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# **THE FATE OF FERTILISER PHOSPHORUS IN WHAREKOHE PODZOLS**

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## ABSTRACT

During the 1980's and early 1990's, the then Ministry of Agriculture and Fisheries (MAF) Soil Fertility Service used the mass balance Computer Fertiliser Advisory Service (CFAS) model to make phosphorus (P) fertiliser recommendations where P requirements were calculated to replace losses from the cycling P pool via the soil and animals. In the late 1980's, concerns were raised that higher P application rates than those calculated by the CFAS model were necessary to maintain Olsen P levels on Wharekohe podzols. The soil loss factor (SLF) was identified as the model parameter which most likely led to the inability of the CFAS model to predict P requirements on these podzols. The new Outlook model also uses a mass balance approach incorporating a soil P loss parameter to calculate pasture P requirements. In this study the apparent limitation of the CFAS model to predict the maintenance P requirements of the Wharekohe soils, and the appropriateness of the soil loss parameter used in the New Outlook model, was investigated by (a) determining the fate of applied fertiliser P, (b) examining the possible mechanisms for any soil P retention or loss, (c) quantifying the SLF and (d) modeling the fate of applied fertiliser P.

A chronosequence study found that pasture development resulted in an increase in total soil P to the top of the E horizon with increased P movement down the profile with increasing pasture age. The Wharekohe silt loam appears to have a maximum P storage capacity which is reached by 8 years in the 0-3 cm depth (approx. 166 kg applied P/ha) and by 11 years in the 0-7.5 cm depth (approx. 350 kg applied P/ha). The maximum total P storage capacity can mostly be attributed to a maximum inorganic P (Pi) storage capacity. Sodium hydroxide (NaOH) extractable iron and aluminium-Pi was found to be limited in the Wharekohe soil, due to its low sesquioxide content, in comparison to other New Zealand soils. Once the P storage capacity at each depth is reached there is little further accumulation of applied P and much of the P applied in subsequent application is lost from the topsoil in runoff waters. Up to 65% of the applied P could not be accounted for by animal loss or accumulation in the top 7.5 cm of older sites (>30 years).

A glass house leaching study using intact soil cores confirmed that substantial quantities of applied P can be transported in subsurface water movement through Wharekohe podzols. Forty times more P moved through the Wharekohe soil cores than through cores of the yellow brown earth, Aponga clay ( $\leq 45.6 \mu\text{g/ml}$  in contrast to  $\leq 1.07 \mu\text{g P/ml}$ ). In a field study using suction cups, concentrations of up to  $18.65 \mu\text{g P/ml}$  were obtained in soil water sampled under fertilised Wharekohe silt loam plots in comparison to  $< 2 \mu\text{g P/ml}$  under unfertilised controls. Movement of dissolved P occurred mostly as DIP after the application

of fertiliser P in the glasshouse and field studies. No difference in P movement could be detected in relation to development history in the glasshouse leaching study or in the field study, although the ability of the Wharekohe silt loam to retain added fertiliser P was found to decline with pasture development in a laboratory based P retention study.

Soil loss factors calculated for the Wharekohe podzols from small plot field trials varied enormously (0.04 in the first year to 1.68 over the two year trial period) as a consequence of the large variation in the rate of P required to maintain a steady Olsen P level at each site. Consequently, it was not possible to determine if the SLF of 0.4 used for podzols in the CFAS model was appropriate. The component of the SLF due to non-labile P accumulation, calculated from the chronosequence data, decreased with pasture age. As P applied surplus to animal production requirements and P accumulation is lost from the root zone in runoff, the SLF should be reduced with increasing pasture age or else P runoff losses will increase.

Relationships between pasture age and available  $P_i$ , organic P, strongly sorbed/precipitated and residual P, and total P accumulation in the top 7.5 cm of a Wharekohe silt loam were successfully modelled. The annual total soil P accumulation was described in a model which was then incorporated into the Phosphorus in Runoff in High Loss Soils (PRIHLS) model developed to predict potential runoff P losses. Runoff P losses predicted by PRIHLS from the Wharekohe silt loam are nearly 3 times higher from older pasture (>30 years) where the Outlook model is used to calculate P requirements (36 kg P/ha lost in runoff from a calculated P requirement of 44 kg P/ha) compared to the CFAS model (13 kg P/ha lost in runoff from a calculated P requirement of 21 kg P/ha), due to the higher soil loss parameter assigned to the Wharekohe soils in the Outlook model. Such high runoff P losses represent a cost to New Zealand both economically, and environmentally through increased P inputs to water ways leading to possible eutrophication. When runoff P losses have been quantified, through further research, they could be used in the PRIHLS model to predict P requirements and would enable more informed decisions to be made about balanced P fertiliser use on Wharekohe podzols.

