Effectiveness of buffer strips in the Netherlands

Research plan

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Effectiveness of buffer strips in the Netherlands.

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1 Why this project?

1.1 Policy context

On 1 July 2004 the European Commission and the Netherlands reached an agreement about the implementation of the Nitrates Directive for the nearby future. This agreement is outlined in the Third Dutch Action Programme (2004-2009) Concerning the Nitrates Directive; 91/676/EEC. Paragraph 4.4 treats the use of fertilizers near watercourses.
According to the Commission, the regulations in the Dutch Discharge Decree (for Open Cultivation and Livestock Farming) may be insufficient to prevent leaching and run-off of nutrients into the surface water. In this decree narrow fertilizer-free strips of 0.25 – 1.50[1] m are prescribed, depending on the type of crop and the method of herbicide application, whereas many other countries use a fertiliser-free zone[2] of at least 5 m.
There are two reasons, however, why the implementation of such wider zones is questionable in The Netherlands. Firstly, the specific soil and water conditions in the Netherlands, especially in the lowland parts below sea or river level (i.e. flat, controlled drainage, high natural background nutrient load) are expected to have a negative influence on the efficiency[3] of buffer strips[2].
Secondly, the Netherlands need a high density of (mainly) artificial surface waters to keep people's feet dry, and the establishment of buffer strips would significantly reduce the area of agricultural land that can be cultivated, with huge economic consequences.

Within the context of the Water Framework Directive, it is expected that other more cost-effective measures will be identified in the coming years, to reduce the loads and to achieve the (ecological) objectives for surface waters. Moreover, the Water Framework Directive offers the possibility to discriminate between artificial and heavily modified water bodies, and natural water bodies.

Based on these arguments the Netherlands differentiates between elevated regions above sea and river level (primarily sand and loam soils) and lowland regions (peat and clay) below sea or river level (Figure 1a and b). For the elevated regions, 5-metre-wide buffer strips will be set up alongside natural watercourses. Their effectiveness will be monitored for future evaluations.

The Netherlands and the European Commission agreed that further research is necessary to judge the efficiency of buffer zones under Dutch conditions, both in the elevated regions and in the lowland regions. The research proposal for this project was consulted with the European Commission and was the first step to fulfil this part of the agreement.

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[1] 5 m Only for tree nurseries
[2] From now on we will use the word buffer strip in stead of fertilizer-free zone. We assume grass strips without fertiliser and no changes in soil profile nor ditch bank.
[3] In this project plan we will use the word efficiency when both effectiveness in terms of reducing loads and cost-effectiveness are meant. Effectiveness is defined as the reduction (%) in nutrient load as compared to the situation without buffer strip.

