFE project was 4 182 050 FIM, with maximum Life funded assistance 2 055 896 FIM (49.16%). The more detailed description on cost breakdown can be found in the separate Financial Report of the project.

Table 2. Summary of total budgeted and eligible final costs of the project in 1997–2000 in FIM.

Item	Total budgeted costs, FIM	Eligible costs, FIM	Final project costs, FIM
1. Personnel	3 117 050	3 117 050	3 622 300
2. Travel	335 000	335 000	345 400
3. External assistance			
4.2. Durables: equipment	150 000	80 000	148 100
4.3. Durables: prototypes	400 000	400 000	366 200
6. Consumables	50 000	50 000	43 400
7. Other costs	130 000	130 000	118 900
TOTAL	**4 182 050**	**4 112 050**	**4 644 300**

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Annex I. Dissemination of information

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An internal seminar on wetlands for the staff of the VIHTA project in the FEI on 19 November 1997

Educational seminar of the VIHTA project in the FEI on 9 - 10 November 1999. Altogether 120 participants from the Ministries of Agriculture & Forestry and the Environment, and from regional environment centres and extension groups.

Joukainen, S. 1998. Seminar on acid sulphate soils for experts and media in the FEI on 30 September 1998.

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Äijö, H. 1999. Presentation of the VIHTA model to students of the Helsinki University of Technology/Laboratory of Water Resources Engineering on 8 June 1999.

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First meeting of a group aiming at improving co-operation and dissemination of information concerning management of acid sulphate soils between different research institutes and authorities (HapsuNet), held on 4 May 1999.

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Presentation of the results of the NETTI subtask. Farmer perspectives on environmental care. The seminar "New water protection methods of agriculture" was held at the Pyhäjärvi Institute in Kauttua on 20 Nov 2000.

Kaljonen, M. & Valve, H. 2000. Presentation of the NETTI subtask and research into agri-environmental policy instruments in the FEI. Annual seminar of the Society of Sociological-Environmental Research on 10 April 2000.

Kaljonen, M. 1999. Farmers as custodians of the environment: their commitment to the agri-environmental programme. Presentation at the Days of Sociologists under the theme "Globalization, nation-state and market forces" in Joensuu on 26 - 27 March 1999.

Final seminar of the VIHTA project held together with the Life-Pyhäjärvi project at Hotel Caribia in Turku on 25 - 27 October 2000. In all, 150 people from the Ministries of Agriculture & Forestry and the Environment, regional environment centres, extension groups and municipalities attended.

Newspaper articles

Presentation of the VIHTA project in the FEI staff magazine Ympäristö SYKE 3/1998.

Short reports of the launching of the Life-VIHTA project in the main Finnish newspapers in late 1997.

Article on the launching of the Life-VIHTA project in Maaseudun Tulevaisuus in late 1997.

Article on erosion in agricultural catchments in Turun Sanomat on 14 April 1998.

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News items on an extension meeting arranged by the NETTI subtask, published in Uusimaa and Orimattilan Sanomat in January 1998.

An article about the work done in the NETTI subtask in Uusimaa in September 1998

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Statements, given in April- May 1999 to the group preparing the Finnish agri-environmental support scheme 2000-2006, concerning the results of the VIHTA project.

Statement requested by the Ministry of the Environment about management of acid sulphate soils and given in April 1999.

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Educational and extensional gatherings

Life-Vihta training course about agricultural water management for regional environment centres, 9-10 November 1999.

Several consultations and briefings arranged within the NETTI sub-project in eastern Uusimaa in 1997-98.

Briefing in Siuntio (11/1998) to inform local farmers about the potential of wetlands and their role in preventing water pollution of agricultural origin.

Training events based on the results of the project and arranged for regional environment centres and agricultural authorities in late 1999 and spring 2000.

