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Novel Methods for Monitoring and Managing Land and Water Resources in Siberia

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Preface

Inducement for the Book

A breakthrough in soil evaluation was achieved in the year 2006. The working group, Soil Classification of the International Union of Soil Sciences, published a new version of the World Reference Base of Soil Resources (WRB) for improving international communication about soils. It enabled an apposite name to be allocated to all soils of the globe. This name characterises typical features of soils and the processes behind them.

At the same time discussion about the need to improve public awareness about the functions of soils for humankind had reached a climax. It seemed to be difficult or even impossible to characterise soil functions using globally valid evaluation schemes. This was a momentous occasion for the editors and some of the authors of this book to remember a vision of the Russian geographer V.V. Dokuchaev (1846–1903), the father of modern soil science. He pointed out that the findings of soil science needed to improve the food security of the population. According to his vision, the characterisation and classification of soils should focus on characterising and maintaining or even improving their fertility.

Interesting work was carried out by scientists from the United States, Australia and New Zealand to evaluate the performance of soil for cropping and grazing. Russia, too, has long-standing traditions in such work. The approaches had a clear focus on soil structure but did not closely correlate with crop yields outside of their home areas, because other soil and climate factors dominated, such as drought.

Based on all these considerations the framework of the Muencheberg Soil Quality Rating (M-SQR) was born: a system which allocates fertility numbers to soils. Now we had a combination of two tools available to characterise soils by meaningful names and by their fertility potential. We were keen to test the feasibility of the M-SQR along with the WRB in very different climate and soil regions. The Russian partners and the German Federal Office for Agriculture and Food (BLE) were very open for this idea. In 2007 the project 05/07 "Indicators of fertility and function of agricultural soils" got started. It enabled joint fieldwork about soil classification and evaluation on numerous agricultural sites in both countries. The main partners were the Institute of Soil Science and Agrochemistry (ISSA) from Novosibirsk, Russia, and the Leibniz Centre of Agricultural Landscape Research (ZALF) from Müncheberg, Germany. Two years later the Pryanishnikov All Russian Research Institute of Agrochemistry (VNIIA) Moscow joined this project. Many sites studied and sampled were in Siberia.

Another small-budget project "Effect of climate change in boreal and sub-arctic ecosystems on water quality and soil functions, code 01DJ12058" was supported by the German Federal Ministry of Education and Research (BMBF) and enabled this cooperation between ZALF Müncheberg and ISSA Novosibirsk to be deepened jointly with IWEP Barnaul during 2012–2013. Overall, more than 15 joint publications appeared as an outcome of both projects.

Contacts deepened, and the network of researchers became broader. Gaps in the knowledge became clear and interest in closer cooperation accrued. However, first it was necessary to combine the numerous results, to interlink them with other running projects and extremely innovative activities, and to make them available for application in research and practice. That is the intention behind editing this book.

The focus on Siberia was obvious because of the exciting, remote landscapes and their great potential for the future of the population and of our whole planet. Land degradation and desertification are threats there which will have implications not only for food security but also for water resources and their quality, for biodiversity, the livelihood of the population and other crucial targets of landscape development and evolution. We put the emphasis on the unity and interactions between land and water, their resources, functions and quality. Reliable data are required about the status of land and water resources based on advanced, internationally proven and acknowledged methods.

One of the most important recognitions of our project activities was that many scientific and practical solutions for monitoring of land resources are available in Europe but not yet in Siberia.

All this is to be revealed in detail and some more eyes must be opened to see the potential improvements and the need for them. Learning from neighbours and cooperating with them helps to avoid same mistakes that they have already made, and it helps to save time and money. Based on the knowledge and technologies presented here, it is the responsibility of the current generation of scientists, decision-makers and other stakeholders that practical measures of monitoring and sustainable resources have to be taken.