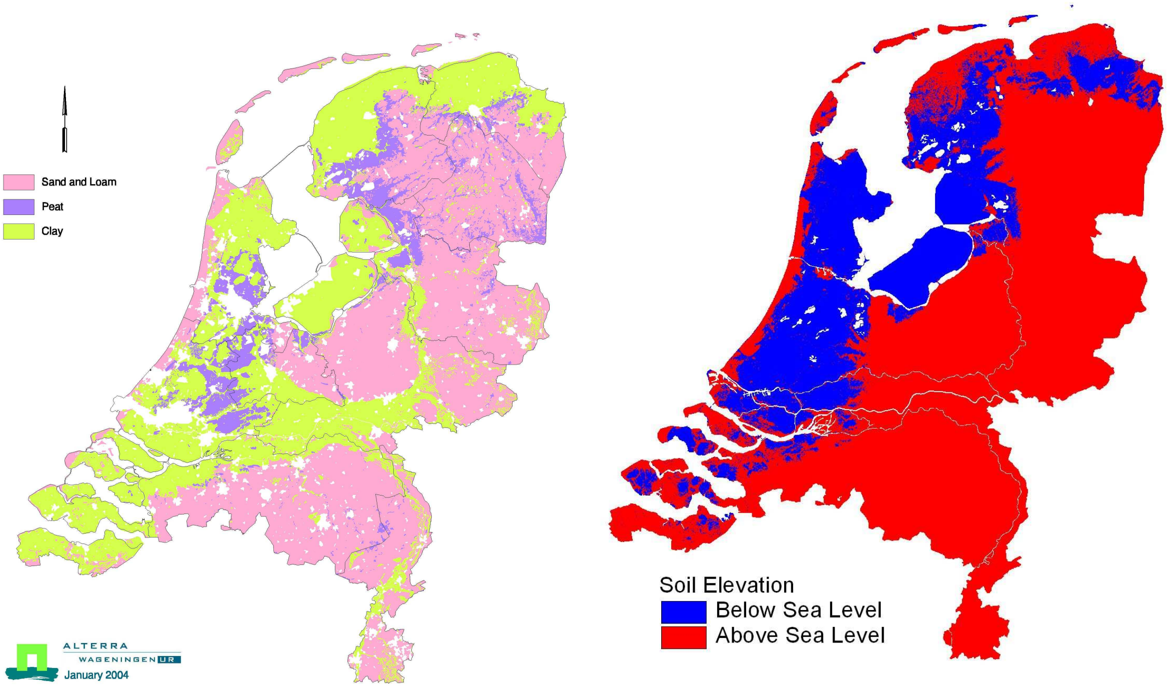


Figure 1: Major soil types in the Netherlands (left) and parts above and below sea level (right)

1.2 Knowledge gap

Unfortunately, little research has been carried out on the efficiency of buffer strips in the Netherlands, until now. The available experimental results apply to slopy areas with impermeable boulder clay in the subsoil in the East of the Netherlands, and are by no means representative for the Dutch situation. More recently an experiment has started to monitor the effects in the groundwater of a buffer strip on a sandy soil with arable crop. This experiment, however, does not measure nutrient load to surface water, and does not compare situations with and without a buffer strip.
Apart from this there are two preliminary model results on buffer strip effectiveness with very variable results because of differences in assumed hydrological boundary conditions. Desk studies have shown a moderate estimated effectiveness in the order of a few tens of percents, mostly based on international literature. Most of these are not applicable to the Netherlands because of the different soil and water conditions (slope, impermeable subsoil, uncontrolled drainage).

1.3 Research priorities

We held a workshop with representatives from involved research institutes and Ministries to make an inventory of the research items and to set priorities. The first versions of the proposal that proceeded form the workshop were discussed in two subsequent meetings. The resulting proposal was consulted with the EC, leading to a subdivision of the following priorities.

Part 1: experiments

- Direct measurements of nutrient loads to surface water
- Effect of buffer strips and strip width
- Five locations representing three major soil groups and the most important drainage situations
- Both grassland and arable land

Part 2: model study

- Estimation of the variation in buffer effectiveness[3] according to soil and hydrology by means of a model study

Part 3: cost-effectiveness

- Cost-effectiveness of buffer strips of varying width at the farm level
- Comparison of the efficiency of buffer strips with alternative measures

