

**Development, testing and application of a crop nitrogen and phosphorus model to investigate leaching losses at the local scale**

**by**

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## CONTENTS

<b>List of Figures</b> .....	<b>vii</b>
<b>List of Tables</b> .....	<b>xi</b>
<b>Acknowledgements</b> .....	<b>xiii</b>
<b>Declaration</b> .....	<b>xv</b>
<b>Abstract</b> .....	<b>xvi</b>
<b>Chapter 1: Introduction</b> .....	<b>1</b>
1.1 Rationale.....	1
1.2 Nitrogen leaching from cropping systems.....	4
1.3 Phosphorus leaching from cropping systems.....	5
1.4 Mitigation measures.....	6
1.4.1 Reducing N leaching in cropping systems.....	7
1.4.2 Reducing P leaching in cropping systems.....	9
1.5 Modelling N and P dynamics in agro-ecosystems.....	10
1.5.1 Overview.....	10
1.5.2 Background to SWB-Sci.....	12
1.6 Thesis objectives.....	13
1.6.1 Model development.....	13
1.6.2 Model testing.....	14
1.6.3 Model application.....	15
1.7 References.....	15
<b>Chapter 2: Development of a local scale nitrogen and phosphorus crop model</b> .....	<b>25</b>
2.1 Introduction.....	25
2.1 Source models from which algorithms were obtained.....	25
2.2 Model description.....	26
2.2.1 Nitrogen and P simulation initialization.....	26
2.2.1.1 Model interface.....	26
2.2.1.2 Soil initialization.....	26



2.2.1.3 Estimation of <i>Labile P</i> .....	28
2.2.1.4 Estimation of P availability index (PAI).....	28
2.2.1.5 Estimation of <i>Active P</i> and <i>Stable P</i> pools.....	29
2.2.1.6 Crop residues.....	29
2.2.1.7 Inputs that can be estimated by the model.....	29
2.2.1.8 Nutrient related crop parameters.....	30
2.2.2 Fertilization.....	30
2.2.2.1 Banded P applications.....	31
2.2.2.2 Addition of N and P via rainfall and irrigation.....	31
2.2.3 Tillage management.....	31
2.2.4 Soil temperature, water and pH functions.....	32
2.2.4.1 Soil temperature function.....	32
2.2.4.2 Soil water function.....	33
2.2.4.3 Soil pH function.....	34
2.2.5 Processes simulated.....	34
2.2.5.1 Mineralization and immobilization.....	34
2.2.5.2 Inorganic N transformation processes.....	36
2.2.5.2.1 Ammonia volatilization.....	36
2.2.5.2.2 Nitrification.....	36
2.2.5.2.3 Denitrification.....	37
2.2.5.2.4 Nitrogen fixation.....	37
2.2.5.3 Inorganic P transformation processes.....	38
2.2.5.3.1 Soil inorganic P.....	38
2.2.5.4 Crop N and P uptake.....	39
2.2.5.4.1 Crop N uptake and stress effects.....	39
2.2.5.4.2 Crop P uptake and stress effects.....	41
2.2.5.5 Nutrient runoff losses.....	42
2.2.5.5.1 Phosphorus.....	42
2.2.5.5.2 Nitrogen.....	43
2.2.5.6 Vertical solute movement.....	44
2.2.6 Mass balances.....	44
2.3 Conclusions.....	45
2.4 Acknowledgements.....	45
2.5 References.....	45



<b>Chapter 3: Obtaining the parameters required to model labile phosphorus for South African soils.....</b>	<b>48</b>
3.1 Introduction.....	49
3.2 Review of inorganic P modelling approach.....	50
3.3 Calcareous, slightly weathered and highly weathered soils.....	51
3.4 Estimation of inorganic P pool sizes.....	53
3.5 Obtaining inputs at catchment scale.....	58
3.6 General discussion.....	60
3.7 Conclusions.....	61
3.8 Acknowledgements.....	62
3.9 References.....	62
<b>Chapter 4: Assessment of the ability of SWB-Sci to simulate nitrogen dynamics in agronomic cropping systems.....</b>	<b>67</b>
4.1 Introduction.....	68
4.2 Materials and methods.....	69
4.2.1 <i>Bouwing</i> field trial.....	69
4.2.1.1 Trial description.....	69
4.2.1.2 Model set-up.....	70
4.2.2 <i>Glen</i> field trial.....	70
4.2.2.1 Trial description.....	70
4.2.2.2 Model set-up.....	71
4.2.3 Testing model performance.....	71
4.3 Results.....	72
4.3.1 <i>Bouwing</i> field trial.....	72
4.3.1.1 Total aboveground dry matter and yield.....	72
4.3.1.2 Profile water content and deep drainage.....	74
4.3.1.3 Crop N uptake.....	74
4.3.1.4 Soil inorganic N.....	76
4.3.2 <i>Glen</i> field trial.....	79
4.3.2.1 Total aboveground dry matter and yield.....	79
4.3.2.2 Profile water content and deep drainage.....	80



