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Peter Finke

Modelling Soil Development Under Global Change

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Preface

Soil, largely equivalent to the critical zone, is the outer crust of the earth essential to support life by enabling plants, animals and microorganisms to thrive. The properties of this crust develop out of an intricate and complicated system of physical, chemical, mineralogical and biological processes, affecting a parent material. The part of this development that took place over past millenniums with limited human influence is traditionally called *soil formation* and leads to the identification of soil horizons. Since the impact of human activities on soils has increased, with considerable impact on the performance of soils for their various functions and in cases even the "rerouting" of soil formation, it seems better to use a more neutral and wider term like *soil development*. As the factor time is of importance and soil development has a much slower response to external influences than a super tanker to its helmsman, measurement of changes is insufficient to predict the effect and effectiveness of human impact. That is why modelling soil development is important to assess the impact of global change (i.e. climate and land use change). This book gives a personal perspective on the state of progress in the modelling of soil development.

During my Ph.D., I started to recognize the value of modelling, for short: the simulation of site-specific N-addition scenarios under precision agriculture to combine good crop productivity with minimal nitrate leaching. It was the combination of extending a water- and solute flow model (LEACHM) with crop biomass production routines, its testing, calibration and subsequent application in scenario studies that made me recognize the potential of modelling to answer scientific questions. The seed for all of this was sown by Johan Bouma, Jeff Wagenet† and John Hutson in the 1980s. Much later, the announcement of a workshop on modelling of pedogenesis (in Orléans, 2006) gave me the idea to develop a new model (starting from LEACHM) to simulate, at pedogenetic (multimillennial) timescales, aspects of soil formation such as C-cycling, (de)calcification, cation exchange chemistry. This triggered thinking on questions like *What soil properties can be considered constant at a chosen timescale*; *What feedbacks between soil properties exist and should be modelled* and *How to deal with processes with yet unquantified dynamics*, such as clay migration and bioturbation. As these are not minor questions, they stimulated usage of part of my brain capacity over a substantial period of time, largely outside working hours. In other words: the topic became a passion. Frequent visits to Sophie Cornu, Jérôme Balesdent† and coworkers at INRA between 2012 and 2018, and the fact that I inherited an M.Sc.-course on soil genesis certainly contributed to working on these questions as well. A soil development model produces great teaching material! A network of colleagues with interest in soil development modelling developed as a consequence of the IUSS working group on modelling of soil and landscape evolution that I led between 2013 and 2018. We organized several workshops in Pedometrics and EGU-conferences. Research collaborations, an Erasmus Mundus master programme on soils and global change as well as various PhDs are still keeping the topic alive today in my personal environment. More generally, soil development modelling is at present recognized as one of the 10 challenges of Pedometrics because it allows the quantification of the supporting ecosystem service "soil formation".

The precipitate of my own work on soil development modelling is the SoilGen model. This booklet describes the status of soil development modelling, and especially of SoilGen, at the time of my retirement, as some form of legacy document. This legacy includes the release of the source code of the model via a public domain repository, to be used, criticized, extended, simplified or cannibalized by colleagues.

Understanding and quantifying soil development is complicated because it involves the interaction between biological, physical, chemical and mineralogical processes acting at various temporal resolutions. Knowledge on some of these processes is still limited, which implies that an entirely mechanistic description is not possible. At the same time, mechanistic process descriptions allow better incorporation of feedback relations between processes in a model than empirical descriptions. The challenge is in finding the balance that maximally represents the state of knowledge. Another challenge is to keep potential users in mind, which requires a user interface and recognizing what a user may want to do with a soil development model. I surely used my Ph.D. students as guinea pigs to try out application domains (sorry!) I hope that these challenges are partly met in this book and model.

I am grateful for support by the research fund of the Faculty Bioscience Engineering at Ghent University for granting a sabbatical shortly before my retirement (which is not obvious). Equally grateful I am to Nicholas Jarvis and coworkers from the research group Soil and Environmental Physics, Department of Soil and Environment at the Sveriges Landbruksuniversitet in Uppsala for hosting this sabbatical and fruitful interactions. Several of my own Ph.D. students were SoilGen users and asked so many questions stimulating its development and robustness: Ann Zwertvaegher, Saba Keyvanshokouhi, Keerthika Nirmani Ranathunga, Sastrika Anindita and especially Emmanuel Opolot who codeveloped code on mineral weathering. Several coauthors significantly contributed to model development, testing and application studies: John Hutson, Yanyan Yu, Daniela Sauer, Sophie Cornu and Jérôme Balesdent†, Tom Vanwalleghem and especially Qiuzhen Yin, who added the dimension of palaeoclimate modelling. To Alex McBratney, Budiman Minasny and Arnaud

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