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Modelling of vegetative filter strips in catchment scale erosion control

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The efficiency of vegetative filter strips to reduce erosion was assessed by simulation modelling in two catchments located in different parts of Finland. The areas of high erosion risk were identified by a Geographical Information System (GIS) combining digital spatial data of soil type, land use and field slopes. The efficiency of vegetative filter strips (VFS) was assessed by the ICECREAM model, a derivative of the CREAMS model which has been modified and adapted for Finnish conditions. The simulation runs were performed without the filter strips and with strips of 1 m, 3 m and 15 m width. Four soil types and two crops (spring barley, winter wheat) were studied. The model assessments for fields without VFS showed that the amount of erosion is clearly dominated by slope gradient. The soil texture had a greater impact on erosion than the crop. The impact of the VFS on erosion reduction was highly variable. These model results were scaled up by combining them to the digital spatial data. The simulated efficiency of the VFS in erosion control in the whole catchment varied from 50 to 89%. A GIS-based erosion risk map of the other study catchment and an identification carried out by manual study using topographical paper maps were evaluated and validated by ground truthing. Both methods were able to identify major erosion risk areas, i.e areas where VFS are particularly necessary. A combination of the GIS and the field method gives the best outcome.

Key words: vegetated strips, erosion control, Geographical Information System, mathematical modelling, cereal crops, overlay analysis, erosion, eutrophication

Introduction

Eutrophication of surface waters is one of the prime environmental concerns in Finland, and agriculture comprises the major single source of nutrients to surface waters (Rekolainen et al. 1995). The emphasis of the water protection policy (Ministry of the Environment 1999) is currently on controlling the non-point nutrient losses from agriculture. The most extensive policy measure has been implementation of the Agri-Environmental Support Scheme in accordance with the European Union's Common Agricultural Policy regulations (EEC 1992, EC 1999, Valpasvuo-Jaatinen et al. 1997).

A vegetative filter strip (VFS) is a vegetated area designed into the downhill edge of a field

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slope to filter suspended material from surface runoff water. By decreasing the runoff volume and velocity, these strips may enhance deposition of eroded particles. To establish vegetative filter strips of minimum one meter width along main ditches, and not less than 3 meters wide along rivers and other water courses are one of the obligatory requirements for farmers joining the program. An extra monetary incentive is given for a 15 meters wide buffer zone. More than 80% of Finnish farmers have joined the support scheme since 1995, when Finland joined the European Union. Several experimental studies have shown that the reduction efficiencies of vegetative filter strips (width usually < 10 m) often exceed 50% for sediment and sediment-bound nutrients, whereas no impact or even a slight increase may occur in dissolved nutrients (Young et al. 1980, Dillaha et al. 1989, Magette et al. 1989, Schmitt et al. 1999, Uusi-Kämppä et al. 2000). However, Ekholm et al. (1999) proposed that reduction of soil loss may also reduce soluble phosphorus, since some P release from eroded soil particles may take place later in the channel network. In Finland, the efficiency of vegetative filter strips in controlling erosion and nutrient losses was earlier studied experimentally in one hill slope (Uusi-Kämppä and Yläranta 1996) and in a test field (Puustinen 1999), and as a model assessment for the impact of filter strip width on erosion (Rekolainen et al. 1993). Due to the heterogeneity of soil and slopes, scaling up of the results obtained from a single hill slope is often difficult.

Several modelling studies have been performed to assess the efficiencies of filter strips (e.g. Tollner et al. 1976, 1977, Hayes et al. 1984, Williams and Nicks 1988, Flanagan et al. 1989, Munos-Carpena et al. 1999). Williams and Nicks (1988) and Flanagan et al. (1989) used the CREAMS model (Knisel 1980), which has been criticized (see Munos-Carpena et al. 1999) because the CREAMS hydrology component does not take into account the possible changes in runoff volume and rate in the filter strip. However, during the high flow period in Finland, i.e. the spring snowmelt, it is probable that the soil conditions in a filter strip and in a field above it remain rather similar due to the persisting groundfrost or high soil water content. A derivative of CREAMS, the ICECREAM model (Tattari et al. 2001) was selected to be used in this study. It has been adopted and validated to fit to the local conditions already in earlier studies (Rekolainen and Posch 1993, Tattari et al. 2001), and these parameter sets were available in this study. There are insufficient data available to estimate parameters for physically based complex multi-parameter models, like EUROSEM and WEPP, but the ICECREAM model can be parameterisized in drainage basin scale (Rekolainen et al. unpublished).

The objective of this study was to identify the high erosion risk areas and to assess the efficiency of vegetative filter strips in a catchment scale. The areas of high erosion risk were identified by a Geographical Information System (GIS) combining the digital spatial data of soil type, land use and field slopes. The efficiency of VFS was assessed by applying the ICECREAM model to homogeneous geographical units. These model results were scaled up by combining them to the digital spatial data. Furthermore, GIS-based erosion risk maps and an identification carried out by manual study using topographical paper maps were evaluated and validated by ground truthing. Both methods, GIS-based erosion risk assessment and manual VFS study, were able to identify major erosion risk areas, i.e areas where VFS is particularly necessary. A combination of the GIS and the field method gives the best outcome. The efficiency of the VFS in erosion control in the whole catchment area varied from 50% to 89%.

