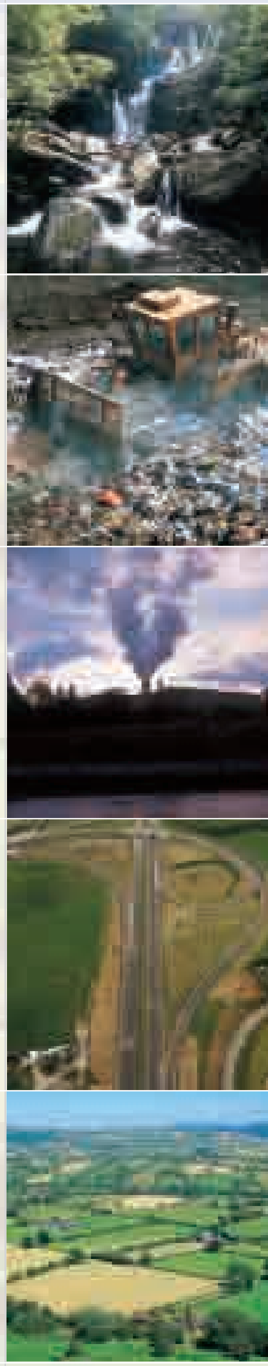
National Development Plan 2007 - 2013

ERTDI Report Series No. 78

FORESTRY OPERATIONS AND EUTROPHICATION – PEnrich



Synthesis Report

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

COFORD
NATIONAL COUNCIL FOR FOREST RESEARCH & DEVELOPMENT
AN CHOMHAIRLE NÁISIÚNTA UM THAIGHDE AGUS FORBAIRT FORAOISE

Environmental Research Technological Development and Innovation (ERTDI) Programme 2000-2006

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Heritage and Local Government.

OUR RESPONSIBILITIES

LICENSING

We license the following to ensure that their emissions do not endanger human health or harm the environment:

- waste facilities (e.g., landfills, incinerators, waste transfer stations);
- large scale industrial activities (e.g., pharmaceutical manufacturing, cement manufacturing, power plants);
- intensive agriculture;
- the contained use and controlled release of Genetically Modified Organisms (GMOs);
- large petrol storage facilities.

NATIONAL ENVIRONMENTAL ENFORCEMENT

- Conducting over 2,000 audits and inspections of EPA licensed facilities every year.
- Overseeing local authorities' environmental protection responsibilities in the areas of - air, noise, waste, waste-water and water quality.
- Working with local authorities and the Gardaí to stamp out illegal waste activity by co-ordinating a national enforcement network, targeting offenders, conducting investigations and overseeing remediation.
- Prosecuting those who flout environmental law and damage the environment as a result of their actions.

MONITORING, ANALYSING AND REPORTING ON THE ENVIRONMENT

- Monitoring air quality and the quality of rivers, lakes, tidal waters and ground waters; measuring water levels and river flows.
- Independent reporting to inform decision making by national and local government.

REGULATING IRELAND'S GREENHOUSE GAS EMISSIONS

- Quantifying Ireland's emissions of greenhouse gases in the context of our Kyoto commitments.
- Implementing the Emissions Trading Directive, involving over 100 companies who are major generators of carbon dioxide in Ireland.

ENVIRONMENTAL RESEARCH AND DEVELOPMENT

- Co-ordinating research on environmental issues (including air and water quality, climate change, biodiversity, environmental technologies).

STRATEGIC ENVIRONMENTAL ASSESSMENT

- Assessing the impact of plans and programmes on the Irish environment (such as waste management and development plans).

ENVIRONMENTAL PLANNING, EDUCATION AND GUIDANCE

- Providing guidance to the public and to industry on various environmental topics (including licence applications, waste prevention and environmental regulations).
- Generating greater environmental awareness (through environmental television programmes and primary and secondary schools' resource packs).

PROACTIVE WASTE MANAGEMENT

- Promoting waste prevention and minimisation projects through the co-ordination of the National Waste Prevention Programme, including input into the implementation of Producer Responsibility Initiatives.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

MANAGEMENT AND STRUCTURE OF THE EPA

The organisation is managed by a full time Board, consisting of a Director General and four Directors.

The work of the EPA is carried out across four offices:

- Office of Climate, Licensing and Resource Use
- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

Environmental RTDI Programme 2000–2006

Forestry Operations and Eutrophication – PEnrich

(2000-LS-3.2.2-M2)

Synthesis Report

(Final Report available for download on http://www.epa.ie/downloads/pubs/research/water/)

Prepared for the Environmental Protection Agency and COFORD

by

Forest Ecosystems Research Group,

University College Dublin

Authors:

Ján Machava, Olive McCabe, Philip O'Dea,

Raquel Cabral and Edward P. Farrell

ENVIRONMENTAL PROTECTION AGENCY

An Ghníomhaireacht um Chaomhnú Comhshaoil
PO Box 3000, Johnstown Castle, Co. Wexford, Ireland

Telephone: +353 53 916 0600 Fax: +353 53 916 0699
E-mail: info@epa.ie Website: www.epa.ie

ACKNOWLEDGEMENTS

This report has been prepared as part of the Environmental Research Technological Development and Innovation (ERTDI) Programme under the Productive Sector Operational Programme 2000–2006. The programme is financed by the Irish Government under the National Development Plan 2000–2006. It is administered on behalf of the Department of the Environment, Heritage and Local Government by the Environmental Protection Agency which has the statutory function of co-ordinating and promoting environmental research. The ERTDI programme 2000–2006 has been replaced by the Science, Technology, Research and Innovation for the Environment (STRIVE) programme 2007–2013. The STRIVE programme is funded by the Irish Government under the National Development Plan 2007–2013. The research presented in this report was co-funded by the National Council for Forest Research and Development, COFORD.

The authors would like to thank the following for their time and assistance over the course of this study: Mr Alan Wood and Mr Matt Reed for use of their land for this research and Mr Frank Gibbons (Greenbelt) and Mr Frank Reed (Coillte) for their assistance in locating suitable study sites, Mr Norman Butler, Ms Marina Conway, Mr Séamus Breslin (Greenbelt), Mr Fergus McCaffrey, Mr Francesco Quiroga-Lago, Ms Rebecca Quinane, Mr Donal Grant and Mr Stefan Schröder for their help with fieldwork, Ms Erica Geurts, Ms Yvonne Kelleher and Ms Gillian McGrath from the Forest Ecosystem Research Group, UCD, and Mr Andrew Bryan and staff at the Coillte Research Laboratory for analysis of samples each week, Mr Michael Stapleton, Mr Michael Browne and Mr Hugh McGinley from the Environmental Protection Agency for their assistance with flow measurements in Co. Wicklow and Co. Mayo.

WATER QUALITY

The Water Quality Section of the Environmental RTDI Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in this area. The reports in this series are intended as contributions to the necessary debate on water quality and the environment.

ENVIRONMENTAL RTDI PROGRAMME 2000–2006

Published by the Environmental Protection Agency and COFORD, Ireland

PRINTED ON RECYCLED PAPER

ISBN: 1-84095-250-4

Price: Free

12/07/300

Details of Project Partners

Ján Machava
Faculty of Forestry
Technical University in Zvolen
T.G. Masaryka 24
960 53 Zvolen
Slovakia

Tel.: +421 45 5206216
E-mail: machava@vsld.tuzvo.sk

Olive McCabe
UCD Conway Institute
University College Dublin
Belfield
Dublin 4
Ireland

Tel.: +353 1 7167658
E-mail: olive.mccabe@ucd.ie

Philip O'Dea
Coillte Laboratories
Church Road
Newtownmountkennedy
Co. Wicklow
Ireland

Tel.: + 353 1 2811451
E-mail: philip.odea@coillte.ie

Raquel Cabral
Urban Institute Ireland
UCD Richview
Clonskeagh Drive
Dublin 14
Ireland

Tel.: + 353 1 7162697
E-mail: raquel.cabral@ucd.ie

E.P. Farrell
School of Biology and Environmental Science
University College Dublin
Belfield
Dublin 4
Ireland
Tel.: +353 1 7167716
E-mail: ted.farrell@ucd.ie

Table of Contents

Executive Summary

Approximately 10% of the total land area of the Republic of Ireland is covered by forest. The Forest Service has introduced a series of initiatives designed to ensure the development of the sector on a sustainable basis. These initiatives include measures aimed at mitigating any potential negative impacts of forests or forest operations on water quality. Despite this, there are concerns that forestry could contribute either to eutrophication or acidification, under certain circumstances.

Eutrophication, defined as the enrichment of waters beyond natural levels, principally by the nutrient phosphorus (P), is a serious cause of concern in Ireland at the present time. The contribution of forestry to P loading in catchment waters has not been intensively studied in Ireland, but is potentially important because forests are often located in near-pristine environments.

The concentration of P in drainage waters from forest ecosystems is usually very low due to its low concentration in soil solution. Phosphorus is retained by most mineral soils and, as a consequence, losses are usually negligible. However, it is much more mobile in peat soils where it can be relatively easily leached or lost through surface run-off, as these soils have a low capacity to retain free phosphate.

The overall objective of the PEnrich project was to study the influence of forestry and forest operations on water quality, specifically in the context of eutrophication of surface waters. This was investigated in three distinct tasks. The first task studied the influence of forest operations such as harvesting – clearfelling, thinning and re-establishment of forests on a large scale in a blanket peatland catchment – on the Ballinagee River, in the Wicklow Uplands. Automated monitoring stations were located both above and below forestry at Ballinagee Bridge. Within this defined monitoring area, the percentage of forest was 51%. Furthermore, and at this site only, the acidity of the surface waters above and below the forest study site was monitored. The second task, at Crossmolina, Co. Mayo, explored the impact of afforestation of land previously used for agriculture, which had a high P index as a result of intensive farm management. In the third task, at Ardvarney, Co. Mayo, the effect of fertilisation on water quality was studied under experimental conditions, using different formulations of rock phosphate.

There was no evidence of any negative influence of the forest, or forest operations, at either the Ballinagee River catchment, nor at the former agricultural site at Crossmolina. At Ballinagee, neither P concentrations nor transported P were elevated below the forest in comparison with the conditions above. Furthermore, despite the high sensitivity of these waters to acidification at Ballinagee, the absence of a significant difference between pH values above and below the forest clearly establishes that neither the presence of the forest nor associated activities contributed to the acidification of the surface waters. At the Crossmolina study site, no adverse impact of forest operations on surface water quality was detected. In fact, P concentrations in surface water were actually lower after afforestation than before.