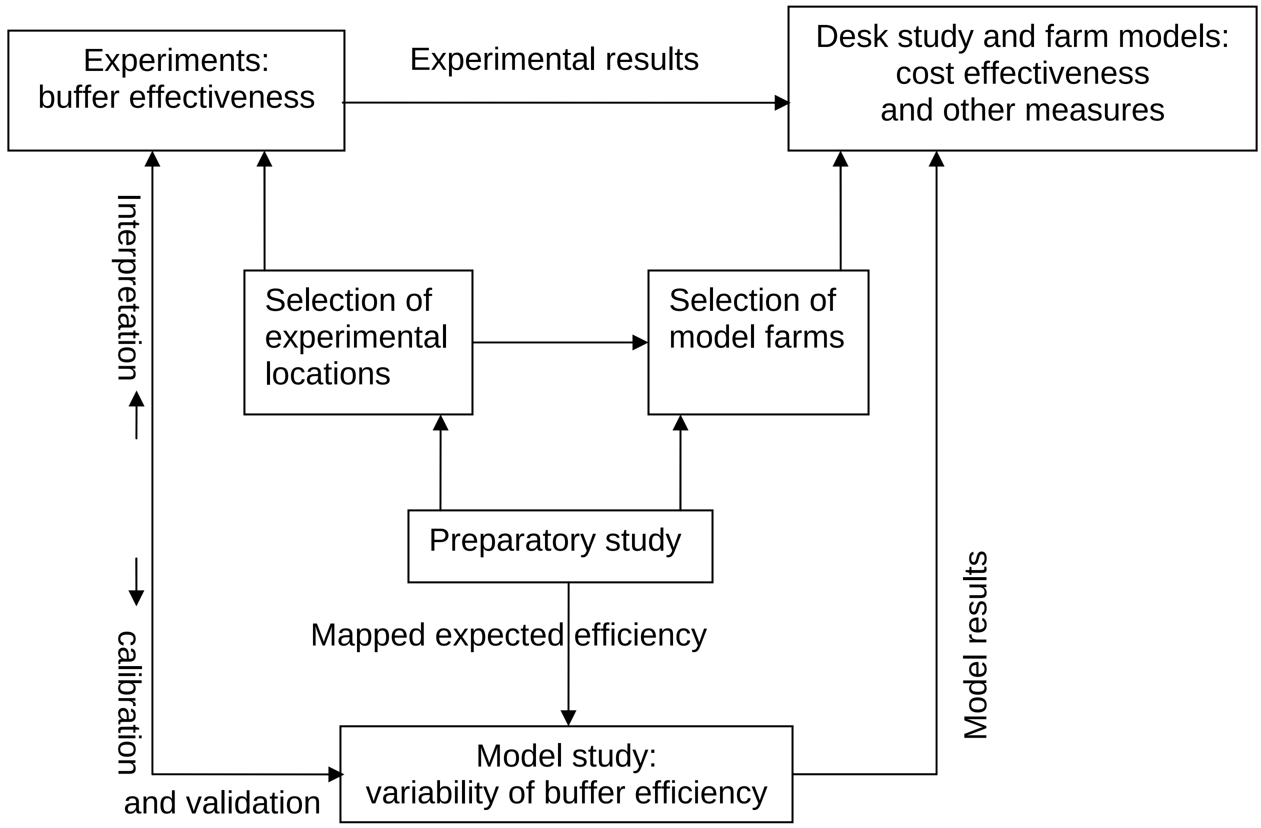
1.4 Objectives

The main objective of the study is to supply a scientifically based estimate of the efficiency[3] of buffer strips in reducing nutrient loads from agriculture to surface waters in the Netherlands. The study should provide experimentally based estimates for the three major Dutch soil types sand (including loam), clay and peat, for both grassland and arable land. The study will quantify variation due to soil conditions and hydrology based on models and it will compare the cost efficiency of buffer strips with alternative measures that can be taken by farmers. Attention will also be given to the effect of buffer strip width.

This scientific basis can be used for policy decisions on the application of buffer strips in the Netherlands. The experimental locations of the peat and clay soil will be chosen in the lower parts of the Netherlands in order to be able to pay special attention to the efficiency of buffer strips in these areas, as agreed upon with the European Commission.

1.5 Results

The project will deliver an English end-report and one interim report, and at least two peer-reviewed scientific articles in English. One article will focus on the results of the five experiments and discuss the reduction of nutrient loads by the applied buffer strips, the other will treat the results of the model study on the variation in expected efficiency of buffer strips due to varying soil conditions and hydrology.


Experiments:
buffer effectiveness
Experimental results
Desk study and farm models:
cost effectiveness
and other measures
Interpretation
Selection of
experimental
locations
Selection of
model farms
Preparatory study
Mapped expected efficiency
calibration
and validation
Model study:
variability of buffer efficiency
Model results

2 Project approach

2.1 Over-all structure

The preparatory study underpins the selection of experimental locations, that are representative for the major soil group regions in terms of expected buffer efficiency. The model farms that have to be selected for the study of cost-effectiveness should also be representative for these regions.

The mapped information on the expected efficiency of buffer strips in the Netherlands may be used in the subsequent model study.

The model study will support the interpretation of the experimental results. It can provide an explanation for temporal variation and time delay effects of the buffer system. On the other hand experimental results provide measurements that may be used for calibration and validation of the models. The experimental results on buffer efficiency and related variability from the model study will be input to the desk study on the cost-effectiveness of buffer strips for farms, compared to alternative measures.