Purpose of the Book

This book summarises the outcomes of the above-mentioned projects and of a number of other recent studies related to the topic of land and water monitoring and management. It is intended to be a source of information for all those dealing with its subject: methods for the characterisation and wise utilisation of land and water resources in Siberia. Besides information, it aims to deliver motivation for thinking about applications and new site-adapted solutions. It will also provide understanding and confidence that those better solutions are feasible based on the power of scientific-technical innovations and people's creativity and efforts in handling them.

The book will not overfeed readers with facts and data. The main intended innovation of the book is its focus on transferrable novel methods. Scientific tools will be proposed for measuring, evaluating, modelling and controlling processes in the landscapes of Siberia, especially in rural landscapes. The application of these new scientific tools requires not only open minds but also high levels of motivation and education. In some cases investments are needed. Thus, outreach and the adaption of new methods can only be realistically carried out in the framework of pilot studies based on further strengthened international scientific cooperation. The book is to serve as an advanced platform for new and more sustainable research cooperation between inventors and protagonists of new methods coming from different leading research institutions of Russia, Germany and other regions of the globe.

Content and Structure

The book offers a broad array of methods to measure, assess, forecast and control land and water resources: laboratory and field measurement methods of water and soil quality, methods of resource evaluation, functional mapping and remote sensing methods for monitoring and modelling large areas. It contains methods for ecosystem modelling, and the field monitoring of soils, and methods and technologies for optimising land use systems.

The book has 32 individual chapters in four parts and seven thematic clusters. In order to focus on the scientific value of individual chapters and the expertise of their authors, the editors have decided to keep the structure on a flat level of hierarchy and to allocate the chapters to four parts of the book only. These are

Part I, "Environmental and Societal Framework for Monitoring and Managing Land and Water Resources". It analyses the status of land and water resources in Asian Russia, evaluates the agri-environmental research and points out gaps in the knowledge.

Part II "Methods and Case Studies for Understanding and Monitoring the Landscapes of Siberia", presents further advanced research studies from Siberia about water and land monitoring and their methodologies.

Part III "Novel Approaches and Technologies of Application Potentials for Siberia" offers methods developed outside Siberia, but with great potential to be applied there in the near future.

Another Part IV "Synopsis and Overall Conclusions" consists of the chapter "Potential of Applying Novel Monitoring and Management Methods to Siberian

Landscapes" It reviews all thematic clusters and their individual chapters, summarises the overall book and draws conclusions for the application of novel methods.

Readers and Authors

Our addressees are scientists, planners, teachers, students, decision-makers and all readers who feel responsible for initiating the sustainable use of resources by scientific-technical innovations. Readers will gain some information and inspiration for their own work from this book. Based on this, they are encouraged to find their individual optimum when drawing conclusions and acting imaginatively.

Readers are also encouraged to contact the authors for more information. The chapter authors are pioneers behind novel methods, as well as being innovative and experienced scientists. Most of them come from Russia and Germany, others from different regions of the globe. Possible divergences between the findings, conclusions and statements of individual authors are natural. Data given in the various chapters of this book may include slight uncertainties, biases and inconsistencies. The editors have made no attempt to harmonise them because this is natural and reflects the different sources and local and temporal scales of the data. The chapter authors' conclusions do not necessarily need to coincide with the particular opinion of the editors. Chapters reflect the views of their author, and editors cannot be held responsible for any interpretation which may be made based on the information contained therein.

It is important to mention that in some chapters, trade names are used to provide specific information about proven technologies applied in the study. Mentioning a trade name does not constitute a guarantee of the product by the authors or editors. It does also not mean a preference for, or recommendation of this product.

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Many people and institutions provided the basis for this publication. We would like to thank the German Federal Office for Agriculture and Food (BLE) for travel funding as part of the project 05/07 of the German–Russian list of agricultural research cooperation. The International Bureau of the German Federal Ministry of Education and Research also provided travel funding for research work in project 01DJ12058.

Ms. Anne Koth (Dresden) proofread the chapters with prudence and expertise. The Springer publishing house ensured that the editorial and printing process was smoothly managed and completed. The editors would like to thank all funding bodies and other supporters for their help and engagement.