Results from the P run-off experiment at Ardvarney were anomalous. Very high concentrations of P were measured in run-off water. However, the occurrence of the highest concentrations in the control plots, where no fertiliser treatment was applied, suggests that these P concentrations were not the result of the presence of the forest or of the conduct of forest operations. It is suspected, but unproven, that they are an unforeseen artefact of the experimental design.

The results of this project emphasise the complexity of forest–site interactions. The indications from the study sites are positive. They suggest that commercial forest operations, can, if Forest Service guidelines are strictly adhered to, be conducted without detrimental effects on water quality. However, the conclusions of other studies cannot be ignored. Further research is needed. It should include both intensive studies in order to elucidate ecosystem processes controlling the retention and release of P in forested catchments and also an extensive catchment-scale network of monitoring sites designed to capture the range of variation in P loss and to refine the identification of vulnerable site types.

1 The Project in Outline

Approximately 10% of the total land area of the Republic of Ireland is covered by forest. The Forest Service (2000) has introduced a series of initiatives designed to ensure the development of the sector on a sustainable basis. These initiatives include measures aimed at mitigating any potential negative impacts of forests or forest operations on water quality. Despite this, there are concerns that forestry could contribute either to eutrophication or to acidification, under certain circumstances.

Eutrophication, defined as the enrichment of waters beyond natural levels, principally by the nutrient phosphorus (P), is a serious cause of concern in Ireland at the present time. Anthropogenic-increased eutrophication has been identified as the greatest threat to the quality of Irish rivers and lakes. The contribution of forestry to P loading in catchment waters has not been intensively studied in Ireland, but is potentially important because forests are often located in near-pristine environments.

The concentration of P in drainage waters from forest ecosystems is usually very low due to its low concentration in soil solution. Phosphorus is retained by most mineral soils and, as a consequence, losses are usually negligible. However, it is much more mobile in peat soils where it can be relatively easily leached or lost through surface run-off, as these soils have a low capacity to retain free phosphate.

The overall objective of the PEnrich project was to study the influence of forestry and forest operations on water quality, specifically in the context of eutrophication of surface waters. Forest operations that are most likely to influence eutrophication of surface waters include those that add nutrients directly to the soil (such as fertilisation), but the contribution of harvest residues (such as lop and top), and operations that result in soil disturbance (such as site preparation, harvesting, etc.) are also important.

The influence of forest operations on P in surface waters was investigated in three distinct tasks. The first task studied the influence of forest operations such as harvesting – clearfelling, thinning and re-establishment of forests on a large scale in a blanket peatland catchment – on the Ballinagee River, in the Wicklow Uplands. Furthermore, and at this site only, the acidity of the surface waters above and below the forest study site was monitored. The second task, at Crossmolina, Co. Mayo, explored the impact of afforestation of land previously used for agriculture, which had a high P index as a result of intensive farm management. In the third task, at Ardvarney, Co. Mayo, the effect of fertilisation on water quality was studied under experimental conditions, using different formulations of rock phosphate.

Phosphorus occurs in waters almost solely as phosphates. Many different phosphate fractions occur in surface waters. Due to its important ecological role in the aquatic environment, the concentration of total reactive phosphorus (TRP), also known as molybdate reactive phosphorus (MRP), is the most frequently used parameter in assessing water quality. In this synthesis report, we focus on this fraction; reference is also made to total phosphorus (TP) and dissolved reactive phosphorus (DRP). Other fractions determined are fully reported in the final report of the project (Machava *et al*., 2007).

1.1 The Study Sites

1.1.1 Ballinagee River catchment

The Ballinagee River catchment (O 036 023, Irish Grid) is situated in the Wicklow Uplands. To the bridge on the Wicklow Gap road (identified as WB), the catchment is 14.439 km^2. The study area, labelled ‘Forested Area’ (Fig. 1.1) is described in the text below as WF. It is approximately 3.67 km^2 in area, 51% of which was forested. The remaining 49% consisted of unplanted areas, unenclosed land used for extensive sheep grazing, the river channel and associated riparian or buffer zones. Furthermore, the predominant land use of the sub-catchment above the forested area (WA) was sheep grazing. Finally, WH is a sub-catchment of a tributary to the main channel; it is located above the forested area. The location and area of each catchment/sub-catchment are shown in Fig. 1.1 and Table 1.1, respectively.

The Ballinagee River catchment is dominated by blanket peat, which covers about 95% of the site. Over most of the area the peat is highly humified and ranges in depth from 50 to 80 cm. The dominant species in the ground

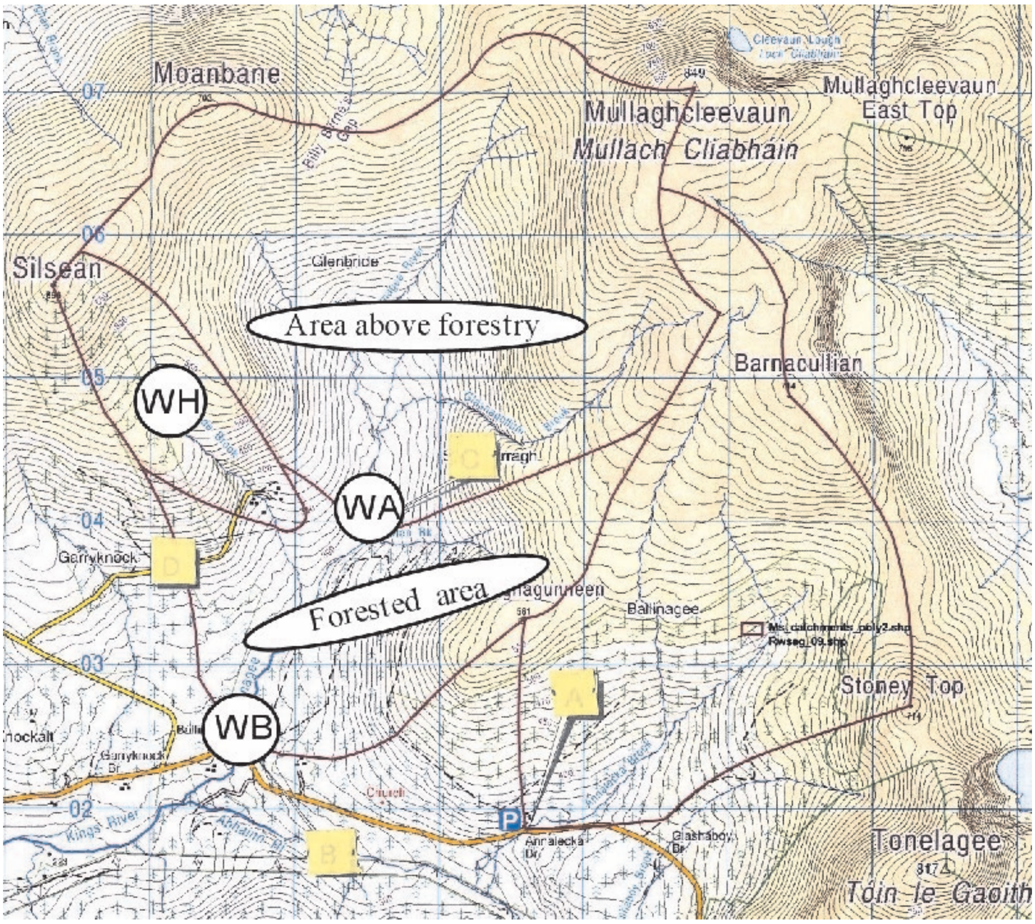


Figure 1.1. The Ballinagee River catchment and sampling sites (WA, above forested area; WH, tributary; WB, below forested area, Ballinagee River Bridge). Includes Ordnance Survey Ireland data reproduced under OSI Licence number DOE/10/07 v1.0. Unauthorised reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright. © Ordnance Survey Ireland, 2007.

Table 1.1. Ballinagee River catchment and selected sub-catchment areas.

Variable	WB[1]	WA[2]	WH[3]	WF[4]
	14.438 km^2	9.696 km^2	1.072 km^2	3.670 km^2

[1]The entire catchment to Ballinagee River Bridge, including sub-catchments WA, WH and WF.
[2]The sub-catchment of the main channel above the forest.
[3]The sub-catchment of a tributary to the main channel above the forest.
[4]The forested area (WF = WB – WA – WH).

vegetation are *Calluna vulgaris, Ulex europaeus, Juncus effusus, Molinia caerulea* and *Sphagnum* mosses. During the period 1994–2003, approximately 29% of WF (equating to 105 ha or 7% of the entire catchment to Ballinagee Bridge) experienced one or more of the following forest operations: felling (48 ha), thinning (34 ha), re-establishment of the clearfelled forest (48 ha), establishment of a new Coillte Farm Partnership forest plantation (36 ha); this last operation included fertilisation with ground rock phosphate (350 kg/ha) at time of planting in 1999.

In the 2-year period prior to the commencement of the study (2000–2002), 17.2 ha of forest were clearfelled in the catchment. This was was replanted, together with an additional 25 ha felled in previous years. During the course of the study (October 2002 to June 2004), the only forest operation that took place in the study catchment was the thinning of approximately 7 ha in 2003.

Table 1.2. Installations at the study site in the Ballinagee River catchment.

Sampling point	Equipment	Measurement frequency	Variable
WA, WH, WB	Autosampler	Daily	TP, TRP, DRP, pH, conductivity, TSS, major cations[1], anions[2], alkalinity, NH_4^+
	127-mm rain gauge	Continuously	Rainfall
WB	Staff gauge and data logger	30 min	Flow rate

[1]Ca^{2+}, Mg^{2+}, K^+, Na^+, Mn^{n+}, Fe^{n+}, and Al^{n+}. (Note: n+ is used to signify variable ionic charge.)
[2]SO_4^{2-}, NO_3^- and Cl^-.

Forest species composition in the study area was as follows: Sitka spruce (*Picea sitchensis*) (<15 years), 29.2%; Sitka spruce (>15 years), 19.9%; lodgepole pine (*Pinus contorta*), 0.2% and oak (*Quercus robur*) and sycamore (*Acer pseudoplatanus*), 0.23%.

WF was particularly suitable for the purpose of quantifying nutrient export coefficients from a forest area because it was possible to monitor water quality above and below this area. Monitoring began in October 2002 and ended in June 2004.

Autosamplers with data loggers were installed at monitoring points on the banks of the Ballinagee River above and below the forested area, WF. These samplers were located at points WA and WB, respectively. An autosampler was also located at a tributary of the main river (WH). Sampling details, equipment used and variables measured are given in Table 1.2.

