Alternative Farming Methods (Arable)

A Study of the Effects of an Integrated Arable Management System on Levels of Herbicide and Nutrients Reaching "Controlled Waters"

Long Ashton Research Centre

R&D Technical Report P17

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A Study of the Effects of an Integrated Arable Management System on Levels of Herbicide and Nutrients Reaching "Controlled Waters"

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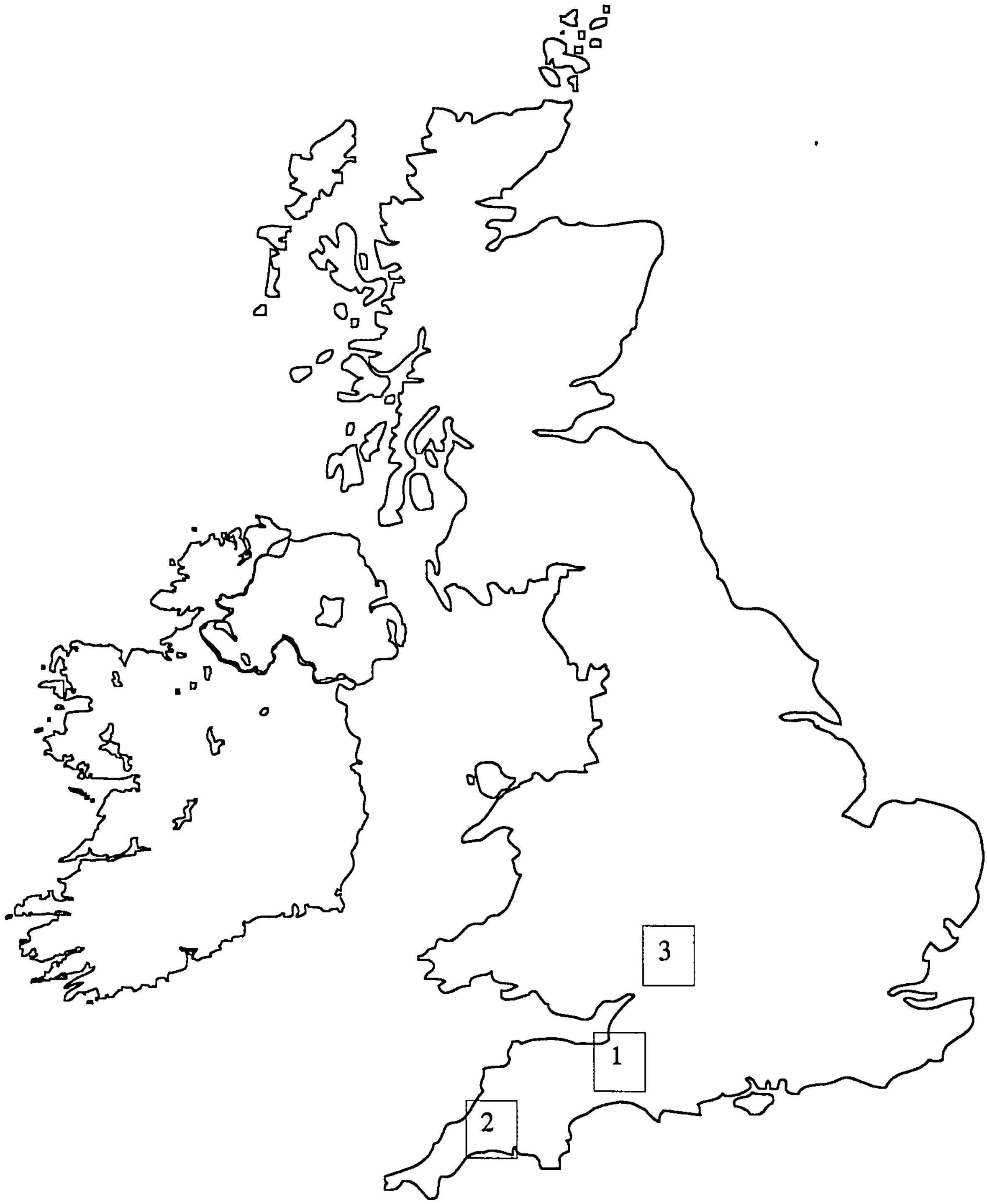
CONTENTS

List of Tables and Illustrations:

APPENDIX

Study Sites



1 IACR - Long Ashton

2 Trerulefoot

3 Harnhill

EXECUTIVE SUMMARY

1. This document summarises the data gained, results and conclusions of a research project investigating the influence and impact of conventional and integrated arable crop production systems on herbicide and nutrient emissions and water pollution from diffuse sources during the period September 1994 - August 1996.

2. The main purpose of the project was to monitor levels of total oxidised nitrogen and soluble phosphate, and of selected autumn-applied herbicides, isoproturon, diflufenican, mecoprop-P, pendimethalin, propyzamide, triallate and trifluralin, and two spring-applied herbicides, fenoxaprop ethyl and fluroxypyr, in stream waters bordering on, or within, agricultural catchments from conventionally farmed crop areas and those farmed under the guidelines for integrated production (IFS Farmlets), at two commercial farms (Trerulefoot, Cornwall and Harnhill, Gloucestershire) in south-west England. Additional monitoring was done of drain water discharges, surface run-off, soil erosion and the loss of sediment-associated total-P, from fields farmed conventionally and under the guidelines for integrated production (IFS) within the IACR-Long Ashton LIFE Project near Bristol.

3. The project aimed to study the agrochemical and nutrient concentrations in water courses within these agricultural catchments that resulted from the conventional and reduced-input use of agrochemicals on alternative systems of arable crop production. All chemicals and nutrients were applied by tractor-mounted sprayers and according to good agricultural practice. Measurements were taken pre- and post-herbicide application, either in response to rainfall(15mm rain) or at regular intervals thereafter.

4. The project found that concentrations for fluroxypyr, mecoprop-P, pendimethalin, propyzamide, triallate, trifluralin and fluroxpyr in streamwater were below detection limits throughout the sampling periods in both years. Concentrations of diflufenican ranged from below detection limits to maximum levels 8.5 ug/l, and for the spring-applied fenoxaprop-ethyl to maximum levels of 46.5 ug/l in 1994/95, but neither herbicide exceeded detection limits in 1995/96. Only isoproturon exceeded detection limits in both years. Although levels of herbicides detected were variable at both sites they were, in general, lower from integrated (IFS) production systems than those conventionally farmed.

5. Isoproturon was the most commonly detected herbicide, and was generally detected within three days of application in all catchments. Significant rainfall events two or three months after application tended to produce further positive samples. Similar concentration levels were found in all samples.

6. Total oxidised nitrogen monitoring in streams at Trerulefoot and Harnhill revealed little difference in nitrate concentrations in the stream water between conventional and integrated production systems.

7. Monitoring phosphate in stream waters at both Harnhill and Trerulefoot showed that consistently lower concentrations of PO_4-P were detected in samples from the IFS Farmlet Catchments than from the Conventional Catchments, with greatest reductions occurring in the autumn. At Trerulefoot in 1995/96, concentrations of phosphate in streamwaters from the Conventional Catchment averaged 15.4 ugP/l over the sampling period, whereas concentrations exported from the IFS Catchment were 45% lower, averaging 8.41 ugP/l over the same period. Phosphate concentrations in stream water from the Conventional Catchment at Harnhill were much higher than those detected at Trerulefoot and averaged 61.2 ugP/l over the sampling period, whereas levels detected at the IFS total export sampling point were 90% lower, averaging 6.4 ugP/l over the same period.
The differences in emissions between the two sites, to some extent, reflects the traditionally greater intensity of applied fertiliser inputs and cultivations by farmers in the Cotswold area than those in Cornwall.

8. Monitoring discharges from drain outlets from conventional and integrated production field units within the long-term, farm-scale IACR Long Ashton LIFE project during autumn/winter 1995/96 revealed that isoproturon concentrations detected in discharges from the conventional field ranged between 0.19 and 0.36 ug/l whereas in discharges from the integrated production system, levels never exceeded detection limits.

9. Monitoring nutrient emissions in drainwater discharges showed that concentrations of total oxidised nitrogen were between 35% and 63% lower from the integrated field units than from the conventional system, with an average overall reduction in TON loading of 82%. On the first occasion when field drains ran, concentrations of PO_4-P in discharges from the integrated field unit(46 ugP/l) were much lower than those detected in discharges from the conventional field unit (165 ugP/l), but thereafter levels were low ($<$ 10 ugP/l) from both production systems, nevertheless average phosphate loading was 81% lower in discharges from the integrated field drains.

10. Data from monitoring surface run-off, erosion and the loss of sediment-associated total-P, on land with Soil P-Index 2, showed that run-off was reduced by 48%, total sediment loss(erosion) by 68% and total-P loss by 81% in the integrated production system compared to the conventional production system. These responses are mainly attributed to the differences in crop structure and function resulting from the different tillage systems used for crop establishment over the past six years. Crops grown in the integrated production system Field Units have been established using soil conservation tillage (a one-pass non-inversion tillage system) whereas crops grown in conventional production Field Units have been sown following ploughing and subsequent springtine cultivations.

Key Words: agriculture, conventional production, integrated farming systems(IFS), non-inversion tillage, herbicides, nitrate, phosphate, pollution, water quality, "controlled waters".

BACKGROUND.

IACR Long Ashton has been pioneering research into less-intensive farming and environmental protection in the UK (the LIFE Project) as part of a European network of integrated farming systems research, and in response to current/future National and European agricultural policy requirements. The objectives of the LIFE project are to provide fundamental information on effects, interactions and ecological/environmental implications of alternative arable production systems which are economically and ecologically sound, more environmentally benign, and sustainable in the long term. Based on data generated since 1989, an integrated farming systems approach has been identified as a practical option to sustain production, maintain the competitiveness of farmers and farm income, and to safeguard the environment (Jordan & Hutcheon 1993;1994). This, with support from MAFF and CEC (DGVI), is now being researched and developed further at IACR-Long Ashton, and being evaluated in commercial practice.

Two commercial farms, one at Trerulefoot in Cornwall, and one at Cirencester in Gloucestershire, were selected for conversion in autumn 1992. Prototype cropping systems, designed to be more environmentally benign than those currently adopted, have been formulated and implemented during autumn 1992. The farms are being managed according to the strict rules for Integrated Production (El Titi et al 1993), based on a multifunctional crop rotation, maximum soil cover indices, minimum soil cultivation for crop establishment and where strict limitations have been imposed on agrochemical, nutrient and fertiliser use, to minimise off-farm inputs, and reduce the impact both of crop protection chemicals on non-target flora and fauna and of potentially polluting elements in the soil and water.

These two IFS farms(farmlets) are sited within larger conventionally farmed areas, and thus, provide opportunities for appropriate comparisons to be made with conventional management strategies. Furthermore, watercourses occur at the boundaries of each farmlet, whereby water quality emanating from both conventional and integrated management practices can be monitored.

The following report presents data from monitoring herbicide and nutrient levels in the watercourses that flow around the boundaries of the IFS farmlets, and within the conventionally farmed areas, of the two Demonstration Farms in Cornwall and Gloucestershire and, in 1995/96, on the quality of water draining from selected LIFE experimental field units at Long Ashton, in response to application timing and rainfall events.

1. OBJECTIVES.

The overall objective of the project is to demonstrate, through an alternative and integrated approach to arable crop management on commercial farms, that levels of certain agrochemicals and nutrients reaching "controlled waters" can be reduced by adoption and implementation of guidelines for integrated production within whole systems.

More specifically, and using selected herbicides and nutrients as response indicators, the project aims to provide data on the effects of the two crop management systems on herbicide and nutrient levels in the respective streamwater catchments as determinants of the environmental impact of such systems and their influence on water quality. In addition, attempts will be made to qualify and quantify the amounts of the response indicators exported from the agricultural catchments into "controlled waters", which may provide indications of the influence, relationship and contributions of some specific component practices adopted.

To address these objectives, five autumn-applied herbicides (diflufenican, isoproturon, propyzamide, triallate, trifluralin) and one spring-applied herbicide (fenoxaprop-ethyl) that have potential to reach "controlled waters", and are used in both conventional and integrated arable production systems, were selected as candidates to demonstrate the effect of alternative farming practices on the quality of water draining from different arable production systems during autumn and spring 1994/95. These, and additional herbicides, where appropriate, were also monitored in the 1995/1996 cropping season. Furthermore, as integrated production systems use lower amounts of applied nutrients, and are reliant upon soil conservation techniques and minimum intervention for crop establishment, the monitoring of nutrient emissions (nitrate and phosphate) should also provide an indication of differences between traditional and alternative systems of production and farming practices. Thus, an additional objective, within the LIFE Project, is to provide quantitative information on the comparative effects and interactions of conventional tillage (ploughing) and conservation soil management (non-inversion tillage) practices used for crop establishment in the different systems, together with differing levels of agrochemical and nutrient inputs, on agrochemical emissions and concentrations in drainwater, and their effects on the water environment.

Following the selection of streamwater sampling points at each farm, an agreed and regular sampling programme commenced in October 1994, prior to herbicide treatment. Subsequent samples were taken post herbicide application either in response to rain quantity triggers (15mm rain) and/or at specific intervals thereafter in autumn and spring 1994-1996.
In 1994/1995 monitoring the system effects on autumn-applied herbicides, each catchment was sampled on seven occasions between October and February. To monitor the effects on spring-applied herbicides in 1995, the catchments were sampled on three occasions at Trerulefoot, and on four occasions at Harnhill. All samples were analysed by Sensory Research Laboratories Ltd for the selected herbicides until levels were below the detection limits(ND). Analyses for nutrient content (total oxidised nitrogen and orthophosphate) were done "in-house" by IACR. In 1995/1996 cropping season the Trerulefoot catchments were sampled on 9 occasions between October 1995 and May 1996 and Harnhill on six occasions between November 1995 and April 1996. All analyses were done by IACR.