It was our pleasure to serve as editors of this book by coordinating and reviewing the written concepts and findings of motivated, enthusiastic scientists. We hope that our book can contribute to initiating the sustainable use of the land and water resources in Siberia.

Letschin Lothar Mueller
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April 2015

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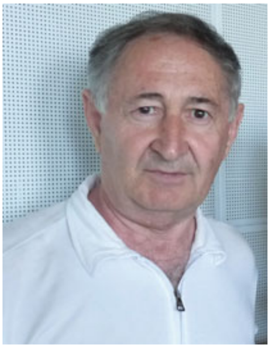
Lothar Mueller has published more than 350 papers, amongst them more than 100 peer-reviewed publications and book chapters. Most of this work was done in cooperation with his colleague Uwe Schindler.

Since 2013 he has been an Honorary Professor at the Kuban State Agrarian University in Krasnodar (Russian Federation) and an Honorary Doctor of the Russian Research Institute of Rice in Krasnodar. Since 2015 he is an Honorary Doctor of the Uspanov Institute for Soil Science and Agrochemistry in Almaty, Kazakhstan.

Over the past 20 years Lothar Mueller has built up international cooperation with leading experts around the world on the topic of agricultural soil and water monitoring and management. Many of them are contributors to this book.



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Part I
Environmental and Societal Framework for Monitoring and Managing Land and Water Resources

Chapter 1
Land and Water Resources of Siberia, Their Functioning and Ecological State

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Abstract Siberia is the backbone of the economy of modern Russia due to huge reserves of gas, oil, land and water. Not only resource extracting and processing industries, but also forestry and agriculture capitalize these resources with implications for local and global processes of nature and society. We analysed the state of land and water resources with regard to the impacts of human activity and climate change. The environmental status of forests, agricultural lands and inland water bodies was evaluated based on our own research and the recent literature. The focus was on agro-ecosystems. Our synthetic review revealed that peatlands and

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Tundra ecosystems are endangered by resource-extracting industries and industrial air pollution. Mining and industrial activity damage soil and vegetation and accelerate thermokarst processes. Forest ecosystems suffer increasingly from fires, insect outbreaks and improper management. Past and recent mining and industrial activity has polluted soils and water seriously in many regions. Permafrost melting could expose cases of old and inherited pollution. The impact of agriculture on water quality is still low but will increase. Agriculture is in a recession and operates inefficiently, destroying the soil. There is largely a lack of any agri-environmental monitoring in many regions. The rural infrastructure is on the verge of collapse, in the High North and the Far East in particular. State natural reserves (zapovedniks) are endangered by illegal activities and lack integration into scientific monitoring. Overall, monitoring programmes on the status of land and water resources lack consistency and modern technology. Climate change will put a great deal of additional pressure on Siberian landscapes, but hard data are required, and monitoring systems need to be modernized. Siberian landscapes have great potential for the mitigation of climate change through carbon sequestration and for improving people's livelihoods. Environmentally friendly business activities such as organic food production, environmental tourism and recreational fishing are still underdeveloped. We conclude that the status of food production and the disintegration of rural areas are risks for Russian food security and national security. Modern technologies for monitoring and research ecosystems are needed to generate sustainable developments in managing the land and water resources of Siberia.

Keywords Siberia · Land · Water · Quality · Environment · Ecosystems · Monitoring

1 Attributes and Resources of Siberia

Siberia is the region beyond the Urals, the Asian part of Russia, from a European perspective. It is a region of extremes and superlatives. The extremely harsh climate and massive stocks of natural resources—land, water, oil, gas, and minerals—determine its status of recognition and further development. Siberia is the coldest populated area on the planet, characterised by permafrost soil, snow and ice. The Siberian Taiga is one of the largest global ecosystems, comprising about one third of the total forest land on our planet. Siberia includes vast and impassable bogs and swamps, amongst them the Vasyugan bog, the largest global peatland. Forest Steppe and steppe regions in the south are part of the longest agricultural belt in the world. Yenisei, Lena, Ob-Irtysh and Amur rank amongst the top twelve global rivers, and Lake Baikal is the deepest freshwater lake, containing the largest available freshwater volume of the planet. Siberia's huge dimensions are impressive, always creating the illusion of the exhaustlessness of its resources.