2.2 Preparatory study

The preparatory study remains to be reported, but has already been carried out. The aim of the preparatory study was to find five adequate locations for the experiment. For this there were two criteria. On the one hand a location should be representative for the respective major soil type and for the geo-hydrological situation in the Netherlands (figure 3). This implies that the locations on sandy soil are freely drained, whereas drainage is controlled on the peat and clay soils (i.e. polders). Only the clay soil is pipe drained.
On the other hand the location should be suitable for the experimental lay-out. Nor the spatial variation within the field nor the background nutrient load to surface water may override the effect of the experimental treatments.

Representative locations were characterized in qualitative terms of expected efficiency of buffer strips (figure 3). For this we used earlier model studies on nutrient loads in the Netherlands and mapped geo-hydrological information. This included expected background nutrient load due to seepage and mineralization, and hydrological characteristics that determine residence time of discharged water, such as presence of pipe drains, trenches and ditches, soil conductivity, groundwater level and alike. This information will also be utilised in the model study.

For the second criterion “suitability” we analyzed the available information on the experimental locations from water boards and farmers, including some preliminary measurements on soil and water.

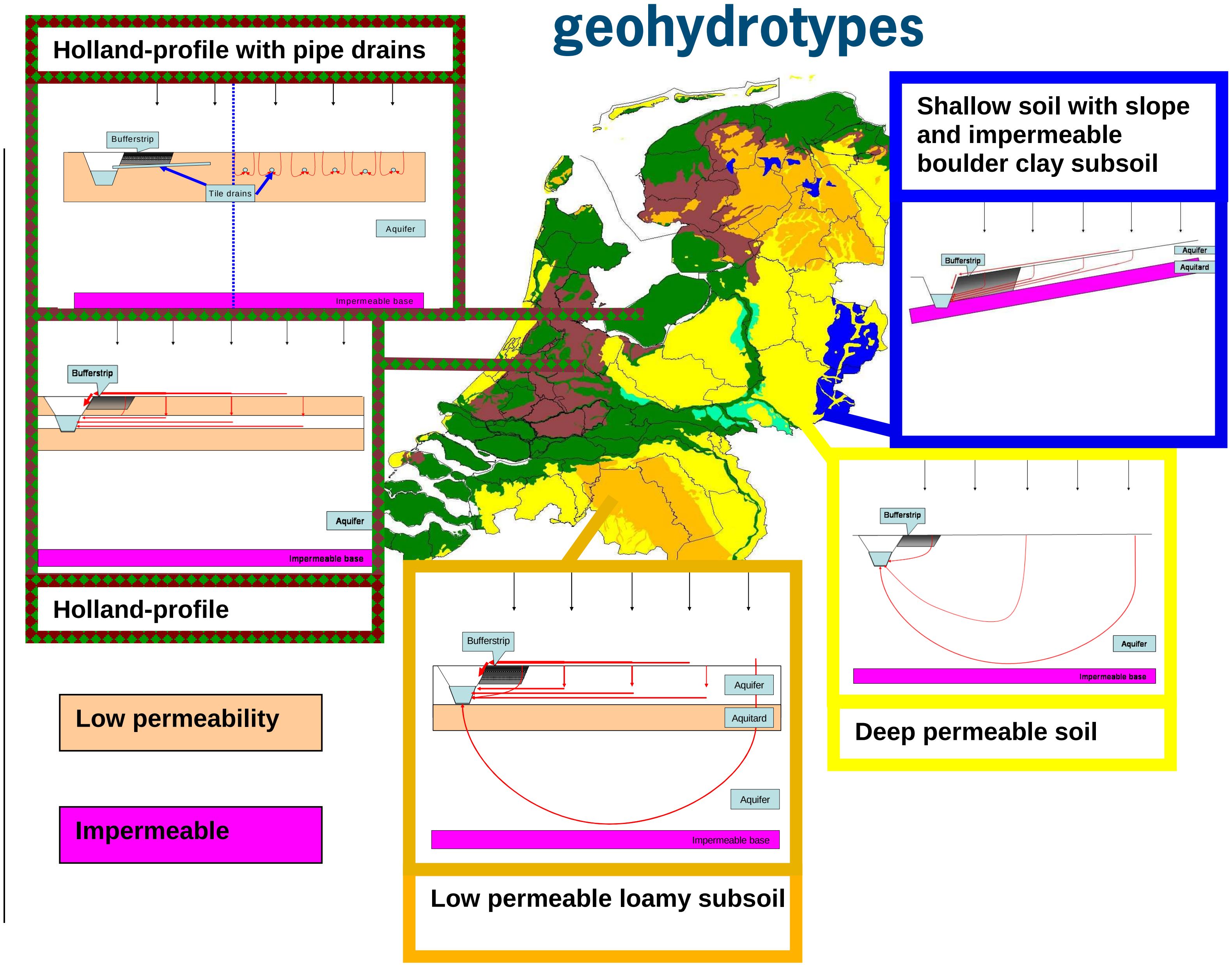


Figure 3: representative geo-hydrological situations in the Netherlands, see table 1 also.

2.3 Experiments

Three grassland and two maize fields were chosen on sandy, peat and clay soils according to table 1. The geo-hydrological situations correspond with figure 3.