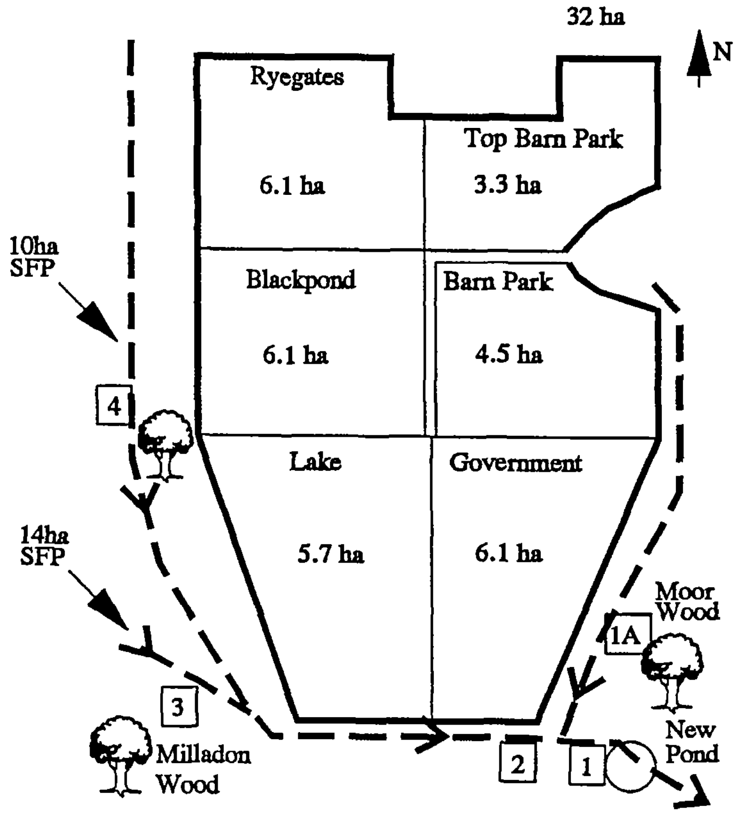


Fig 1. IFS Farmlet catchment, Trerule Farm

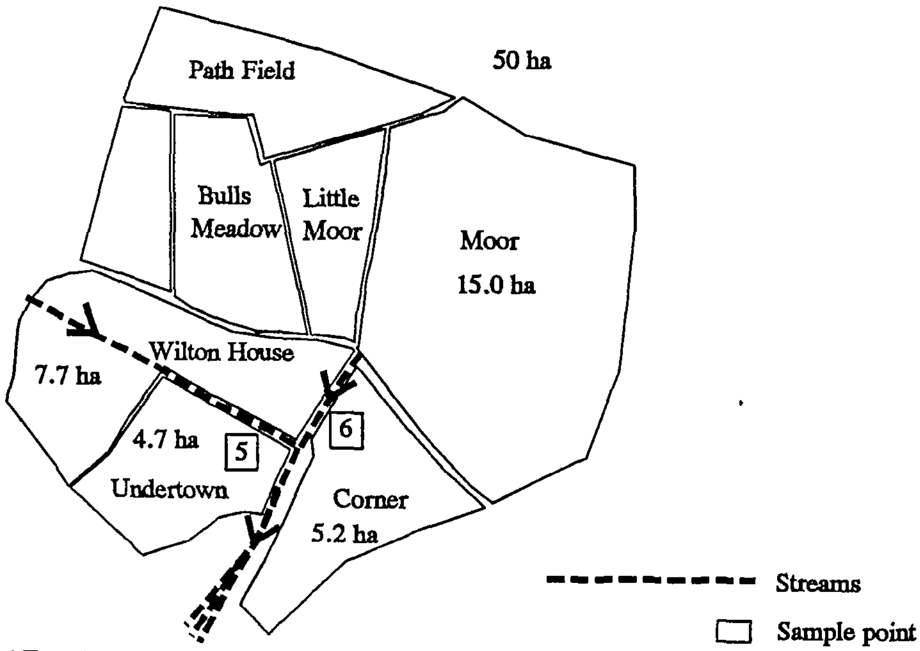


Fig 2. Conventional Farmlet catchment, Trerule Farm

2. SITE LOCATIONS/CATCHMENTS.

2.1 Trerulefoot, Cornwall.

The IFS Farmlet catchment at Trerulefoot has an area of 32 ha, with a gradual slope to the south. It comprises 6 fields, with traditional Cornish raised banks (Figure 1), in which rotational crops were grown under Integrated Production guidelines (El Titi et al; 1993).
In the 1994/1995 cropping season the 6-course rotation comprised:- winter wheat: winter oilseed rape: winter oats: set-aside: winter barley: spring beans. In the 1995/1996 cropping year the rotation was modified, in response to market-driven and integrated production requirements, such that the following crops were grown:- winter barley (2 fields): winter oats: spring beans: winter wheat: spring oilseed rape.
A Conventional Farm catchment area (30 ha) was selected at Trerule Farm for comparison (Figure 2). It comprised four fields (Moor, Corner, Wilton House and Undertown) with a main stream and tributary flowing within the field boundaries.
The soil type at Trerulefoot is Trusham, Denbeigh Series interbedded Devonian slates, fine loam-brown earths over hard rock. In the IFS Farmlet the soil is free-draining, but less so in the heavier soil in the Conventional Farm area.

2.1.1. IFS Farmlet Catchment.

Within this catchment, initially four streamwater sampling points were established in early September 1955 in the streams around the IFS farmlet boundary. Following initial data collation, a further sampling point (T1A) was sited upstream in the main watercourse on the north-east IFS farmlet boundary to reflect more closely the IFS emissions.

T4 - Sampling Point: the stream to the West of IFS Farmlet, but receives water imported from the conventional farm area to North and East(SFP) - flow from North;
T3 - Sampling Point: stream tributary joining main watercourse below T4; importing from conventional farm, woodland and permanent pasture to West - flow from West;
T2 - Sampling Point: the stream South East of IFS Farmlet, importing from T4 and T3, and representing some drainage from Lake Field (IFS) to the East - flow from North-West;
T1A - Sampling Point: stream to the East of the IFS Farmlet, representing drainage from the IFS farmlet; merges with the main watercourse below T2.
T1 - Sampling Point: the main watercourse below the point where all streams merge. This site provides the total catchment export, including the stream to the east of the IFS Farmlet (main IFS catchment), where no sampling point was initially sited.

2.1.2. Conventional Farm Catchment.

Within this catchment, two sampling points were selected in September 1995.
T5 - Sampling Point: downstream of a "tributary" stream that passes through Wilton House Field and along the lower boundary of this and Undertown Fields - flow from North-West;
T6 - Sampling Point: the main watercourse that passes the lower boundary of Moor Field and between Wilton House and Corner Field, upstream of the "tributary" - flow from North.

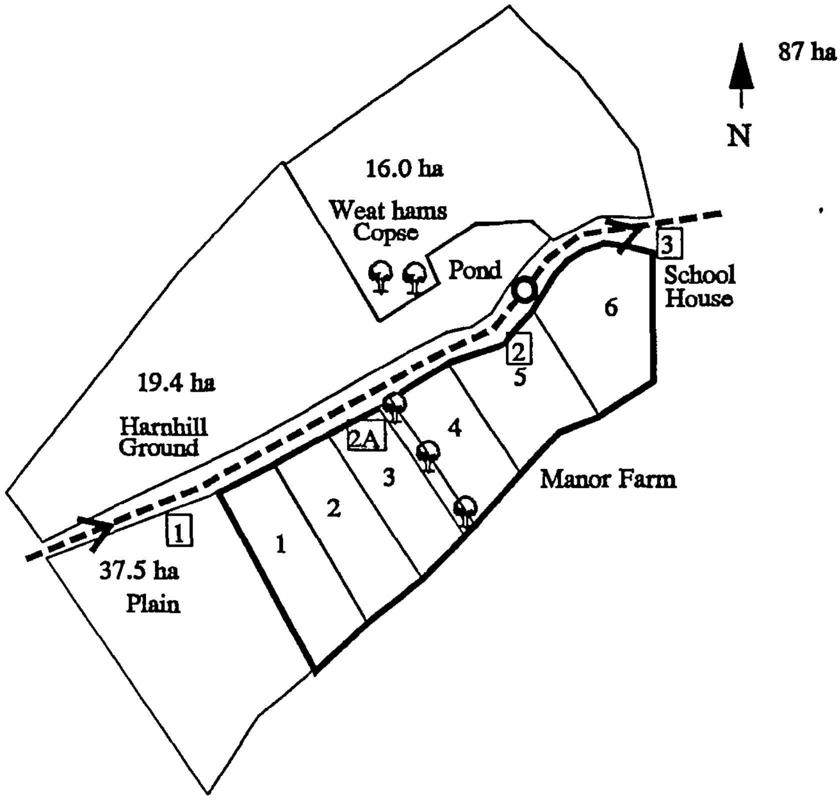


Fig 3. IFS Farmlet catchment, Harnhill Driffield

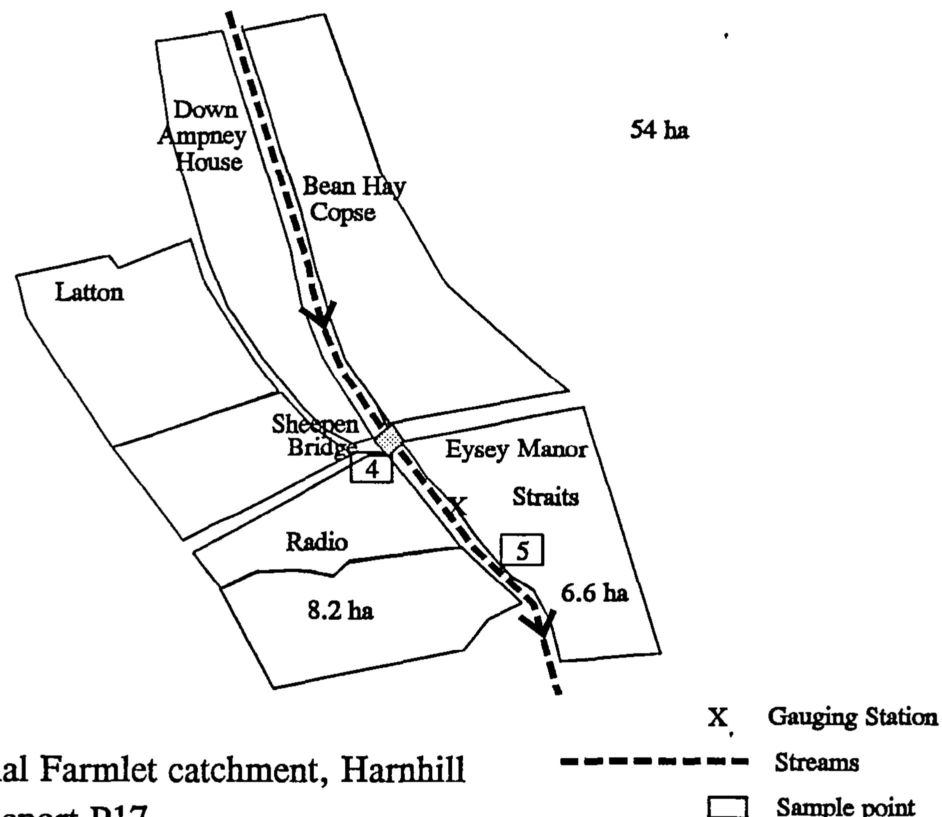
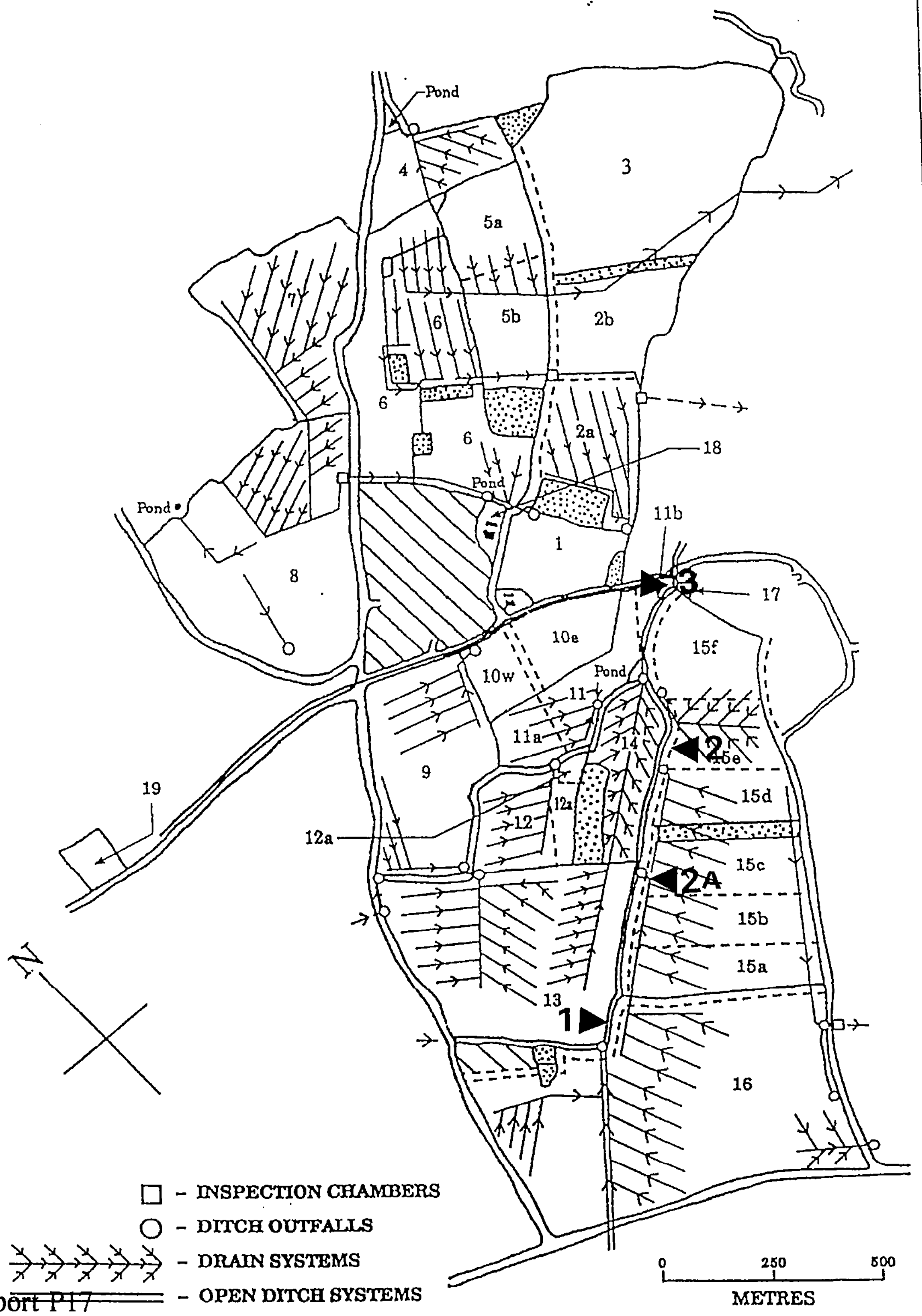