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## TABLE OF CONTENTS

ABSTRACT .....	i
ACKNOWLEDGMENTS .....	iii
TABLE OF CONTENTS .....	iv
LIST OF FIGURES .....	x
LIST OF TABLES .....	xiii

### CHAPTER 1

INTRODUCTION .....	1
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### CHAPTER 2

#### REVIEW OF THE LITERATURE

2.1	INTRODUCTION .....	5
2.2	THE PHOSPHORUS CYCLE UNDER GRAZED PASTURE .....	5
2.3	SOIL PHOSPHORUS .....	7
2.4	FATE OF FERTILISER P IN NEW ZEALAND SOILS UNDER PERMANENT PASTURE .....	8
	2.4.1 Total Soil P .....	9
	2.4.2 Inorganic Soil P .....	9
	2.4.3. Organic Soil P .....	10
	2.4.4 Losses of Applied P from the Pasture Root Zone .....	12
	2.4.5 Other Chemical Characteristics .....	12
2.5	FATE OF FERTILISER P IN PODZOLS .....	13
	2.5.1 The Podzol .....	13
	2.5.1.1 Podzol Development .....	13
	2.5.1.2 Characteristics of Podzols .....	13
	2.5.1.3 Podzol Classification .....	14
	2.5.2 Phosphorus Chemistry of Podzols .....	16
	2.5.2.1 Phosphorus in Undeveloped Podzols .....	16
	2.5.2.2 Podzol Pasture P Chronosequence Studies .....	18
	2.5.2.3 Losses of P from New Zealand Podzols .....	19
2.6	MODELLING P FERTILISER REQUIREMENTS .....	21
	2.6.1 CFAS Model .....	22
	2.6.1.1 Sensitivity of Calculated P Requirements to Incorrect Estimation of Model Parameters .....	24
	2.6.1.2 Modifications to the CFAS Model .....	27
	2.6.1.3 Difficulties with the CFAS model on Wharekohe soils .....	29

2.6.2	P Requirement Models Developed Since the CFAS Model .....	32
2.7	SUMMARY OF LITERATURE REVIEW .....	33

### CHAPTER 3 FATE OF APPLIED P

3.1	INTRODUCTION .....	36
3.2	OBJECTIVES .....	37
3.3	MATERIALS AND METHODS .....	38
3.3.1	Site Selection .....	38
3.3.2	Fertiliser and Lime History .....	39
3.3.3	Soil Sampling .....	42
3.3.4	Soil Analysis .....	44
3.3.4.1	Total P .....	44
3.3.4.2	Olsen P .....	44
3.3.5	Pasture Sampling and Analysis .....	45
3.3.5.1	Dry Matter Yield .....	45
3.3.5.2	Botanical Composition .....	45
3.3.5.3	N and P Concentration .....	45
3.3.6	Statistical Analysis .....	46
3.4	RESULTS AND DISCUSSION .....	47
3.4.1	Effect of Pasture Development on the Fate of Applied P .....	47
3.4.1.1	Total P .....	47
3.4.1.2	Losses of Applied P .....	56
3.4.2	Effect of Pasture Development on Olsen P .....	61
3.4.3	Effect of Pasture Development on Pasture Production and Composition .....	63
3.4.3.1	Dry Matter Yield .....	63
3.4.3.2	Botanical Composition .....	66
3.4.3.3	Pasture N and P Concentration and Uptake .....	66
3.5	CONCLUSIONS .....	68