Table 1. treatments and measurements at the selected locations. Colours correspond with figure 3.

Experimental location				Treatments[1]				Measurements				
Soil	Crop	Geohydrotype	Location	0	3	5	10	NP-load	D_2O tracer	Cl tracer	N, P Groundwater	N, P Soil[2]
Sand	Maize	Deep Profile	Beltrum				n.b.[1]					
Clay	Maize	Pipe-drained H.P.[3]	Lelystad									
Peat	Grass	Holland Profile[3]	Zegveld									
Sand	Grass	Impermeable	Winterswijk									
Sand	Grass	Loamy subsoil	Loon-op-zand									

[1] Buffer strip width (m). Zero treatment is the minimum according to legislation in force, e.g. 0.25 m on grassland and 0.50 m on maize land. 10 m treatment will not be measured from the beginning.
[2] focussed on start and end of the experiment; including general parameters at start
[3] The typical Holland Profile consists of an aquitard on top of an aquifer

The location with maize on sandy soil will be monitored most intensively, including two tracers and groundwater sampling. At the intensive location two extra treatments (3 and 10 m buffer width) will be considered, to get insight in the effect of buffer strip width on the reduction of load towards ditch water. The 10 m treatment, however will not be monitored from the beginning, but will be kept in reserve. The frequency at which samples are taken is the same for all locations. At each of the extensive locations only two widths of buffer strips will be considered.
More specific details about the experimental design can be found in Frame 1 below. The emphasis lies on registering the reduction in load of N and P towards the ditch water. For this purpose automatic sampling equipment will be used in isolated parts of the ditch, both at the intensive and extensive locations.