Following consultation with the EPA, flow rates for the two sites above the forested area (WA and WH) were determined on the basis of calibration measurements at the beginning of the project. Flow rate at the WA sampling point was estimated to represent 73% and at the WH point 7.8% of the flow volume at the WB site. Rainfall volume was measured in the Ballinagee River catchment in order to quantify the input of major elements to the catchment.

1.1.2 Crossmolina

The study site, located in Longford Townland, Crossmolina, Co. Mayo (Fig. 1.2), was about 3.5 ha isolated on all sides by watercourses (G 155 177). The dominant soil at Crossmolina is a cambic podzol, derived from parent material of limestone origin, with and without a peaty horizon. The study plot was characterised by a high Morgan's soil P content (Morgan, 1941) (13.5 mg/l) of index 4. In addition, the hydraulic conductivity of the soil was very low and it was poorly drained. The combination of these properties suggests a high potential risk of nutrient run-off.

The site had been intensively used for agricultural purposes and received regular applications of fertiliser up to 3 years before afforestation. A vegetation survey carried out in spring 2003, revealed that the dominant species at the site were *Juncus effusus*, *Holcus lanatus*, *Ranunculus repens*, *Cirsium vulgare*, *Rumex acetosella*, *Iris pseudacorus*, *Scrophularia nodosa*, and *Angelica sylvestris*. The same species occurred over the whole area, with only minor variations in the percentage cover between species.

Monitoring of this study site commenced in September 2002. Sampling details, equipment used and variables measured are given in Table 1.3. In the initial stage, automatic liquid samplers (passive stream samplers (PSS)) (RTM-Arkon QS®) and an autosampler (Sigma 900 MAX®) were installed to collect composite water samples. Water samples from the main outlet were collected with an automatic sampler from an unnamed stream bordering the western side of the study area. This stream ultimately drains into Lough Conn. Sampling was also carried out at locations upstream (PSS1) and midstream (PSS3) with passive samplers. Furthermore, the outlets of two drains into this stream were also sampled at locations PSS2 and PSS4 with passive samplers; the latter watercourse, in particular, had typically a very slow flow rate.

A set of data from sampling point PSS1, which was not influenced by forest operations, served as a baseline for other variables recorded in the study area. Data from PSS3 reflected the influence of the area up to PSS1 while the data obtained at PSS2 and PSS4 reflected a partial impact and most of the impact, respectively, from the forest establishment on the study site.

Sampling commenced in September 2002 prior to site preparation and planting and ceased in June 2004. Site preparation, comprising the drainage system and mounding, was carried out over a period of 1 week (19–25 March 2003). The site was planted with a pedunculate

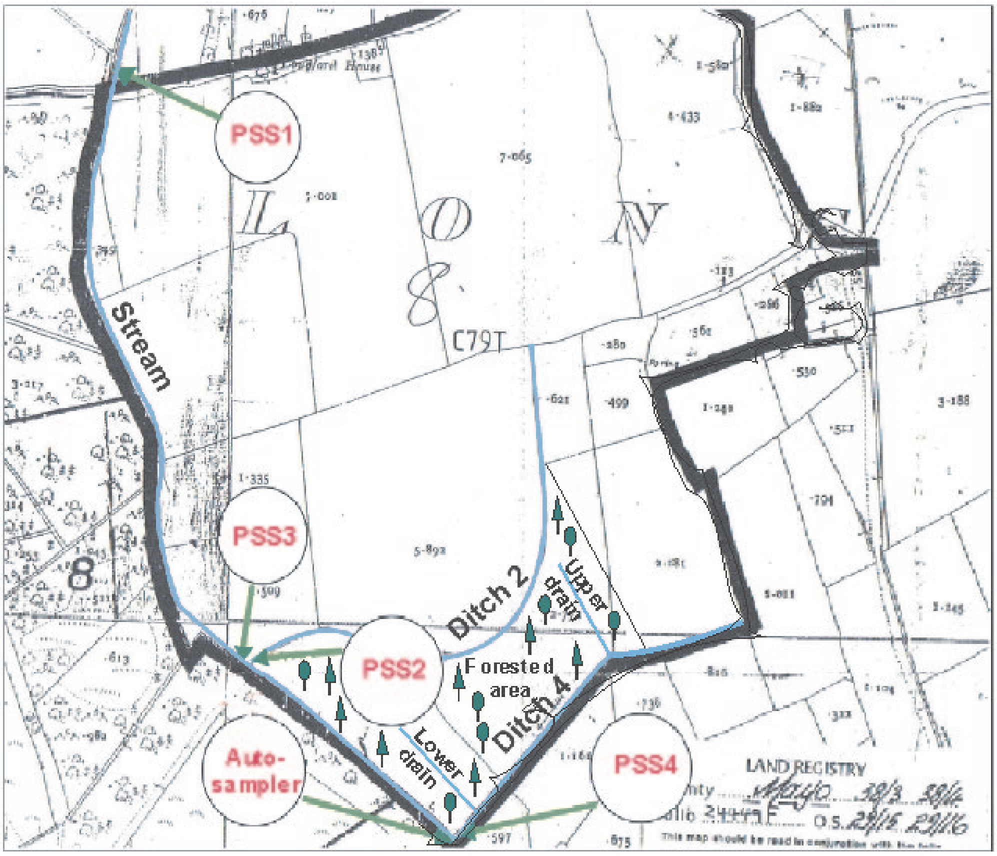


Figure 1.2. The Crossmolina study site. Includes Ordnance Survey Ireland data reproduced under OSI Licence number DOE/10/07 v1.0. Unauthorised reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright. © Ordnance Survey Ireland, 2007.

Table 1.3. Installations in the study site in Crossmolina.

Sampling point	Equipment	Measurement frequency	Variable
PSS1	Passive stream sampler	Weekly	TP, TRP, DRP, pH, conductivity, TSS, major cations[1], anions[2], alkalinity, NH_4^+
PSS2			
PSS3			
PSS4			
Main outlet	Autosampler	Daily	
	Doppler system	30 min	Flow rate

[1]Ca^{2+}, Mg^{2+}, K^+, Na^+, Mn^{n+}, Fe^{n+}, and Al^{3+}.
[2]SO_4^{2-}, NO_3^- and Cl^-.

oak (*Quercus robur*)/Scots pine (*Pinus sylvestris*) mixture (73:27) at a stocking rate of 4,550 stems/ha during April 2003. All forest operations conformed to the measures outlined in the *Forestry and Water Quality Guidelines* (Forest Service, 2000) and included installation of buffer zones (approximately 10 m, although this was bypassed at the upper drain to facilitate proper drainage at the site), with the specific aim of decreasing the amount of P in the surface run-off. Data collected were used to establish a baseline of measured variables. Flow rate was measured at the main outlet of the study site by the Doppler system on a 15-min basis over the period January 2003 to June 2004. Precipitation amounts at Crossmolina were measured at a meteorological station situated approximately 4 km from the study site, at a similar altitude. Details of sampling equipment, sampling protocols and analytical methods at all sites can be found in the project final report (Machava *et al*., 2007).

1.1.3 Ardvarney

The study site at Ardvarney (M 150 953) (Fig. 1.3), occupying 8 ha of a gently sloping site, was previously used for rough grazing with no history of fertiliser application. A Haplic Stagnosol (gleysol) was the dominant soil type, characterised by poor drainage properties and the potential for surface run-off after heavy rainfall. The main species present at the site were *Ranunculus repens* and *Rumex acetosa* followed by *Trifolium pratense, Potentilla erecta, Stellaria graminea, Senecio jacobea, Cirsium vulgare, Equisetum arvense, Myosotis arvensis, Lychnis flos-cuculi, Plantago lanceolata, Rumex crispus* and *Juncus effusus.*

The site was planted in April 2002 with Sitka spruce (5.4 ha) and Japanese larch (*Larix leptolepis*) (1.4 ha). Twelve

Figure 1.3. The Ardvarney study site. Includes Ordnance Survey Ireland data reproduced under OSI Licence number DOE/10/07 v1.0. Unauthorised reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright. © Ordnance Survey Ireland, 2007.

plots were established, each 27 m^2, separated from each other by wooden planks. At the bottom edge of each plot (3 m wide), a damp-proof course was placed just under the sod. Surface run-off from each plot ran via this into an open PVC collection pipe, through which it was carried until it reached the tipping bucket used for measuring run-off volume.

Three treatments (two phosphate sources and a control) were replicated three times. Fertiliser was applied at a rate of 350 kg/ha. The materials used were ground rock phosphate (14.5% P) and granulated rock phosphate (12% P). A wood ash treatment, originally proposed, was excluded due to administrative delays in obtaining clearance to use the material; three plots remained unused for this reason. Tree height was measured in April 2002 and then in autumn 2003 and 2004. Foliar samples were collected at the end of monitoring in October 2004. Details of sampling equipment, sampling protocols and analytical methods at all sites can be found in the project final report (Machava *et al.*, 2007).

2 Results

2.1 Ballinagee River Catchment

Mean monthly TRP concentrations at WB, with the exception of February 2004 – the driest month of that year – did not exceed 4 µg/l, which is well within the acceptable EPA limit of 20 µg/l (EPA, 2001) for such waters (Fig. 2.1). Total reactive phosphorus concentrations at the individual sampling points showed no consistent seasonal pattern over the study period and generally varied between below limit of detection (BLD) and 15 µg/l, with some exceptions at WH, where the highest values were generally recorded. While in the first half of the monitoring period several monthly TRP concentrations recorded at WB were lower than those at WA, in the second half higher values were recorded at WB. The increased values were generally recorded in the case of low or high flow rates, depending on the local weather conditions.

Dissolved reactive phosphorus concentrations were also measured as this is considered to be the mostly readily available form of P for the growth of algae in natural waters. It was found that monthly median DRP levels were generally very low (<10 µg/l) at Ballinagee. All third quartile values were below the detection limit. There was no evidence from the study to suggest that the forest, or forest operations had any impact on eutrophication in the Ballinagee River.

Concentrations of NO_3^-, which is the principal cause of eutrophication after P, were low. From June to September 2003 they were below the detection limit (0.02 mg/l).

The highest pH values of surface water in the Ballinagee River catchment were usually recorded at WH. pH values measured at WA and WB were similar to each other. Despite very low alkalinity values and low alkalinity/sulphate ratios (Table 2.1), which indicate that surface waters are very sensitive to acidification, the absence of a significant difference between the pH values at WB and WA clearly establishes that neither the presence of the forest, nor forest operations conducted in this catchment prior to or during this investigation, have contributed to the process of acidification in surface waters.