### CHAPTER 4 CHANGE IN P FRACTIONS IN A PASTURE DEVELOPMENT CHRONOSEQUENCE ON A WHAREKOHE PODZOL

4.1	INTRODUCTION .....	70
4.2	OBJECTIVES .....	71
4.3	MATERIALS AND METHODS .....	72
4.3.1	Soils .....	72

4.3.2	Soil Treatment .....	73
4.3.3	Soil Analysis .....	73
4.3.3.1	P Fractionation .....	73
4.3.3.2	pH .....	76
4.3.3.3	Cation Exchange Capacity and Exchangeable Cations .....	76
4.3.3.4	Total Calcium .....	76
4.3.3	Statistical Analysis .....	77
4.4	RESULTS AND DISCUSSION .....	77
4.4.1	Effect of Pasture Age on the Accumulation of Applied P into Soil Fractions in a Wharekohe silt loam .....	77
4.4.1.1	Inorganic P .....	71
4.4.1.2	Organic P .....	81
4.4.1.3	Po/Pi Ratio .....	83
4.4.1.4	Changes in P Fractions .....	84
4.4.1.5	Spring 1993 .....	93
4.4.2	Contribution of P Fractions to the SLF for the Wharekohe silt loam ..	96
4.4.3	Movement of P Through the Profile of a Wharekohe silt loam .....	98
4.4.4	The Influence of P Fertiliser Form and Liming History on P Fractions in a Wharekohe silt loam .....	99
4.4.5	Effect of Parent Material on P Fractions in Wharekohe Podzols ...	103
4.4.6	Effect of the Degree of Weathering of Silt Sediments on P Fractions .....	106
4.5	SUMMARY AND CONCLUSIONS .....	108
4.5.1	Effect of Pasture Age on the Accumulation of Applied P into Soil Fractions in a Wharekohe silt loam .....	108
4.5.2	Contribution of P Fractions to the SLF for a Wharekohe silt loam ..	110
4.5.3	Movement of P Through the Profile of a Wharekohe silt loam .....	110
4.5.4	Influence of P Fertiliser Form and Historic Lime Application on P Fractions in Wharekohe podzols .....	111
4.5.5	Effect of Parent Material on P Fractions in Wharekohe Podzols ...	111
4.5.6	Effect of Degree of Weathering of Silt Sediments on P Fractions ..	111

## CHAPTER 5

### P MOVEMENT IN SUBSURFACE RUNOFF

5.1	INTRODUCTION .....	113
5.2	OBJECTIVES .....	115
5.3	MATERIALS AND METHOD .....	115
5.3.1	Glasshouse Trial .....	115
5.3.1.1	Collection and Preparation of Soil Cores .....	115



5.3.1.2	Leaching Technique .....	117
5.3.1.3	Chemical Analysis of Leachate .....	118
5.3.1.4	Statistical Analysis .....	119
5.3.2	Field Trial .....	119
5.3.2.1	Field Sites and Fertiliser Treatments .....	119
5.3.2.2	Soil Solution Collection .....	119
5.3.2.3	Chemical Analysis of Soil Solutions .....	120
5.3.2.4	Statistical Analysis .....	120
5.4	RESULTS AND DISCUSSION .....	120
5.4.1	Glasshouse Trial .....	120
5.4.1.1	Amounts of DIP and DOP Lost by Leaching .....	120
5.4.1.2	Effect of Pasture Age on P Leaching .....	124
5.4.1.3	Effect of Parent Material on P Leaching .....	124
5.4.1.4	Effect of Time on P Leaching .....	125
5.4.1.5	Water Movement Through Intact Cores .....	128
5.4.2	Field Trial .....	131
5.4.2.1	Movement of Applied P .....	131
5.4.2.2	Effect of Pasture Age on P Movement .....	138
5.5	GENERAL DISCUSSION .....	139
5.5.1	Comparison of the P Concentration in Leachate from the Intact Soil Core and Soil Solution Collected in the Suction Cups .....	139
5.5.2	Effect of Pasture Age and P Saturation on P Losses .....	140
5.5.3	Effect of Waterlogging on P Loss .....	142
5.5.4	Loss of P in Subsurface and Surface Runoff .....	143
5.5.5	Loss of Particulate and Dissolved P .....	144
5.5.6	Predicting Runoff P Losses from Soil P Tests .....	144
5.5.7	Minimising P Losses .....	145
5.6	CONCLUSIONS .....	149

## CHAPTER 6

### P RETENTION IN WHAREKOHE SOILS

6.1	INTRODUCTION .....	151
6.2	OBJECTIVES .....	153
6.3	MATERIALS AND METHODS .....	153
6.4	RESULTS AND DISCUSSION .....	154
6.4.1	Effect of Pasture Age on P Retention .....	154
6.4.1.1	Possible Explanations for Differences in P Retention Between Developed Sites .....	157
6.4.1.2	Implications of Decreasing P Retention with Pasture Age on Modelling P Requirements .....	164