Koskiaho, J. 1999. Laskeutusallas ja kosteikko vesien rehevöitymisen ehkäisijänä. (Sedimentation ponds and constructed wetlands as preventive measures against eutrophication of waters). A lecture in the seminar "Practical Water Protection Measures on Farms" arranged for Finnish organic farmers at the Pargas farm in Tammisaari on 30 May 1999.

Koskiaho, J. 2000. Kosteikkojen merkitys kuormituksen vähentämisessä. (The relevance of constructed wetlands in load mitigation). A lecture held in the seminar "Interactive Restoration of Lakes" arranged by the Finnish Environment Institute at the University of Helsinki's Lammi Biological Station on 13 April 2000.

Syrjälä, K. & Koskiaho, J. 2000. The Rantamo wetland in the municipality of Tuusula: Master implementation plan.

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Documentation page

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Author(s)	Markku Puustinen	
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Abstract	Reducing the diffuse eutrophication-promoting nutrients load that agriculture places on the aquatic environment requires knowledge of the effects of treatment methods for runoff water from farmland, processing this information to meet a variety of planning-related and practical needs as well as constant implementation of measures to protect water bodies. Numerous economic and environment-related aspects must be taken into consideration in planning environmental protection in the agricultural sector. Also farmers need more information on the effects of these measures before they can arrive at their own decisions. Good cooperation between all parties involved in the production, processing and use of information is an *a priori* condition for environmental measures being carried out on farms. Life VIHTA-project was financed out of the EU Life (Environment) Fund. Life VIHTA comprised four sub-projects: Constructed Wetlands VESIKOT (markku.puustinen@vyh.fi), Management of Runoff Waters from Acid Sulphate Soils HAPSU2 (sirpa.joukainen@vyh.fi), Decision-support System for Environmental Protection in Agriculture PÄÄTÖS (sirkka.tattari@vyh.fi) and Methods for Extension and Dissemination of Information NETTI (helena.valve@vyh.fi). The results of the sub-projects were availed of in the development of the VIHTA model. This contains data on the effects and costs of wetlands, sedimentation ponds, riparian buffer zones and controlled drainage. The method comparisons made using the model show that it pays to begin with buffer zones and wetlands when attempting to treat runoff waters from arable land. This is the best way to derive the greatest benefits from environmental investments. As measures gradually advance, controlled drainage enters the picture as a useful method. However, a very important point that needs to be understood is that the implementability of treatment methods for runoff waters depends on the characteristics of the catchment in question.	
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Tiivistelmä	Vesistöjä rehevöittävän maatalouden hajakuormituksen vähentäminen edellyttää valumavesien käsittelymenetelmien vaikutusten tuntemista, tiedon soveltamista erilaisiin suunnittelu- ja käyttötarpeisiin sekä säännönmukaista vesiensuojeluratkaisujen toteuttamista. Maatalouden ympäristönsuojelun suunnittelussa joudutaan ottamaan huomioon erilaisia taloudellisia ja ympäristönäkökohtia. Myös viljelijät tarvitsevat lisää tietoa toimenpiteiden vaikutuksista omien ratkaisujensa pohjaksi. Ympäristötoimenpiteet maatiloilla edellyttävät hyvää yhteistyötä kaikkien tiedon tuotantoon, käsittelyyn ja käyttöön osallistuvien tahojen kesken. EU:n LIFE Environment rahoituksella toteutettu 'Viljelyalueiden valumavesien hallinta-projekti' (VIHTA) lähestyi näitä kysymyksiä käytännön tarpeiden näkökulmasta. Projekti muodostui neljästä osaprojektista Vesiensuojelukosteikot VESIKOT (markku.puustinen@vyh.fi), Happamien sulfaattimaiden valumavesien hallinta HAPSU2 (sirpa.joukainen@vyh.fi), Päätöksenteon tuki maatalouden