The run-off coefficients for the Ballinagee River catchment and sub-catchments were calculated using precipitation amounts and flow rates for 2003 and 2004 (Table 2.2). The differences in run-off coefficients calculated for the forested area (WF) and those obtained above (WA) and below (WB) were thought to be caused by the water yield reduction arising from the presence of the forest and possibly by differences in terrain.

Total reactive phosphorus quantities exported from the individual sub-catchments of the Ballinagee River

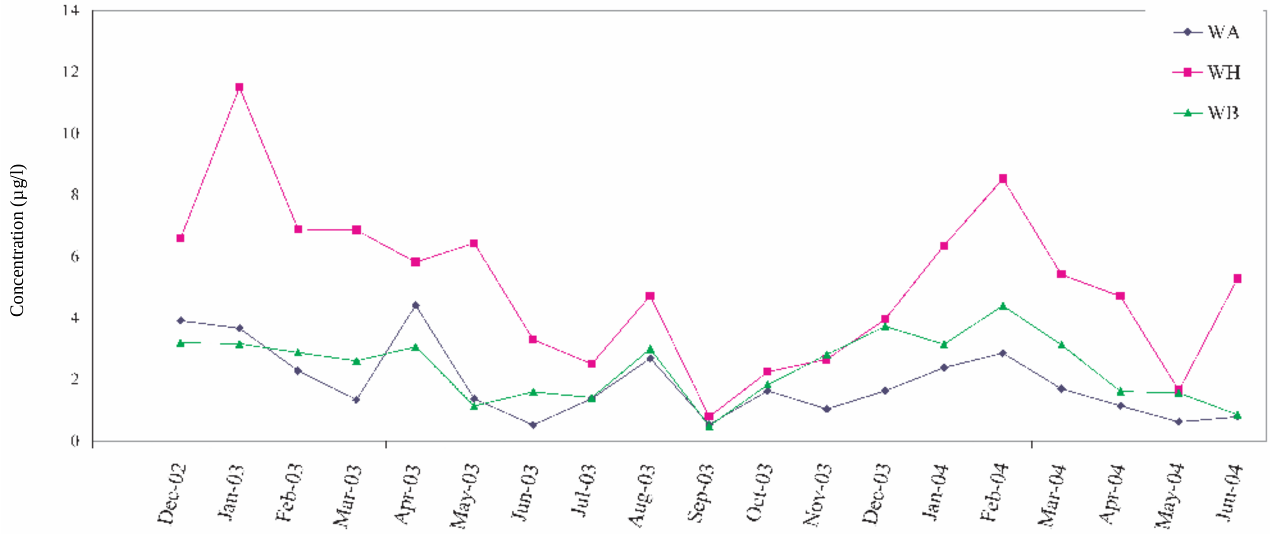


Figure 2.1. Arithmetic mean TRP concentrations in surface water from the Ballinagee River (December 2002–June 2004).

Table 2.1. Mean alkalinity, sulphate and alkalinity/sulphate ratios in surface waters at WA and WB in Ballinagee River catchment during the sampling period 2003–2004.

Period	Alkalinity*		SO_4^{2-}	Alkalinity/SO_4^{2-}*	
	WA	WB		WA	WB
	(meq/l)				
2003					
1.Q	0.040	0.040	0.086	0.465	0.465
2.Q	0.090	0.080	0.104	0.865	0.769
3.Q	0.110	0.100	0.086	1.279	1.163
4.Q	0.030	0.040	0.104	0.288	0.385
2004					
1.Q	0.050	0.050	0.086	0.581	0.581
2.Q	0.080	0.100	0.104	0.769	0.962

*Alkalinity values <200 meq/l and alkalinity/sulphate ratios <1 indicate acid-sensitive waters.

Table 2.2. Run-off coefficients calculated for the Ballinagee River catchment and selected sub-catchments.

Variable	WB[1]	WA[2]	WH[3]	WF[4]
Area (km^2)	14.438	9.696	1.072	3.670
Precipitation (m^3)	21,886,333	14,697,348	1,625,544	5,563,441
Run-off (m^3)	17,703,101	12,920,170	1,381,363	3,401,568
Run-off coefficient	0.809	0.879	0.850	0.611

[1]The entire catchment to Ballinagee River Bridge, including sub-catchments WA, WH and WF.
[2]The sub-catchment of the main channel above the forest.
[3]The sub-catchment of a tributary to the main channel above the forest.
[4]The forested area (WF = WB – WA – WH).

throughout the monitoring period are shown in Fig. 2.2 and Table 2.3. The highest contribution to TRP output at WB was generally from WA (i.e. for 13 of the 18 months where results are presented). Total reactive phosphorus export rates were highly dependent on flow rate and hence on local weather conditions. It was noted that the highest TRP export rates from forested land usually occurred, though not always, during the first high flow event after a dry spell.

As can be seen from Table 2.3, the TRP export rate at WF in January to June 2004 was double that for the same period in 2003, with smaller increasesof 22% and 7%, respectively, noted at WB and WA. In contrast, TRP export rates at WH actually decreased by 27% in this period. The significant differences in export rates noted at all sample locations, but most especially at WF, were thought to be related to the difference in flow rates recorded in the first half of 2004 in comparison to 2003 (see Fig. 2.3).

The nutrient export coefficients were calculated per quarterly period to investigate whether the Ballinagee River catchment had been impoverished or enriched over the course of a year. This coefficient, defined as a ratio between output and input of elements related to a particular sub-catchment, varied during the monitoring period, depending mainly on season and weather conditions. Export coefficients for TRP and Ca^{2+} between forested and non-forested areas are presented in Figs 2.4 and 2.5.

The highest value of TRP export coefficient, recorded in the first quarter of 2004, was in line with the high TRP export rate from the forested area in that period. The highest Ca^{2+} export coefficient recorded in the third quarter of 2003 can be associated with decomposition of vegetation.

Export coefficients for both SO_4^{2-} and Fe^{n+} (n+ is used to signify variable ionic charge) were similar at WA and WF. Both sub-catchments lost iron through run-off and were enriched by sulphate. Despite the fact that non-sea-salt

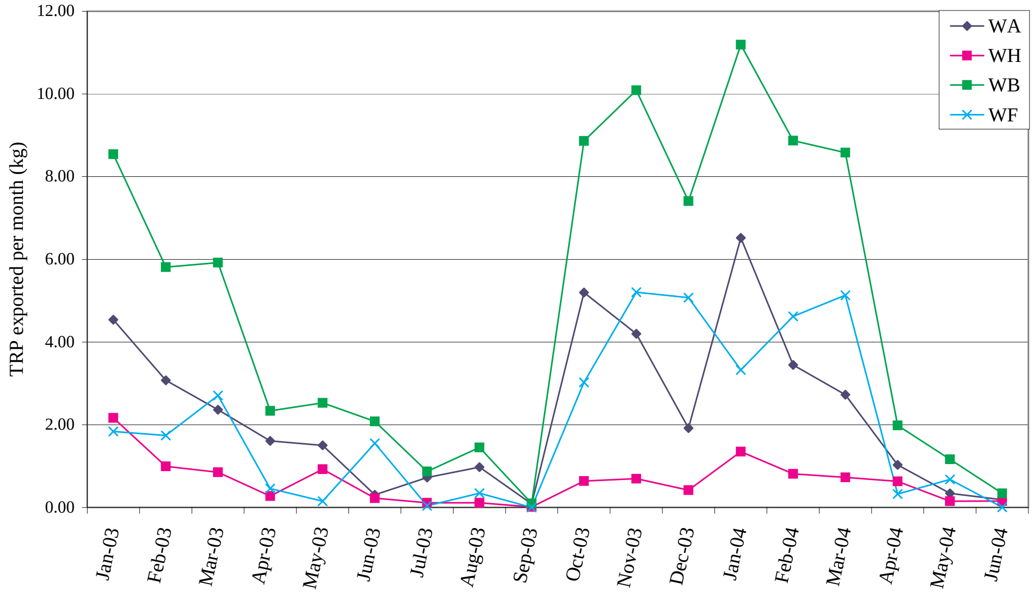


Figure 2.2. Total reactive phosphorus export rates (kg/month) from the Ballinagee River catchment in 2003–2004 (WF is given by difference calculation, based on daily figures: WF = WB – WA – WH).

Table 2.3. Total reactive phosphorus (kg/ha) export from the Ballinagee River sub-catchments in the period 2003–2004.

Year	Duration	TRP export rate (kg/ha)			
		WA	WH	WF	WB
2003 (January–June)	6 months	0.014	0.049	0.019	0.018
2003 (July–December)	6 months	0.013	0.018	0.027	0.017
2003 (January –December)	12 months	0.027	0.067	0.046	0.035
2004 (January–June)	6 months	0.015	0.036	0.038	0.022
2004 (January–December)	12 months (est.)	0.028	0.054	0.065	0.039

Figure 2.3. Monthly flow rate and precipitation amounts in the Ballinagee River catchment (r = 0.63; p < 0.01).

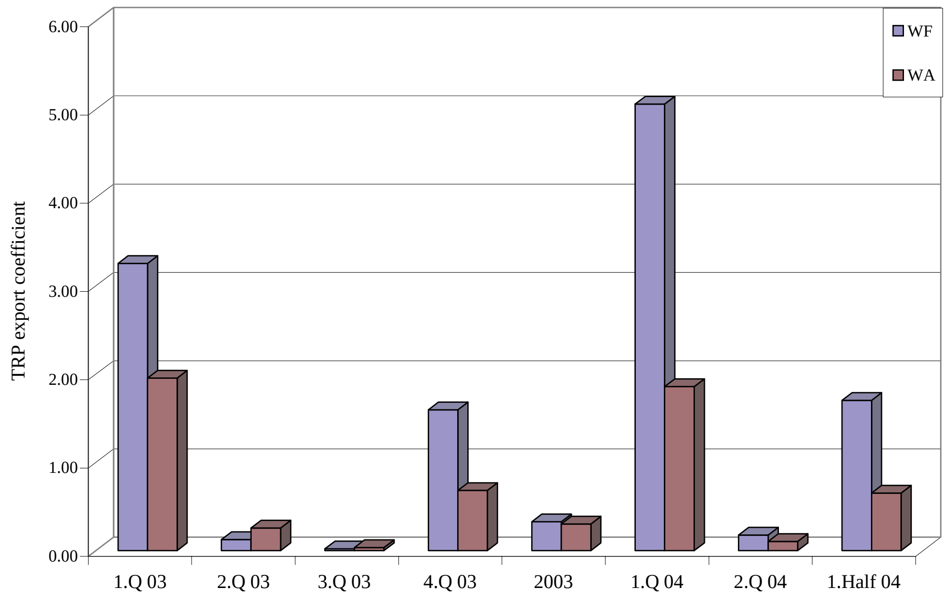


Figure 2.4. Total reactive phosphorus export coefficients from the area WF and WA (2003–2004).