Fig 4. Conventional Farmlet catchment, Harnhill

HARNHILL MANOR FARM

Drainage Map



2.2 Harnhill, Gloucestershire.

At Harnhill, the IFS Farmlet occupies 30 ha, with slopes to the north. It comprises 1 large field, subdivided into 6 field units by the establishment of 2 m wide ecological reservoirs (grass and wild flower mixtures) between the crops, and with a 10m wide grass headland surrounding the IFS farmlet (Figure 3).
In 1994/1995 cropping season, the following crops were grown in rotation, under the guidelines for integrated production:- winter barley: winter beans: winter wheat: set-aside: winter oilseed rape: winter wheat. In 1995/96 the cropping sequence was modified; a sown grass ley replaced set-aside, and spring oilseed rape replaced winter oilseed rape.
For comparative purposes, a conventionally farmed area was selected at Down Ampney, approximately 1 mile from the IFS Farmlet, with Ampney Brook running through the middle of this area (Figure 4). This was used for monitoring streamwater emanating from the Conventionally Farmed catchment.
The soil type is Sherborne/ Moreton Series overlying Cornbrash and Forest Marble; brown clay, variable, stony over calcareous limestone, difficult to work, shallow and drought prone. Most of the fields have been under-drained (see Drainage Map; Figure 4a)

2.2.1. IFS Farmlet Catchment.

Within the IFS Farmlet catchment, a single stream runs (flow from west) along the northern boundary of the area, and at the bottom of the whole farmlet slope, thus providing an ideal requirement for monitoring. Three sampling points were sited along this stream, the first to provide information on the levels imported from the conventional farmed area upstream to the west, the second further downstream, to monitor exports from the IFS Farmlet area, and the third, furthest downstream boundary of the IFS Farmlet. In addition, a field drain outlet was located in early spring 1995, at the mid-site point of the IFS farmlet, and was monitored when drainflow occurred.
H1 - Sampling Point: the stream at the western extreme of the IFS area, importing all drainage from conventional areas to the west - flow from west(including highway drainage);
H2A - Sampling Point: Field drain outlet upstream from Sampling Point H2
H2 - Sampling Point: downstream from H1, at the mid-point of the IFS farmed area, receiving flow from west;
H3 - Sampling Point: sited downstream from H2, at the furthest downstream IFS boundary, to monitor total export from the IFS catchment.
The IFS Catchment Field Drainage Map is given in Annex 1

2.2.2. Conventional Farm Catchment.

Within this catchment, two sampling points were selected in September 1995.
H4 - Sampling Point: Ampney Brook just below Sheepen Bridge; streamwater -flow from conventional farmed area to the North
H5 - Sampling Point: Ampney Brook, further downstream from H4 adjoining the boundary of Straits and Radio Fields.
These two catchment sites and location of sampling points within the IFS and conventional farm catchments are given in Figure 4.

2.3. The LIFE Project at IACR-Long Ashton

The site, at Wraxall, is part of the IACR-Long Ashton LIFE Project, which is a long term, farm scale experiment occupying 23 ha, and where comparisons of conventional and less-intensive integrated farming systems approaches have been under investigation since 1989. Data on all previous farming practices and inputs have been maintained throughout.
At harvest 1994, the first full rotational cycle was completed, and results have already provided indications of ways to lower agrochemical input requirements whilst maintaining economically sound and more environmentally benign quality production. It is now (from autumn 1994) embarking on a new 7-year rotational sequence, with crops grown under both conventional integrated crop management strategies and under guidelines for advanced, less-intensive integrated production systems.

Within the LIFE project, Field 56 - a North facing field with a 4.5° rectilinear slope, divided into four field units of approx 1 ha each in size, offers the best opportunity to meet the aforesaid objectives. Within this field, with seasonal groundwater table between 80-120cm, 60mm PVC drainage pipes were inserted on the lower 80m of each field unit, spaced at 12m intervals (running along each tramline) to a depth of 1m, at the beginning of the project in 1989, with outflows into an adjacent ditch.

3. CROP MANAGEMENT STRATEGIES

In the conventionally farmed areas at both Commercial Demonstration Farms, crops are established following the traditional plough and associated cultivations, sown in September, and managed thereafter under codes of good practice for conventional integrated crop management (ICM). They receive somewhat "routine" managed pest, disease and weed control programmes and fertiliser is applied to attain optimum yields. It is difficult to generalise on management strategies and inputs for conventional farm practice in both catchments, as they reflect both routine and "at-need" treatments in response to perceived or identified individual field specific problems, according to non-rotational or rotationally-based cropping patterns in the fields near or adjoining the conventional streamwater catchment sampling points.

In both IFS Farmlets, crops are grown under the strict guidelines for Integrated Production (El Titi et al; 1993). Only grain is removed from the fields, crop residues are chopped and lightly incorporated after harvest, which also promotes weed and volunteer growth during the intercrop period. The crops are established using minimum, non-inversion tillage techniques and sown later (October), to provide soil stability, minimise nutrient losses and lower pest and disease incidence/risk. Weed control strategies are rotationally and specifically targeted, and usually involve lower dose herbicides. Fertiliser recommendations are based on predictive models to achieve an attainable yield (Jordan & Hutcheon, 1994).

3.1. Trerulefoot: Conventional.

In autumn 1995, Moor Field and Corner Field were sown with winter barley and Wilton House Field and Undertown Field sown with winter wheat. Isoproturon was applied to three of the fields, pendamethlin to two fields, and diflufenican + mecaprop-P to two fields, in October/November 1995; the herbicide loading is given in Appendix 1

3.2. Trerulefoot: IFS Farmlet.

In the IFS Farmlet Catchment, ca 30 ha, six crops were grown (rotationally) in six fields:- winter wheat, winter oats, winter barley (2), spring beans and spring oilseed rape. Herbicides were not applied to winter oats, spring beans and oilseed rape but were applied to both winter barley crops and to winter wheat. The total loading of isoproturon and diflufenican was slightly higher than in the conventionally farmed catchment - a specifically targeted rotational weed control strategy, but the total herbicide loading to the IFS Farmlet catchment was lower (Appendix 2).

3.3. Harnhill: Conventional.

The Conventional Farm Catchment, at Eyesey Manor, has fields (Straits and Radio) bordering onto Ampney Brook (Figure 4). In 1994/95, winter wheat, winter barley and winter oilseed rape was sown in fields within this catchment. In 1995/96 both the above fields, ca 15 ha, were sown in September 1995 with winter barley following a conventional plough and associated cultivations, then managed according to conventional farm practice. The herbicides, isoproturon, simazine, trifluralin and diflufenican were applied to both fields, as a tank mix, on 30 October 1995 (Appendix 3).

3.4. Harnhill: IFS Farmlet.

In the IFS Farm Catchment, ca 30 ha, six crops were grown rotationally in six Field Units, ca 5 ha each. In the furthest upstream Field Unit, a grass ley was established to replace natural regeneration set-aside. In successive Field Units, downstream from the grass ley, crops of winter wheat, spring oilseed rape, winter wheat, winter barley and winter beans were grown (Figure 3). Isoproturon, fenoxaprop-ethyl, trifluralin and diflufenican were applied to two field units (wheat and barley), ca 10 ha, in November 1995 and January 1996, with the total loading of isoproturon and diflufenican/unit area being 50% of that applied to the conventional area (Appendix 4).
The area upstream of the IFS Farmlet (Plain Field), was sown with winter oilseed rape and farmed conventionally, and as this field drained into the stream (see Drainage Map: Annex 1), it would import herbicide into the streamwater passing through the IFS Farmlet. However, the herbicides used for weed control were not among those identified for selective monitoring. In the fields adjoining the IFS Farmlet, Harnhill Ground and Long Ground, conventional winter barley and organic spring oats were grown. Isoproturon, simazine, trifluralin and diflufenican were applied as a tank mix, 2 November 1995, to Harnhill Ground Field (19 ha) (Appendix 5). However, the field drainage plans (Figure 4a) indicate that drainage from Harnhill Ground and Long Ground were likely to import below the IFS Farmlet and into the Catchment export sampling point(H3).

3.5 The LIFE Project: Field 56 - Wraxall

The study site, is divided into four Field Units, ca 1 ha each. Winter wheat was sown in Field Unit 561 (28 September 1995), following a primary cultivation (Simba Maximix) after oilseed rape, conventional ploughing and two springtine cultivations. Herbicide (isoproturon + diflufenican) was applied on 1 November, and the crop managed thereafter (from March 1996) by conventional standard farm practice. In the contrasting system, Field Unit 564, winter wheat was established following one primary cultivation (Simba Maximix) and sown, using a one-pass non-inversion tillage system (Dutzi) on 9 October 1995. For the comparative purposes of this study, the same herbicides were applied to the integrated wheat crop, but at half-rate compared with that applied to the conventional field unit. Thereafter, the crop was managed according to the guidelines for less-intensive, integrated production (Appendix 7; Figure 5). The two central field units, FU 562 and FU 563 remained as natural regeneration (weeds and volunteers), and sown with either oilseed rape or spring beans in March 1996.

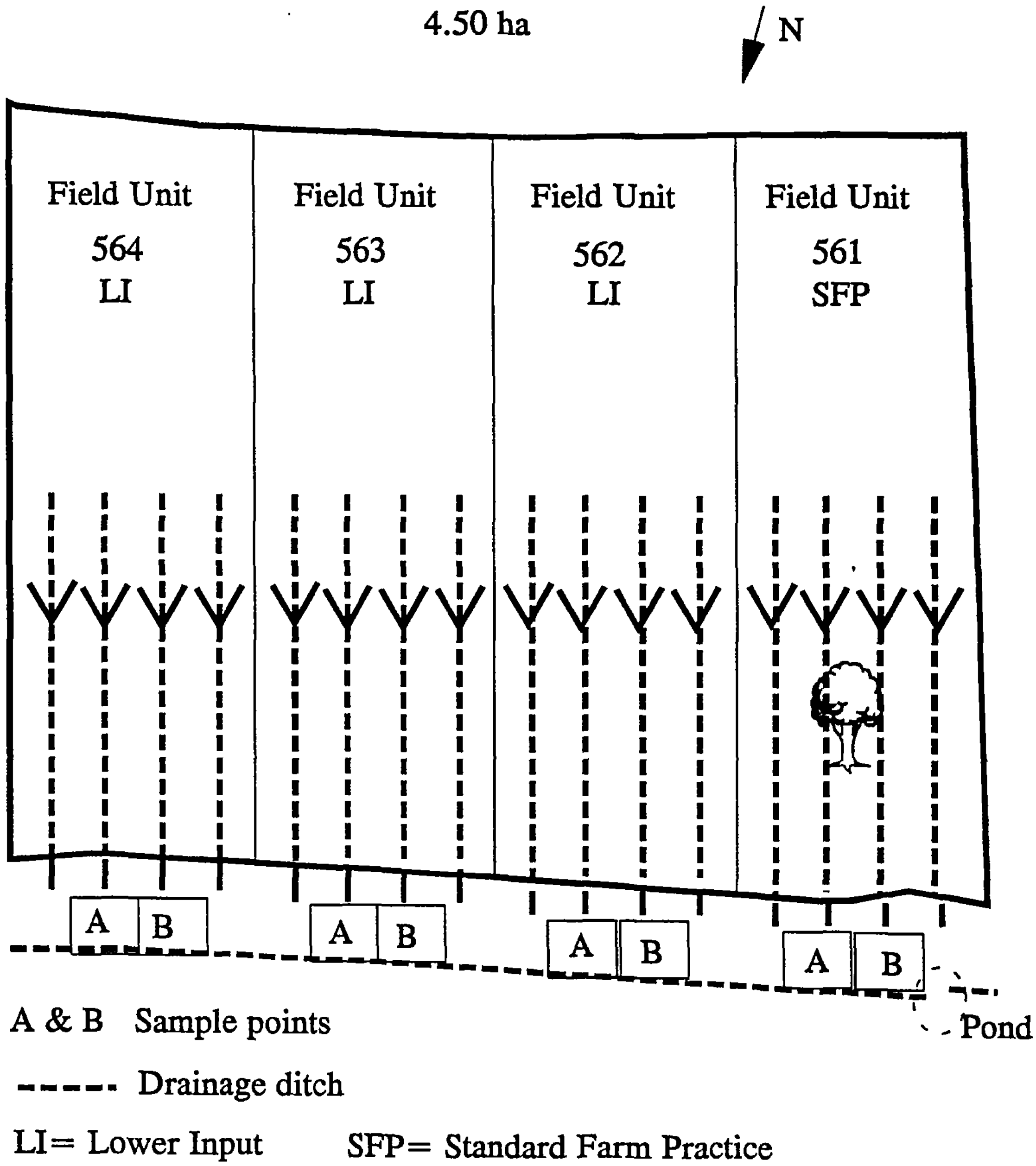


Fig 5. IFS LIFE Project catchment, IACR Long Ashton

4. METHODOLOGY

4.1 Streamwater sampling.

4.1.1. Trerulefoot.

In the IFS Farmlet Catchment, Sampling Points T4,T3 and T2 represents drainage importing into the Catchment, with some drainage from Lake Field(IFS) at T2. Sampling Point T1A represents the drainage from Top Barn Park, Barn Park and Government Fields(IFS) and T1 the total Catchment exportation.
The Conventional Catchment covers ca 33 ha, Moor Field is upstream from, and Corner Field adjoins, Sampling Point T6. The stream from the west bisects Wilton House Field and Undertown Field and Sampling Point T5 was sited at the downstream end of these two fields (Figure 2).

