5 Modelling P dynamics in the soil plant system

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Abstract

The importance of phosphorus as both sparingly mobile essential nutrient and pollutant is reflected by the large number of P models at different scales and with different purposes.
In this chapter, give an overview on models of P dynamics and generally discuss the approach to developing a mathematical model. Then, we demonstrate this concept by means of four case studies that focus on different plant traits that enhance plant phosphate uptake from soil. The first case study presents a model for phosphate uptake by a mycorrhizal root; the second case study shows a model for time-varying root exudation on the single root scale; the third case study is based on a root system scale model that includes root plasticity, and the fourth case study presents a model for crop response to soil phosphate supply.

5.1 Introduction

The importance of phosphorus (P) as both sparingly mobile essential nutrient and pollutant (e.g. Jones and Oburger 2009) is reflected by the large number of P models at different scales and with different purposes. P dynamics have been studied at a wide range of spatial scales. Examples include the global scale (Harrison et al. 2005), watershed scale (Radcliffe et al. 2009), ecosystem scale (Schlecht and Hiernaux 2005), farming systems scale (Schils et al. 2007), field scale (Schoumans and Groenendijk 2000; Torbert et al. 2008), whole plant scale (Mollier et al. 2008), soil profile scale (Roose and Fowler 2004), and single root scale (Kirk 1999; Roose et al. 2001). In Figure 5.1, we show various P models in a space-time diagram. The position in the space time diagram illustrates the main temporal and spatial scale of application. A full symbol means that this specific model includes smaller-scale submodels. The colour illustrates whether the model is mechanistic or empirical, deterministic or stochastic. Most of the models are mechanistic and deterministic; the degree of empiricality generally increases with spatial scale.

Chapter 5 Modelling Phosphorus Dynamics In The Soil Plant

Kathleen Armour

Chapter 5 Modelling Phosphorus Dynamics In The Soil Plant:

Phosphorus in Action Else K. Bünemann,Astrid Oberson,Emmanuel Frossard,2010-11-08 Phosphorus P is a finite resource which is essential for life It is a limiting nutrient in many ecosystems but also a pollutant which can affect biodiversity in terrestrial ecosystems and change the ecology of water bodies This book collects the latest information on biological processes in soil P cycling which to date have remained much less understood than physico chemical processes The methods section presents spectroscopic techniques and the characterization of microbial P forms as well as the use of tracers molecular approaches and modeling of soil plant systems The section on processes deals with mycorrhizal symbioses microbial P solubilization soil macrofauna phosphatase enzymes and rhizosphere processes On the system level P cycling is examined for grasslands arctic and alpine soils forest plantations tropical forests and dryland regions Further P management with respect to animal production and cropping and the interactions between global change and P cycling are treated