Material and methods

Catchments

Two catchments located in different parts of Finland, Kanteleenjärvi and Ilmajoki, were chosen as study areas (Fig. 1). Soil type information of topsoil (0–25 cm) was available as percentages of the area of each Agricultural Advisory District in Finland (Kähäri et al. 1987).

The Kanteleenjärvi catchment (30.85 km^2) is a subcatchment of the River Porvoonjoki drainage basin in southern Finland. The river Porvoonjoki flows into the Gulf of Finland. The Kanteleenjärvi catchment is a hilly district where the slope varies up to 30%. In the middle of the catchment there is a small important bird lake. The area surrounding the lake is flooding regularly. The dominant soil textural types in this area are sandy clay (49%) and silty clay (18%). The percentage of peat fields in the Kanteleenjärvi catchment is 4.6%.

The Ilmajoki catchment (66.60 km^2) is located in western Finland. The River Kyrönjoki divides the area into two parts. The Ilmajoki catchment is a flat district where the slope varies mainly between 1% and 2%, but the fields near the river may be rather steep (slope >10%). The typical soil textural types in the area are sandy loam (45%) and silt loam (17%). The percentage of peat fields is 8.2%.

Typical land use in both catchments is agriculture (Table 1), but geographically and topographically the areas differ from each other. Typical crops in these areas are spring barley and winter wheat but no spatial data of the crops were available. In the Ilmajoki catchment there are also cultivated grasslands. There are about 2.8 km^2 fields bordering water courses (≤50 m distance from the nearest stream) in the Kanteleenjärvi catchment and 6.6 km^2 in the Ilmajoki catchment.

Table 1. Land use classes of Kanteleenjärvi and Ilmajoki catchments.

Classification	Kanteleenjärvi [%]	Ilmajoki [%]
Water	2.7	0.8
Field	42.8	44.4
Cut forest	0.1	1.5
Open area	3.4	3.6
Open peatland	0.0	0.0
Scattered settlement	0.2	2.5
Forest	50.8	47.2

Fig. 1. Location of the Kanteleenjärvi catchment (Porvoonjoki) and the Ilmajoki catchment (Kyrönjoki).

Digital geographical data bases

Land use data is based on land cover and forest classification of Finland provided by the National Land Survey of Finland (Vuorela 1997). It is based on satellite images from the years 1986–1994. The results have been improved by using an agricultural area mask, which is based on 1:50 000 topographic maps. The cell size is 25 m*25 m. The database covers the whole of Finland. It includes a total of 78 land use classes but in this work they are combined into 7 classes, namely water, field, open area, peatland, forest, cut forest and scattered settlement.

Soil type data is based on soil textural information of the Finnish Environment Institute

(FEI) and the Geological Survey of Finland (GSF). Soil type information of FEI covers southern Finland in a scale of 1:100 000 and it is available in 25 m*25 m cells. Soil type information of GSF covers the whole country in a scale of 1:1000 000 and it is available in format 85 m*85 m cells. Both soil type data are based on maps of quaternary deposits in Finland. Maps represent the soil type in 50 cm depth.

Field slopes were calculated from the Digital Elevation Model (DEM), which is prepared by the National Land Survey of Finland (NLS). The cell size of the DEM is 25 m*25 m. The model is based on contour and shore lines of Finnish base maps (1:20 000). The interval of contours in the base map is 5 metres for the greater part of the country and 2.5 metres in some flatter areas. The DEM in raster format has been generated from vector data of contour lines and shore lines by using the TIN (Triangulated Irregular Network) interpolation method.

Watercourses and ditches are digitized from digital maps (1:20 000) provided by NLS. The drainage basin boundaries have been prepared by the FEI in scale 1:50 000.

The ICECREAM model

The ICECREAM model (Rekolainen and Posch 1993, Tattari et al. 2001) has been modified and adapted for Finnish conditions. It is based on several existing models: CREAMS (Knisel 1980), GLEAMS (Leonard et al. 1987, Knisel 1993), SOILN (Johnsson et al. 1987) and WEPP (Lane and Nearing 1989). Snow accumulation melt are calculated with a simple temperature index model, where snowmelt is a function of the daily mean temperature and degree-day constant (Vehviläinen 1992).

As a derivative of CREAMS and GLEAMS, ICECREAM is capable of predicting sediment delivery through strips covered with homogeneous vegetation (Williams and Nicks 1988, Flanagan et al. 1989). However, as pointed out by Dillaha and Hayes (1991), CREAMS-based models do not simulate the principal physical processes affecting transport within a VFS. For example, the hydrology component does not take into account the altered infiltration conditions (soil parameters are the same for VFS as for the source field). The surface runoff is simulated using a modification of the SCS curve number method (USDA-SCS 1972). The curve number as well as the roughness parameter (Manning's n) can be given for both vegetation covers. The same applies for cultivation practices.