4.1.2. Harnhill.

In the IFS Farmlet Catchment, Sampling Point H1 represents drainage from Conventional fields upstream importing into H2, which represents drainage from IFS Field Units 1-5, and H3 represents the total Catchment exportation, including some drainage from Field Barn (Conventional) to the north.
In the Conventional Catchment, H4 represents drainage importing from conventionally farmed land upstream and H5 drainage from Fields Radio and Straits.

At each location site within each catchment, one or two litre streamwater samples were taken prior to, within 3-5 days following herbicide applications, and subsequently at intervals in response to rainfall quantity triggers (15mm rain). Streamwater Sampling Points were sampled directly using separate, pre-cleaned (acid-washed) 2 litre glass DURAN bottles. These were then transported in a cool-box to the laboratory and stored in a refrigerator at 3°C until delivery to the analytical laboratory (Sensory Research Laboratories Ltd, 1994/95; IACR Long Ashton 1995/96). Following analysis, all bottles were washed using a "chromic acid" cleaning mixture (sodium dichromate + concentrated sulphuric acid), then thoroughly rinsed successively with tap and distilled water prior to re-use.

4.1.3 Drain water discharge sampling.

In Field 56 of the LIFE Project, on each occasion when drains ran, water samples (2 litres) were taken from drain outlets from the two central field drains in each field unit, with the outside two drains acting as appropriate buffers. The drainwater flow rate was measured on each occasion as the time taken to fill a 1 litre measuring cylinder. Although initially, five event-triggered (15mm rain) and two routine samples were planned, in response to specific herbicide treatments, the prevailing weather conditions during autumn 1995 limited the frequency of occasions when drainflow occurred. Thus samples were taken on each drainflow event, and analysed for nutrient and herbicide content.

4.2 Analytical Methods -1994/5 Sampling Year (Sensory Research Laboratories).

Determination of triallate, triflufenican and propyzamide:

1(2) litre(s) of each sample was extracted initially with 25 *ml* hexane, then a further extraction done using 25 ml hexane. The combined extracts were subsequently dried with anhydrous sodium sulphate and rotary evaporated, made up to 1.0 ml, then analysed using a Finnigan 4000 gas chromatograph - mass spectrometer (GCMS) coupled to an Incos 2100 data system.

Determination of diflufenican, isoproturon, difenzoquat, fenoxaprop ethyl, fluroxypyr and metasulfuron methyl:

1(2) litre(s) of each catchment sample was passed through a conditioned C18 solid phase extraction cartridge. Retained herbicides were eluted with 2ml methanol and either concentrated to 1 ml under nitrogen or made up to 2ml with mobile phase and then analysed using a Waters HPLC connected to a Kratos UV detector.

4.3. Analytical Methods -1995/6 Sampling Year (IACR Long Ashton).

Determination of triallate, trifluralin, propyzamide and pendimethalin

One litre of each sample was extracted with 2 x 25ml + 1 x 15ml n-hexane. The three extracts were combined, dried over anhydrous sodium sulphate, and evaporated down to 200ul in a stream of dry nitrogen. Samples were analysed using a Kratos MS80RFA Mass spectrometer

Determination of diflufenican

Extraction as above. Samples analysed using a GC Column:25m x 0.32mm BPI(0.25u)-SGE

Determination of isoproturon, mecoprop and fenoxaprop ethyl.

500ml of each sample was passed through a conditioned Extract-Clean C18 column (500mg.6.0ml - Alltech)[1] or Supelclean ENVI - 18SPE tube (500mg/6.0ml - Supelco)[2]. The tubes were eluted with 4.0ml HPLC grade methanol and the extract concentrated to 1.0ml in a stream of nitrogen. Samples were analysed using a LDC/Milton Roy HPLC

4.4. Examination of Water Samples for selected nutrients.

Low level orthophosphate

Filtered aqueous samples were injected into a carrier stream and merged with acidic ammonium molybdate reagent solution to form heteropoly acid. The heteropoly acid is then reduced to molybdenum blue by adding acidic stannous chloride in a second reagent stream. The developed colour is measured spectrophotometrically at 674nm, using a Tecator FIAstar flow injection analyser. Injection volume - 260ul, injection time - 20 sec, delay time- 30 sec, cycle time - 50 sec, sample throughput 70h; range 5 - 100 ug/l P (detection limit 2ug/l).

Total oxidised nitrogen

Nitrate is reduced quantitatively to nitrite by passing the sample through a copperised cadmium reductor(coil). The nitrite thus formed, plus any originally present reacts with sulphanilamide in an acidic solution to form a diazo compound. The diazotised product is then coupled with N-(1- naphthyl)-ethylenediamide dihydrochloride. The intensity of the formed azo dye is then measured at 540nm. Turbid samples are pre-filtered through a 0.45um membrane prior to analysis. EDTA is added to eliminate interference from iron, copper or other metals. Range 0.001-100mg/l; precision 0.05mg/l; detection limit 0.001mg/l.

5. RESULTS

5.1. Autumn-applied herbicides in streamwater samples.

5.1.1 Trerulefoot Catchments

At the IFS Farmlet in 1994/95, isoproturon was detected 5 and 15 days post application (maximum level 0.22 ug/l) but levels did not exceed detection limits thereafter. Isoproturon was not applied to the conventional farm area catchment in autumn 1994, therefore direct comparisons could not be made. Diflufenican was detected in baseline stream water samples, prior to field application on 17 November 1994, and again 5 and 15 days post application to Conventional fields upstream, with the highest concentrations (8.5 ug/l) found at the IFS Farmlet import sampling point (T4). There was no further increase in levels detected at the IFS Farmlet export sampling point (T1), indicating that there were no losses from the IFS fields. Levels of propyzamide, triallate and trifluralin did not exceed detection limits in stream water samples throughout the sampling period (October- January).

In the IFS Farmlet in 1995/96, pendamethlin and isoproturon were applied to Lake Field; isoproturon, diflufenican, trifluralin and mecaprop-P were applied to Barn Park and Government Fields, upstream from Sampling Point T1A, where levels of diflufenican and trifluralin did not exceed detection limits after application. Isoproturon did not exceed detection limits (0.08 ug/l) until 15 February 1996, three months after application. Isoproturon concentrations ranged from 0.97 - 2.71 ug/l, at the four sampling occasions in spring 1996 (Table 1).

At the import sampling point T4, receiving water from conventional fields upstream, isoproturon was first detected (0.15 ug/l) on 16 November 1995, three days after herbicide application. It was not detected again until 15 February 1996 (0.65 ug/l), reaching a maximum level (2.76 ug/l) on 17 April 1996. Levels of diflufenican, trifluralin and pendamethlin did not exceed detection limits on any sampling occasion. At Sampling Point T3, a stream tributary from the conventional farm, woodland and permanent pasture, only isoproturon was detected at levels above detection limits in spring 1966 (15 February - 17 April) with maximum levels detected (3.16 ug/l) on 17 April 1966 (Table 1). At Sampling Point T2, receiving waters from T3 and T4 and the lower part of Lake Field (IFS), levels of isoproturon exceeded detection limits only at the four spring sampling occasions (15 February, 14 March, 17 April, 22 May) and concentrations averaged 0.58 ug/l. By extrapolation, and indicative of emissions exported from the adjoining integrated production field (Lake) the increase in average concentration was 0.07 ug/l. At Sampling Point T1A, indicative of emissions from Top Barn Park, Barn Park and Government Fields (IFS) isoproturon concentrations averaged 0.72 ug/l over the sampling period. At the total export sampling point (T1), the level of isoproturon detected in the four spring samplings ranged from 0.24ug/l - 2.77 ug/l, with an average isoproturon concentration of 0.5 ug/l (Table 1).

In the Conventional Farm Catchment, pendimethalin was applied to both Moor and Corner ields in October 1995, but did not exceed detection limits in any of the six sampling occasions thereafter. Isoproturon was applied to Corner Field on 14 October 1995, and to both Undertown and Wilton Field on 13 November 1995, but not to Moor Field.

Isoproturon was detected (0.08 ug/l and 0.9 ug/l) in receiving waters from Undertown and Wilton Fields (T5) 3 and 10 days, respectively, after application, but did not exceed detection limits until 14 March 1996, reaching a maximum level (2.71 ug/l) on 17 April 1996. Levels of diflufenican, also applied to these two fields, never exceeded detection limits on any sampling occasion. Although isoproturon was applied to Corner Field in October 1995, it did not exceed detection limits during autumn/winter 1995 (Table 2), but was first detected in samples taken on 15 February 1996, reaching a maximum level (3.0 ug/l) on 17 April 1996 (Table 2).

5.1.2 Harnhill Catchments

In 1994/95, isoproturon was applied to two upstream conventional fields (The Plain and Harnhill Ground), to two Field Units in the IFS Farmlet, and to fields in the Conventional Farm Catchment(Down Ampney) in November 1994. It was only detected in the first streamwater sampling post application at both sites, thereafter levels did not exceed detection limits. Diflufenican was also applied to both conventional and IFS Farmlet areas and, as at Trerulefoot, it was detected in baseline samples prior to field application. It was also detected in streamwater samples taken 6 and 48 days post application, but did not exceed detection limits thereafter In the IFS Farmlet, levels exported (H3) did not exceed those imported from the conventional fields upstream (H1), suggesting no losses from the IFS Farmlet.
Similar levels of diflufenican were detected in the water course at the conventional catchment. Levels of propyzamide, triallate and trifluralin did not exceed detection limits throughout the sampling period.

In 1995/96, neither isoproturon nor diflufenican were detected in any streamwater samples importing into the IFS Farmlet(H1), throughout the monitoring period (November 1995 - April 1996). This was mainly due to lack of stream flow throughout November and, on subsequent occasions when sampling was possible (8 December, 25 January, 24 April), levels did not exceed detection limits. Isoproturon and diflufenican did not exceed detection limits in drain outlet discharges(H2A) throughout the sampling period (Table 3).

Isoproturon was only detected (0.35 ug/l) in streamwater samples at the IFS Farmlet mid-point(H2) - adjoining Field Unit 4 to which isoproturon had been applied 2 days previously, but not thereafter. Isoproturon was also only detected at the furthest downstream IFS Farmlet export sampling point(H3), on 22 November - 0.28 ug/l and again 25 January - 0.44 ug/l; on all other sampling occasions it did not exceed detection limits (Table 3).
These levels are more likely to have originated from Field Unit 5 (Winter Barley), to which isoproturon had been applied 6 days before detection in stream water in November, although field drains from the adjacent conventionally farmed Harnhill Ground Field, and to which isoproturon was applied on 2 November 1995, may also drain to this sampling point(H3), below the IFS Farmlet (see Drainage Map - Appendix 6). The concentration of isoproturon at the total export sampling point averaged 0.12 ug/l over the sampling period.
No other herbicide exceeded detection limits (Table 3).

Thus, whilst the herbicides isoproturon, diflufenican, trifluralin and fenoxaprop-ethyl were applied to the IFS farmlet area, only isoproturon exceeded detection limits in stream water samples exported from the IFS Catchment, and only at very low levels on two occasions - in each case within 6 days of field application of herbicide.

In the Conventional Farm Catchment, isoproturon, simazine, trifluralin and diflufenican were applied on 30 October 1995, to both winter wheat (12.4 ha) and winter barley (6.6 ha) fields. Isoproturon was detected in streamwater samples at both sampling points (H4 - 0.35 ug/l; H5 - 0.36 ug/l) on the first sampling occasion, 14 days after application to both Straits and Radio Fields, but at only sampling point H5 (0.36 ug/l) on 23 November 1995, 22 days after application (Table 4). Isoproturon was again detected (0.65 ug/l) on 25 January 1996 and concentrations detected averaged 0.23 ug/l over the sampling period.

At Harnhill, isoproturon was applied at 1800 g.a.i/ha to Straits and Radio Fields, and to Harnhill Ground Field (adjoining the IFS Farmlet which may also drain into the total IFS export sampling point), whereas it was applied at 1000 and 1500g a.i./ha to two Field Units(4&5) within the IFS Farmlet. The concentrations of isoproturon detected in samples taken on 28 November 1995 and 25 January 1996 were 28% and 48% higher, respectively, in the Conventional Farm Catchment than those detected in the IFS total export sampling point on the same occasions (Table 11).

5.2. Spring-applied herbicides.

Trerulefoot Loading

At Trerulefoot, fenoxyprop ethyl exceeded detection limits in streamwater samples on only one occasion, four days after field application.
In the Conventional farm catchment, the level of fenoxaprop ethyl detected in streamwater downstream from Moor Field(T6) was 46.5 ug/l, almost double that detected in the water course between Wilton House and Undertown Fields(T5). By comparison, it was only detected(26 ug/l) at one of the IFS Farmlet import sampling points (T3), and at a lower level (10.5 ug/l) at the sampling point(T1A) denoting emissions from the eastern boundary of integrated production fields. Levels detected at the IFS total export sampling point(T1) did not exceed import levels, indicating minimum losses of this herbicide from the IFS Farmlet. Fluroxypyr did not exceed detection limits (0.05 ug/l) in any stream water samples(Table 5).

Harnhill Loading

In the IFS Farmlet at Harnhill, 8.5 ug/l of fenoxyprop ethyl detected at the import sampling point(H1), 6.5 ug/l fenoxaprop ethyl was detected in the discharge from the drain outlet (H2A) which contributed to the increased levels at the mid-IFS Farmlet sampling point(H2) and the higher levels detected at the downstream total export sampling point (H3). The levels of fenoxyprop ethyl detected in the water course at the Conventional Farm Catchment were similar to those exported from the IFS Farmlet on 27 April 1995, but were markedly higher in the downstream sampling point(H5) on 17 May (Table 6).