Handbook of Processes and Modeling in the Soil-Plant System Rolf Nieder,D. Benbi,2024-11-01 Learn to create and use simulation modelsthe most reliable and cost effective tools for predicting real world results The Handbook of Processes and Modeling in the Soil Plant System is the first book to present a holistic view of the processes within the soil plant atmosphere continuum Unlike other publications which tend to be more specialized this book covers nearly all of the processes in the soil plant system including the fundamental processes of soil formation degradation and the dynamics of water and matter It also illustrates how simulation modeling can be used to understand and forecast multiple interactions among various processes and predict their environmental impact This unique volume assembles information that until now was scattered among journals bulletins reports and symposia proceedings to present models that simulate almost all of the processes occurring in the soil plant system and explores the results that these models are capable of producing With chapters authored by experts with years of research and teaching experience the Handbook of Processes and Modeling in the Soil Plant System examines physical chemical and biological soil processes the soil formation and weathering process and its modeling the impact of radioactive fallout on the soil plant system soil degradation processes and ways to control them water and matter dynamics in the soil plant system growth and development of crops at various levels of production the potentials and limitations of using simulation models Students educators and professionals alike will find the Handbook of Processes and Modeling in the Soil Plant System an invaluable reference on the soil plant atmosphere system and an ideal tool to help develop an effective decision support system **Arbuscular Mycorrhizal Fungi as Plant Biostimulants for Sustainable Agriculture** Arvind Kumar Rai,Priyanka Chandra,Nirmalendu Basak,Parul Sundha,Rajender Kumar Yadav,2025-06-05 Global agriculture production systems are confronted with difficulties due to increased food demand rising hunger and malnutrition negative climate change effects and overuse of natural resources According to the FAO s definition of sustainable food and agriculture agricultural strategies should support technologies that increase output without having a negative impact on biodiversity or natural resources while also boosting productivity A plant s biostimulants are natural products which stimulate a plant s nutrition and productivity through enhancing nutrient use efficiency tolerance to abiotic stress and quality traits The present book studies arbuscular mycorrhizal fungi AMF a plant biostimulant which forms symbiotic relations with plants having a significant impact on performance and nutrition particularly regarding plant mineral intake capacity AMF through several mechanisms in plants can boost immunity against biotic and abiotic stresses Exploitation of AMF to improve crop productivity will be the key for future sustainable agriculture *Advances in crop modelling for a sustainable agriculture* Emeritus Professor Ken Boote,2019-12-03 Focus on development of next generation of whole farm models to improve decision making and support for farmers Addresses the challenges of combining modular sub systems into whole farm system models Reviews the performance of specific models such as APSIM and DSSAT *SOIL MICROBIOLOGY A MODEL OF DECOMPOSITION & NUTR CYCLING* O. L. Smith,1982-05-11 A perspective of modeling A review of models in soil microbiology Mathematical development A decomposition and nutrient cycling model Mathematical basis of the spatial approximation The decomposers The general microbe population The nitrifiers Symbols Parameters The carbon cycle Disintegration of dead plant and animal matter Free polysaccharide in soil Bound polysaccharide Simple sugar in soil solution The phosphorus cycle Free organic phosphorus in soil Bound phosphorus Mineral phosphorus Soil solution phosphorus The potassium cycle Potassium leached from live cells Potassium leached or dissolved from dead cells Nonexchangeable potassium Exchangeable potassium Soluble mineral potassium Atmospheric input and groundwater loss Soil solution potassium The nitrogen aromatic cycle Free organic nitrogen in soil Bound organic nitrogen Condensable aromatics Soil solution NH 4 Soil solution NO 2 and NO 3 Cell chemistry Plants Microbes Temperature and moisture dependence of processes Organic and inorganic reactions The role of plants in decomposition and nutrient cycling Model development Comparison of model with experiment Comparison of model with theories of plant growth Simplified version of the plant model The steady state Phosphorus Potassium Nitrogen The dynamic state Overall pattern of decomposition and microbe growth The influence of substrate carbon and nitrogen content on mineralization and immobilization