The ICECREAM erosion submodel computes soil loss along a given slope and sediment yield at the end of a hill slope in accordance with modified USLE (Foster et al. 1977). Erosion is divided into detachment and transport of sediment caused by rainfall or runoff and deposition. Erosion caused by rainfall is pronounced in the upper part of the slope, whereas the runoff typically cumulates in the direction of slope and is thus dominant in the lower part of the slope. Deposition of sediment occurs when the transport capacity is less than the sediment load. Typically, the fine-grained particles drift with the water for the greatest distance. In ICECREAM, two types of erosion are distinguished, namely sheet erosion, also called interrill erosion, and rill erosion. The sediment transport capacity for each particle size class, based on the potential sediment load, is computed using Yalin's sediment transport equation (Yalin 1963).

Model input data and parameterization

Four databases were available for VFS simulation runs. The first included the crop-specific parameters for 11 most typical plants in Finland. The soil database consists of physical and chemical properties of 13 different soil textural classes. Tillage implements are described by their mixing efficiency as well as their efficiency for residue incorporation in the tillage database. Cultivation practices for each crop are described in the separate files including information on the dates of planting, fertilization, harvesting and ploughing as well as used fertilizer amounts and the depth of incorporation for each crop.

Table 2. Soil properties and SCS curve number (CN2) for four soils after different cultivation practices for barley and grass.

	Soil type			
Property	Silt loam	Silty clay	Sandy clay	Sandy loam
Clay content [m^3 m^{-3}]	0.19	0.46	0.36	0.09
Sand content [m^3 m^{-3}]	0.13	0.09	0.46	0.69
Saturated hydraulic conductivity [mm h^{-1}]	2	0.5	1.7	18
Soil erodibility factor	0.303	0.250	0.282	0.272
CN2, Planting, barley	63	83	79	57
CN2, Planting, grass	61	74	67	25
CN2, Ploughing	77	91	88	70

In this study, four different textural soil types (silt loam, silty clay, sandy clay and sandy loam) and two cereals, spring barley and winter wheat, were selected for VFS analysis. These crops are typical in the research areas. However, the cultivation operations of these two small grains deviate from one another. Spring barley is ploughed in autumn and sowed in the beginning of May. Winter wheat instead is ploughed, harrowed and sowed in autumn making the soil surface quite smooth and vulnerable for erosion (Puustinen 1999). In practice winter wheat is not often cultivated during successive years due to the late harvest of the crop.

Finnish soil classification is based on soil texture and organic matter content. Soil types are divided into mineral soils, which have less than 20% organic matter, and organic soils, which have over 20% organic matter (Heinonen et al. 1996). English names of mineral soil types are given according to the soil textural classes of Soil Taxonomy. Organic soils were omitted from this study because the model is unable to simulate them. Approximately 10% of Finnish agricultural fields are classified as organic soils (Puustinen et al. 1994).

The simulation runs were performed with daily meteorological data over a ten-year period (1981–1990) from Jokioinen, south-western Finland (Lat. 60°49', Long. 23°30'). A 10-year period was selected in order to include sufficient variation in climatic and hydrological conditions. A fixed field segment, size, 9 m * 50 m, was applied in all the simulation runs. The VFS was added as an extension of the field segment.

The ICECREAM model was first used to calculate erosion rates for field representing all relevant slope-soil-crop combinations. The simulation runs were performed without the filter strips, and similar runs were simulated by adding grass-covered filter strips representing widths of 1 m, 3 m and 15 m to the field. Filter strips were supposed to be fully established. In the simulation runs, the VFS was harvested at the end of July. The main parameters affecting erosion are presented in Table 2.

Identification of high erosion risk and potential VFS areas

Erosion risk areas were identified by GIS. All fields which were bordering (≤50 m) the main ditches or other watercourses were analysed. The automatic identification procedure combined digital soil type maps to slopes of the fields and the final result was an erosion risk map. Weighting of the grids representing soil type, land use and slope was based on the ICECREAM model results. Soil type maps of FEI were used in the Kanteleenjärvi catchment and soil type maps of GSF were used in the Ilmajoki catchment. Silt and clay areas in digital soil type maps were assumed to correspond to silty clay and sandy clay in the Kähäri et al. (1987) material in the Kanteleenjärvi catchment and to silt loam in the Ilmajoki catchment, and till and moraine areas in soil type maps were assumed to correspond to sandy loam.

The impact of vegetated filter strips for high risk areas within the catchments was assessed by combining the ICECREAM model results to the digital data. Land use maps, textural soil type maps and field slope maps were combined to find out how much eroded material leaves fields according to ICECREAM model results. It was assumed that 1 m, 3 m and 15 m wide vegetative filter strips were established for all the fields bordering the ditches and other watercourses. The slope of the filter strip has been assumed to be the same as the source field above. This evaluation was carried out separately for winter-wheat and spring barley.