Siberia is the treasure chamber and a basis of the economy of modern Russia. More than 70 % of the oil resources and more than 80 % of the gas resources of the country are stored in the north-west of West Siberia (Adam and Mamin 2001). The exploitation of gas, oil and minerals has been the driver for the increasing welfare of the urban population over the past years.

Siberia has much potential but faces some risks. Human exploration and climate change will induce a dynamic of ecosystem alterations with impacts for global cycles (Shvidenko et al. 2013). Some aspects and trends of climate change have been already recognized. These are global warming and the release of greenhouse gases into the atmosphere. Further resource exploration and utilisation and accelerated global warming may pose threats to nature including the human population. When thinking in terms of "environmental currencies" such as carbon sequestration potentials, Russia will be a leading global player due to Siberia's resources (Lioubimtseva 2010).

Food security is another issue of importance for Russia, but agricultural land and water management are in a recession (Gordeev and Romanenko 2008). The sustainable production of traditional goods such as local food or timber, which are based on healthy soil and water bodies, requires more scientific data and public awareness. We are at the beginning of understanding the complexity of these processes and re-evaluating land and water resources. Decisions about possible controlling and mitigating mechanisms need a permanent scientific background. What are the consequences of global warming and resource utilisation for soil and water quality, for the agriculture, forestry, human health and biodiversity of Siberia? There is a high risk that our understanding of these processes cannot keep pace with the speed of alterations, making them more and more uncontrollable. Trends in changes to the terrestrial and aquatic ecosystem need to be monitored permanently.

Are our available methods and tools for research and monitoring landscape processes doing well and do they meet future requirements? One aim of this book is to help maintain human society's capability to control processes and minimise the risks for future generations. This will be done by explaining some scientific, technological methods for understanding, monitoring, forecasting and controlling landscape processes in Siberia. The focus is on the main resources of land and water, on terrestrial and aquatic ecosystems. This introductory chapter analyses some basic settings and drivers of ecosystem change.

2 Geographical Regions and Landscapes in a Nutshell

From its physical geography, Siberia can be subdivided into several geomorphological areas: the West Siberian Plain, the Central Siberian Plateau, the Mountains of South Siberia and the Uplands of Northeast Siberia (Fig. 1). In-between the upland areas are further large lowlands such as the North Siberian Lowland, the Central Yakutia Lowland and the East Siberian Lowland.