Table 1. **Amounts of isoproturon detected in stream water samples from the IFS Farmlet Catchment at Trerulefoot; 1995/96 cropping season.**

Herbicide applied: isoproturon 14.10.95; 26.10.95; 13.11.95

Date	T4 IFS Import		T3 IFS Import		T2-Import(T4+T3) +IFS(LakeField)		T1A - IFS Farmlet (eastern boundary)		T1 -IFS Farmlet Total Export	
	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)
04.10.95	ND	-	ND	-	ND	-	ND	-	ND	-
19.10.95	ND	-	ND	-	ND	-	ND	-	ND	-
25.10.95	ND	4	ND	2	ND	6	ND	5	ND	11
16.11.95	0.15	15	ND	4	ND	20	ND	24	ND	44
23.11.95	ND	24	ND	6	ND	34	ND	23	ND	57
15.02.96	0.65	36	1.26	16	2.00	51	1.71	25	1.52	76
14.03.96	0.24	-	0.16	-	0.73	-	1.10	-	0.24	-
17.04.96	2.76	12	3.16	2	1.05	14	2.71	9	2.77	23
25.05.96	1.22	-	ND	-	1.46	-	0.97	-	ND	-
Average*	0.56		0.51		0.58		0.72		0.50	

ND= below detection limits (**0.08 ug/l**), Not Detected; - flow guaging not done.
* Average calculated on the basis that Not Detected(ND) values are zero

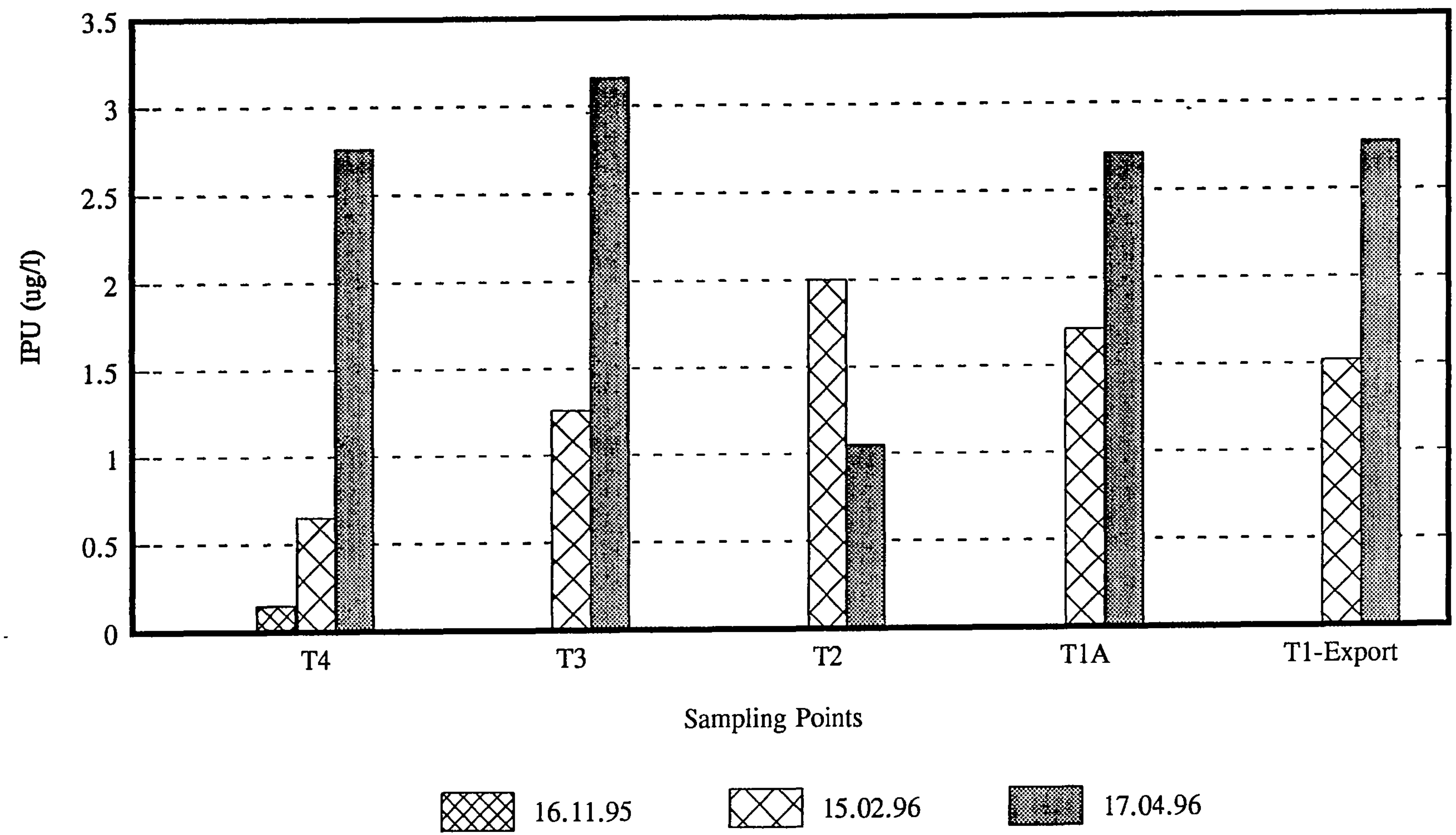


Fig 6.Isoproturon concentration in stream water samples IFS Farmlet Trerulefoot

Table 2. Amounts of isoproturon detected in stream water samples from the Conventional Farm Catchment at Trerulefoot; 1995/96 cropping season (IFS Farmlet export for comparison)

Herbicide applied: isoproturon - 13.11.95.

Date	T5-Wilton House + Undertown Fields		T6 - Moor, Corner, Wilton House Fields		T1 -IFS Farmlet Export	
	concn. (ug/l)	flowrate(l/sec)	concn.(ug/l)	flowrate(l/sec)	concn.(ug/l)	flowrate(l/sec)
04.10.95	ND	-	ND	-	ND	-
19.10.95	ND	-	ND	-	ND	-
25.10.95	ND	2	ND	16	ND	11
16.11.95	0.08	3	ND	7	ND	44
23.11.95	0.09	6	ND	9	ND	57
15.02.96	ND	15	0.87	11	1.52	76
14.03.96	0.19	-	0.32	-	0.24	-
17.04.96	2.71	1	3.00	8	2.77	23
25.05.96	0.63	-	0.54	-	ND	-
Average*	0.41		0.53		0.50	

ND= below detection limits **(0.08 ug/l)**, Not Detected; - flow guaging not done.
* Average calculated on the basis that Not Detected(ND) values are zero

Table 3. Amounts of isoproturon detected in stream water samples from the IFS Farmlet Catchment at Harnhill; 1995/96 cropping season.

Herbicide applied: isoproturon - 19.11.95; 19.01.96

Date	H1-IFS Farmlet import		H2A-(drain outlet)		H2-(mid IFS Farmlet)		H3-IFS Total Export	
	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)
14.11.95	NF	-	ND	-	ND	-	ND	-
22.11.95	NF	-	ND	-	0.35	-	0.28	2
08.12.95	ND	-	ND	-	ND	-	ND	-
14.12.95	NF	-	ND	-	NF	-	ND	4
25.01.96	ND	-	ND	-	ND	1	0.44	3
24.04.96	ND	-	ND	-	ND	1	ND	3
Average *	0.0	-	0.0	-	0.06		0.12	

ND= below detection limits (**0.08 ug/l**), Not Detected; NF= stream not running, No Flow; - flow guaging not done.
* Average calculated on the basis that Not Detected(ND) values are zero

Table 4. **Amounts of isoproturon detected in stream water samples from the Conventional Farm Catchment at Harnhill; (by comparison, that exported from the IFS Farmlet; 1995/96 cropping season).**

Herbicide applied: isoproturon - 30.10.95 (19.11.95; 19.01.96 - IFS Farmlet)

Date	Sampling Point H4		Sampling Point H5		H3-IFS Farmlet Export	
	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)	concn. (ug/l)	flowrate (l/sec)
14.11.95	0.35	-	0.36	-	ND	-
22.11.95	ND	105	0.36	105	0.28	2
08.12.95	ND	-	ND	-	ND	-
14.12.95	ND	694	ND	694	ND	4
25.01.96	ND	408	0.65	408	0.44	3
24.04.96	ND	354	ND	354	ND	3
Average *	0.058		0.23		0.12	

ND= below detection limits (**0.08 ug/l**), Not Detected; - flow guaging not done.
* Average calculated on the basis that Not Detected(ND) values are zero

Table 5. Concentrations of fenoxaprop ethyl(ug/l) detected in stream water samples from Trerulefoot Catchments 1994/1995

Sampling Site	T1	T1A	T2	T3	T4	T5	T6
05 April 1995	ND	ND	ND	ND	ND	ND	ND
26 April 1995	23.0	10.5	23.0	26.0	ND	27.5	46.5
23 May 1995	ND	ND	ND	ND	ND	ND	ND
Detection Limit	2.0 ug/l						

Table 6. Concentrations of fenoxaprop ethyl(ug/l) detected in stream water samples from Harnhill Catchments 1994/1995.

Sampling Site	H1	H2A	H2	H3	H4	H5
06 April 1995	ND	ND	ND	ND	ND	ND
27 April 1995	8.5	6.5	19.5	15.5	9.5	16.5
17 May 1995	15.0	Not running	20.0	15.0	22.5	37.5
01 June 1995	ND	Not running	ND	ND	ND	ND
Detection Limit	2.0 ug/l					

ND = below detection limits, Not detected

5.3. Nutrient Losses

5.3.1. Total Oxidised Nitrogen

Although determinations were done for total oxidised nitrogen, virtually all detected could be regarded as nitrate.

Trerulefoot Catchments

At Trerulefoot, in 1994/5, although levels of total oxidised nitrogen (2.1 - 3.5 mgN/l) were detected in stream water at T1A, representing losses from the IFS Farmlet fields, levels detected at the IFS Farmlet export sampling point did not exceed mean import levels. In the Conventional Farm water courses, levels of total oxidised nitrogen were not appreciably different to those in the IFS Farmlet.

In 1995/96, total oxidised nitrogen levels in stream water from the Conventional Farm were very low during autumn 1995 (range 0.28 - 3.33 mgN/l), but increased slightly in spring 1996. However, concentrations detected did not exceed 8 mgN/l on any sampling occasion, and averaged 3.73 mgN/l over the sampling period (Table 7).

At the IFS Farmlet, concentrations of total oxidised nitrogen in streamwater samples were similar to those detected in the conventional farm catchment. Import levels of total oxidised nitrogen did not exceed 4.25 mgN/l in the autumn, reaching a maximum level of 8.7 mgN/l in spring 1966, with an average of 3.93 mgN/l over the sampling period. Levels detected at the receiving water from the integrated production fields at the eastern border of the IFS Farmlet (T1A) were slightly lower(10%), and averaged 3.51 mgN/l over the sampling period. The concentrations detected at the total export sampling point averaged 3.73 mgN/l, (Table 8).

This lack of appreciable differences between Conventional- and IFS- farmed areas at Trerulefoot was largely expected. The general farm policy for "standard farm practice" has been to move towards more rational use of nutrients and agrochemicals, associated with care and protection of the environment, following experiences gained from the IFS Demonstration Farmlet. Thus relatively low inputs of nutrients are used conventionally on this farm.

Harnhill Catchments

In contrast to Trerulefoot, relatively higher concentrations of total oxidised nitrogen were detected in water courses at Harnhill. This, to some extent, reflects the traditionally greater intensity of inputs by farmers in the Cotswold area.

At the IFS Farmlet in 1994/95, levels importing from the upstream conventional area (H1) gave values ranging from 4.5 mgN/l - 6.5 mgN/l between November and December, with further increases in January. Levels detected in the mid-IFS Farmlet sampling point (H2) and those detected at the total export sampling point(H3) were, on average, only 1 mgN/l higher than those imported.

At the Conventional Farm catchment, baseline concentrations of total oxidised nitrogen in streamwater samples were 4 times higher than those in the IFS Farmlet and, overall, levels detected in subsequent samplings were greater than those from the IFS Farmlet.

In 1995/96 cropping season, there was no stream flow at the IFS Farmlet import point (H1) in November, thus total oxidised nitrogen levels detected in the discharges from the drain outlet (H2A), the mid-IFS Farmlet sampling point(H2) and the total export sampling point (H3) reflect the losses from the integrated production fields. Concentrations ranged from 5.43 - 13.01 mgN/l(average 8.81 mgN/l) at the mid-IFS Farmlet sampling point (H2), and levels were consistently lower at the total export sampling point (H3) which averaged 5.67 mgN/l over the sampling period (Table 9), presumably as a result of dilution from cleaner water draining from land to the North East. Concentrations of total oxidised nitrogen detected in stream water from the Conventional Farm (Ampney Brook) were similar to those detected at the IFS total export sampling point (Table 10).

5.3.2. Phosphate

Trerulefoot Catchments

In 1994/95, overall the sampling period, levels of PO_4-P detected in the stream water importing into the IFS Farmlet(T4) was 4.06 ug P/l, and the mean level exported from the IFS Farmlet (at T1), was 5.79 ug P/l, indicating by extrapolation, 1.73 ug P/l emanating from the integrated production fields in the IFS Farmlet.

In the conventional farm catchment, concentrations of PO_4-P detected in streamwaters ranged from 6.2 ugP/l, at the first sampling occasion, to a maximum of 23.4 ugP/l on 3 November 1994. Overall, the average levels of PO_4-P, from the two sampling points (T5 & T6), were 23 and 14ug P/l, respectively, over the sampling period October 1994 - February 1995, and almost double those from the IFS Farmlet catchment.

In 1995/96, concentrations of PO_4-P detected in streamwater samplings at the Conventional Farm Catchment averaged 33 ugP/l and 17 ugP/l during October/November 1995, whereas concentrations detected in the streamwater at the IFS total export sampling point averaged 12 ugP/l over the same period (Table 12). Nevertheless, there was little difference between the two catchments in concentrations of PO_4-P detected in spring samplings.