The manual identification of high erosion-risk areas for the Kanteleenjärvi catchment was carried out by the Uusimaa Regional Environment Centre (Lamminpää 1999). This procedure was based on field visits and manual studies of the topographic 1:20 000 maps of the area. In addition, farmers were asked to supply information on inclined erodible stream banks, and visible rills and gullies. Farmers were also asked to report the frequency of flood events in their fields. A regional manager constructed a VFS plan for the catchment according to this information. Filter strips were recommended in appropriate places where the slope fell towards a river, a stream or a main ditch. In the plan, the following classifications were applied: filter strip (1) not necessary, (2) necessary and (3) highly necessary. Typically, on broad fields (with a large erodible area) and on narrower but very steep fields the filter strips were “highly necessary”, whereas on moderately steep, easily erodible or flooded fields filter strips were classified as “necessary”. The automatic and manual identification procedures for Kanteleenjärvi were compared and the areas of greatest differences were verified by ground truthing.

Results and discussion

Effect of slope, crop and soil type

The model assessments for fields without any VFS showed that the amount of erosion is clearly dominated by slope gradient (Fig. 2.). As slope increases from 0% to 3% the calculated erosion increased by two orders of magnitude. Winter wheat produced more erosion than spring barley, but the difference in the total amount of erosion between these two crops diminished when the soil became more coarse grained.

The soil texture was estimated to have greater impact on erosion than the crop, silt loam producing approximately three times more erosion than sandy loam (Fig. 2). Mineral soils according to Finnish soil type classification may include more organic matter than mineral soils according to international classifications (Soil Taxonomy, FAO), when proportion of clay is small (Yli-Halla et al. 2000). Probably the erosion rate decreases when the amount of organic matter in soil increases. In soil map the control section for soil texture is 50 cm, and that information is combined with the soil textural type information of topsoil. But if the topsoil is different from the control section of soil map, wrong estimates for erosion may be obtained.

The impact of the VFS on erosion reduction was estimated to be highly variable, from 10% to 86%, when the field above was spring barley, and from 33 to 91% for winter wheat. Widening the strip to 3 m and further to 15 m increased the reduction efficiency, but the further reduction in erosion was less than the reduction achieved by a 1 m VFS. The reduction efficiency of wider strips was slightly better when the source field above the strip was winter wheat compared to spring barley. Generally, the retention efficiency was slightly lower for winter wheat than for spring barley. Scanty vegetation added to low surface roughness resulted in lower efficiency of VFS for winter wheat than for spring barley, especially during late autumn.

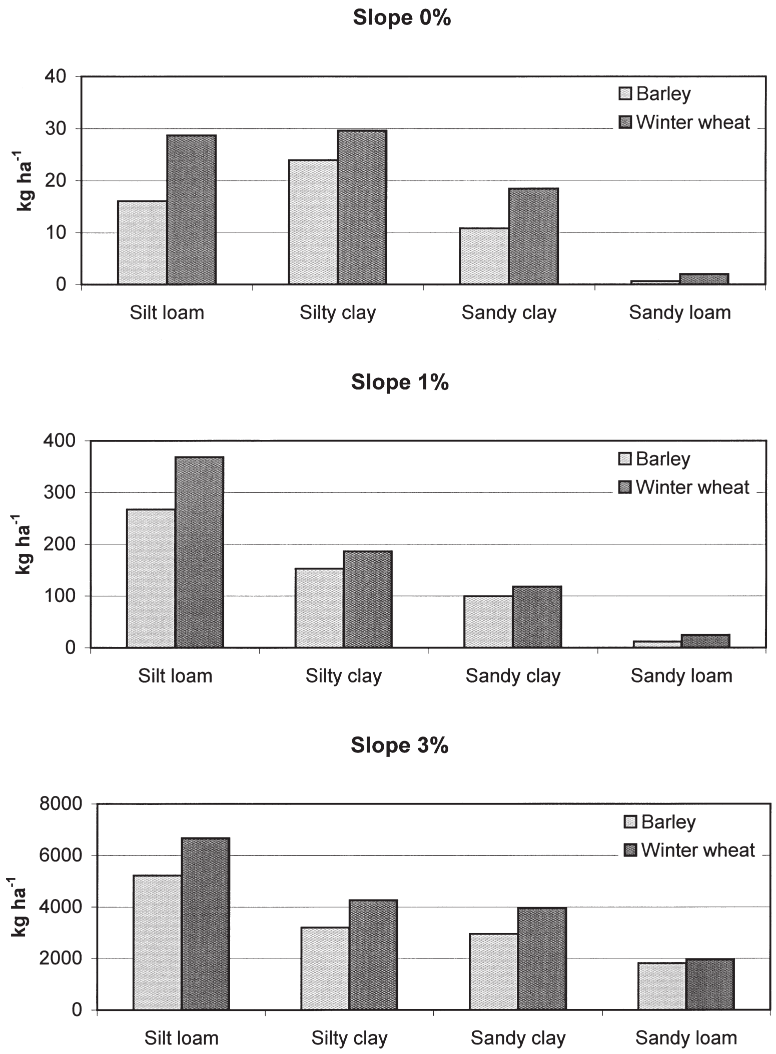
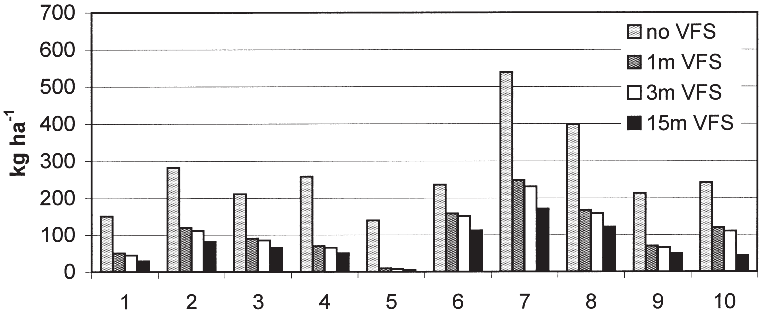