6.4.2	Effect of Soil Weathering and Parent Material on P Retention .....	169
6.5	CONCLUSIONS .....	172

## CHAPTER 7

### QUANTIFYING THE SLF FOR WHAREKOHE SOILS

7.1	INTRODUCTION .....	174
7.2	OBJECTIVES .....	176
7.3	MATERIALS AND METHODS .....	177
	7.3.1 Small-Plot Field Trials .....	177
	7.3.1.1 Trial Sites .....	177
	7.3.1.2 Trial Design and Establishment .....	178
	7.3.1.3 Pasture Sampling and Analysis .....	182
	7.3.1.4 Soil Sampling and Analysis .....	183
	7.3.1.5 Calculation of the SLF .....	184
	7.3.2 Chronosequence Trial .....	185
7.4	RESULTS AND DISCUSSION .....	186
	7.4.1 Effect of Applied P on Pasture Growth .....	186
	7.4.1.1 Effect of Applied MCP on Pasture Growth .....	186
	7.4.1.2 Effect of Fertiliser Solubility on Pasture Growth .....	192
	7.4.2 Effect of Applied P on Available P Soil Tests .....	194
	7.4.2.1 Effect of MCP Application Rate on Maintaining Olsen P Levels .....	194
	7.4.2.2 Effect of P Fertiliser Solubility on Maintaining Available Soil P Levels .....	201
	7.4.3 Quantifying the SLF .....	206
	7.4.3.1 Effect of Soil Fertility Status on the SLF .....	208
	7.4.3.2 Effect of Parent Material on the SLF .....	209
	7.4.3.3 Effect of Degree of Soil Weathering on the SLF .....	209
	7.4.3.4 Effect of P Fertiliser Solubility on the SLF .....	210
	7.4.3.5 Sensitivity the SLF .....	210
	7.4.3.6 Effect of Pasture Age on the SLF .....	214
	7.4.3.7 Implications of Soil Loss Estimation on P Fertiliser Requirements .....	218
7.5	CONCLUSIONS .....	219

## CHAPTER 8

### MODELLING THE FATE OF P IN A WHAREKOHE SILT LOAM

8.1	INTRODUCTION .....	222
8.2	OBJECTIVES .....	223
8.3	THE P CYCLE OF A GRAZED PASTURE .....	
	224	
8.4	MODEL DEVELOPMENT .....	224
	8.4.1 Soil P Accumulation .....	224
	8.4.2 Runoff P Losses .....	228
8.5	PREDICTING P ACCUMULATION IN EACH SOIL P POOL .....	228
8.6	PREDICTING TOTAL P ACCUMULATION .....	229
8.7	PREDICTING RUNOFF P LOSS .....	233
	8.7.1 Validation of the PRIHLS Model .....	233
	8.7.2 Effect of Fertiliser and Stocking Rates on Runoff P Losses .....	235
8.8	USING THE PRIHLS MODEL TO PREDICT P REQUIREMENTS .....	238
8.9	CONCLUSIONS .....	239