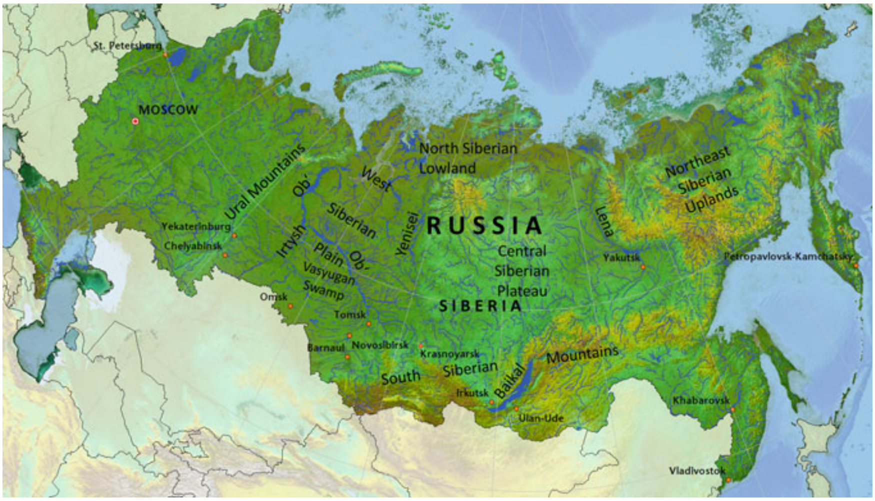

Fig. 1 Sketch of geomorphological landscape units. *Map* Ralf Dannowski

The West Siberian Plain begins east of the Urals and mainly covers the Ob River basin, along with some western parts of the Yenisei basin. In a world without glaciers much of this land and of the North Siberian Lowland would fall under the elevated sea level. The Yamal Peninsula and the land south of the Ob mouth would disappear. On a sketch drawn by M.G. Groswald and M.N. Sverkova one can recognise it as the largest closed area on the Northern Hemisphere which the ocean would claim back (Kotlyakov 1986). The West Siberian Lowland comprises more than a thousand lakes and ponds with an area of more than 100 thousand square kilometres (Antipov 2006).

The Central Siberian Plateau stretches roughly from the Yenisei River to the Lena River. It is bounded on the south by the Baikal mountain system and on the north by the North Siberian Lowland. The South Siberian Mountains system comprises a number of mountains such as the Altai, Sayan and Baikal Mountains. It is the spring and headwater area of the Ob, Yenisei and Lena rivers. The Northeast Siberian Uplands consist of some average and high mountain chains east of the Lena River.

From a historical European perspective, Siberia is considered the Non-European part of Russia. As Europe and Asia have no clear natural border, Siberia is also not an exactly defined geographical region. Based on administrative units of the Russian Federation the designation of Siberia is associated with the Federal District of Siberia (administrative centre: Novosibirsk). Other Federal Districts (Fig. 2) east of Europe are Ural (adm. centre: Yekaterinburg) and the Far East (adm. centre: Khabarovsk). Adding the area and population of these three Federal Districts (Siberia in a wider sense) reveals an area of 13.1 million square kilometres and a population of 37.6 million (Wikipedia 2013a). This is roughly comparable with Canada, the second largest country in the world, covering an area of about

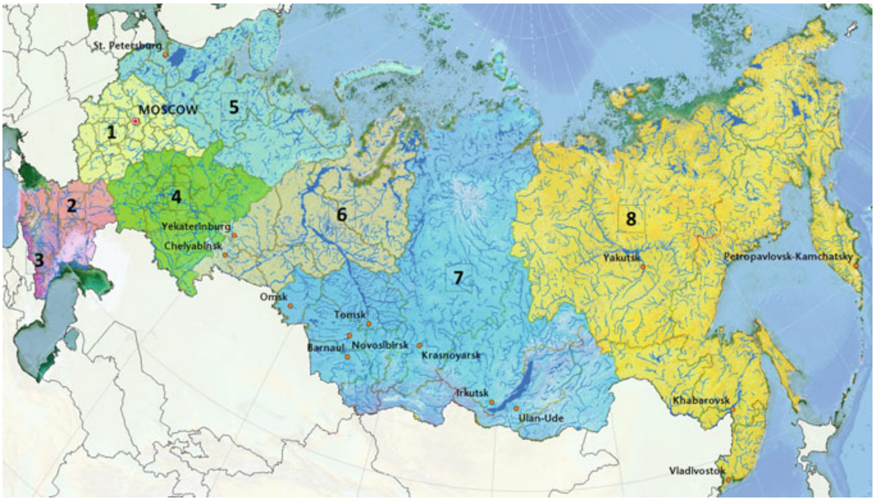

Fig. 2 Federal Districts (FD) of the Russian Federation. *1* Central, *2* Southern, *3* North Caucasian, *4* Volga, *5* Northwestern, *6* Ural, *7* Siberian, *8* Far Eastern. The map demonstrates the huge dimensions of the FD in Asian Russia (*7*, *8* and partly *6*). Note that FD's are administrative units and not the Federal subjects. Detailed information is given in Wikipedia (2013a). *Map* Ralf Dannowski

10 million square kilometres and inhabited by about 35 million people. Other sources exclude areas of the Russian Far East and the Ural districts from the definition of Siberia, then referring to an area of about 10 million square kilometres (Antipov 2006; Groisman and Gutman 2013).