Fig. 2. Erosion at different slopes in different soil-crop combinations (no vegetative filter strip) based on the model results. (Different scales on the y axes).

Efficiency of VFS was modelled also when field slope was 7% and soil textural class silty clay. Reduction was 53–71% when crop was winter wheat and about 90% when crop was barley. This is of same magnitude as measured by Puustinen (1999) at Aurajoki experimental field, where 14 m VFS reduced erosion 58–67%. Crop was winter wheat, slope of the field was 8% and soil textural type was heavy clay. According to Uusi-Kämppä (2000) erosion load was 60% smaller from experimental fields with VFS than from those without VFS. However, it is difficult to compare these measured results to simulated, because the slope of the test field was only a few per cent but the slope of the filter strip was 10–20%. Soil textural type was clay, crop was barley or oats and width of the filter strip 10 m.

On average, the retention percentage increased when the slope steepness of the source field increased. The inter-annual variation in erosion rates was high (Fig. 3), mostly due to variation in temperature and precipitation. Moreo-

Barley



Winter wheat

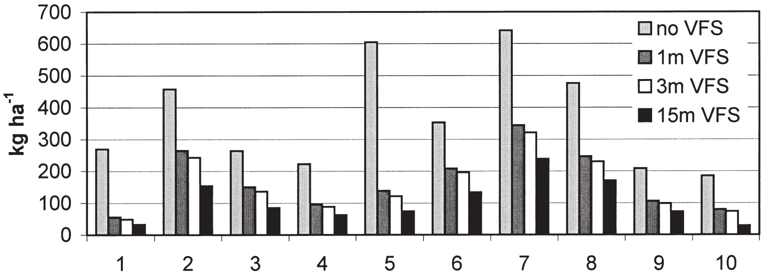


Fig. 3. Modelled erosion from fields which have no vegetative filter strip (VFS) or a vegetative filter strip of a different width on erosion for spring barley and winter wheat fields over a period of ten years. Slope is 1%.

ver, the filter strip efficiency varied between years. However, this variation was not dependent on the erosion rate, i.e. the retention efficiency was also different in high erosion years. This was probably due to the intra-annual variation of the rainfall, i.e. the retention efficiency differs for rains with different intensity falling in different stages of the year.

Catchment scale efficiency of VFS

The automatic identification procedure combined digital soil type maps to slopes of the fields in order to produce an erosion risk map (Figs. 4 and 5). Weighting of the grids representing soil type, land use and slope was performed based on the ICECREAM model results. Generally, there were more high risk areas in the Kanteleenjärvi catchment than in the Ilmajoki catchment in relation to the total length of ditches and rivers. This was mainly due to the topographical differences between these catchments.

The efficiency of the VFS in erosion control in the whole catchment areas varied from 50% to 89% (Table 3), being higher if the fields were assumed to be under spring barley rather than

Table 3. Simulated retention of erosion (%) in study catchments as percent of total amount for three widths of vegetated filter strips (VFS).

	1 m VFS	3 m VFS	15 m VFS
Kanteleenjärvi			
spring barley	82	83	86
winter wheat	64	67	76
Ilmajoki			
spring barley	85	86	89
winter wheat	50	55	67