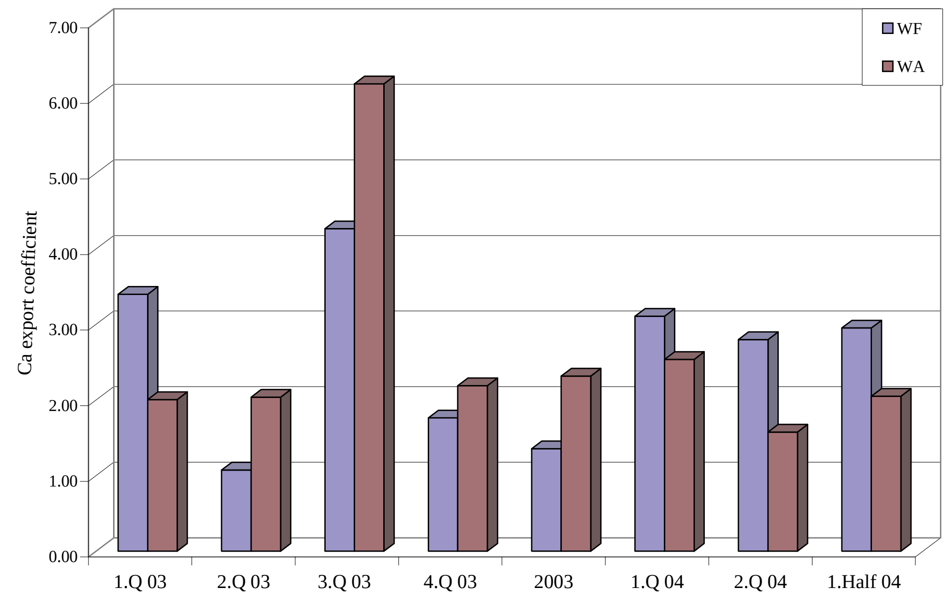


Figure 2.5. Export coefficients for Ca^{2+} from the WF and WA areas (2003–2004).

sulphate represents as much as 73% of all transported sulphate, multifunction regression revealed that sulphate had no significance influence on the acidification process. In inputs, nearly 60% of the sulphate was of non-sea-salt origin and therefore acidifying. There was no significant correlation nor significant β coefficients between pH values and sulphate concentrations. Catchment sources of sulphate include mineralisation and oxidation of soil organic matter and probably metal sulphide oxidation within the bedrock.

2.2 Crossmolina

The source of P at sampling points PSS1–PSS4, and particularly at PSS1–PSS3, cannot be definitively identified. PSS1 was located upstream of the study area and therefore reflects the quality of the water entering the area. The PSS4 sampling point provides the best indication of the quality of water coming from the study area and changes in P concentrations at this point over the course of the study period are of particular interest. On the other hand, water quality at the stream outlet provides the best measure of the impact of the site on water quality in Lough Conn. The TRP concentrations at the passive sampling sites showed no evidence of any increase following afforestation (Fig. 2.6).

The highest concentrations of TRP were recorded at the PSS4 study site. This sampler was located in a drain with sluggish water. These high concentrations were due, at least in part, to the history of fertiliser application in the study area. In the years preceding the study, compound (NPK) fertiliser was applied as follows: 250 kg/ha in 1997 and 1998, 220 kg/ha in 1999, and 150 kg/ha in 2000. Water from this area fed through upper and lower drains into the PSS4 ditch.

Dissolved reactive phosphorus concentrations recorded at the passive sampling sites and at the main outlet were generally low during the monitoring period. The median DRP concentrations at all sites were below the detection limit (<10 µg/l) with the exception of the last quarter of 2002 when median DRP concentrations at PSS1–PSS4 were 10 µg/l. Therefore, although TRP and TP (not shown) concentrations were generally high at the passive sampling sites, the proportion of P in forms that were directly available to organisms was relatively small.

The high concentrations of both TP and TRP at PSS4 were not reflected in concentrations at the main outlet (Fig. 2.7), which leads into Lough Conn. This can be explained, in part, by the relatively low flow rate and flow volume at the PSS4 sampling point. The main source of the stream current at the main outlet was water flowing through the PSS1 and PSS3 sampling points. Median TRP values at the main outlet were always below the critical concentration of 20 µg/l.

Amongst the anions, nitrate is of particular interest as it is a potential pollutant of surface waters. However, measured concentrations were very low at both the main outlet and at the passive sampling points throughout the study period. Mean concentrations for the entire study period are presented in Table 2.4. Both mean concentrations and the range in monthly means were greater at the passive sampling points than in the stream outlet.

There was no impact of site preparation on pH levels of surface water draining the study area. pH values fluctuated over the monitoring period, mainly due to changes in flow rates. Mean pH values recorded at all measurement points were relatively high due to the alkaline bedrock, varying between pH values of 7.4 and 8.1.

Total phosphorus and TRP amounts transported from the stream outlet of the study site in Crossmolina over the monitoring period are shown in Fig. 2.8. The amounts

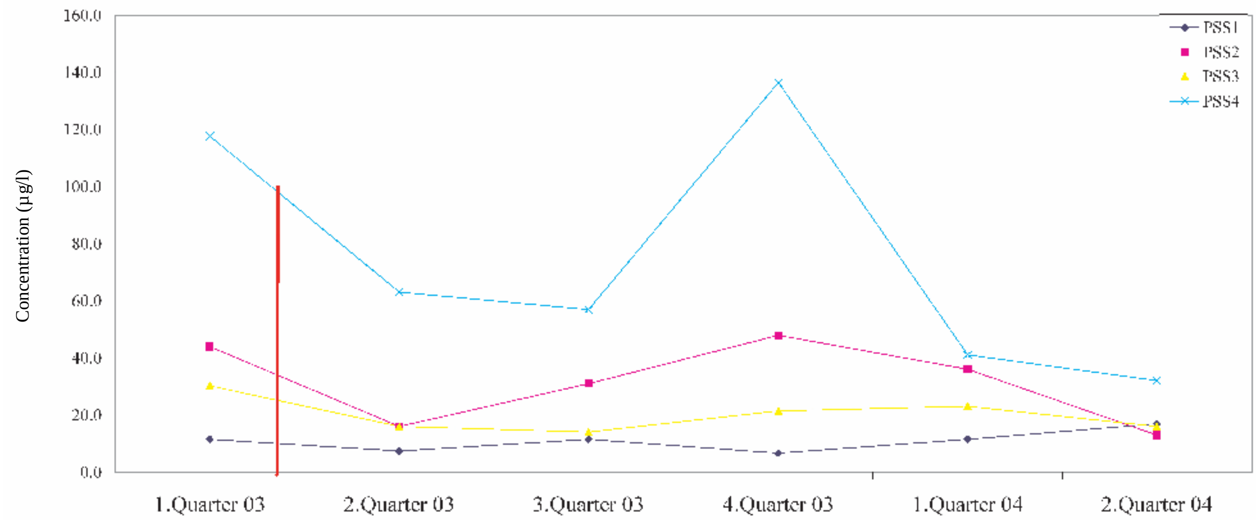


Figure 2.6. Median TRP concentrations, calculated on a quarterly basis, at PSS1–PSS4 sampling points at the Crossmolina study area (January 2003–June 2004). The red line represents the time of site preparation (March 2003).

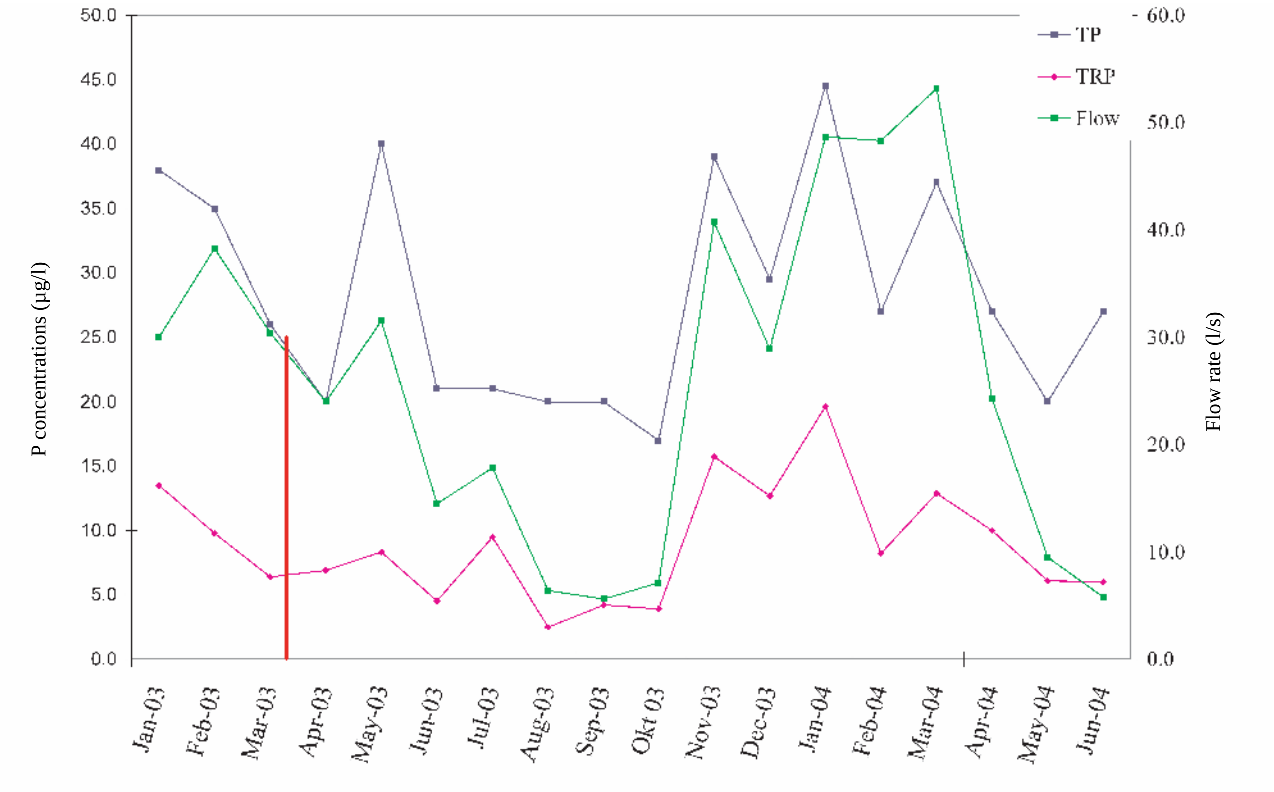


Figure 2.7. Median TP, TRP concentrations and flow rate, calculated on a monthly basis, at the main stream outlet from the Crossmolina study site (2003 and 2004). The red line represents the time of site preparation.