ympäristönsuojelussa PÄÄTÖS, (sirkka.tattari@vyh.fi) ja Neuvonnan ja tiedonkulun tehokkuus NETTI (helena.valve@vyh.fi). Tässä loppuraportissa esitellään keskeisimmät projekti tulokset ja johtopäätökset. Osaprojektien tuloksia hyödynnettiin VIHTA-mallia kehitettäessä. Menetelmä sisältää kosteikkoja, laskeutusaltaita, suojavyöhykkeitä ja säätösalaojitusta koskevaa vaikutus- ja kustannustietoa. VIHTA-mallin menetelmävertailut osoittavat, että viljelyalueiden valumavesien käsittely kannattaa aloittaa suojavyöhykkeistä ja kosteikoista. Näin toimien ympäristöinvestoinneilla saadaan eniten hyötyjä aikaiseksi. Vaiheittain toimenpiteiden edetessä säätösalaojitus tulee kuvaan mukaan hyödyllisenä menetelmänä. Erityisen tärkeää on kuitenkin tiedostaa, että valumavesien käsittelymenetelmien toteutettavuus riippuu valuma-alueiden ominaisuuksista.	
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Sammandrag	Minskandet av den diffusa belastningen från jordbruk, som eutrofierar vattendragen, förutsätter att man känner till effekterna av behandlingen av lakvatten, tillämpandet av kunskapen för olika planerings- och användningsbehov sam genomförandet av regelmässiga vattenskyddsåtgärder. I planeringen av jordbrukets vattenskydd måste man ta i beaktandeolika ekonomiska och miljösynpunkter. Även jordbrukarna behöver mera information om åtgärdernas effekter som grund för sina egna beslut. Miljöåtgärderna på gårdarna förutsätter ett gott samarbete mellan alla parter som är med om att producera, behandla och använda information. Projektet ”Kontroll av jordbruksområdenas lakvatten” (VIHTA), som genomförts med finansiering från EU:s LIFE Environment, angrep dessa frågor ur praktisk synvinkel. Projektet bestod av fyra delprojekt: Vattenskyddsvåtmarker VESIKOT (Kontroll lakvatten från sura sulfatjordar HAPSU2 (Stöd från beslutsfattandet i jordbrukets miljöskydd PÄÄTÖS (och Effektiviteten hos rådgivning och information NETTI (I denna slutrapport presenteras de centralaste projektresultaten och -besluten. Delprojektens resultat utnyttjas i utvecklingen av VIHTA-modellen. Metoden innehåller effekt- och kostnadsinformation om våtmarker, sedimenteringsdammar, skyddszoner och reglerande täckdikning. VIHTA-modellens metodjämförelse visar att det lönar sig att börja behandlingen av odlingsområdenas lakvatten från skyddszonerna och våtmarkerna. På detta sätt får man mest ut av miljöinvesteringarna. Småningom, då åtgärderna framskrider, tar man med den reglerande täckdikningen som en nyttig metod. Speciellt viktigt är att inse att genomförbarheten av lakvattnens behandling beror på avrinnignsområdets egenskaper.	
Nyckelord	våtmarker, lakvatten, jordbruk, vattenskydd	
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INTERNATIONAL COOPERATION

Management of the Runoff Waters from Arable Land
Final Report of the EU/LIFE Project

When Finland joined the EU in 1995, a comprehensive Finnish Agri-Environmental Programme (FAEP) was established. The FAEP includes a great number of optional measures and cultivation practices for mitigation of agricultural diffuse loading. One element of the FAEP is formed by measures for treatment of agricultural runoff waters. During the first stage of the FAEP (1995-1999), the treatment methods comprised constructed wetlands, sedimentation ponds, riparian buffer zones, controlled drainage, lime filter drainage, and surface liming of acid sulphate soils.

In 1997, the EU Commission approved a demonstration project "Management of the Runoff Waters from Arable Land" of the Finnish Environment Institute to be financed by the EU LIFE Environment funding. Objectives of the project were (1) to elaborate practicability of the treatment measures, (2) to develop a decision-making tool for priorisations of the measures, and (3) to promote activity of farmers by developing group-oriented, participatory extension processes.

This report presents the project`s aims, implementation, conclusions, and environmental benefits.

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