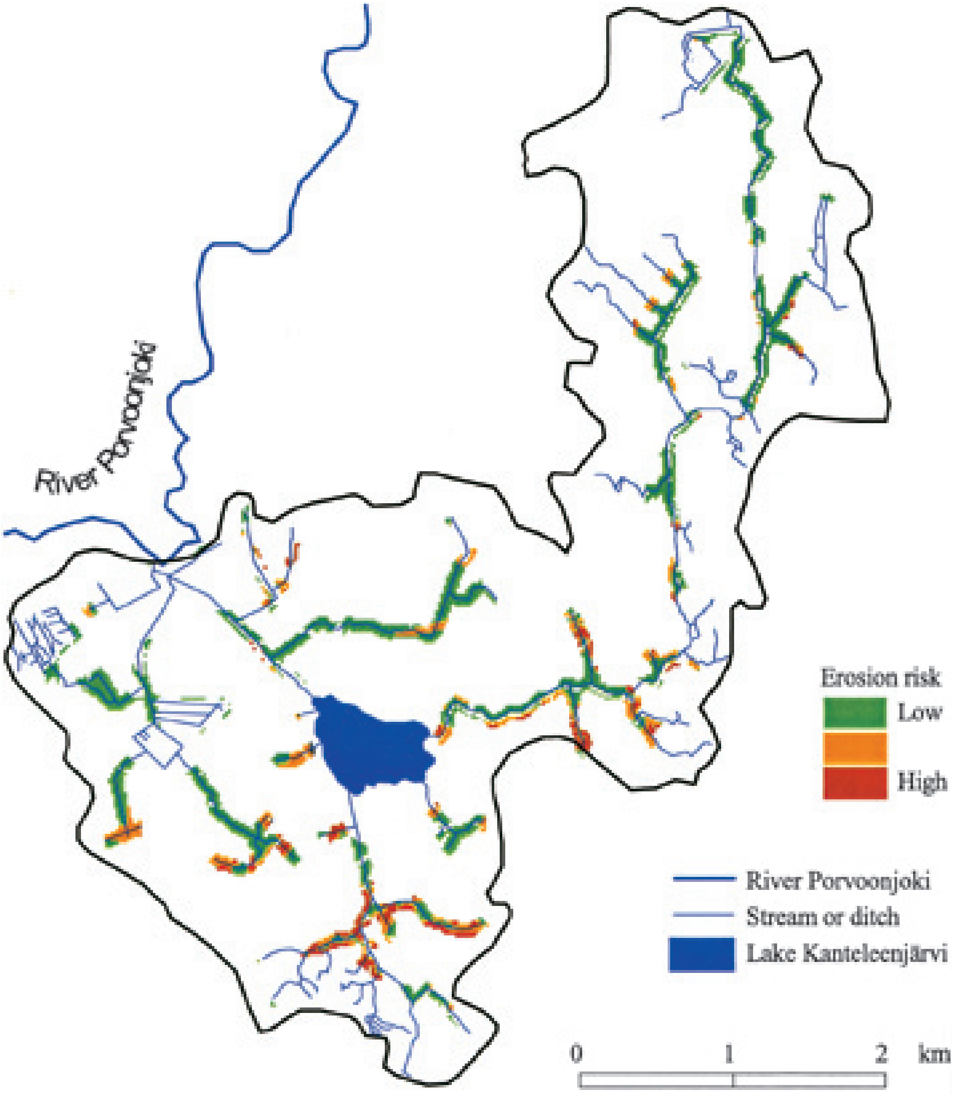


Fig. 4. Relative risk of erosion in areas bordering the main ditches or the river in the Kanteleenjärvi catchment.

winter wheat. These are estimates for eroded soil leaving the field but not eroded soil entering a watercourse. Increasing the width of the strips increased the erosion reduction only slightly for spring barley, but more in winter wheat. This is probably due to the higher erosion amounts for winter wheat than for spring barley.

According to the model assessments even narrow (1 m) strips may reduce erosion remarkably. However, the assessment method used in this study cannot take into account the possible ageing and thus decreasing efficiency of the narrow strips nor the potential for higher probability of more concentrated flow resulting in a higher risk of gully formation directly through the narrow strips (Dillaha and Inamdar 1997).