## CHAPTER 9

SUMMARY AND CONCLUSIONS .....	240
REFERENCES .....	247
GLOSSARY OF TERMS .....	274
APPENDICES .....	275

## LIST OF FIGURES

Figure 2.1	Phosphorus cycle under grazed, fertilised pasture .....	6
Figure 3.1	Effect of pasture age on soil total P concentration (SED's varied, Table in Appendix 3.1) .....	48
Figure 3.2	Comparison of total P measured in original 1990 sites (◇) and total P measured in additional sites in 1993 (◆) .....	55
Figure 3.3	Fate of applied P showing losses from each depth with time from pasture development, a) 0-7.5 cm, b) 0 cm - top of E Horizon, c) soil profile to 30 cm below E Horizon .....	57
Figure 3.4	Effect of pasture age on Olsen P (MAF Quicktest) for each depth and a calculated value for the 0-7.5 cm depth. (Vertical bars=S.E.D.s for developed sites sampled to 0-3 cm, 3-7.5 cm and 7.5 cm to the E horizon) .....	62
Figure 3.5	Effect of pasture age on dry matter yield in 1991 and 1992 .....	64
Figure 3.5	Effect of pasture age on P uptake in 1991 and 1992 .....	64
Figure 4.1	Flow chart of sequential P extraction .....	74
Figure 4.2	Effect of pasture age on inorganic and organic P concentration in each depth of a pasture chronosequence on a Wharekohe silt loam .....	78
Figure 4.3	Effect of pasture age on organic P content (%) at each depth .....	84
Figure 4.4	Comparison of inorganic and organic P fractions measured in each site at each depth .....	85
Figure 4.5	Effect of pasture age on each P fraction at each depth .....	89
Figure 4.6	Effect of pasture age on pH at each depth .....	101
Figure 4.7	Effect of parent material on inorganic and organic P fractions in Wharekohe podzols .....	104
Figure 4.8	Effect of degree of weathering of silt sediments on inorganic and organic P fractions in the soil .....	107
Figure 5.1	Intact soil cores, with petrolatum (vaseline) seal between galvanised steel casing and soil, and the dual leachate collection system .....	116
Figure 5.2	Sum of dissolved inorganic P leached through soil cores after four 11.4 mm rainfall events on days 3, 5, 10 and 13 .....	121

Figure 5.3	DIP and DOP leached through cores after three 11.4 mm rainfall events, a) 3, b) 13 and c) 94 days after P fertiliser application ...	122
Figure 5.4	Effect of time on the amount of DIP leached from fertilised cores during each 11.4 mm rainfall event .....	126
Figure 5.5	Comparison of DIP leached from fertilised and unfertilised site cores with time from P application for the cores collected from each site .....	127
Figure 5.6	Rainfall recorded over period of field trial .....	132
Figure 5.7	Dissolved inorganic P measured in water samples collected from 2-7.5 cm depth, a) 11 years under developed pasture, and b) 33/35 years under developed pasture .....	133
Figure 5.8	Dissolved inorganic P measured in water samples collected from 7.5-13 cm depth, a) 11 years under developed pasture, and b) 33/35 years under developed pasture .....	134
Figure 5.9	Dissolved organic P measured in water samples collected from 2-7.5 cm depth, a) 11 years under developed pasture, and b) 33/35 years under developed pasture .....	136
Figure 5.10	Dissolved organic P measured in water samples collected from 7.5-13 cm depth, a) 11 years under developed pasture, and b) 33/35 years under developed pasture .....	137
Figure 5.11	Effect of time on DIP concentration in the 2-7.5 cm within the fertilised plots and 10 m away (controls) .....	138
Figure 6.1	Effect of increasing solution P concentration and shaking time on the retention of added P from 0.01 M CaCl <sub>2</sub> by Wharekohe silt loam developed for 0, 11 and 35 years and Wharekohe sandy loam during a) 16 hour, b) 40 hour and c) 136 hour shaking periods .....	155
Figure 6.2	Effect of pasture age on P storage by Wharekohe silt loam at various solution P concentrations .....	156
Figure 6.3	Influence of shaking time on the storage of added P by a) Wharekohe silt loam, 0 years, b) Wharekohe silt loam, 11 years, c) Wharekohe silt loam, 35 years, d) Wharekohe sandy loam and e) Aponga clay ....	158
Figure 6.4	Effect of cation species on the storage of added P by a) Wharekohe silt loam, 0 years, b) Wharekohe silt loam, 11 years, c) Wharekohe silt loam, 35 years, d) Wharekohe sandy loam and e) Aponga clay ....	160
Figure 6.5	Effect of added P, pasture age and soil type on the final pH of the shaking solution in a) CaCl <sub>2</sub> shaken for 16 hours, b) CaCl <sub>2</sub> shaken for 40 hours, c) CaCl <sub>2</sub> shaken for 136 hours, and d) NaCl shaken for 40 hours .....	163