In the Conventional Farm, there were marked differences between the two sampling points in the concentrations of PO_4-P detected. In the receiving water from the more steeply sloping Wilton and Undertown Fields (T5), the initial PO_4-P concentration detected on 4 October 1995, following a 15mm "rain trigger", was 57.37 ug/l but in subsequent autumn samplings levels gradually declined (19.21 ugP/l being detected on 23 November following 30mm rain). During spring 1996, concentrations never exceeded 3.12 ugP/l. By comparison, in the receiving waters from Moor and Corner Fields(T6), the initial PO_4-P concentration was 19.86 ug/l, reaching a maximum (30.44 ug/l) on 25 October 1995 with lower concentrations (range 1.99 - 9.39 ugP/l) detected in spring samplings (Table 13). Overall the losses from the IFS Catchment were slightly lower than from the Conventional Catchment.

Harnhill Catchments

At the IFS Farmlet Catchment in 1994/95, PO_4-P was not detected in any stream water samples until 1 December 1994, when a concentration of 1.5 ugP/l was detected in samples taken at the mid-IFS Farmlet(H2). On 8 December 1994, a concentration of 9.4 ugP/l was imported into the IFS Farmlet (H1), with similar amounts detected at the mid-Farmlet point. On this occasion, however, an unexplainable higher concentration (18.8 ugP/l) was detected at the total export sampling point(H3). Nevertheless, in subsequent samplings the PO_4-P levels were substantially lower, and concentrations exported did not exceed the IFS Farmlet import levels. Overall, the phosphate concentrations detected in stream water from the IFS Farmlet were substantially lower (50%) than those detected in streamwater from the Conventional Farm Catchment at Down Ampney.

In 1995/96, on the three occasions when stream flow occurred at the IFS Farmlet import sampling point (December, January and April), concentrations of PO_4-P imported into the IFS Farmlet were 5.5 ugP/l, 11.7 ugP/l and 2.7 ugP/l, respectively, with higher amounts, average 10 ugP/l detected at the mid-IFS Farmlet sampling point. Concentrations of PO_4-P in discharges from the drain outlet ranged from nil detected - 9.9 ug/l, with average loading of 0.24 ugP/sec. With the exception of an unusually high (28.8 ugP/l - tenfold factor) and unexplainable concentration of PO_4-P detected on 25 January 1996, concentrations detected at the total export sampling point were relatively low throughout the sampling period, and averaged 6.4 ugP/l over the whole sampling period (Table 14).

At the Conventional Farm Catchment in 1994/95, 12 ugP/l was detected at the first sampling of stream water, with greater amounts of phosphate detected in subsequent samplings (> 35 ugP/l, on 8 December 1994).

In 1995/96, concentrations of PO_4-P detected at the first two samplings were substantially higher (200 fold) than those concentrations detected in streamwater sampled from the IFS Farmlet (Table 15). Rainfall between 8 and 14 November 1995 totaled 32mm; concentrations of 183 ugP/l and 169 ugP/l were found in samples taken on 14 November from the two Conventional Farm sampling points. By 22 November a further 15mm rain fell, and although concentrations detected were slightly lower (average 129 ugP/l) the highest streamflow occurred in the monitored watercourse. Concentrations dropped substantially in the December samples (17 ugP/l) but were again more than 3 times greater than from the IFS farmlet Catchment. Thereafter, in January and April 1996, amounts detected were similar to those from the IFS Farmlet (Table 15).

The main reasons for the lower PO_4-P concentrations in stream water at the IFS Farmlet, we attribute to improved stability of soil structure, and erosion prevention, through minimum tillage techniques used for integrated crop production establishment (previously this site was soil erosion prone). Furthermore, the relatively higher concentrations detected in the Conventional Farm Catchment watercourse could be due to losses from overland flow and phosphate in sediment yield (soil erosion) as a consequence of ploughing and several subsequent cultivations, which is the standard practice for crop establishment.

Table 7. **Amounts of total oxidised nitrogen detected in stream water samples from the Conventional Farm Catchment at Trerulefoot; 1995/96 cropping season (IFS Farmlet export for comparison).**

Date	T5-Wilton House + Undertown Fields		T6- Moor, Corner, Wilton House Fields		T1 -IFS Farmlet Export	
	concn.(mgN/l)	flowrate (l/sec)	concn.(mgN/l)	flowrate (l/sec)	concn.(mgN/l)	flowrate (l/sec)
04.10.95	2.40	-	1.73	-	1.64	-
19.10.95	1.66	-	0.91	-	2.30	-
25.10.95	3.33	2	0.28	16	1.04	11
16.11.95	3.24	3	1.66	7	2.54	44
23.11.95	2.23	6	0.91	9	1.95	57
15.02.96	7.02	15	7.58	11	6.92	76
14.03.96	3.57	-	7.82	-	7.47	-
17.04.96	6.37	1	5.65	8	6.00	23
25.05.96	nt	-	nt	-	nt	-
Average*	3.73		3.32		3.73	

- flow guaging not done; nt = not tested
Average* calculated on the basis that Not Detected(ND) values are zero

Table 8. **Amounts of total oxidised nitrogen detected in stream water samples from the IFS Farmlet Catchment at Trerulefoot; 1995/96 cropping season.**

Date	T4 IFS Import		T3 IFS Import		T2 - Import (T4+T3) + IFS(LakeField)		T1A - IFS Farmlet (eastern boundary)		T1 -IFS Farmlet Total Export	
	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)
04.10.95	0.90	-	1.73	-	2.40	-	0.81	-	1.64	-
19.10.95	0.91	-	0.91	-	1.92	-	3.29	-	2.30	-
25.10.95	1.28	4	2.92	2	1.85	6	1.66	5	1.04	11
16.11.95	1.86	15	1.38	4	1.86	20	1.19	24	2.54	44
23.11.95	1.37	24	4.25	6	2.53	34	1.19	23	1.95	57
15.02.96	8.35	36	6.31	16	7.38	51	7.24	25	6.92	76
14.03.96	6.59	-	5.98	-	6.35	-	6.52	-	7.47	-
17.04.96	6.46	12	8.70	2	7.13	14	6.20	9	6.00	23
25.05.96	nt	-	nt	-	nt	-	nt	-	nt	-
Average*	3.47		4.03		3.93		3.51		3.73	

- flow guaging not done; nt = not tested
Average* calculated on the basis that Not Detected(ND) values are zero

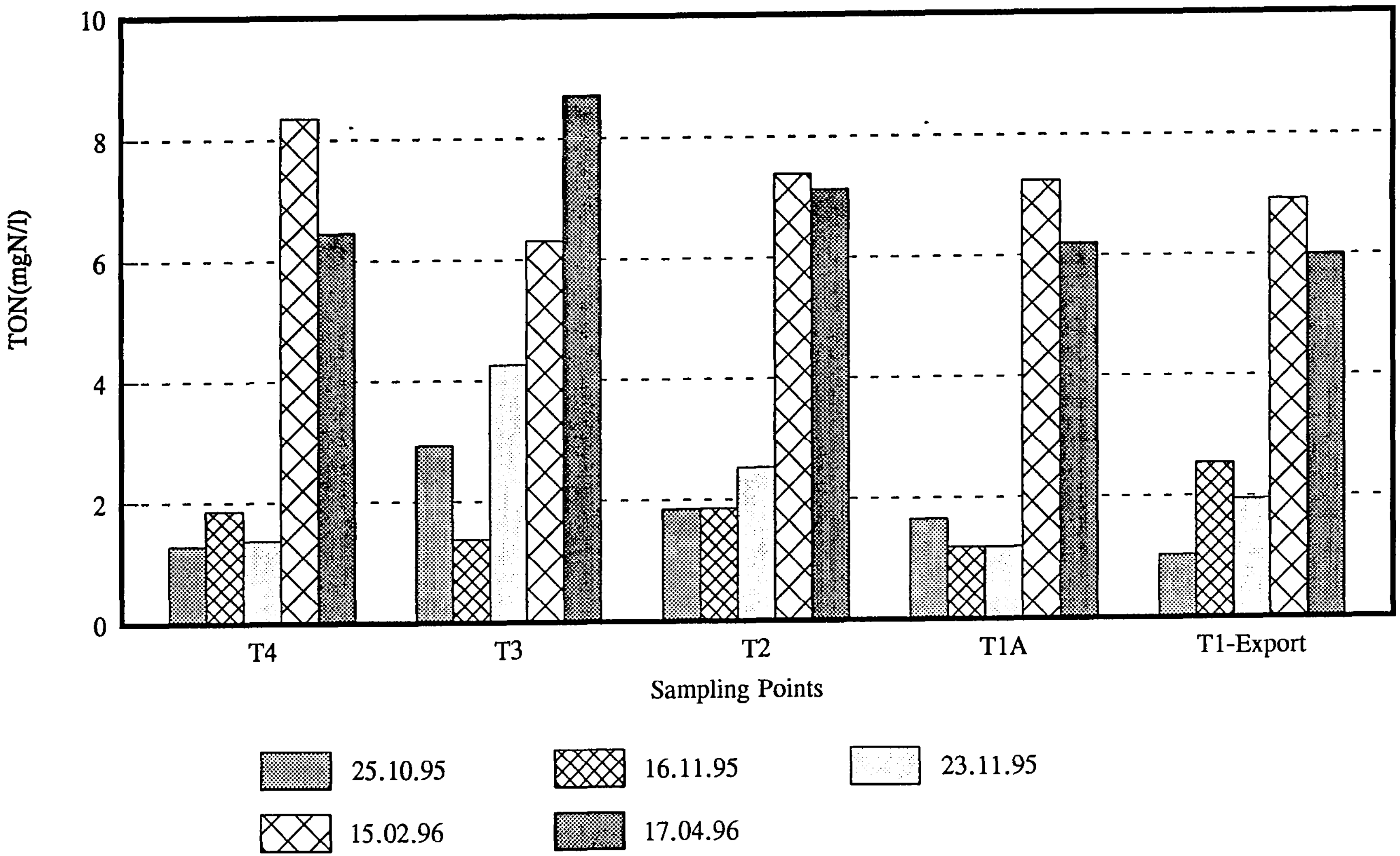


Fig 7. Total oxidised nitrogen concentration in stream water samples IFS Farmlet Trerulefoot

Table 9. **Amounts of total oxidised nitrogen in stream water samples from the IFS Farmlet Catchment at Harnhill; 1995/96 cropping season.**

Date	H1-IFS Farmlet import		H2A-(drain outlet)		H2-(mid IFS Farmlet)		H3-IFS Farmlet Export	
	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)
14.11.95	NF	-	7.55	-	11.71	-	4.14	-
22.11.95	NF	-	2.29	-	5.43	-	3.21	2
08.12.95	6.12	-	9.44	-	13.01	-	5.35	-
14.12.95	NF	-	4.75	-	6.83	-	4.44	4
25.01.96	7.20	-	7.43	-	7.09	1	5.79	3
24.04.96	5.28	-	10.76	-	8.79	1	11.09	3
Average *	6.20	-	7.04	-	8.81	-	5.67	

NF= stream not running, No Flow; - flow guaging not done.
*Average calculated on the basis that Not Detected(ND) values are zero

Table 10. **Amounts of total oxidised nitrogen in stream water samples from the Conventional Farm Catchment at Harnhill; (by comparison, that exported from the IFS Farmlet; 1995/96 cropping season.**

Date	Sampling Point H4		Sampling Point H5		H3-IFS Farmlet Export	
	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)	concn. (mgN/l)	flowrate (l/sec)
14.11.95	3.21	-	3.58	-	4.14	-
22.11.95	2.66	105	2.85	105	3.21	2
08.12.95	5.93	-	5.94	-	5.35	-
14.12.95	5.63	694	4.03	694	4.44	4
25.01.96	6.54	408	6.39	408	5.79	3
24.04.96	11.33	354	10.33	354	11.09	3
Average*	5.88		5.52		5.67	

- flow guaging not done.

Table 11. **Flow Guaging at the Harnhill Catchments - 1995/96.**
Flows measured in Cubic Metres/second.

Date	20.11.95	14.12.95	25.01.96	24.04.96
Sampling Site	IFS Farmlet			
H1	-	-	-	-
H2	-	-	0.001	0.001
H3(Export)	0.002	0.004	0.003	0.003
	Conventional Farmlet			
H4	0.105	0.694	0.408	0.354
H5	0.105	0.694	0.408	0.354

Table 12. **Amounts of phosphate detected in stream water samples from the IFS Farmlet Catchment at Treralefoot; 1995/96 cropping season.**

Date	T4 IFS Import		T3 IFS Import		T2 - Import (T4+T3) + IFS (LakeField)		T1A - IFS Farmlet (eastern boundary)		T1 -IFS Farmlet Total Export	
	concn. (ugP/l)	loading (ug/sec)	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)
04.10.95	11.20	-	11.52	-	13.44	-	19.86	-	15.69	-
19.10.95	19.86	-	21.14	-	16.97	-	ND	-	18.57	-
25.10.95	4.15	4	21.46	2	11.84	6	14.41	5	10.56	11
16.11.95	13.12	15	ND	4	0.30	20	15.37	24	12.48	44
23.11.95	30.11	24	ND	6	7.99	34	ND	23	1.26	57
15.02.96	3.03	36	4.39	16	1.82	51	9.22	25	5.79	76
14.03.96	3.90	-	2.63	-	1.87	-	3.34	-	4.10	-
17.04.96	2.20	12	11.70	2	3.42	14	5.63	9	2.32	23
25.05.96	3.71	-	2.71	-	3.76	-	7.79	-	4.92	-
Average*	10.14		8.93		6.82		8.40		8.41	

ND= Not Detected; - flow guaging not done;
* Average calculated on the basis that Not Detected(ND) values are zero