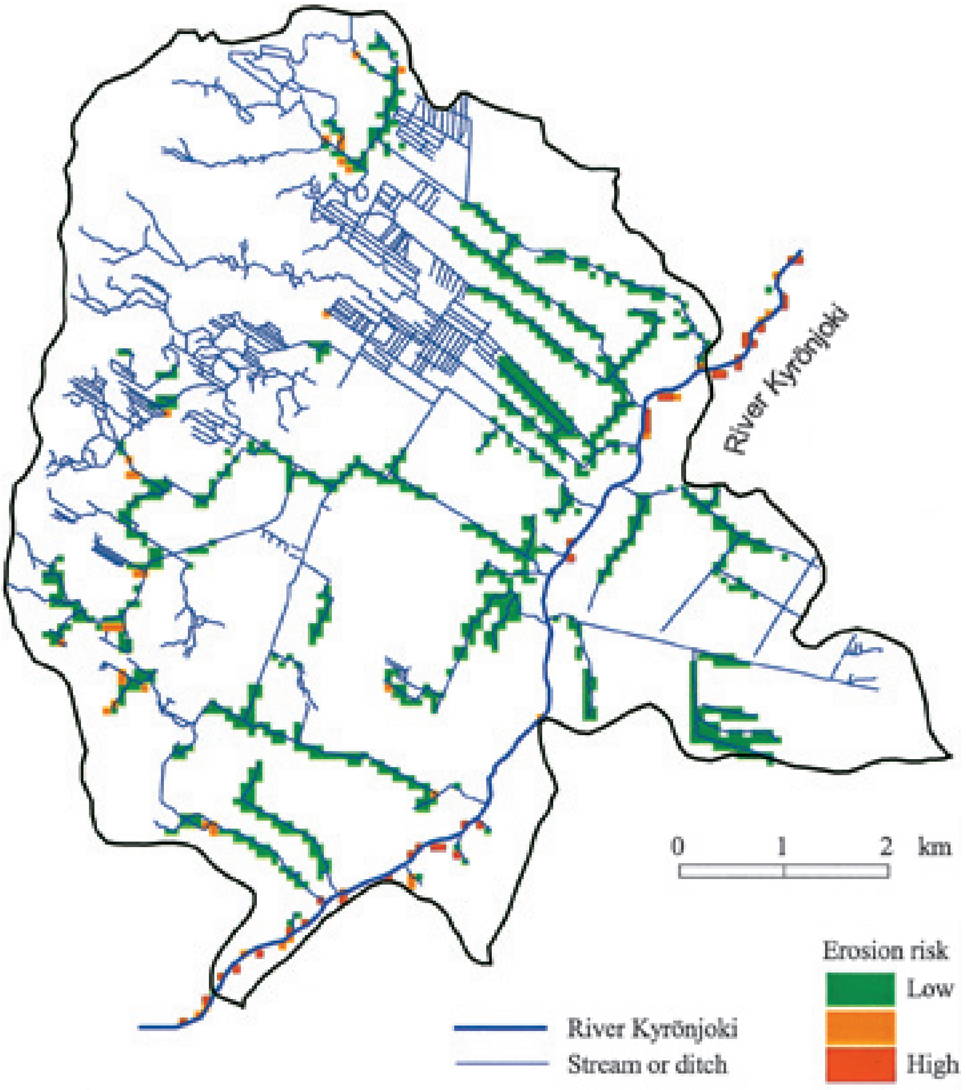


Fig. 5. Relative risk of erosion in areas bordering the main ditches or the river in the Ilmajoki catchment.

Comparison of GIS and field analysis for VFS

The GIS-based erosion risk map of the Kanteleenjärvi catchment (Fig. 4) was compared with the results of the manual VFS study of the Uusimaa Regional Environment Centre (Fig. 6) by field truthing. The repeatedly flooded areas are also shown in Fig. 6.

Some appropriate locations for VFS were systematically missed in the GIS-system due to outdated or poor quality digital data. The main reasons for this are: (1) some farmers had installed new subsurface drainage systems, whereas the open drains were still seen in the maps;

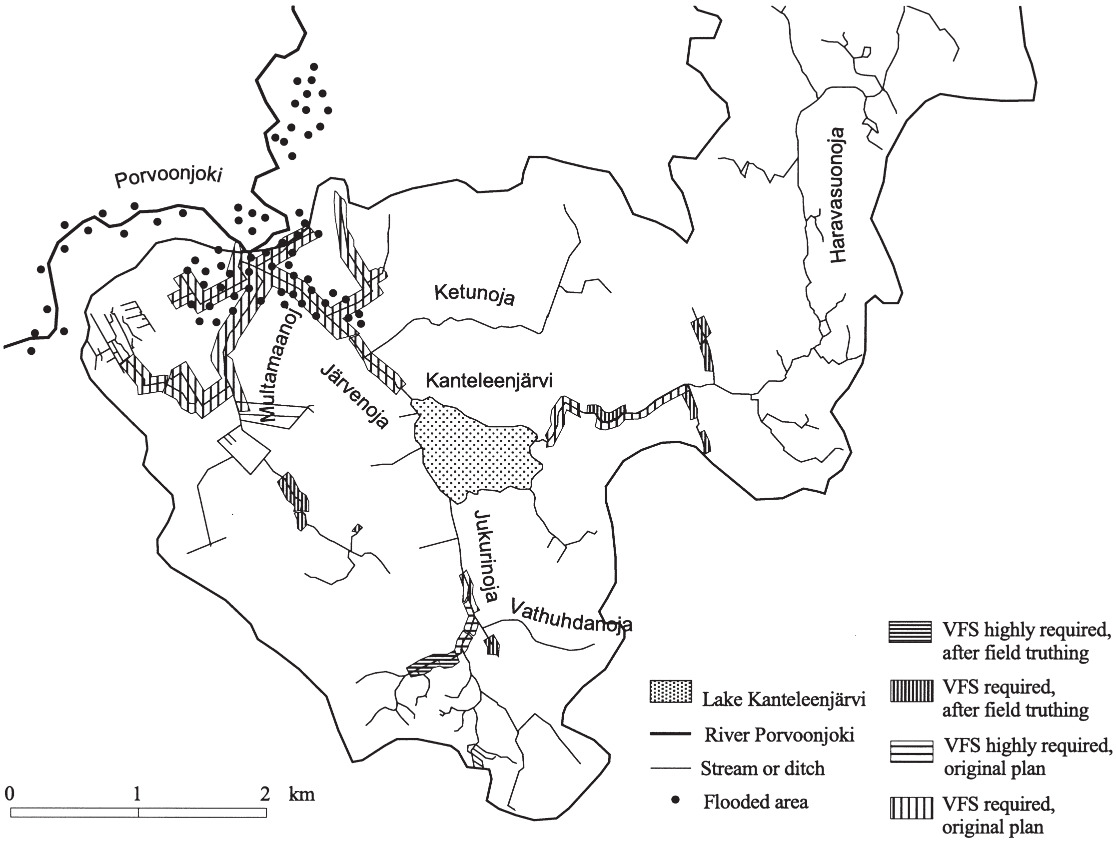


Fig. 6. The original vegetative filter strip plan of the Uusimaa environment centre and the areas added to the original plan based on Geographical Information System analyses.

