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Soil Quality and Crop Yield Potential of Sites in North and Central Asian

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ZUSAMMENFASSUNG/ SUMMARY

Science and technology may help to find solutions for sustainable use of soils. The awareness about limited and degrading natural resources have fired the energy and creativity of responsible and innovative people to develop and install monitoring systems and countermeasures. However, the access to modern monitoring systems and agri-environmental technologies is different over regions of Eurasia. Some regions of Central Asia and Asian Russia require modern monitoring systems for their land and water resources in order to avoid their accelerating degradation and maintain their productivity function and ecosystem services for the population

SCHLÜSSELWORTE/ Keywords: Land, soil, water, ecosystems, sustainability, research cooperation, monitoring, methods, soil quality, crop yield, Central Asia, Siberia

EINLEITUNG/ INTRODUCTION

The paper aims to initiate a sustainable use of soils in Eurasia by the application and transfer of novel scientific methods. Tailored solutions have to be based on detailed analyses and data. We start with an extended analysis of water and land resources, characterising the natural conditions of North and Central Asian landscapes, their ecosystems, crucial processes, and human impacts on soil and water quality. The status of research and monitoring is also characterised, pointing both on substantial progress achieved during the past decades, but also on gaps in our knowledge.

Following our analysis, rural landscapes in North and Central Asia have great potential for economically and ecologically viable business activities, but are currently characterized by inefficient and unsustainable land and water management practices, industrial pollution and the decay of the rural infrastructure. The land and water resources of Central Asia are in a particular critical state. Some keywords are: grassland degradation, humus loss and wind erosion on cropping land, salinisation of irrigated land, low agricultural productivity and water use efficiency, water scarcity, water pollution. Sustainable practices should be introduced soon, and this must be based on modern monitoring and management technologies.

To promote this, we offer an array of methods of measuring, assessing, forecasting, utilizing and controlling processes in agricultural landscapes. These are laboratory and field measurement methods, methods of resource evaluation, functional mapping

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and risk assessment, and remote sensing methods for monitoring and modelling large areas. Novel methods of data analysis and ecosystem modelling, of bioremediation of soil and water, field monitoring of soils, and methods and technologies for optimizing land use systems have been developed as well.

Status of agricultural land

Industrial pollution of soil

Industrial pollution of soil is a serious problem worldwide and also in Siberia. The air quality in Siberian cities and their industrial areas is very bad (Adam and Mamin 2001, Kashapov et al 2008). Urban air quality in several Siberian cities (e.g. Norilsk, Barnaul, and Novokuznetsk) is considered among the worst in Russian (Baklanov et al 2013). Siberian ecosystems have begun to show stress from the accumulation of pollution depositions that come from cities and industrial plants (Gutman et al 2013). Pollutants are being dispersed over soils of the region. Mining, transport and storage of industrial minerals or products has also led to point source pollution. Many areas around major metallurgical, chemical, and energy enterprises have been found to be polluted by toxic substances such as heavy metals, oil and oil products, sulphur oxides and chemical wastes. About 3.6 Million ha of agricultural land in Russia are contaminated with radionuclides and heavy metals (FAO 2013a). Under permafrost conditions industrial pollution is a particular threat because the damage to vegetation initiates thermokarst processes (Chuprova 2006, Baranov et al 2010).

Soil quality for agriculture

For environmental monitoring, both soil and water and quality can be measured using sets of chemical, biological and physical data. In the case of soils, there is a lack of conventions and international standards on the parameters required for this kind of monitoring. Some approaches do not meet a basic requirement of Dokuchaev (1951) that soil quality assessment on agricultural land should reflect crop yield potentials. It is useful to measure and evaluate soil quality in terms of its functions for society. For example, the specific role of soil and land in producing plant biomass for humans (productivity function, Mueller et al., 2011) remains crucial. Consequently, higher soil quality means the land has a higher crop yield potential. Land rating approaches of the former Soviet Union (Gavrilyuk 1974, Vostokova and Yakushevskaya 1979) meet these requirements in general. However, they base on yield data which are 60 and more years old and do not consider soil functional properties and climate conditions. More recent approaches (Krupkin and Toptygin 1999) based on important functional properties of soils like humus content or nutrient stocks have more regional meaning and cannot be transferred to other parts of Russia.

The overall situation of soil quality in Asian Russia and future trends in the context of the Eurasian and global situation does not seem to be clear yet but could be found out by using the Muencheberg Soil Quality Rating (M-SQR, Mueller et al., 2010) to create a strategy of assessing food security for Eurasia or the world. Work of Smolentseva et al (2014) showed that loess born soils of South Siberia have excellent basic soil properties in terms of texture, structure, rooting potential and water and nutrient storage capacity. However, climatic conditions like too late warming and drought are serious yield-declining factors. This leads to low overall rating values on a global scale (Smolentseva et al., 2014). Some examples are given in Figure.