4.3.2.3 Nitrogen uptake.....	81
4.3.2.4 Soil inorganic N.....	82
4.4 General discussion.....	83
4.5 Conclusions.....	85
4.6 Acknowledgements.....	86
4.7 References.....	86

**Chapter 5: Modelling the effects of nitrogen and phosphorus stress on crop growth using SWB-Sci: An example using maize.....89**

5.1 Introduction.....	90
5.1.1 Review of model development.....	91
5.1.2 Modelling of crop P uptake and stress effects and banded P fertilizer applications.....	92
5.2 Materials and methods.....	93
5.2.1 Brief overview of dataset used to test the model.....	93
5.2.2 Model set-up and calibration.....	95
5.2.3 Statistical criteria for validation.....	96
5.2.4 Nitrogen:Phosphorus ratios.....	96
5.3 Results.....	97
5.3.1 Total aboveground dry matter and yield.....	97
5.3.2 Leaf area index.....	101
5.3.3 Profile water content and deep drainage.....	102
5.3.4 Aboveground N and P mass.....	103
5.3.5 Nitrogen:Phosphorus ratios.....	107
5.4 General discussion.....	108
5.5 Conclusions.....	111
5.6 Acknowledgements.....	112
5.7 References.....	112

**Chapter 6: Monitoring and modelling soil water nitrogen and phosphorus concentrations to estimate leaching losses.....116**

6.1 Introduction.....	117
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## CONTENTS

---

6.2 Materials and methods.....	119
6.2.1 Drainage lysimeter trial.....	119
6.2.2 Modelling incomplete solute mixing.....	121
6.3 Results.....	123
6.3.1 Rainfall and irrigation.....	123
6.3.2 Soil water content and response of wetting front detectors.....	123
6.3.3 Cumulative aboveground dry matter production and N and P uptake.....	126
6.3.4 Drainage and leaching.....	126
6.3.5 Soil water nitrate and P concentrations.....	128
6.3.5.1 Nitrate.....	128
6.3.5.2 Phosphorus.....	131
6.4 General discussion.....	134
6.5 Conclusions.....	136
6.6 Acknowledgements.....	137
6.7 References.....	137

### **Chapter 7: Analysis of nitrogen and phosphorus leaching from dryland and irrigated cropping systems using long-term modelling.....141**

7.1 Introduction.....	142
7.2 Materials and methods.....	144
7.3 Results.....	147
7.3.1 Dryland versus irrigated cropping systems.....	147
7.3.2 Irrigation scheduling.....	150
7.3.3 Crop rotation.....	154
7.4 Overview and discussion.....	157
7.5 Conclusions.....	160
7.6 Acknowledgements.....	161
7.7 References.....	161