Table 2.4. Mean NO_3^- concentrations in water at the sampling points in Crossmolina (October 2002–June 2004).

Site	Mean (mg/l)	Std deviation	Std error	95% confidence interval	
				Lower (mg/l)	Upper (mg/l)
Outlet	1.25	0.51	0.11	0.58	2.67
PSS1	1.81	0.66	0.14	0.93	3.39
PSS2	1.61	1.45	0.32	0.07	4.97
PSS3	1.53	0.52	0.11	0.85	2.56
PSS4	1.61	0.86	0.19	0.47	3.80

cannot be expressed per unit area as the drained catchment is larger than the study area. Water levels in the main outlet of the study site were recorded on a 15-min basis from January 2003 to June 2004.

Transported amounts of both TP and TRP varied with local weather conditions. In general, high TP transport rates corresponded with high flow rates as a result of same-day high precipitation values (Figs 2.8 and 2.11). The soil disturbance in March 2003 due to site preparation did not result in an increase in TP transport in the months following. In fact, TP transport amounts were lower after site preparation than before, under similar weather conditions, probably as a result of the increased depth to the water table following the installation of mound drains.

Over the monitoring period, with the exception of the months of April and May 2003, the transported amounts of TRP mirrored TP trends. As with TP, the soil disturbance in March 2003 due to mounding of the site, did not result in significantly higher TRP transport in that month.

The highest amounts of ions transported from the main outlet in Crossmolina after afforestation were recorded in November 2003 and in February and March 2004, mainly

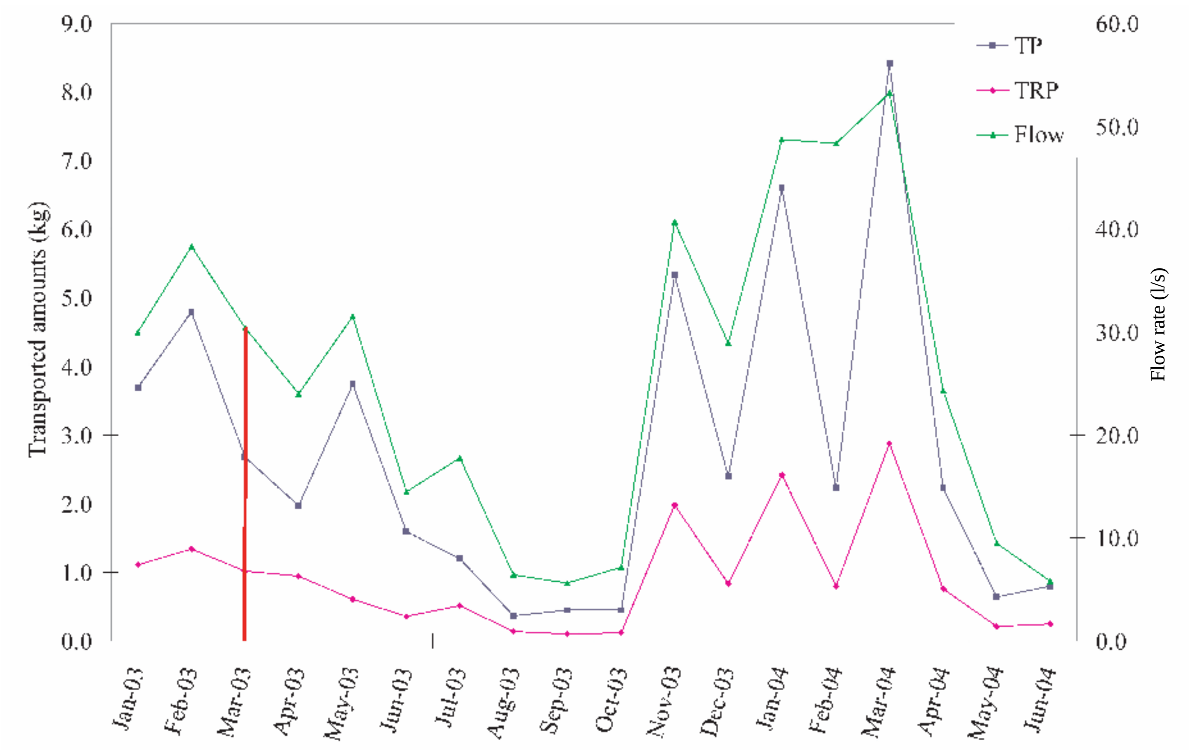


Figure 2.8. Transported amounts of TP and TRP from the study site and flow rate in Crossmolina in 2003–2004. The red line represents the time of site preparation.

Table 2.5. Transported amounts of elements from the main outlet in Crossmolina.

Element	2003		2004	
	March	April	March	April
Ca (t)	6.723	6.990	10.430	5.994
Mg (t)	0.620	0.627	0.963	0.538
Na (t)	1.263	1.045	2.248	1.045
K (kg)	161.790	97.884	291.694	93.533
Mn (kg)	3.093	1.131	4.777	1.855
Fe (kg)	31.034	13.034	22.071	63.074
Al (kg)	7.708	0.929	63.775	34.677

connected with a high discharge. Due to the fact that amounts of transported ions correlate well with flow, it is difficult to reach a definite conclusion as to whether or not site preparation (prior to afforestation) resulted in increased output of ions, such as Mn^{n+}, Fe^{n+} and Al^{3+}, which are usually connected with the soil perturbation (Table 2.5). The concentration data for Fe^{n+} (Fig. 2.9) and Al^{3+} (not shown) showed a peak following site preparation; however, Fe^{n+} concentrations showed a declining trend from March to May 2003. Data Mn^{n+} showed a similar peak in January 2003, but before any site works had begun (Fig. 2.10). Apart from this peak, concentrations of Mn^{n+} at PSS4 were below those at the PSS1 control site. For each ion, transported amounts were greater in March 2004 than in the same month of the preceding year, due mainly to increased rainfall and, consequently, flow rate in that period in the latter year (Fig. 2.11).

Concentrations of TSS at the main outlet and at the passive sampling points fluctuated over the monitoring period depending on local weather conditions. However,

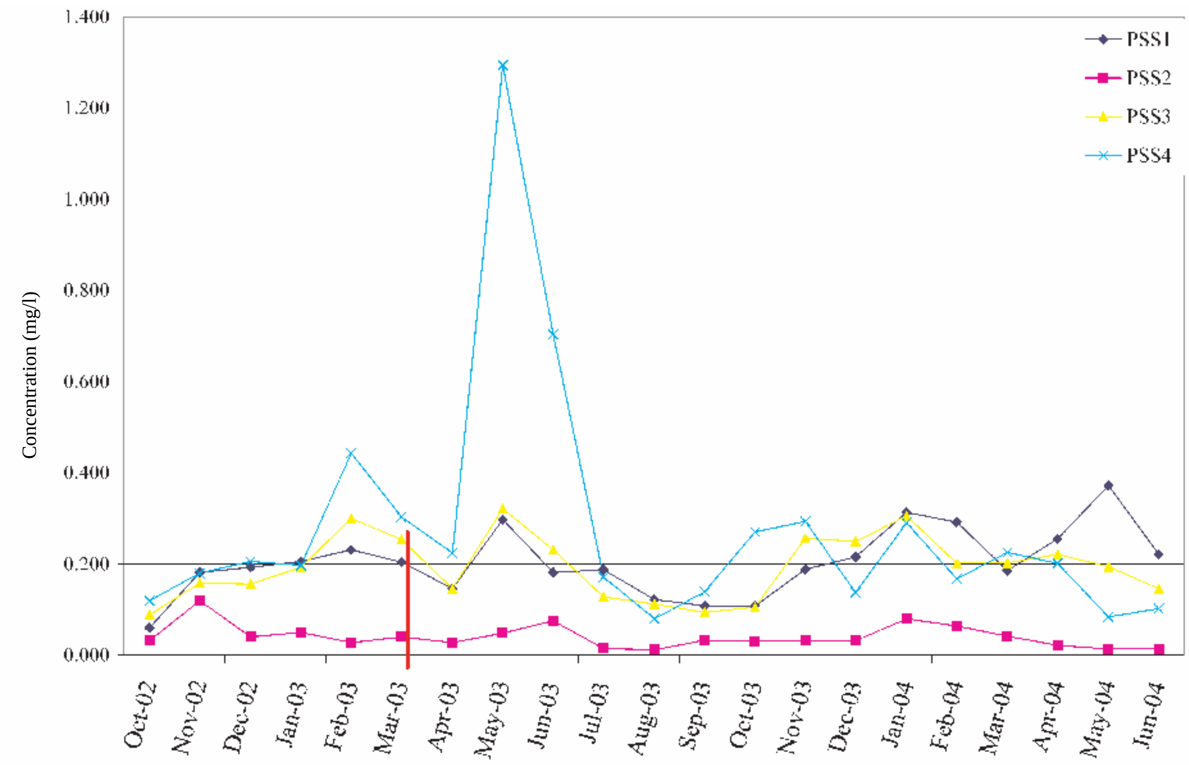


Figure 2.9. Mean Fe^{n+} concentrations at the PSS1, PSS2, PSS3, and PSS4 sampling points (October 2002–June 2004) in Crossmolina. The red line represents the time of site preparation.

