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978-0-521-86561-6 - Soil Carbon Dynamics: An Integrated Methodology

Edited by Werner L. Kutsch, Michael Bahn and Andreas Heinemeyer

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## Soil Carbon Dynamics An Integrated Methodology

Carbon stored in soils represents the largest terrestrial carbon pool and factors affecting this will be vital in the understanding of future atmospheric CO<sub>2</sub> concentrations. Through the understanding of the dynamics of this pool and its component fluxes, accurate model predictions of future climate changes will be possible. This book provides an integrated view on measuring and modeling soil carbon dynamics. Based on a broad range of in-depth contributions by leading scientists it gives an overview of current research concepts, developments and outlooks and introduces cutting-edge methodologies, ranging from questions of appropriate measurement design to the potential application of stable isotopes and molecular tools. It also includes a standardized soil CO<sub>2</sub> efflux protocol, aimed at data consistency and inter-site comparability and thus underpins a regional and global understanding of soil carbon dynamics. This book provides an important reference work for students and scientists interested in many aspects of soil ecology, and biogeochemical cycles, but also for policy makers, carbon traders and others concerned with the global carbon cycle.

WERNER L. KUTSCH coordinates the ecosystem fluxes group at the Max-Planck-Institute for Biogeochemistry, Jena, Germany. Previously, he worked at the University of Kiel, Germany and the Kruger National Park, South Africa. His research interests lie in dynamics of ecosystem fluxes, soil and ecosystem carbon balances, soil respiration and plant and microbial eco-physiology in temperate and tropical ecosystems. He has been awarded the Horst Wiehe Award 1994 by the Ecological Society of Germany, Austria, and Switzerland (GfÖ) for an 'outstanding scientific work in the field of Ecology'.

MICHAEL BAHN is senior scientist at the Institute of Ecology, University of Innsbruck, where he teaches ecosystem and plant ecology and ecophysiology. He has carried out research on plant resource utilization, functional biodiversity and ecosystem processes in numerous mountain ecosystems across Europe. For several years he has been particularly concerned with understanding abiotic and biotic controls on ecosystem and soil C fluxes and their components across a range of spatial and temporal scales, with a focus on global change and the plant - soil interface.

ANDREAS HEINEMEYER has been a soil scientist for more than 10 years, first at the University of Göttingen, Germany, and then at the University of York in 2002, where he continued to work as a research associate within the UK Centre for Terrestrial Carbon Dynamics. His research focus is on relating soil carbon stocks and fluxes to climate with a particular focus on the mycorrhizal symbioses, linking plant carbon supply to soil respiration. He was the first to have continuously measured mycorrhizal soil carbon fluxes in the field and is increasingly involved in plant-soil carbon flux model developments.

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# Soil Carbon Dynamics

## An Integrated Methodology

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## Preface

Soil has played a major role in human history. The literature of ancient Middle Eastern, Mediterranean, Chinese and Indian civilizations highlight the importance given to soil management and soil fertility. John Steinbeck's famous novel, *Grapes of Wrath* (1939), is one of numerous literary examples describing the dependency of human welfare on soil fertility. Set during the Great Depression Steinbeck focuses on a poor family of tenant farmers driven from their home by the Dust Bowl, droughts, economic turmoil and changes in agriculture practices. Despite this historical and literary context, our scientific understanding of soil and soil-associated processes, particularly the more biotic components, has remained limited. It is only in the last few decades that we have started to understand, in detail, the complex nature of soil biological communities and their environment, and soil biota's functional significance for ecosystem processes. We are now also considerably more aware of the role of soils, and soil biota, in regulating and determining the response of ecosystems to global environmental change.

Excluding carbonate rocks, soils represent the largest terrestrial stock of carbon, holding approximately 1,500 Pg ( $10^{15}$  g) C in the top metre. This is approximately twice the amount held in the atmosphere and thrice the amount held in terrestrial vegetation. Soils, and soil organic carbon in particular, currently receive much attention in terms of the role they can play in mitigating the effects of elevated atmospheric carbon dioxide ( $\text{CO}_2$ ) and associated global warming. Protecting soil carbon stocks and the process of soil carbon sequestration, or flux of carbon into the soil, have become integral parts of managing the global carbon balance. This has been mainly because many of the factors affecting the flow of carbon into and out of the soil are affected directly by land-management practices.