### **Chapter 8: Conclusions and recommendations.....164**



8.1 Overview of study.....164

8.2 General conclusions and recommendations for modelling N and P at the local  
scale.....164

8.3 Monitoring and modelling mobile and immobile soil water phase solute  
concentrations.....168

8.4 Long-term simulations to investigate N and P leaching losses from cropping  
systems.....169

8.5 Best management practices.....170

8.6 References.....171

**Summary.....172**

**Appendix.....175**



## LIST OF FIGURES

<b>Figure 1.1</b>	Total global increase in irrigated area and nitrogenous and phosphate fertilizer since the 1960's (www.worldwater.org; http://faostat.fao.org) and forecasted increase in irrigated area and nitrogenous and phosphate fertilizer consumption until 2050 (from Tilman et al., 2001).....	2
<b>Figure 3.1</b>	Structural diagram of the various P pools simulated using the EPIC approach.....	51
<b>Figure 4.1</b>	Total aboveground dry matter (TDM) and wheat grain yield for treatments N1, N2 and N3 for the 1983/83 growth season.....	72
<b>Figure 4.2</b>	Total aboveground dry matter (TDM) and yield for treatments N1, N2 and N3 for the 1983/84 growth season.....	73
<b>Figure 4.3</b>	Aboveground N mass (left) and grain N mass (right) for the 1982/83 growth season.....	75
<b>Figure 4.4</b>	Aboveground N mass (left) and grain N mass (right) for the 1983/84 growth season.....	76
<b>Figure 4.5</b>	Soil mineral N content for the 1982/1983 growth season for treatments N1, N2 and N3 at depths of 0-30, 60-30 and 60-100cm.....	77
<b>Figure 4.6</b>	Soil NO <sub>3</sub> <sup>-</sup> content for the 1983/84 growth season for treatments N1, N2 and N3 at depths of 0-30 cm, 60-30 cm and 60-100cm.....	78
<b>Figure 4.7</b>	Soil NH <sub>4</sub> <sup>+</sup> levels for the 1983/1984 growth season for treatments N1, N2 and N3 at depths of 0-30, 60-30 and 60-100 cm.....	79
<b>Figure 4.8</b>	Total aboveground dry matter (TDM) and yield for treatments N1, N2 and N3.....	80
<b>Figure 4.9</b>	Aboveground and grain N mass for treatments N1, N2 and N3.....	81
<b>Figure 4.10</b>	Soil NO <sub>3</sub> <sup>-</sup> content for treatments N1, N2 and N3 at depths of 0-60 and 60-180 cm.....	82
<b>Figure 4.11</b>	Soil NH <sub>4</sub> <sup>+</sup> content for treatments N1, N2 and N3 at depths of 0-60 and 60-180 cm.....	83
<b>Figure 5.1</b>	Measured and simulated values for total above ground dry matter (TDM) production for the five treatments for the SR89 growth season.....	98
<b>Figure 5.2</b>	Measured versus simulated values for yield for the five treatments for the SR89 growth season.....	98
<b>Figure 5.3</b>	Measured and simulated values for total dry matter production for the five treatments for the LR90 growth season.....	100



**Figure 5.4** Simulated versus measured values for yield for the five treatments for the LR90 growth season.....100

**Figure 5.5** Simulated versus measured values for leaf area index (LAI) for the LR 90 growth season.....102

**Figure 5.6** Profile water content (PWC) for the SR89 N2P1 treatment and the LR90 F40 treatment.....103

**Figure 5.7** Measured and simulated values for aboveground N mass (left) and aboveground P mass (right) for the SR89 growth season.....104

**Figure 5.8** Simulated versus measured values for grain N mass (left) and grain P mass (right) for the SR 89 growth season.....105

**Figure 5.9** Measured and simulated values for above ground P mass for the LR90 growth season.....106

**Figure 5.10** Simulated versus measured values for grain N (left) and grain P (right) for the LR 90 growth season.....107

**Figure 5.11** ratios for the five treatments in the SR89 growth season for the analyses done on 5 February 1990 (before grain filling).....107

**Figure 5.12** Measured and simulated nitrogen:phosphorus ratios for the five treatments in the LR90 growth season for the analyses done on 12 June 1990 (before grain filling).....108

**Figure 6.1** Rainfall and irrigation for the growth season.....123

**Figure 6.2** Measured and simulated profile water content over the growing season (measurements are based on data from the capacitance sensors).....124

**Figure 6.3** Measured and simulated volumetric water content (VWC), and WFD response at depths of 15, 30, 45 and 60 cm.....125

**Figure 6.4** Cumulative aboveground dry matter (TDM) production (primary y-axis), and N and P removal (secondary y-axis) over the growth season.....126

**Figure 6.5** Measured and simulated cumulative drainage (mm) over the growth season.....127

**Figure 6.6** Measured and simulated cumulative N leached (left) and drainage water  $\text{NO}_3^-$  concentrations (right).....127

**Figure 6.7** Measured and simulated cumulative P leached (left) and drainage water P concentrations (right).....128

**Figure 6.8** Measured  $\text{NO}_3^-$  concentrations from suction cups compared to simulated immobile soil water phase concentrations (Sim\_Im; left) and measured  $\text{NO}_3^-$  concentrations from wetting front detectors compared to simulated mobile soil water phase concentrations (Sim\_Mob; right) at depths of 15, 30, 45 and 60 cm.....130

**Figure 6.9** Measured  $\text{NO}_3^-$  concentrations from suction cups compared to simulated immobile soil water phase concentrations at depths of 80 and 100 cm.....131

**Figure 6.10** Measured P concentrations from wetting front detectors and simulated mobile soil water phase P concentrations at depths of 15, 30, 45 and 60 cm.....133