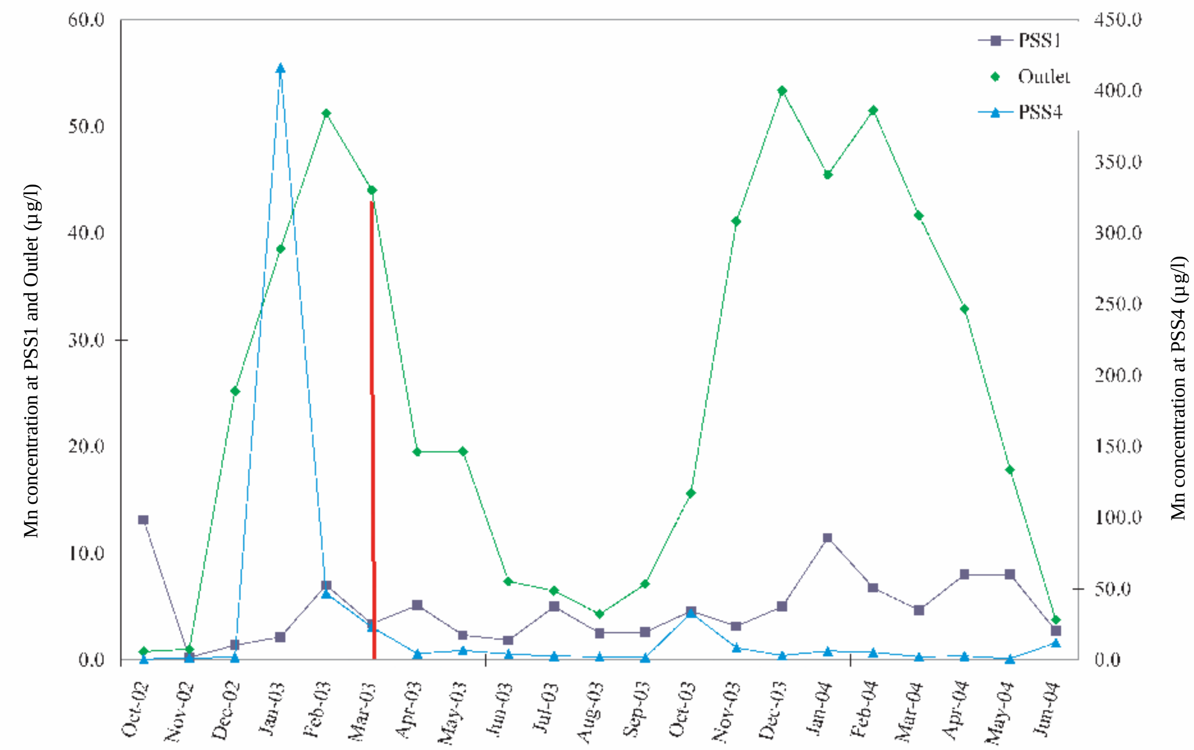


Figure 2.10. Mean Mn^{n+} concentrations at the PSS1 and PSS4 sampling points and the main outlet (October 2002–June 2004) in Crossmolina (µg/l). The red line represents the time of site preparation.

Figure 2.11. Monthly precipitation (measured at Crossmolina meteorological station) and mean monthly flow rate at the stream outlet of the study site.

Table 2.6. Mean concentrations of TSS at all sampling points in Crossmolina for the period October 2002–June 2004.

Site	Mean (mg/l)	Std deviation	Std error	95% confidence interval	
				Lower (mg/l)	Upper (mg/l)
Outlet	5.57	1.79	0.67	4.00	9.00
PSS1	20.71	20.13	7.61	8.00	65.50
PSS2	7.64	3.19	1.21	3.00	11.00
PSS3	10.79	4.99	1.89	4.00	18.00
PSS4	35.64	23.45	8.86	13.00	81.00

even the highest median value recorded at the main outlet, 3.5 mg/l (December 2003), was below the accepted threshold concentration of 50 mg/l (EPA, 2001). Mean concentrations for the whole period were lowest at the main outlet and highest at PSS4 (Table 2.6). Site preparation, in March 2003, produced no sustained increase in TSS concentrations.

The data provide no evidence of a detrimental influence of forest establishment operations on water quality at the site.

2.3 Ardvarney

At Ardvarney, P, in all measured forms, in surface run-off from the experimental plots was far in excess of acceptable concentrations. Surprisingly, the highest values of both TRP and DRP were observed at the control plots. This is illustrated for the period July to December 2003 in Fig. 2.12. Concentrations were highest in the first year of measurement, but even in the second year were well in excess of threshold values. Differences between DRP and TRP concentrations over the monitoring period and between plots in 2003 and 2004 were not significant (Mann–Whitney test). Phosphorus concentrations in surface run-off did not correlate with precipitation rates collected on a weekly basis at the site. Mean TRP concentrations for each treatment are compared with those from the control plots in Table 2.7.

Phosphorus concentrations in soil samples collected in February 2005 (Table 2.8) were compared with concentrations measured before fertilisation. The results indicate that the soil concentrations of all examined elements remained essentially unaltered.

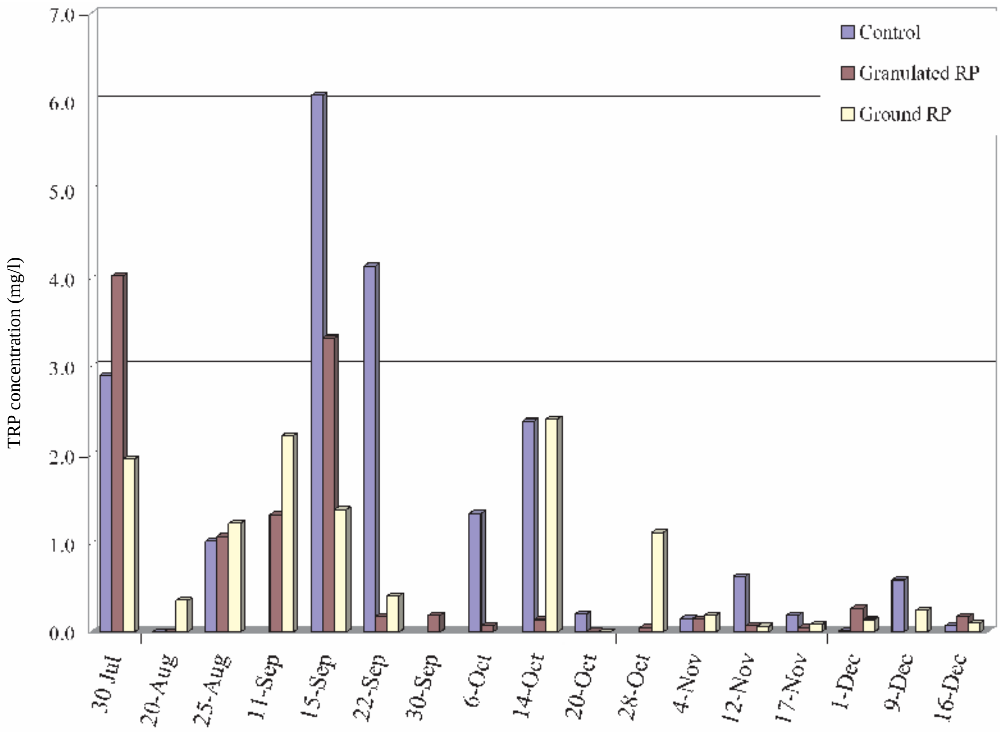


Figure 2.12. Treatment TRP concentrations at Ardvarney (July–December 2003).

Table 2.7. Mean TRP (mg/l) concentrations in run-off from the study sites at Ardvarney.

Statistic	Granulated RP			Ground RP		
	Control	2003	2004	Control	2003	2004
Mean	0.957	0.550	0.699	1.426	0.679	0.491
Std deviation	1.723	1.390	1.168	4.493	0.987	1.015
Std error	0.368	0.297	0.213	0.670	0.197	0.139
Minimum	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	6.070	6.410	4.940	24.570	4.090	4.980
Skewness	2.128	0.491	2.344	4.072	2.250	2.901
Kurtosis	3.604	16.366	5.553	17.786	5.506	8.686

Table 2.8. pH and P, Ca, Mg and K concentrations (Morgan's extractant) of treatment plots at Ardvarney before and after treatment (0–20 cm).

Treatment		Control	Ground RP	Granulated RP
pH	**Before**	5.14 ± 0.09	5.05 ± 0.19	5.14 ± 0.05
	After	5.17 ± 0.11	5.06 ± 0.04	5.05 ± 0.07
P (mg/l)	**Before**	2.91 ± 1.75	2.59 ± 1.22	2.18 ± 0.79
	After	1.79 ± 0.37	2.08 ± 0.45	1.88 ± 0.53
Ca (mg/l)	**Before**	1075 ± 876	695 ± 227	425 ± 216
	After	852 ± 566	619 ± 39	3845 ± 156
Mg (mg/l)	**Before**	221.2 ± 95.4	223.5 ± 82.6	153.8 ± 57.4
	After	188.7 ± 76.2	189.5 ± 22.6	137.2 ± 45.7
K (mg/l)	**Before**	139.0 ± 76.5	111.1 ± 51.7	121.5 ± 41.3
	After	81.1 ± 1.5	86.1 ± 23.6	92.9 ± 31.7

3 Discussion and Conclusions

The most striking result of the study was the absence of any significant detrimental influence of forestry or forest operations on P concentrations or transported P in surface waters in the Ballinagee River catchment.

Ballinagee is a large catchment with a relatively large forest area. Despite the fact that most of the catchment has a cover of blanket peat, a soil type most susceptible to phosphate loss, concentrations in the outlet waters gave no cause for concern in either the current study, or in a previous one (Three Rivers Project, 2002). Total reactive phosphorus levels in stream water were generally below the critical concentration (20 µg/l) and even TP values were usually below this concentration. This suggests that Forest Service guidelines (buffer zone along the watercourse, no crossing through the river, no direct outlet of drainage system into the river, etc.) are effective. However, continued monitoring of this catchment is strongly recommended in order to monitor the impact of future forest operations.

There is a need for further large-catchment-scale studies such as this. The results of an earlier study on blanket peatland at Cloosh Forest, in the west of Ireland (Cummins and Farrell, 2003) emphasise the need for caution in extrapolating from one or two studies. High phosphate losses were recorded in that study, particularly following fertiliser application and after clearfelling. There were, however, some important differences between the two studies. The catchments in the Cloosh study were relatively small (ranging from 1 to 300 ha), the proportion of forest in each catchment was high and they were subjected to intensive management operations. Perhaps of greatest significance is the fact that while the water systems studied in Cloosh do qualify as streams under relevant Irish statutes, they were all peat-bedded, though some had occasional mineral exposures. In Ballinagee, by contrast, the stream had a mineral bed and, upstream of sample point WB, the river bank consisted of mineral soil. It is reasonable to suppose that contact with acid mineral soil will significantly reduce the solubility of P.