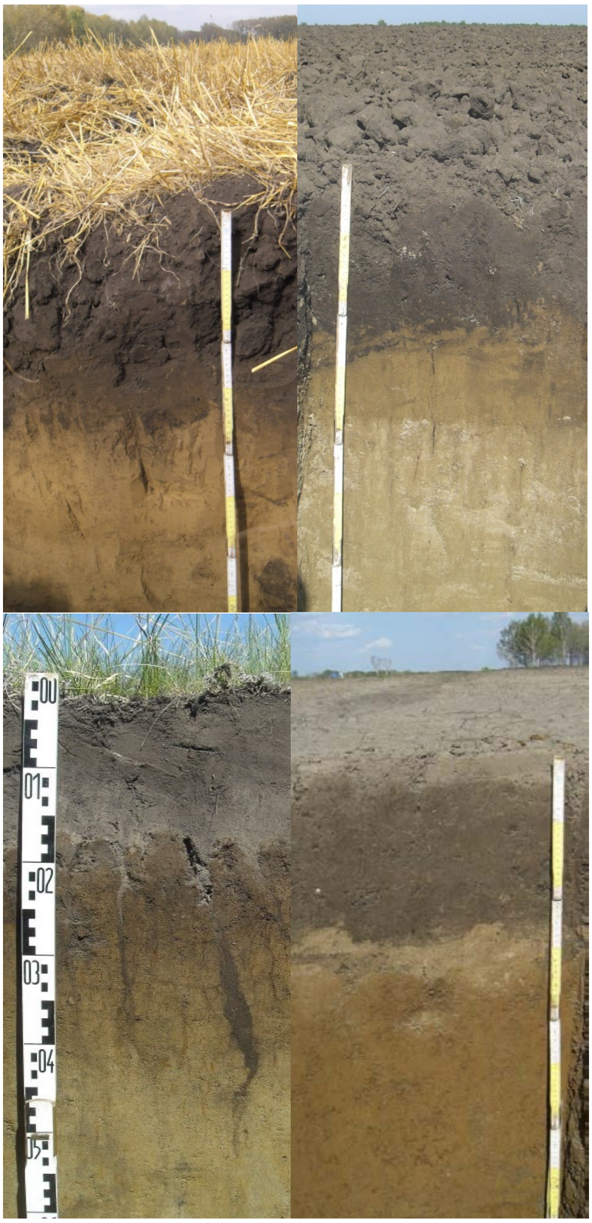

Figure 1: Examples of agricultural soils in Siberia and their quality for cereal cropping: a) Ordinary Chernozem of the research station Krasnoobsk, Forest Steppe, Rating points of M-SQR (Mueller et al 2011) 98 (Upgraded Basic Rating) /42 (Final Rating, including climate factors) b) Southern Chernozem of the Grushevka field near Bagan, Kulunda Steppe, degraded by wind erosion, Rating points 78/20, c) Solonetz near Bagan, Kulunda Steppe, Rating points 55/14, d) Luvisol of the Kochky site, Baraba Forest Steppe, Rating points 74/24. Classes of rating points are 0-20 very poor, 20-40 poor, 40-60 moderate, 60-80 good, 80-100 very good

Land degradation by agriculture

Degradation of agricultural land by wasteful and unsustainable management is one of the most important socioeconomic problems worldwide. This is also true for lands of Russia including Siberia. It poses a threat to ecological, economic and national security of the country. Data are inconsistent and differ depending on their assessment methodology but demonstrate huge dimensions of the problem.

The worst damage to Russian soils is caused by water and wind erosion (50 million ha), waterlogging (40 million ha), droughts (up to 170 million ha), land salinization and alkalinisation (40 million ha) (FAO 2014a).

Cropping agriculture if associated with soil tillage is risky for soil fertility and associated with permanent loss of soil humus and fertility. Schepaschenko et al (2012) calculated that arable land of Russia was a carbon source (carbon loss 0.8 t/ha and year), whilst pasture and hayfields were a sink of 0.29 t/ha and year. Zhulanova (2013) found negative carbon balances of the Dry Steppe (0.76 t/ha and year) and Steppe (0.19 t/ha and year), whilst carbon of the Forest Steppe was about balanced under agriculture in south Siberia. Table shows the percentage of degraded agricultural land in Siberia.

Wetness of agricultural land is a permanent yield-declining issue in West Siberia and the Far East. It is often combined with salinization and wind erosion in Steppe regions. Degradation means an irreversible loss of soil productivity potential. Drought as a most severe productivity –limiting factor leading to desertification in current Dry Steppe and Steppe regions is not listed here. Also data about other soil degrading factors like permanent humus loss and soil compaction are not included in Table.