**Figure 7.1** Daily rainfall (a) and daily  $\text{ET}_o$  (b) for the Bethal area for the simulation period (1970 -2000).....145

**Figure 7.2** Seasonal yields over the 30 year simulation period for the Dryland Maize (DM) and Irrigated Maize (IM) scenarios.....147

**Figure 7.3** Cumulative deep drainage (mm) over the 30 year simulation period for the Dryland Maize (DM) and Irrigated Maize (IM) scenarios.....148

**Figure 7.4** Cumulative N leached (a) and drainage water  $\text{NO}_3^-$  concentrations (b) over the 30 year simulation period for the Dryland Maize (DM) and Irrigated Maize (IM) scenarios.....149

**Figure 7.5** Cumulative P leached over the 30 year simulation period for the Dryland Maize (DM) and Irrigated Maize (IM) scenarios.....150

**Figure 7.6** Seasonal yields over the 30 year simulation period for Irrigated Maize (IM) scenarios and Irrigated Maize ‘room for rain’ (IMrr) scenarios.....151

**Figure 7.7** Cumulative deep drainage (mm) over the 30 year simulation period for the Irrigated Maize (IM) and Irrigated Maize ‘room for rain’ (IMrr) scenarios.....151

**Figure 7.8** Cumulative deep drainage (mm) over a selected period within the 1975/76 maize growth season.....152

**Figure 7.9** Cumulative deep drainage (mm) (a) and profile water content (b) over a selected period within the 1996/97 maize growth season.....153

**Figure 7.10** Cumulative N leached over the 30 year simulation period for the Irrigated Maize (IM) and Irrigated Maize ‘room for rain’ scenarios...154

**Figure 7.11** Seasonal yields over the 30 year simulation period for the Dryland Irrigated Maize (IM) and Irrigated Maize-wheat rotation (IMwr) scenarios.....155

**Figure 7.12** Cumulative deep drainage (mm) over the 30 year simulation period for the Irrigated Maize (IM) and Irrigated Maize-wheat rotation (IMwr) scenarios.....156

**Figure 7.13** Cumulative N leached over the 30 year simulation period for the Irrigated Maize (IM) and Irrigated Maize-wheat rotation (IMwr) scenarios.....156

**Figure 7.14** Cumulative P leached over the 30 year simulation period for the Irrigated Maize (IM) and Irrigated Maize-wheat rotation (IMwr) scenarios.....157



**LIST OF TABLES**

<b>Table 2.1</b>	Soil inputs required to initialize a simulation for N and P.....	27
<b>Table 2.2</b>	Crop parameters required for N and P simulations.....	30
<b>Table 3.1</b>	Ranges of soil properties for five soil groups tested by Sharpley et al. (1984) and Sharpley et al. (1989).....	54
<b>Table 3.2</b>	Current and suggested equations for the estimation of labile P pool size for South African soils.....	56
<b>Table 3.3</b>	Grouping of soil forms used for Land-type mapping to facilitate categorization as slightly weathered, highly weathered or calcareous.....	59
<b>Table 4.1</b>	N fertilizer application rates applied to the Bouwing trial for the 1982/83 and 1983/84 growing seasons.....	70
<b>Table 4.2</b>	Statistical evaluation of measured and simulated values for total aboveground dry matter (TDM) and yield during the 1982/83 season.....	73
<b>Table 4.3</b>	Statistical evaluation of measured and simulated values for total aboveground dry matter (TDM) and yield during the 1983/84 season.....	74
<b>Table 4.4</b>	Statistical evaluation of measured and simulated values for profile water content during the 1982/83 and 1983/84 seasons.....	74
<b>Table 4.5</b>	Statistical evaluation of measured and simulated values for top N mass and grain N during the 1982/83 season.....	75
<b>Table 4.6</b>	Statistical evaluation of measured and simulated values for aboveground N and grain N during the 1983/84 season.....	76
<b>Table 4.7</b>	Statistical evaluation of measured and simulated values for total aboveground dry matter (TDM) and yield during the 1982/83 season.....	80
<b>Table 4.8</b>	Statistical evaluation of measured and simulated values for profile water content for soil layers 0-60 and 60-180 cm.....	81
<b>Table 4.9</b>	Statistical evaluation of measured and simulated values for aboveground N mass and grain N.....	81
<b>Table 5.1</b>	N and P rates applied in the first season (SR 89).....	94
<b>Table 5.2</b>	Rates of banded P applied to modified treatments over the SR89 and LR90 seasons.....	94
<b>Table 5.3</b>	Crop model parameters for maize determined from N2P2 field data, literature and previous SWB research.....	95