Frame 1: details of the experimental design

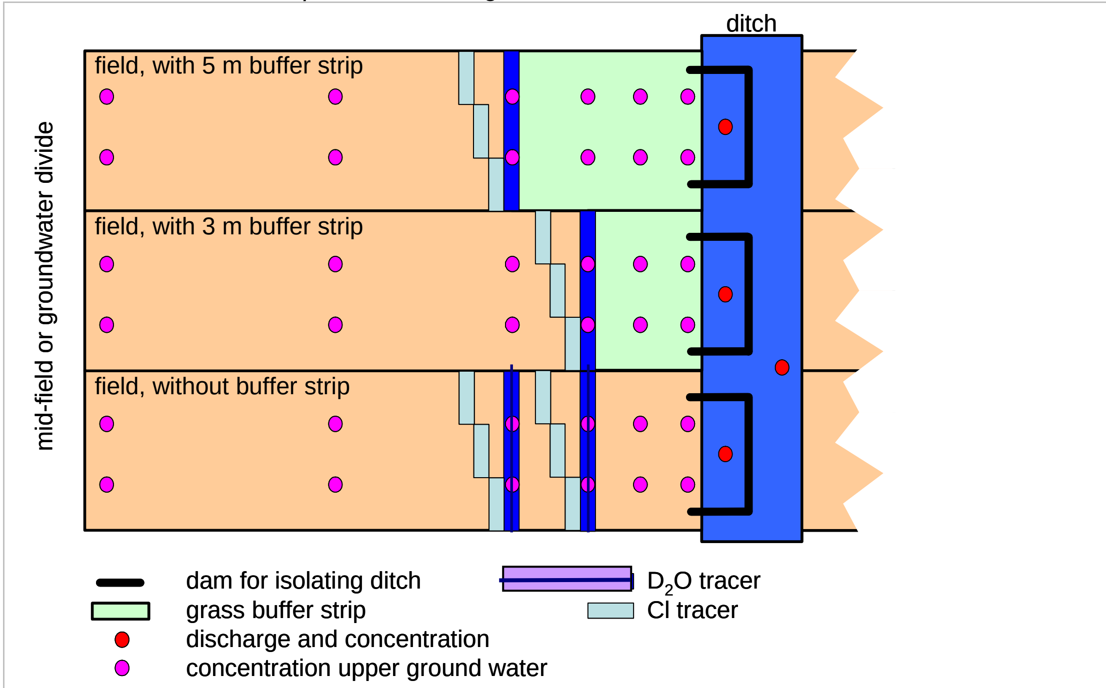


Figure 4. Experimental lay-out of the intensive location. At the extensive locations: no 3 m buffer strip and no measurements of upper ground water nor Cl-tracer. Not shown: position of ground water and piezometer wells.

Basic measurements (all locations)

The basic aspects include monitoring rainfall, ground water levels, piezometric head, soil and crop analysis. These data are used for interpretation of the results and model validation (*Model study)*. The budget for this item also includes some general costs for travelling, rent of field, and purchase of small matter.

Load towards ditch water (all locations)

The main quantity to be measured is the load of N and P from the soil towards the surface water in the ditch. There are no direct techniques to measure the load at the interface soil-water. We will monitor the changes in concentration in, and the discharge from an isolated part of the ditch. The water level in the isolated part will be kept equal to the remainder of the ditch by pumping water out in case of discharge and letting water in case of infiltration. Each 1 mm of discharge a sub-sample from the isolated water is taken (five sub-samples are mixed for analysis). The load of N and P is then estimated as the amount of water discharge times the measured concentration. In order to capture peak loads frequent sampling is required. We will therefore use an automated discharge proportional sampling device, one for each treatment. At each location an additional device is needed to sample water that is pumped into the isolated parts from the remainder of the ditch.

D_2O tracer (all locations)

After introducing a non-fertilised buffer strip in a field, it will take some time before changes in load will occur, as the first outflow from a field with buffer strip is historic groundwater, that is not yet influenced by the recent treatment. Until the historic water below the buffer strip is removed no major effects of the treatment may be expected. The time needed to achieve this situation will be determined by applying an inert tracer (D_2O) at the field boundary of the buffer strip and measuring the breakthrough of D_2O in the isolated part of the ditch. This time will depend on the width of the buffer strip, and thus needs to be determined for each treatment. In case of the zero treatment (no buffer strip) the tracer experiment can be regarded as a replicate. The breakthrough data will also be used for model validation (see 2nd bullet in “model study”).

Upper ground water (intensive location only)

Non-fertilised buffer strips will result in lowering of the N and P concentration in the upper part of the groundwater. However measuring upper groundwater does not give direct information about the load of N and P towards the ditch water, there are three reasons for their implementation. They will support interpretation of the experimental results, including the time delay effect treated above (the effect of treatment will be revealed earlier in the upper groundwater). They will be used for model validation and for the comparison with the effect of alternative measures (cost-effectiveness). There is more information on the effect of alternative measures on groundwater quality as compared to loads to surface water.

Cl tracer (intensive location)

The purpose of this tracer experiment is to gain experimental evidence on the interception effect (3rd bullet “model study”) Inert tracers (Cl) will be applied at several distances from the field boundary of the buffer strip (fig 3). At this boundary, suction cups will be installed at several depths to sample and analyse for this tracer. From these measurements the distance can be determined from which discharged water from the field moves through the buffer strip (both soil and surface). These results will be used for model validation. In case of the zero treatment (no buffer strip) this tracer experiment can be regarded as a replicate.

2.4 Model study

In order to quantify the spatial variability of the buffer strip efficiency and to assess the efficiency for other locations (extrapolation) and greater areas (upscaling) it is necessary to find the dominant key factors which control the nutrient load from these unfertilized strips. The model study aims to identify the most determinant spatial factors that can be derived from geo-databases, so that the influence of location on buffer efficiency can be quantified. We distinguish three mechanisms for load reduction, that are all influenced by soil conditions and hydrology.