Microbe growth limited by nitrogen Wastage of substrate The rate limiting step of nitrogen mineralization The priming effect of soil amendments on rate of mineralization Accumulation of organic matter in soils Effect on microbes of oscillating low soil temperatures Effect on microbes of soil moist dry cycles Microbe and plant competition for nutrients Strategy of optimum crop fertilization A look ahead Mathematical and numerical techniques The runge kutta method Solution of coupled nonlinear algebraic equations **Global Ecodynamics** ,2004-07 Opening with a survey of contemporary global ecodynamics including its basic components this book goes on to discuss greenhouse effect problems in the context of global carbon cycle dynamics The coverage includes land ecosystem changes air sea exchange models high latitude environmental dynamics and a discussion of basic aspects of global environmental modelling and relevant monitoring systems The volume concludes by examining society systems with emphasis on the problems of sustainable development **Ecology of Arable Land — Perspectives and Challenges** M. Clarholm,L. Bergström,2012-12-06 Agriculture in the industrial world has gone A common interest of the contributors is increas through dramatic changes over the past decades ing the understanding of the turnover of carbon Mechanization in combination with high inputs of and inorganic nutrients in terestrial ecosystems fertilizers and pesticides has turned deficits of agri The authors approach this topic from different cultural products into surplus Over the same directions depending on their interests and ex period we have experienced increased environment pertise Difficulties are identified in the quantifica al problems in both the atmosphere and our water tion of below ground production where death and resources which have been associated with the re growth if incorporated into the calculations changes in management practices can change production figures considerably as Concern about the potential pollution by compared to values derived from peak estimates nitrogen fertilizers as well as the low utilization The role of root derived carbon is investigated in efficiency of applied nitrogen by plants has created relation to nutrient competition between roots and a need for a better understanding of nitrogen microorganisms the cost of N2 fixation and the cycling in the plant soil water system To achieve decomposition of organic nitrogen Mycorrhizae this it is neccessary to study process interactions use root derived carbon and their roles in phos and process regulation in an ecosystem context phorus conservation and in supplying nutrients to During the last decade many ecosystem studies the host are exemplified **Global Ecodynamics** Kirill Y. Kondratyev,Vladimir F. Krapivin,V. P. Savinykh,Costas A. Varotsos,2012-12-06 During recent decades the stirring up of the processes of globalization practically in all spheres of present day civilization activities has aggravated and brought forth numerous problems resulting from the nature society N S interaction It has become apparent that to solve these problems it is necessary to develop new concepts and approaches to the interpretation of global environmental changes that would enable one to select the first priority directions in studies and to reliably assess the state of the nature society system NSS One of these priorities is to predict global climate change The growing interest in the problem of global climate change determined by its practical importance and by available contra dictory estimates of the anthropogenic contribution to climate change necessitates a systematization of knowledge of and data on the observed climate change and causes of this change Despite an enormous amount of projects and programmes of studies of past and present climatic trends the problem of reliable prediction of future climate change remains far from being solved Emissions to the atmosphere of greenhouse gases GHGs mainly carbon dioxide is considered as one of the main causes of an expected climate warming resulting in sufficiently negative consequences for humankind Therefore an attempt has been made in this book to construct a formalized technology to assess the levelof the greenhouse effectdue to anthropogenic sources of carbon dioxide as well as the effects of other gas components *Plant Growth Modeling RES Mgmt* Karen Wisiol,1987-11-30 Part I Current plant growth models applications and data Mathematical descriptions of plant growth and development Applied plant growth models for grazinglands forests and crops Data for plant growth modeling and evaluation Parte II Forescasting and estimating plant yield Choosing a basis for yield forecasts and estimates Forecasting andestimating effects of weather on yield The scale problem modeling plant yield over time and space Part III The future of applied plant growth modeling The future of applied plant growth modeling