<b>Table 5.4</b> Statistical criteria used to judge model performance.....	96
<b>Table 5.5</b> Statistical evaluation of measured and simulated values for total above ground dry matter (TDM) during the SR 89 season.....	97
<b>Table 5.6</b> Statistical evaluation of measured and simulated values for total above ground dry matter (TDM) during the LR90 season.....	99
<b>Table 5.7</b> Statistical evaluation of measured and simulated values for leaf area index (LAI).....	101
<b>Table 5.8</b> Statistical evaluation of measured and simulated values for profile water content (PWC) over consecutive growth seasons for selected treatments.....	103
<b>Table 5.9</b> Statistical evaluation of measured and simulated values for crop nitrogen (N) and phosphorus (P) uptake during the SR89 season.....	104
<b>Table 5.10</b> Statistical evaluation of measured and simulated values for crop nitrogen (N) and phosphorus (P) uptake for the LR 90 season.....	106
<b>Table 6.1</b> Properties for the drainage lysimeter soil.....	120
<b>Table 6.2</b> Nitrogen (N) and phosphorus (P) fertilization over the growth season....	121
<b>Table 7.1</b> Cumulative water, N and P additions and losses for the IM, DS, IMrr and IMwr scenarios after the 30 year simulation period.....	158



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**DECLARATION**

I, Michael van der Laan, hereby declare that this dissertation for the degree PhD (Agronomy) at the University of Pretoria is my own work and has never been submitted by myself at any other University. The research work reported is the result of my own investigation, except where acknowledged.

M VAN DER LAAN  
31 August 2009



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**ABSTRACT**

The leaching of nitrogen (N) and phosphorus (P) from the rootzone of cropping systems is a major contributor of non-point source pollution resulting in deterioration of fresh water supplies. An escalating world population is forcing further intensification of agricultural production practices and the identification of suitable and effective management practices to reduce N and P leaching losses is becoming ever more important. Such leaching losses are, however, extremely challenging to measure and quantify due to uncertainties associated with the estimation of deep drainage and N and P concentrations in this drainage water. SWB-Sci is a locally developed, mechanistic crop model to which N and P subroutines have been added to enable analysis of leaching losses at the local scale. This involved novel approaches to estimate the effects of N deficiencies on yield; to simulate crop P demand, uptake and stress effects; to simulate banded P fertilizer applications; and to estimate incomplete solute mixing. New equations to estimate the size of the *Labile P* pool from soil P tests commonly used in South Africa, and guidelines on the classification of South African soils as calcareous, slightly weathered or highly weathered which is required to simulate P, were also developed. The upgraded more versatile model was tested using historical datasets from the Netherlands, Kenya and South Africa, and performed well in simulating N and P dynamics in maize and wheat cropping systems. Variables tested included aboveground dry matter production, yield, leaf area index, aboveground crop N and P mass, grain N and P mass, soil water content



and soil inorganic N levels. A study was also conducted on a large drainage lysimeter into which suction cups and wetting front detectors were installed, and data from this experiment together with the SWB-Sci model was used to study vertical solute movement more closely. As hypothesized, wetting front detector nitrate ( $\text{NO}_3^-$ ) and P concentrations were observed to align closely with simulated mobile phase concentrations, and suction cup  $\text{NO}_3^-$  concentrations were observed to align closely with simulated immobile phase concentrations. These results confirm that monitoring and modelling can be used together to improve understanding and obtain more accurate estimates of N and P leaching losses, and further work on this approach is recommended for a wide range of soils and cropping systems. Finally, long-term modelling with the SWB-Sci model was used to analyse and compare N and P leaching losses from a dryland versus an irrigated monoculture maize production system. Over a 30 year simulation period, irrigated maize was estimated to leach considerably higher loads of N and P (~ 4-fold higher). For dryland production, zero leaching was observed for consecutive years on several occasions, with major leaching losses associated with high rainfall events. A 'room for rain' irrigation scheduling management practice was estimated to reduce N leaching by 12% and P leaching by 14%, while a crop rotation system which incorporated wheat grown over the winter months was estimated to reduce N leaching by 23% and P leaching by 24%. From this study, long-term modelling was confirmed as an effective approach to investigate N and P leaching losses, to assist with the planning and design of field trials, and to assess the effectiveness of best management practices. It is envisaged that SWB-Sci will continue to evolve as a valuable tool for analysing and reducing N and P leaching losses from cropping systems to further reduce non-point source pollution.