Figure 6.6	Effect of increasing solution P concentration on the storage of added P from 0.01 M CaCl <sub>2</sub> by Wharekohe silt loam, Wharekohe sandy loam and Aponga clay during a) 16 hour, b) 40 hour and c) 136 hour shaking periods .....	170
Figure 7.1	Layout of small-plot field trials .....	180
Figure 7.2	Effect of applied MCP on annual pasture yield for years 1 and 2 for a) Wharekohe silt loam NFt, b) Wharekohe silt loam Ft, c) Wharekohe sandy loam and d) Aponga clay. (Vertical bars=S.E.D.) .....	187
Figure 7.3	Effect of P fertiliser solubility on annual pasture yield for years 1 and 2 for Wharekohe silt loam Ft, adjusted for covariates (OP not included). (Vertical bars=S.E.D.) .....	192
Figure 7.4	Effect of applied MCP on Olsen P levels over time for a) Wharekohe silt loam NFt, b) Wharekohe silt loam Ft, c) Wharekohe sandy loam and d) Aponga clay. Arrows indicate P fertiliser application times ..	195
Figure 7.5	Effect of P fertiliser solubility on Olsen P levels over time where a) MCP and b) SPR were applied on the Wharekohe silt loam Ft site. Arrows indicate P fertiliser application times .....	202
Figure 7.6	Effect of applied SPR on Resin P levels over time on the Wharekohe silt loam Ft site. Arrows indicate P fertiliser application times .....	205
Figure 8.1	Fate of fertiliser P in a grazed Wharekohe podzol .....	225
Figure 8.2	Effect of pasture age on predicted and measured a) Available Pi, b) Organic P, c) Calcium Pi and d) Strongly sorbed and precipitated and residual P accumulation in the top 7.5 cm of a Wharekohe silt loam .....	229
Figure 8.3	Effect of pasture age on predicted and measured total P accumulation in the top 7.5 cm of a Wharekohe silt loam .....	232
Figure 8.4	Predicted and measured P runoff losses for additional sites sampled in 1993 .....	234
Figure 8.5	Effect of P application rate and stocking type on annual soil P accumulation and runoff P loss from the top 7.5 cm of a Wharekohe silt loam .....	236

## LIST OF TABLES

Table 2.1	Changes in soil Olsen P levels with P fertiliser addition and calculated maintenance and current P requirements on three properties on Wharekohe soils in Northland .....	30
Table 3.1	Descriptions of Wharekohe silt loam sites selected in 1990 .....	39
Table 3.2	P application history of pasture chronosequence sites selected in 1990 (additional sites selected in 1993 in brackets) .....	40
Table 3.3	Lime application history of selected pasture chronosequence sites sampled in 1990 .....	41
Table 3.4	Total P content (kg P/ha) of Wharekohe silt loam samples .....	49
Table 3.5	Accumulation of applied P at each depth to the top of the E horizon .	50
Table 3.6	Accumulation of P applied from spring 1990 - 1993 in the top 7.5 cm of original sites (additional sites in brackets) .....	54
Table 3.7	Accumulation of applied P in top 7.5 cm of soil sampled from the additional sites in 1993 .....	54
Table 3.8	Losses of applied P from different aged pastures on the Wharekohe silt loam .....	58
Table 4.1	Inorganic and organic P content (kg P/ha) of Wharekohe silt loam samples .....	79
Table 4.2	Estimated alkali and acid Pi accumulation in the original 8 and 32 year sites for a 3 year period compared to estimated accumulation for a 3 year period in MAF 'National Series' soils, TSP and RPR applied at twice maintenance .....	95
Table 4.3	Effect of parent material on the P fractions measured in Wharekohe podzols (% in brackets) .....	104
Table 4.4	Effect of the degree of soil weathering on the P fractions measured in the moderately leached yellow brown earth, Aponga clay, and the podzol, Wharekohe silt loam, derived from similar silty parent material (% in brackets) .....	106
Table 5.1	Pattern of methylene blue stained water infiltration through intact soil cores at the end of the leaching trial .....	129
Table 7.1	Soil properties and slope at each small-plot field trial site, samples collected in May 1991 (pH and anion storage capacity) and in late July 1991 (Olsen P) .....	178
Table 7.2	Basal fertiliser applied to each plot at each application time .....	182

Table 7.3	Rate of applied P as MCP required to maintain a constant Olsen P test at each site for each time period (standard deviations in brackets) .	197
Table 7.4	Effect of fertiliser P solubility on the rate of applied P required to maintain a constant available P soil test for each period (standard deviations in brackets) .....	203
Table 7.5	Soil Loss Factors determined for each sampling period at each site .....	207
Table 7.6	Sensitivity of the SLF to an incorrect estimation of the rate of P to maintain a steady Olsen P level and P uptake .....	211
Table 7.7	Effect of pasture age on the $SLF_{SPA}$ for use in the CFAS model ....	215