When tilled, soil loses its protective vegetation and becomes prone to wind erosion. Just in Steppe regions of Asia wind erosion may be reach global dimensions in future due to mismanagement of soils by ploughing (Suleimenov et al 2014). Halting anthropogenically induced land degradation by introducing more sustainable land management is a challenge for Asian Russia. This has also implications for the sector of agri-environmental research.

Status of grasslands

Grasslands and rangelands are an underestimated resource for biochemical cycles and for human welfare. There is a lack of reliable data on the status of pasture or rangeland degradation in Siberia. The situation is similarly unclear like in landscapes of Kazakhstan and other countries of Central Asia (Mueller et al 2014). Long- term succession studies in grasslands done by the Sochava Institute of Geography (Nechaeva et al (2010) along with chemical soil analyses are important for understanding local grassland ecosystems. However those studies lack linkages with modern diagnostic and monitoring methods. A loss of plant and wild animal diversity, an increase in unpalatable or toxic plants, a loss of soil fertility and productivity and a decline in livestock production are examples of possible indicators. Rangeland recovery may comprise palatable biomass, biodiversity and rare species.

Biodiversity of grasslands is influenced or threatened by several disturbances such as habitat loss, fragmentation of natural communities, over-exploitation such as overgrazing, penetration of non-native species, environmental pollution, climate change, and other elements. Local overgrazing or periodic ploughing of grasslands are crucially negative impact factors. Both overgrazing and underutilization decrease the natural potential of Steppe soils (Kandalova and Lysanova, 2010). Desertification tendencies of Siberian grasslands have been already detected (Meyer et al 2008).

Peatlands and their significance for landscape functioning

Almost 370 Million ha of peatlands are located in the Russian Federation, the majority of them in the Taiga zone of the Asian part (Table). They are of crucial importance for biodiversity, carbon storage, hydrology and other environmental functions (Liss et al 2001, Kremenetski et al 2003). The West Siberian lowlands are the world’s largest high-latitude wetland region including vast and deep peatlands. Sheng et al 2004 estimated the total area of peatlands in West Siberia at 59.2 Million ha and the total carbon pool at 70.21 Pg (Petagrams= Billion tonnes). The Vasyugan Mire is the largest of them covering an area of 5.3 Milion hectares (Inisheva et al 2011).

Humid Taiga and Tundra of Siberia are regions of permanent peat accumulation and thus a permanent natural carbon sink. From recent models based on numerous measurements, sphagnum mosses grow up about by 12 mm/yr. in the northern Taiga, 16 mm/yr. in the middle Taiga and 12 mm/yr. in the southern Taiga. The annual carbon accumulation ranged from 90-160 g/m^2 (Dyukarev et al 2011). Inisheva und Berezina (2013) report on an increasing peat layer by about 0.4-0.7 mm/year and quote an enlargement of the peat area of 92 km^2/year based on data of Neistadt (1971). Also in the warmer Sub-Taiga of south Siberia, Larin and Guselnikov (2011) found an annual increase of wetland areas by 4.6 km^2 and year.

Net primary production in eutrophic swamps of the Forest Steppe was about 600–700 g/m^2 and year of dry mass (Kosykh 2009). It was higher (1285 g/m^2) in peatlands of the Altai mountains where roots of wetland grasses contributed 80% of the NPP (Kosykh et al 2010). About half of the dry biomass is carbon. Inisheva et al (2011) measured NPP of peat sites 171-296 g C/m^2. Lapshina and Bleuten (2011) report on NPP of 150-500 g C/m^2 and year in peatlands of West Siberia. Carbon storage (NPP minus heterotrophic respiration) was 30-70 g C/m^2 and year, and methane emissions were about 0-5 g C/m^2 and year.

Threats to peatlands of Siberia differ from those that are known from peatland regions in Western Europe. In Western Europe, peatlands are a carbon source due to drainage and agriculture in a temperate warm and subhumid climate (Drösler et al 2008, Mueller et al 2008).

Figure 2: Peatlands in the Southern Taiga a) Natural bog with anthill of *Formica spec*. These ants are very important for biological preventing of insect calamities. b) Cultivated and abandoned peatland

Land drainage which is responsible for carbon loss of west European peatlands, had no significant influence on the carbon balance in West Siberia (Inisheva et al 2011). Loss of carbon due to heterotrophic respiration higher than NPP seems to be not a threat to Siberian peatlands. However, more reliable data are required in spite of climate change. In general, measuring NPP and respiration by different methods, which was done in most cited studies of Siberian peatlands may lead to biased results of carbon balances. Meanwhile, more sophisticated and accurate methods of measuring carbon balances in situ are available (Chojnicki et al 2010, Juszczak et al 2013).

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