- Area effect: an unfertilized strip implies a lower average fertilizer dosage on the field and consequently a lower nutrient load to surface water. This effect can be covered by the STONE consensus-model, that is used in the Netherlands to evaluate nutrient policy.
- Effect of position of the strip, adjacent to a watercourse as a consequence of the age distribution of drainage water. The residence time of the water surplus on or in the soil is lower near the water course. Retention processes that may reduce nutrient concentration (like plant uptake, denitrification and phosphorus adsorption) have less effect here. In the normal situation without buffer strip, water discharged through a zone adjacent to a water course contains more nutrients and contributes relatively more to the nutrient load. An extra reduction of nutrient load may be expected by reducing fertilizer rate in a buffer strip near the water course. In order to quantify the effect of the position of an unfertilized strip a 2D flow and transport model is needed. We will choose an existing 2D simulation model.
- Interception of (sub)surface run-off: retention of nutrients in water entering the buffer strip from the field by surface run-off and interflow. In order to cover this effect extra attention will be paid to pathways through (including water balance of) the top soil and the soil surface. Quantitative information obtained by the field study, literature research and model experiments will be incorporated in the two models.

The measurements of the field study will be used to calibrate and validate the model calculations. The model calculations will provide estimates for the variation in buffer efficiency over the Netherlands according to varying soil conditions and hydrology.

2.5 Cost effectiveness

The objective of this part of the study is to compare buffer strips with alternative measures to reduce nutrient load to surface waters in the Netherlands, in terms of cost effectiveness. Good agricultural practice will be the reference scenario. Alternatives may be measures such as lower fertilizer rate, other crop, water level changes, etc. Special attention will be paid to the prevention of losses from accumulated phosphorus in the soil.
Estimates for the effectiveness of buffer strips will be delivered by the field experiments and the model study. We will estimate the reduction of nutrient load by alternative measures by combining results of a desk study, of the farm models, and results of the STONE model for these measures. The costs of buffer strips and the alternative measures will be calculated with integrated farm models. For this goal, a set of at least 10 representative dairy and arable farms will be chosen, subdivided in the three major soil groups.

3 Project management

3.1 Organization

The project will be executed by a team from the following partners:

- Alterra, Wageningen University and Research centre, Environmental Sciences Group, departments of Soil Science, Water and Climate, and Landscape. Main contractor: over-all coordination, experiments and model study.
- Plant Research International, Wageningen UR, Plant Sciences Group, dept. of Agrosystems Research. Subcontractor: coordination of the cost effectiveness study.
- Applied Plant Research, Wageningen UR.
  Subcontractor: integrated arable farm model, crop analysis and treatment of two maize-sites
- Applied Research, Animal Sciences Group, Wageningen UR.
  Subcontractor: integrated dairy farm model, crop analysis and treatment of 3 grassland-sites

As it is important that the study is widely supported, a reference group will be installed by the contracting ministries for advice on scientific aspects, planning options and communication of the results. This group will consist of representatives from the Ministries of LNV and VROM and the Dutch research institutes/universities RIVM, RIZA and UU. Moreover we suggest two external international reviews with scientific representatives from surrounding EU countries and a representation from the European Commission.

3.2 Time schedule

Both the model study and the cost-effectiveness study will be executed in two separate periods. In the first period the models will be applied with little calibration and validation because the experimental results are only available from the first year. The cost-effectiveness study still lacks information on buffer effectiveness in the first period, but will be able to calculate the cost of buffer strips for the model farms and estimate the effects and costs of alternative measures. Both the model calculations and the cost-effectiveness study will provide insight that can be used for the first interim report. In the second period the models will be calibrated and validated before application to calculate variability. The effectiveness of buffer strips will be available from both the experiments and the model study to assess cost-effectiveness.

Table 2. Planned time schedule.

Project activities	2005				2006				2007				2008			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Project plan & funding																
Preparatory study																
Field experiments															Optional	
Model study																
Cost effectiveness																
Over-all coordination																
Reporting																
Communication																
External review																