Total reactive phosphorus loss was lowest during the growing season, when biological uptake of P was high; conversely, during the dormant season, P was released from decaying organic material. Dissolved reactive phosphorus concentrations were, for most of the monitoring period, below the detection limit. Dissolved reactive phosphorus concentrations in surface run-off originate mainly from the desorption of P in surface soil during wet periods (Yli-Halla *et al.*, 1995) and P release from vegetation.

Run-off coefficients were calculated for particular sub-catchments and the Ballinagee River catchment as a whole. Due to higher interception and local conditions (slope steepness, greater evapotranspiration surface, etc.), the lowest coefficient was observed in the forested area. The value 0.61 was in line with that reported by Chang (2003). Export coefficients of the major ions were calculated for particular sub-catchments and for the entire Ballinagee River catchment. They varied seasonally, depending on the local conditions – the previous history of rainfall, precipitation intensity, water soil saturation, etc. Export coefficients greater than 1 indicate that leaching of the element in question exceeds accumulation; this was the case with iron. Values less than 1, as for instance with sulphate, indicate retention in the catchment. The influence of rainfall can be seen in the TRP export coefficients for the first quarters of 2003 and 2004. The higher coefficient for 2004 reflects the considerably greater rainfall amounts in this period.

The annual TRP export rates determined for forest land of 0.05–0.07 kg/ha/year (note that the latter figure is an estimate based on 6 months' data) were substantially less than that reported from the forest study site of the Three Rivers Project (1998 to 2001) (Three Rivers Project, 2002) of 0.14 kg/ha/year. However, there are several important factors that may explain this difference, namely local conditions (size of study catchments, degree of forest cover, soil hydraulic conductivity, etc.) and climate. The Three Rivers forest study site was located in the headwaters of the Kings River. This includes the Ballinagee River, but the size of the catchment was far greater than that of the PEnrich Ballinagee study site. Furthermore, the percentage level of forest cover varied between the two study catchments, 23% of the total catchment area in the Three Rivers forest study site, as opposed to 13% in this study. Nevertheless, unlike the

Three Rivers study, where continuous sampling was conducted at the outlet of the study catchment only, two automated monitoring stations were located both above (WA and WH) and below forestry at Ballinagee Bridge. Within this defined monitoring area in Ballinagee, the percentage forest was 51%.

In the Three Rivers forest study site, the P load in the forest study catchment also included inputs from sheep grazing, soil erosion from disturbed moorland due to recreational use, and some agricultural sources as well as from forestland. As a result of the tighter monitoring scheme adopted in Ballinagee, which took account of TRP transported above and below forestry and avoided including, in so far as was possible, non-forest inputs, a more accurate measure of the TRP export rate (or load) for forest land could be determined in comparison with the Three Rivers study.

In Co. Wicklow, atmospheric pollution and sea salt deposition are both significant sources of sulphate (Boyle *et al*., 2000). Forest canopies intercept dry and occult deposition increasing fluxes to the forest floor. No impact of the forest on acidification of the catchment was determined at Ballinagee. However, given the sensitive nature of the catchment (alkalinity concentrations in surface waters were generally below 10 mg/l $CaCO_3$) and the significant levels of pollutant deposition in the region, continued monitoring is strongly recommended.

At the Crossmolina study site, no adverse impact of forest operations on surface water quality was detected. In fact, P concentrations in surface water were actually lower after afforestation than before. While it is likely that the influence of previous fertiliser applications is declining, it is difficult to accept that this can, on its own, explain this result. More probably, the improved drainage of this extremely wet site resulted in a lowering of the water table and reduced surface run-off. Coupled with this is the likelihood that the previously applied fertiliser was largely conserved in the surface soil. This may have had the most significant beneficial influence on water quality. However, Forest Service guidelines were fully complied with and the evidence suggests that this also contributed to the protection of water quality.

It is striking that soil disturbance during site preparation did not result in significantly increased concentrations of TP, TRP or TSS. Although TSS levels at the passive sampling sites showed increases, the highest concentrations recorded at PSS4 showed a declining trend over the whole monitoring period. Despite these increased values, the TSS concentrations in the main outlet were below the threshold. Again, this suggests that compliance with Forest Service guidelines, and specifically the construction of sediment traps, was effective (in August 2002, prior to commencement of the study, TP concentration determined in a one-off sample at the upper part of the PSS4 ditch was 94.046 µg/l).

The observed decrease in P concentration in the surface run-off, following drainage and planting, may be a significant finding for the afforestation of such sites in the future. It is also encouraging that disturbance of the soil during site preparation did not result in increased levels of P or nitrate in surface water. Although there was some evidence of an increase in Fe^{n+} and Al^{3+} concentrations following soil disturbance, this was inconclusive and any increase in the export of these ions was small in comparison with annual fluctuations related to variation in rainfall. It would be beneficial to conduct further research at this site in order to monitor change in the levels of investigated elements and TSS during the development of the plantation.

Results from the P run-off experiment at Ardvarney were anomalous. Although the absence of a height growth response of Sitka spruce to fertilisation was not unexpected, given the inherent fertility of the site, the very high concentrations of P in run-off are puzzling, especially in the control. The occurrence of the highest concentrations in the control plots, where no fertiliser treatment was applied, does not suggest that these P concentrations were the result of the presence of the forest or of the conduct of forest operations. Controlled experiments of this nature have obvious merit, but they carry risks of obtaining results that are merely artefacts of the experimental design. It is suspected, but unproven, that this indeed is the case with this experiment, that the high concentrations of P in run-off waters were the result of sheep grazing on the plots (evidence of summer grazing was observed) or, more likely, the enormous number of insects trapped in the sampling gutters which, although cleaned regularly, may well have influenced measured P concentrations. It was notable that concentrations were highest in summer, whereas in Ballinagee and Crossmolina, highest concentrations were observed outside the growing season. High summer concentrations correspond with the period when insect numbers would reach their maximum.

One of the tasks in this project was an assessment of the efficacy of the Forest Service guidelines for the protection of water quality. This was best tested at Crossmolina, an ex-agricultural site that had been extensively drained and fertilised, where water quality was examined before forest establishment, during establishment operations, and for a short period following establishment. There was no indication of an adverse effect on water quality resulting from forest operations. In fact, although pipe drains on the site showed very high phosphate concentrations before the study began, measurements at the main outlet gave no cause for concern at any time. Concentrations were actually lower at the end of the study period than prior to establishment. This may have been due to a lowering of the water table and a reduction in surface run-off following the installation of mound drains and/or a reflection of the lengthening period since the last fertiliser application. Whatever the explanation, it suggests that afforestation of sites such as this, which are currently becoming more widely available for afforestation, may mitigate, rather than exacerbate, the problem of surface water eutrophication and sedimentation.

Furthermore, the findings from the Ballinagee catchment study, a blanket peatland catchment with a significant forest cover, show that forestry and associated operations, which since the mid-1980s were conducted according to the current and previous Forest Service guidelines, had little or no medium/long-term impact on water quality. The results also emphasise the importance of the scale of operations. The fact that only a little over 50% of the catchment was forested and that forest operations were confined, at any one time, to a fraction of that area, probably contributed to the maintenance of water quality.

Although, most of the forest operations, such as harvesting and subsequent establishment, as well as some new private planting, took place in the period 1995–2001, no evidence of impacts was detected during the course of either the Three Rivers (Three Rivers Project, 2002) or PEnrich projects.

The results of this project emphasise the complexity of forest–site interactions. The indications from the study sites results are positive. They suggest that commercial forest operations, can, if Forest Service guidelines are strictly adhered to, be conducted without detrimental effects on water quality. However, the conclusions of other studies cannot be ignored. Further research is needed. It should include both intensive studies in order to elucidate ecosystem processes controlling the retention and release of P in forested catchments and also an extensive catchment-scale network of monitoring sites designed to capture the range of variation in P loss and to refine the identification of vulnerable site types.

References

Boyle, G.M., Farrell, E.P., Cummins, T. and Nunan, N., 2000. *Monitoring of Forest Ecosystems in Ireland*. FOREM 4&5 Projects, Final Report. FERG report 48, Department of Environmental Resource Management. University College, Dublin, Ireland.

Chang, M., 2003. *Forest Hydrology*. CRC Press, Boca Raton, FL, USA. 373 pp.

Cummins, T. and Farrell, E.P., 2003. Biochemical impacts of clearfelling and reforestation on blanket peatland streams I. phosphorus. *Forest Ecology and Management* **180:** 545–555.

EPA, 2001. *Parameters of Water Quality. Interpretation and Standards*. Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland.

Forest Service, 2000. *Forestry and Water Quality Guidelines*. Department of the Marine and Natural Resources, Dublin, Ireland.

Machava, J., McCabe, O., O'Dea, P., Cabral, R. and Farrell, E.P., 2007. *Forestry Operations and Eutrophication PEnrich*. Final Report (2000-LS-3.2.2-M2). Final Report prepared by Forest Ecosystems Research Group, University College Dublin, Ireland, for the Environmental Protection Agency, Johnstown Castle Estate, Wexford, Ireland, and COFORD.

Morgan, M.F., 1941. Chemical Soil Diagnosis by the Universal Soil Testing System. *Connecticut Agricultural Experimental Station Bulletin 450*.

Three Rivers Project, 2002. *Three Rivers Project – Water Quality Monitoring & Management*. Final Report. http://www.threeriversproject.ie

Yli-Halla, M., Harikainen, H., Ekholmm, P., Turtola, E., Puustinen, M. and Kallio, K., 1995. Assessment of soluble phosphorus load in surface runoff by soil analyses. *Agriculture, Ecosystems and Environment* **56:** 53–62.

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

National Development Plan 2007 - 2013

Environmental Research Technological Development and Innovation (ERTDI) Programme 2000-2006

The Environmental Research Technological Development and Innovation Programme was allocated €32 million by the Irish Government under the National Development Plan 2000-2006. This funding is being invested in the following research areas:

- Environmentally Sustainable Resource Management
- Sustainable Development
- Cleaner Production
- National Environmental Research Centre of Excellence

The Environmental Protection Agency is implementing this programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

NATIONAL COUNCIL FOR FOREST RESEARCH & DEVELOPMENT
AN CHOMHAIRLE NÁISIÚNTA UM THAIGHDE AGUS FORBAIRT FORAOISE

Environmental Protection Agency
Regional Inspectorate, McCumiskey House, Richview, Clonskeagh Road, Dublin 14, Ireland
Telephone: +353 (0)1 268 0100 Fax: +353 (0)1 268 0199 Website: www.epa.ie
Printed on recycled paper