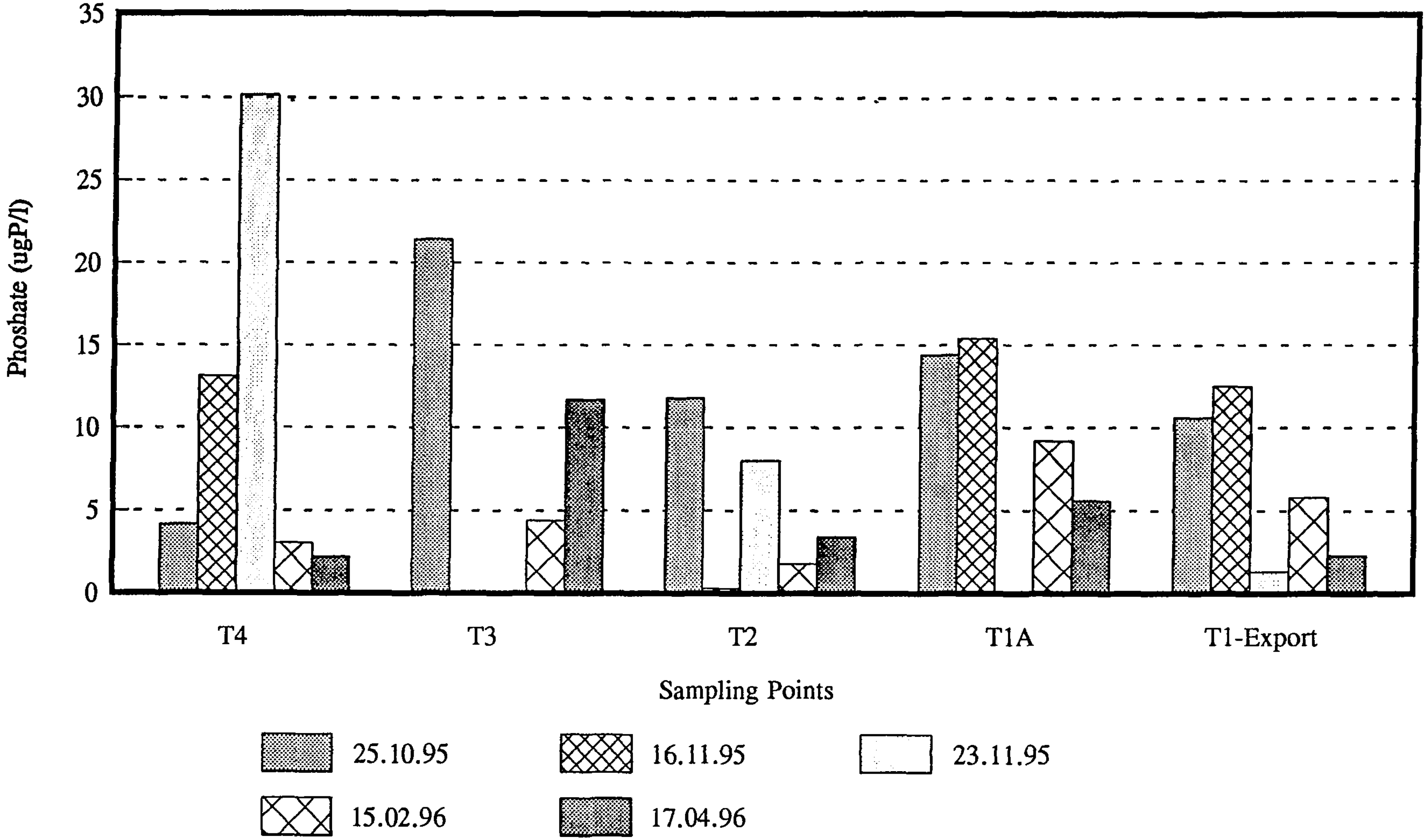


Fig 8. Total phosphate concentration in stream water samples IFS Farmlet Trerulefoot

Table 13. **Amounts of phosphate detected in stream water samples from the Conventional Farm Catchment at Trerulefoot; 1995/96 cropping season (IFS Farmlet export for comparison).**

Date	T5- Wilton House + Undertown Fields		T6-Moor,Corner, Wilton House Fields		T1 -IFS Farmlet Export	
	concn.(ugP/l)	flowrate (l/sec)	concn.(ugP/l)	flowrate (l/sec)	concn.(ugP/l)	flowrate(l/sec)
04.10.95	57.37	-	19.86	-	15.69	-
19.10.95	34.28	-	7.35	-	18.57	-
25.10.95	35.89	2	30.44	16	10.56	11
16.11.95	16.97	3	21.14	7	12.48	44
23.11.95	19.21	6	5.11	9	1.26	57
15.02.96	2.84	15	4.05	11	5.79	76
14.03.96	3.12	-	1.99	-	4.10	-
17.04.96	1.87	1	3.82	8	2.32	23
25.05.96	3.03	-	9.39	-	4.92	-
Average	19.40		11.46		8.41	

- flow guaging not done;

Table 14. Amounts of phosphate in stream water samples from the IFS Farmlet Catchment at Harnhill; 1995/96 cropping season.

Date	H1-IFS Farmlet import		H2A-(drain outlet)		H2-(mid IFS Farmlet)		H3-IFS Total Export	
	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)
14.11.95	NF	-	0.00	-	2.54	-	0.00	-
22.11.95	NF	-	9.88	-	17.22	-	0.42	2
08.12.95	5.49	-	2.22	-	15.31	-	3.87	-
14.12.95	NF	-	6.78	-	11.43	-	2.76	4
25.01.96	11.73	-	4.66	-	11.51	1	28.77	3
24.04.96	2.67	-	3.14	-	1.70	1	2.67	3
Average*	6.63	-	4.45		9.95		6.42	

NF= stream not running, No Flow; - flow guaging not done.

Table 15. **Amounts of phosphate in stream water samples from the Conventional Farm Catchment at Harnhill; (by comparison, that exported from the IFS Farmlet; 1995/96 cropping season.**

Date	Sampling Point H4		Sampling Point H5		H3-IFS Farmlet Export	
	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)	concn. (ugP/l)	flowrate (l/sec)
14.11.95	168.60	-	183.30	-	0.00	-
22.11.95	127.60	105	131.30	105	0.42	2
08.12.95	17.13	-	13.94	-	3.87	-
14.12.95	17.71	694	14.40	694	2.76	4
25.01.96	27.72	408	27.99	408	28.77	3
24.04.96	2.78	354	2.12	354	2.67	3
Average*	60.26		62.18		6.42	

- flow guaging not done.

Table 16. **Flow Guaging at the Trerulefoot Catchments - 1995/96. Flows measured in Cubic Metres/second.**

Date	25.10.95	16.11.95	23.11.95	15.02.96	17.04.96
Sampling Site	IFS Farmlet				
T 4	0.004	0.015	0.024	0.036	0.012
T 3	0.002	0.004	0.006	0.016	0.002
T 2	0.006	0.020	0.034	0.051	0.014
T 1A	0.005	0.024	0.023	0.025	0.009
T 1(Export)	0.011	0.044	0.057	0.076	0.023
	Conventional Farmlet				
T 5	0.002	0.003	0.006	0.015	0.001
T 6	0.016	0.007	0.009	0.011	0.008

5.4. The LIFE Project: Field 56.

The soil water deficit following the 1995 dry summer and the subsequent lack of rain during autumn limited the frequency of discharges from drain outlets and sampling occasions. Discharges from drain outlets first occurred on 20 December 1995, 50 days after application of herbicides. The field drains ran again two days later, then not again until 2 January 1996. Thereafter, discharges occurred on 5 and 12 January, but only from drain outlets in the Conventional Production System (Field Unit 561). No further discharges occurred on this site throughout spring and summer 1996.

On the first sampling occasion, 20 December 1995, isoproturon concentrations did not exceed detection limits (0.08 ug/l). Isoproturon (range 0.19 - 0.36 ug/l) was detected in drain water discharge samples from the conventional system at the four sampling occasion thereafter, but it did not exceed detection limits in any drain water discharged from the integrated production system (Table 17). Although the limited drain flow frequency during autumn and winter reduced the number of sampling occasions, substantial reductions were obtained in the losses of isoproturon in drain discharges from the integrated production system compared to the conventional system. A direct comparison of loadings at this site is seen as legitimate, as the Field Units are of equal size and design.
Diflufenican did not exceed detection limits (0.02 ug/l) in any sample taken.

On each of the three occasions when field drains ran from both conventional and integrated systems, total oxidised nitrogen concentrations detected in the drain discharge samples from the integrated field units were significantly lower (63%, 58% and 35% reductions, respectively) than those detected in discharges from the conventional field unit, with an average overall reduction in loading of 82% (Table 17).
On the first occasion when the field drains ran, greater amounts of phosphate were detected in the water samples taken from field drain discharges from the conventional system (164.9 ugP/l) than from the integrated production system (45.63 ugP/l). Thereafter, levels detected were very low from both production systems. Average loading of phosphate in drain outlet discharges was 81% lower from the integrated production system than from the conventional system (Table 17).

Table 17. Summary of event data and measured concentrations of isoproturon, nitrate and phosphate in drainflow water emanating from wheat crops grown under conventional and integrated production systems.

Date	Treatment	Drainflow rate (l/min)	Isoproturon (ug)		T.O. Nitrogen (mg)		Phosphate (ug)	
			concn./l	loading/sec	concn./l	loading /sec	concn./l	loading /sec
20.12.95	Conventional	3.375	ND	ND	46.96	2.630	164.97	
	Integrated	1.130	ND	ND	17.37	0.327	45.63	
22.12.95	Conventional	5.850	0.36	0.035	53.21	5.190	5.91	5.91
	Integrated	1.830	ND	<0.002	22.16	0.676	9.26	9.26
02.01.96	Conventional	1.481	0.19	0.005	40.60	1.001	3.09	3.09
	Integrated	0.310	ND	<0.0004	26.59	0.138	5.59	5.59
05.01.96	Conventional	0.632	0.29	0.003	40.76	0.430	2.31	2.31
	Integrated	Not running	nt	nt	nt	nt	nt	nt
12.01.96	Conventional	2.550	0.27	0.011	31.67	1.346	1.54	1.54
	Integrated	Not running		nt	nt	nt	nt	nt
12.02.96	Conventional	**Reservoir sample. *NB***		ND	27.60		6.73	6.73
	Integrated			ND	3.73		ND	ND
Detection Limit			**0.08ug/l**					

ND (below detection limits) = Nil Detected; nt = not tested; ***NB*** accumulated drainage 1/2/96 - 12/2/96.

5.5. The LIFE Project: Field 59.

Comparative studies were done on an 8° slope in a field adjacent to LIFE Field 56. Surface run-off, erosion and loss of sediment-associated total-P and available-P was measured using 5 x 30 m plots, hydrologically isolated to a depth of 30 cm to prevent run-off from entering. For crops grown under conventional/standard farm practice regimes, the previous crop residues were removed. The soil was then ploughed, with associated cultivations prior to sowing, and 90 kg/ha P_2O_5 basal fertiliser was applied. By comparison, for crops grown under the less-intensive integrated production system, the previous crop residues were chopped and left in situ. The crop was then established using a one-pass, non-inversion tillage system (Dutzi), and only 60 kg/ha P_2O_5 basal fertiliser was applied.

In the integrated system, with crop residues incorporated in the top 10 cm soil, run-off was reduced by 48%, total sediment loss (erosion) was reduced by 68% and Total P loss by 81% compared with the conventional ploughed system. The effect of these two systems on available- P (sodium bicarbonate extractable) in the surface soil (0-5cm), varied according to the time of year. Following tillage, the available- P in the surface soil of integrated production treatments was higher than in the conventional treatments, despite the lower input of P_2O_5. This was attributed to non-inversion of the soil. However, this difference had little impact on the annual available- P loss, since the sediment loss was so much higher from the conventionally ploughed fields (Table 18).

Furthermore, little erosion occurred in the period immediately after tillage, due to high infiltration rates in all fields at this time. Following post-harvest application of higher amounts of P_2O_5 to the conventional cropping areas, the available- P concentration of the surface soil was higher, at the time of maximum erosion, and considered responsible for the 73% increase in sediment-associated P loss compared to the less-intensive, integrated production crops. (Donaldson et al., 1996).

Table 18. Annual losses from run-off, sediment and total- and available-P in systems comparisons at Long Ashton.

Treatment	Run-off (l/ha)	Sediment yield (kg/ha)	Total P (kg/ha)	Available P (kg/ha)
Conventional/SFP	213,328	2045.3	2.21	3×10^{-2}
Integrated/LI	110,275	648.7	0.42	8×10^{-3}

6. DISCUSSION

Although herbicides, such as propyzamide (Kerb), triallate (Avadex) and trifluralin (Treflan) are considered to be highly residual chemicals, the data obtained from this study indicate that they may not necessarily be leachable because they are usually held in soil colloids. This can support the use of these chemicals as opposed to the more leachable products such as isoproturon (IPU) and fenoxaprop-ethyl (Cheetah), which are usually applied in higher volumes.

In future, there may be restrictions imposed on the use of IPU, especially at the current rate of application (5 l/ha), with a move towards a lower rate (3 l/ha). Indeed, when isoproturon is used in weed control strategies for integrated production systems (IFS) seldom is more than 2 l/ha of IPU applied. There may also be a further potential problem, with the proposed increased use of fenoxaprop-ethyl in the autumn, which is more readily leachable, as a replacement for isoproturon. Furthermore, farmers are using diflufenican as an inexpensive broad-leaf weed control agent, and it is often used in mixtures with relatively high rates of isoproturon (e.g Javelin Gold). This could lead to an increase in the potential loading of isoproturon to watercourses.

Nevertheless, if diflufenican and/or isoproturon were more commonly mixed with less mobile products, such as pendimethalin, chlorotoluron or methabenzthiazuron, this could decrease their overall loading and reduce the potential for leaching. Another confounding factor is that isoproturon is considerably cheaper (£20 at full recommended rate) compared to the contact herbicides (ca £70 at full recommended rate). The use of propyzamide for weed control in oilseed rape grown under integrated production guidelines, is not generally accepted by many farmers, because of its comparatively slow rate of weed kill; farmers prefer the more faster acting graminicides which are used at higher rates, and which again are more leachable.

Common farm practice is to apply an intensive autumn herbicide programme, for grass and broad leaf weed control, with less intensive herbicide use in the spring. However, the policy for integrated production is generally to avoid using leachable products in the autumn, and direct the strategies towards contact herbicides which have a lower emission potential and are spring-applied. This strategy has, in part, contributed to the somewhat higher loading of the graminicide, fenoxaprop-ethyl to the IFS farmlets - but data gained in this study indicates that emissions of fenoxaprop-ethyl into streamwaters occur less frequently than other herbicides.