Siberia is extremely sparsely populated but cannot be considered as a rural region. The region has a relatively short history. The Russian colonization started in about 1750. Siberia's exploration is well set out in the Museum of History in Irkutsk (Fig. 3). The emergence and growth of cities has been associated with the Trans-Siberian Railroad and industrial complexes. The population is concentrated in some large cities of the south. About 70 % of the entire population lives there whilst large regions are virtually uninhabited (Groisman and Gutman 2013). Cultural landscapes with stable rural centres, traditions in soil and water management and owners aware of how to sustainably handle land and water resources are still underdeveloped or not even found in Siberia. This has implications for the perception and evaluation of landscape values by the population.

Novosibirsk, the third largest city of Russia, is the political, social, scientific and cultural centre of Siberia. It lies about 1400 km south-west from the geographical centre of Russia (Lake Vivi, Evenki district of the Krasnoyarsk Krai). The distance from Novosibirsk to locations in the Far East such as Petropavlovsk Kamchatsky, or to the Bering Strait, is greater than the distance to the North Sea at Hamburg.

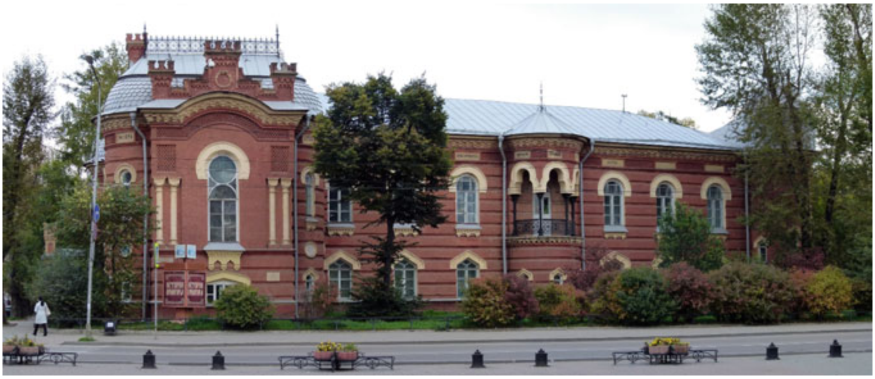

Fig. 3 The historical museum in Irkutsk presents the exploration and development of Siberia. *Photo* Ralf Dannowski

3 Climate

3.1 Temperature

Siberia is cold and dry, with particularly severe and long winters. Towards the south, mountain ranges protect it from the direct influx of water vapour and heat from the tropics and also largely from the moderate Atlantic climate system. The dominating climate-forming factor of Central Siberia is the Arctic Ocean. Cold and dry air masses form over the Arctic and dictate the climate of most parts of Siberia over the winter and the northern parts all year round (Richter 1963; Groisman and Gutman 2013). Most cities of Siberia are located between 52° and 56° Northern Latitude. This is comparable with some West and North European cities. Ulan-Ude has about the same latitude as London, Irkutsk that of Amsterdam or Berlin, Novosibirsk and Omsk that of Copenhagen or Moscow. Yekaterinburg, Tomsk and Krasnoyarsk lie slightly further south than Oslo, Stockholm and St. Petersburg. The position of Yakutsk is comparable with that of Trondheim. Large differences in winter temperatures between Europe and Siberia can largely be explained by the warm water heating system of the Gulf Stream which Europe benefits from. January temperatures in North-Western Europe are not far from the freezing point. They are clearly less than −15 °C in most parts of Siberia (Table 1). Summer temperatures in South Siberia are comparable with or even slightly higher than those in the above-mentioned European cities. Most climate stations have negative mean annual values indicating permafrost soil conditions. The cities of the Far East lie further south. The latitude of Khabarovsk is comparable with that of Paris or Vienna, and Vladivostok with Marseille or Sofia. Much colder winters are found in the Far East than in Europe at the same latitudes.