Phosphorus Dynamics in a Changing Agroecosystem Landscape Curt McConnell,2023 The availability of soil phosphorus P for plants changes as soil develops limiting plant growth in early successional stages as P slowly releases from parent material and doing so again in late soil weathering stages as the little remaining P in system is slowly fixed by the soil matrix Managing P deficiencies in many agricultural systems requires using P fertilizers as grain and hay harvest export nutrients from the soil plant systems However in the post Green Revolution world P excesses from over fertilization are ubiquitous Phosphorus removed with grain from one region is sometimes redeposited as manure in a different region which gradually increases the soil P content and that which is lost from hydrologic transport Agricultural P pollution is the principal driver of aquatic ecosystem eutrophication optimizing on farm soil P levels is therefore essential to sustainable food and fuel production Sustainable production systems are ever more reliant on precision technology predicated on analytical procedures that require a strong theoretical framework of the biogeochemical P cycle Knowing when and where P will be in excess or deficient and how it cycles in varying soils and conditions are integral steps to building the most reliable nutrient models and decision support tools Gaps in the understanding of P are reflected in poor model conceptualizations and in uncertainties of model results Research efforts in this work towards filling these gaps Chapter 2 include increasing the resolution of vertical P distribution measurements Chapter 3 exploring the controls on the microbial cycling of P using oxygen 18 tracers Chapter 4 and applying models to test new production systems that will ultimately shape the P cycle Chapter 5 One example of a gap in understanding soil P dynamics was the failure to predict increased soluble P losses from no till agricultural systems despite long knowing the practice stratifies P at the surface Prior to this research measurements of stratification were taken in 5 10 cm increments which may obscure the distribution of P at the surface extremes and thereby underestimate surface P loss potential I designed a new sampling tool was designed to extract thin cross sections of the surface soil in 1 cm increments It revealed that most nutrients are more stratified within the top 5 cm a pattern typically obscured by routine sampling Understanding the cycling of P has also been slowed by the absence of stable isotope P tracers To overcome this limitation using oxygen 18 to trace P dynamics has gained traction over the past decade As microbes process phosphate labeled with oxygen 18 18OPO4 the oxygen in the phosphate molecule reaches isotopic equilibrium with soil water thus the extent of the microbial P cycling can be tracked by following the oxygen 18 in phosphates However based on the research reviewed and conducted in this dissertation to test whether P saturation and P content affected microbial P use there was no measured equilibration of 18OPO4 This points to either slower turnover of soil P than previously thought a portion of the Mehlich 3 pool untapped by microbes a lack of measurement sensitivity or issues with divergent equilibration depending on the methods of 18O tracer introduction These limitations have only been vaguely addressed in the literature before Clarifying such limitations is a necessary step to improving the use of oxygen 18 as a P tracer our understanding of P biogeochemical cycling and ultimately the representation of P cycling in models Systems modeling can represent complex large scale processes without in field experimentation that become unfeasible at the scope of watersheds P losses from erosion runoff and through tile drains in agricultural systems are a significant contributor to P pollution Planting cover crops is an effective means of controlling nutrient losses but the earlier onset of winter in northern latitudes can hamper establishment of cover crops planted after the cash crop Interseeding cover crops between the rows of growing cash crops can help improve cover crop establishment and provide ecosystem services I used the Cycles model to simulate overall crop yields interspecific competition and nutrient losses and to determine at what latitude the tradeoffs of interseeding could be minimalized The model showed this to be around latitude 41 N where the benefits of interseeding outweigh the potential corn yield drag The constant feedback between model performance and experimental results is what improves our understanding biogeochemical P cycling in agroecosystems Knowing how P is distributed how it is cycled and how the surrounding landscape is changing due to aggressive human alteration of the P cycle globally regionally and within soil profiles will enable better modeling and implementation of sustainable management practices **Grassland Dynamics** J. H. M. Thornley,1998 The development of computer simulation models is an important growth area in both pure and applied ecology The opportunity that mathematical models provide to integrate the components of an ecosystem results in the ability to make quantitative predictions about the future behavior of that system or of elements within it This means that they are powerful tools with wide applications and enormous potential for increasing our understanding of natural systems and our ability to use them in a sustainable way This book is almost uniquely a complete account of one such model the Hurley Pasture Model a dynamic deterministic mechanistic simulation model for grassland which has been developed by the author over some 20 years in collaboration with scientists at several centers Firstly the rationale and theoretical elements of this type of model are described An overview of the Hurley grassland simulator and the derivation and construction of its plant animal soil and litter water and environment and management components is then given Next the model is evaluated by a series of long and short term dynamic simulations and steady state responses which demonstrate how predictions can be made about the effects of for example climate change or particular regimes of fertilizer application grazing or cutting This book will be of great value to grassland agronomists and modellers crop physiologists and plant ecologists and to students of ecology as a case study of a plant ecosystem model It will also be of interest to other ecologists and environmentalists and those in the field of computer modelling and its applications **Bulletin - National Fertilizer Development Center** ,1992

Dissertation Abstracts International ,2008 **Dynamics of Nutrient Cycling and Food Webs** Donald Lee DeAngelis,1992 Discusses aspects of nutrient cycling and food webs covering such areas as nutrients and autotrophs autotroph herbivore interactions disturbances to nutrient limited food webs effects of spatial extent and implications for global change **Effects of Global Change on a California Annual Grassland** Lisa A. Moore,2005 Soils and Fertilizers ,1998 **New Zealand Journal of Crop and Horticultural Science** ,1989 **Journal of Soil and Water Conservation** ,2008 Vol 25 no 1 contains the society s Lincoln Chapter s Resource conservation glossary **Towards Sustainable Land Use** Hans-Peter Blume,1998 *Ecology, Conservation, and Management of Kawar Lake* U. P. Sharma,1995

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