The data gained from monitoring of water courses bordering on or within the IFS Farmlets studied, and those within more conventionally farmed areas, indicate that during most of the autumn and early spring sampling occasions the herbicides applied to these catchments, and detected in the streamwater, were either below the detection limits for the respective herbicides, or were generally low. Although the practices adopted for integrated production (IFS) may well reduce the total export of herbicides into "controlled waters" there are insufficient samples to confirm this.

In the IFS Farmlet at Harnhill, there were two upstream conventionally farmed fields, both of which received autumn applications of isoproturon and diflufenican, and at much higher rates than those used in the IFS Farmlet Field Units. Whilst the import from these two fields into the IFS Farmlet was monitored in both years, isoproturon only exceeded detection limits in the first streamwater sample after application in 1994. However, although it is likely *that* some emissions from an adjacent conventionally farmed field (winter wheat and winter barley) could have been imported into the streamwater above the mid-IFS Farmlet sampling point(H2), the field drainage map of the area indicates that these emissions are more likely to be detected at the IFS total export sampling point(H3). This may, in part, explain some of the relatively higher levels of isoproturon and diflufenican detected in the 1994/95 cropping season. Nevertheless, the total export of these herbicides from the IFS Farmlet catchment did not greatly exceed import levels overall. This may also account for similar responses in levels of total oxidised nitrogen detected at the export sampling point(H3).

During the second year of monitoring streamwaters, flow gauging measurements were done. Whilst this provided the individual catchment loading potential for herbicides and nutrients, differences between the conventional and integrated production systems could not be directly compared due to the substantial differences in stream flow rate between catchments, and lack of detailed knowledge of the exact cropping areas receiving conventional inputs.

Data obtained from the monitoring of total oxidised nitrogen and phosphate in these streamwater catchments at both sites showed that whilst there were only small differences between the conventional and integrated catchments in total oxidised nitrogen concentrations detected in streamwater samples, much higher concentrations of phosphate were detected in streamwater samples from the conventionally farmed areas during the autumn period. This response in phosphate emissions we attribute mainly to differences in cultivation practices. In conventional production systems, ploughing and associated cultivations for crop establishment are done earlier (August/September) for September sowing, especially at Down Ampney. This practice of complete soil inversion, leaves bare ground during the intercrop period which is more likely to increase the potential for phosphate loss and soil erosion.

In integrated production systems (IFS Farmlet areas), by comparison, the lower emissions could be attributed to several interacting factors:

- although no real difference in nitrate emissions were shown on the demonstration farms, the more judicious use(less) of nitrogen in the previous years crops lowered the total load onto the soil (residual soil nitrogen);

- the encouragement of natural regeneration (weeds and volunteer crops) and the presence of surface crop residues which promote a higher soil-cover index during the intercrop period in order to reduce losses/emissions and soil erosion;

- the use of soil conservation tillage for later crop establishment in autumn (October), which not only provides improvements in soil structure over time, but contributes greatly to the prevention of soil erosion and loss of nutrients by run-off.

As much of the erosive rainfall in the UK occurs in the autumn, the amount of soil surface cover during this period will be critical to the annual rate of erosion. During this period, the surface cover (Soil Cover Index) on the less-intensive, integrated production field areas was well above the 30% generally considered to be the threshold for erosion control.

Thus, non-inversion tillage, an integral component of LIFE integrated production systems, was effective in reducing soil erosion and the loss of sediment-associated P. This effect is attributed to improvments in soil aggregate stability and soil cover which protects the soil surface from raindrop impact, and maintains higher infiltration rates throughout the year.

Despite the somewhat climatically-determined limited frequency of drainwater discharge sampling during this study, the data from the experimental plots provides some clear indication that the integrated production system reduces emissions of isoproturon, total oxidised nitrogen and phosphate from drainwater outflows. Furthermore, isoproturon levels did not exceed detection limits in any drain water discharged from the integrated field units, although it should be noted that the herbicide loading on the integrated soil was half that of the conventional system, although these differences could not be shown on the demonstration farms for pesticides and nitrate. On the occasions when all drains flowed, the average total oxidised nitrogen emissions from the integrated production system was reduced by 53%, and phosphate emissions by 65% compared with the conventional system. This effect, supported by data from the supplementary study, was mainly attributed to soil conservation tillage practices (non-inversion tillage) in the integrated system. It should be noted, however, that in the integrated field unit, non-inversion tillage has been adopted during the previous five years and, as a consequence, has markedly affected soil physical, chemical and biological parameters, especially soil structure. The exact time period necessary before such changes are established has not yet been determined.

7. RECOMMENDATION FOR FURTHER STUDY

Non-inversion tillage, therefore, appears to offer substantial improvements in emissions and diffuse pollution from arable crop land. Strategies for protection of water quality should, therefore, consider implementation in risk areas/catchments. One option would be to adopt this practice either in whole fields or along the boundaries of fields adjacent to controlled waters, but further studies are necessary to determine the optimal cropland-width required. Furthermore, it is not yet known whether similar responses could be obtained after just one year of non-inversion tillage or whether these effects only develop over time.

REFERENCES

El Titi A; Boller E F; Gendrier J P. 1993. Integrated Production: Principles and Technical Guidelines. *IOBC/WPRS Bulletin* 16, 96pp

Jordan V W L; Hutcheon J A. 1993. Less intensive integrated farming systems for arable crop production and environmental protection. *Proceedings No 346, The Fertiliser Society, Peterborough, UK,* 32pp

Jordan V W L; Hutcheon J A. 1994. Economic viability of less-intensive farming systems to meet current and future policy requirements: 5-year summary of the LIFE project. *Aspects of Applied Biology* 40, 61-68.

APPENDIX

Appendix 1. Herbicide inputs/ha and loading to the Conventional Farm Catchment - Trerulefoot - 1995/96 Cropping Season

MOOR	CORNER	UNDERTOWN	WILTON HOUSE
W.Barley	W.Barley	W.Wheat	W.Wheat
pendimethalin 800g (26/10/95)	pendimethalin 400g isoproturon 1000g (14/10/95)	ioxynil 112g bromoxynil 112g mecoprop-p 896g (28/10/95) isoproturon 1000g diflufenican 25g (13/11/95)	mecoprop-p 600g isoproturon 500g diflufenican 25g (13.11/95)
15.51ha	5.25ha	4.65ha	7.65ha

TOTAL LOADING:

Herbicide		Area Applied	Average loading/ha
pendimethalin	14 508g	20.76 ha	699g/ha
diflufenican	307g	12.30 ha	25g/ha
isoproturon	13 725g	17.55 ha	782g/ha
ioxynil	521g	4.65 ha	112g/ha
mecoprop-p	8 756g	12.30 ha	712g/ha
bromoxynil	521g	4.65 ha	112g/ha

Appendix 2. Herbicide inputs/ha and loading to IFS Farmlet - Trerulefoot - 1995/96 Cropping Season.

RYEGATES	BLACKPOND	LAKE	TOPBARN PARK	BARN PARK	GOVERNMENT
S.OSRape	W.Oats	W.Barley	S.Beans	W.Barley	W.Wheat
Nil	Nil	pendimethalin 400g isoproturon 1000g	Nil	trifluralin 1104g (12/10/95) mecoprop-p 600g diflufenican 25g isoproturon 250g (13/11/95)	diflufenican 40g isoproturon 900g (13/11/95)
6.58ha	6.27ha	5.66ha	2.44ha	8.33ha	7.95ha

TOTAL LOADING:

Herbicide		Area Applied	Average loading/ha
pendimethalin	2 264g	5.66 ha	400g/ha
isoproturon	14 897g	21.94 ha	679g/ha
trifluralin	9 196g	8.33 ha	1104g/ha
mecoprop-p	4 998g	8.33 ha	600g/ha
diflufenican	526g	16.28 ha	32g/ha

Appendix 3. Herbicide inputs/ha and loading to the Conventional Farm Catchment - Eysey Manor (Harnhill): 1995/96 Cropping Season

STRAITS		RADIO	
W.Barley		W.Barley	
isoproturon simazine trifluralin diflufenican (30/10/95)	1800g 200g 400g 40g	isoproturon simazine trifluralin diflufenican (30/10/95)	1800g 200g 400g 40g
6.56ha		8.17ha	

TOTAL LOADING

Herbicide		Area Applied	Average loading/ha
isoproturon	26 514g	14.73 ha	1800g/ha
simazine	2 946g	14.73 ha	200g/ha
trifluralin	5 892g	14.73 ha	400g/ha
diflufenican	589g	14.73 ha	40g/ha

Appendix 4. Herbicide inputs/ha and loading to the IFS Farmlet area - Harnhill - 1995/96 Cropping Season.

F.UNIT 1	F.UNIT 2	F.UNIT 3	F.UNIT 4	F.UNIT 5	F.UNIT 6
Grass Ley	W.Wheat	S.OSRape	W.Wheat	W.Barley	W.Beans
Nil	Nil	Nil	fenoxaprop-e 22g isoproturon 1000g (19/11/95)	isoproturon 1500g trifluralin 1000g diflufenican 20g (19/01/96)	Nil
4.56ha	4.69ha	4.48ha	4.77ha	4.78ha	4.66ha

TOTAL LOADING -IFS FARMLET

Herbicide		Area Applied	Average loading/ha
fenoxaprop-ethyl	105g	4.77 ha	22g/ha
isoproturon	9 550g	9.55 ha	1000g/ha
trifluralin	4 780g	4.78 ha	1000g/ha
diflufenican	96g	4.78 ha	20g/ha

Appendix 5. Herbicide inputs/ha to the Conventional Farm Fields bordering the IFS Farmlet Catchment - Harnhill: 1995/96 Cropping Season

THE PLAIN		HARNHILL GROUND		LONG GROUND
W.OSRape		W.Barley		Organic S.Oats
metazachlor	750g	isoproturon	1800g	Nil
fluazifop	38g	simazine	200g	
(29/09/95)		trifluralin	400g	
propaquizafop	50g	diflufenican	40g	
(28/10/95)		(02/11/95)		
37.12ha		19.38ha		

TOTAL LOADING

Herbicide		Area Applied	Average loading/ha
metazachlor	27 840g	37.12 ha	750g/ha
fluazifop	1 411g	37.12 ha	38g/ha
propaquizafop	1 856g	37.12 ha	50g/ha
isoproturon	34 884g	19.38 ha	1800g/ha
simazine	3 876g	19.38 ha	200g/ha
trifluralin	7 752g	19.38 ha	400g/ha
diflufenican	775g	19.38 ha	40g/ha

Appendix 6. LIFE Field 56 - Previous crop management - 1994/5

FIELD UNIT/SYSTEM	561 / SFP	562 / IFS	563 / IFS	564 /IFS
INPUT/CROP- 1995	OILSEED RAPE	WINTER WHEAT	WINTER WHEAT	SPRING BEANS
Cultivation Variety/sown	Plough Apex: 17/8/94	Incorporate Genesis: 3/10/94	Incorporate Spark: 3/10/94	Incorporate Victor: 25/3/95
Basal Fertiliser	75P: 75K:	99P: 49K:	85P: 85K:	49P: 49K:
Nitrogen	80N: 10/3/95 80N: 9/4/95	101N: 21/4/95 15N: 26/5/95	100N: 23/4/95 15N:16N26/5/95: 9/6/95	
Herbicides	propyzamide: 720g 1/10/94 cycloxidim: 200g 6/4/95	metsulfuron: 3g bromox/ioxynil: 85/85g 4/4/95 fenoxaprop: 24g fluroxpyr: 100g 18/5/95	metsulfuron: 2g 14/3/95 Harrow (x3)	propaquizafop: 150g 22/5/95
Fungicides	vinclozolin: 500g	propiconazole: 125g tridemorph: 330g	tebuconazole: 188g triadimenol: 94g	
Insecticides	cypermethrin: 20g	cypermethrin: 10g pirimicarb: 75g	pirimicarb 70g	
Dessicant	glyphosate: 1080g			glyphosate: 1080g
Yield	1.84t/ha	8.62t/ha	8.10t/ha	3.14t/ha
Variable Costs	£ 321.41	£ 191.12	£ 152.75	£ 222.23
Gross Margin	£ 524.08	£1123.64	£1098.94	£ 527.66

Appendix 7. LIFE Field 56 : Current crop management - 1995/96 Cropping year.

FIELD UNIT/SYSTEM	561 / SFP	562 / IFS	563 / IFS	564 / IFS
INPUT/CROP- 1996	WINTER WHEAT	SPRING OS RAPE	SPRING BEANS	WINTER WHEAT
Cultivation Variety/sown	Simba + Plough Hereward: 28/9/95	Dynadrive: 9/10/95 Spok: 29/3/96	Dynadrive: 9/10/95 Victor: 29/3/96	Simba + Dutzi Spark: 9/10/95
Herbicide:	isoproturon 1875g diflufenican 75g 1/11/95	glyphosate: 720g 28/9/95	glyphosate: 240g 28/9/95	isoproturon: 750g diflufenican: 25g 1/11/95
OUTFLOW FROM FIELD DRAINS BEGAN 28/11/95 - FIRST SAMPLE TAKEN ***The following crop management inputs were applied after drainflow sampling ceased***				
Nutrients	71P: 96K: 11S: 158N:	20S: 79N:		71P: 71K: 11S: 151N:
Agrochemicals/ Crop Protection	cypermethrin: 20g chlormequat: 1120g epoxiconazole: 125g fluroxypyr: 200g propiconazole: 125g tridemorph: 375g chlorothalonil: 500g chlorpyrifos 400g	Harrow (15/5)	Harrow (15/5)	metsulfuron methyl: 4g (27/4) fluroxypyr: 200g tebuconazole: 188g
Yield*	10.05t/ha	1.63 t/ha	3.77 t/ha	8.05 t/ha
Variable Costs	£278.80	£120.67	£110.29	£206.82
Gross Margin#	£1174.91	£665.82	£758.89	£872.29

does not include operational costs