In his book, *Communities and Ecosystems. Linking the Aboveground and Belowground Components*, Wardle (2002) comments on how the majority of environmental

theory appears to be based on synthesizing what above-ground and aquatic biologists have found, with soil biology seemingly having a negligible effect on the development of this theory. This could be extended from the more biotic components highlighted by Wardle to carbon balance studies that have, for various reasons, been focused on studies based around the above-ground parts of ecosystems. It is not hard to see why! Whereas the carbon stocks and fluxes of the above-ground components can be quantified with relative ease, those of the below-ground parts cannot. That is not to say, however, that little is known quantitatively about the processes taking place within the soil. There is a significant body of work published by soil scientists over the past several decades precisely on this topic. Unfortunately, as so frequently has happened in biology, this work has been very much seen as the remit of the more 'traditional' soil scientists and little has been done to integrate the findings within the broader realms of ecosystem and general carbon balance studies.

Understanding the global circulation of carbon in the context of climate change is at the vanguard of European Science Foundation (ESF)'s Strategic Plan for 2006–2010. In identifying such an aim it was also recognized that there existed an urgent need to develop methods of studying and describing soil carbon balance that are not only empirically robust, but are recognized as being so. As highlighted in the 2007 *Intergovernmental Panel for Climate Change* (IPCC) report, achieving an international consensus on carbon balances and how to include soil carbon in carbon accounting procedures demands that methods of determining, reporting and verifying changes in soil carbon stocks are scientifically valid. To do this, soil carbon research must become more coherent, and develop greater linkages between pure and applied scientists, between mathematical modellers and experimentalists, and between scientists, economists and policy makers. It was for this reason that the Standing Committee for Life, Earth and

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Environmental Sciences (LESC) of ESF established the Role of Soil in the Terrestrial Carbon Balance (RSTCB) Programme, and from whose activities and deliberations this book has arisen. The RSTCB Programme was specifically set up to increase confidence in soil carbon flux and stock change estimates with the aim to generate reliable and consistent datasets; to develop a new generation of models describing soil carbon dynamics; and, finally, to investigate the effects of perturbation on soil carbon balance and the potential for mitigation of carbon emissions.

The increased importance of the issue has led to an increased number of Ph.D. studies in that area. The idea to write this book arose while the editors and most of the authors taught in a Summer School organized within the RSTCB Programme framework in September 2004, where 28 students, over a period of two weeks, were trained both theoretically and practically in soil carbon flux measurements. All students agreed that the course provided an extremely valuable overview and stressed the need of an integrated book on methodology. Since this need was felt across the whole scientific community, encouraging North American colleagues to contribute proved an easy task! Edited by the RSTCB Programme's Steering Committee Chair and two colleagues very much involved with the Programme, many of the volume's authors are internationally recognized in their respective fields of research. Indeed, many have been involved in one or more of the recent European and American networks established on the carbon relations of terrestrial ecosystems (e.g. Fluxnet, CarboEurope, Ameriflux, CarboMont).

Soils vary, spanning the range from the carbon storehouses of the polar and boreal regions to the

arid and semi-arid, desertification-prone soils of the Mediterranean and tropical zones and from the rich, intensively farmed soils of the low-countries to the thin, erosion-prone soil cover of more mountainous regions. The RSTCB Programme managed to bring together soil carbon researchers from all these regions to create a global perspective on the role of soils in the terrestrial carbon balance; the book highlights the value of such collaboration providing, for the first time, the essential standardized protocol for the assessment of soil CO<sub>2</sub> fluxes. Signatories to the Kyoto Protocol, many of which are economically developing nations, will be requested to submit national carbon budgets and/or review their Clean Development Mechanism (CDM) Sink Projects. Many of the authors whose work is presented in this volume have direct experience of working in these countries. It is very much hoped that the volume and its contents will contribute directly to capacity building in this field.

Hefin Jones, Member of the Standing Committee for Life, Earth and Environmental Sciences of the European Science Foundation

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