(2) in some areas the GIS-based maps showed a misleadingly high erosion risk, whereas in reality there was narrow (< 25 m) flat fields next to forested hills (see Fig. 1, on the south side of the ditch Vathuhdanoja). In these cells, the GIS-map shows a combination of deep slope and field; (3) the poor quality of the soil maps. In addition, GIS-analysis totally neglected the areas which are repeatedly flooded.

The manual method had also missed some of the high-risk areas. Because of the diverse information in the 1:20 000 paper map, the VFS-planner might not “see” all the appropriate locations. Furthermore, if the fields are located in remote places, far from local roads, the planner has no easy access to these sites. Even if the planner does visit all the possible VFS locations, perspective, i.e. difference in the view from the upper end of the field that from the lowest part of the field, might lead to misinterpretation. As a result of the GIS-study, the VFS-planner revisited some VFS locations and added them to her VFS-plan (Fig. 6).

Both methods were able to identify major erosion risk areas, i.e areas where VFS is highly necessary. A combination of the GIS and the field method gives the best outcome.

Conclusions

The model assessments for fields without any VFS showed that the amount of erosion is clearly dominated by slope gradient. The soil texture was estimated to have greater impact on erosion than the nature of the crop. The impact of the VFS on erosion reduction was estimated to be highly variable. The results of this study demonstrated that vegetative filter strips may be effective in erosion control in catchments, but that the greatest advantage can be achieved in areas with a high proportion of erosion risk areas, such as high-slope fields neighbouring open ditches and rivers.

According to the model assessments even narrow (1 m) strips may reduce erosion remarkably. However, the assessment method used in this study cannot take into account the possible ageing and thus decreasing efficiency of the narrow strips nor the potential for higher probability of more concentrated flow resulting in a higher risk of gully formation directly through the narrow strips. Dissolved phosphorus in surface runoff should have a higher priority than less available sediment-bound phosphorus in water protection policy. No or even increasing effects of filter strips in dissolved phosphorus losses have been reported (Uusi-Kämppä et al. 2000). Uusitalo et al. (2000) concluded, that the importance of erosion control increases with increasing soil P status; the eroded matter from a high P soil has a higher potential to produce dissolved P in the receiving body of water than the eroded matter from a low P soil. A narrow filter strip may be sufficient if the soil has a low P status but in high P soils a wider filter strip (> 1 m) may be justified.

Finnish Environment Institute has invested to GIS and nowadays cost of daily use is minor. Digital data bases and modern GIS techniques may provide a useful and inexpensive tool in watershed management and may be an asset for regional authorities in VFS planning. A combination of the GIS and the field method probably gives the best outcome in defining the optimal settings of filter strips.

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SELOSTUS

Valuma-aluetason mallisovellus suojakaistojen käytöstä eroosion torjunnassa

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Tämän työn tarkoituksena oli kehittää käytännöllinen menetelmä herkästi erodoituvien peltoalueiden kartoittamiseksi, eli niiden alueiden, jotka ovat optimaalisia paikkoja suojakaistoille. Samalla arvioitiin myös suojakaistojen tehokkuutta eroosion torjunnassa. Tutkimusalueiksi valittiin kaksi valuma-aluetta eri puolilta Suomea. Helposti erodoituvat alueet arvioitiin paikkatietojärjestelmällä yhdistämällä tiedot maalajista, maan käytöstä ja pellon kaltevuudesta. Suojakaistojen tehokkuutta arvioitiin ICECREAM-mallilla, joka on Suomen oloihin sovellettu versio CREAMS-mallista. Mallinnus tehtiin ilman suojakaistoja sekä lisäämällä peltoon 1 m, 3 m ja 15 m leveät suojakaistat. Ilman suojakaistoja tehtyjen malliajojen perusteella eroosion määrä riippuu lähinnä pellon kaltevuudesta. Maalajilla on suurempi vaikutus eroosion määrään kuin kasvilla. Suojakaistojen tehokkuudet vaihtelivat suuresti eri tilanteissa. Malliajojen tulokset yhdistettiin paikkatietojärjestelmään ja tulokseksi saatiin, että valuma-aluetasolla suojakaistojen teho eroosion vähentämisessä ojiin rajautuvilta pelloilta oli 50–89 %. Paikkatietojärjestelmään perustuvaa suojakaistojen paikan arviointia verrattiin kenttätutkimukseen, joka oli tehty toisella valuma-alueella. Molemmilla menetelmillä löydettiin ne alueet, joilta eroosio on suurinta, mutta menetelmien yhdistelmällä päästiin parhaaseen lopputulokseen.