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# Assessing soil degradation in northern Eurasia

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ABSTRACT

Soil degradation in Northern Eurasia was given much less attention than hotspots in tropics. Our review of the maps showed that the arable lands of the region were impacted by degradation. We intended to compare soil degradation assessments for the region, to outline the gaps in the studies and to propose ways forward in the soil degradation studies. The organization of monitoring of the state of land and soil is needed for maintaining soil productivity and supporting soil ecosystem services. The regular surveys in Russia do not always adequately address salinization, erosion and soil contamination. Both the status and the rate of soil degradation should be assessed on the basis of combined remote sensing and field surveys.



**Contents**



## 1. Introduction

Soil degradation is defined as the diminishing capacity of the soil to provide ecosystem goods and services as desired by its stakeholders (FAO, 2015). Degradation can result from truncation of the soil by erosion by wind, water, or tillage; changes to the soil chemical and

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biological environment through acidification, salinization, or contamination; accelerated loss (through erosion, decomposition, leaching, or export in crops) of nutrients derived from soil mineral and organic materials and of the organic matter itself; suppression or elimination of soil biota through deliberate or indiscriminate actions; reductions in soil pore space by soil structural modifications due to compaction or other stresses imposed on the soil; and soil sealing (land take) by infrastructure and housing development. Soil degradation is frequently confused with land degradation that concerns a more holistic phenomenon related to the loss of productivity of ecosystems, biodiversity, water quality etc., which may include or not soil degradation. Soil and land degradation strongly affect the efficiency of agriculture (Blaikie and Brookfield, 1987; Nachtergaele et al., 2011). These negative processes also affect ecosystem services (Robinson et al., 2013) and human health (Oliver, 1997). During the last decades the pressures on land significantly increased: these pressures include rapid growth of population and the effects of climate change that is at least partly induced by humans (Oldeman, 1998; Hooke et al., 2012). The major drivers of soil degradation are climate aridization (D'Odorico et al., 2013), unsustainable agricultural practices, industrial and mining activities (Dudka and Adriano, 1997), expansion of crop production to fragile and marginal areas (Shangguan et al., 2014), inadequate maintenance of irrigation and drainage networks, and overgrazing (Hooke et al., 2012). According to the estimation made in 1990s on a world-wide basis in the frame of the GLASOD project, discussed in more detail below, more than 1964 million hectares of land was considered affected by human-induced soil degradation: 749 million hectares was lightly degraded, 910 million hectares was moderately degraded, 296 million hectares was strongly degraded, while 9.3 million hectares was considered extremely degraded (Oldeman, 1998).

In the second part of the 20th century the importance of soil degradation as an important threat to food security and other ecosystem services was accepted in many countries, including the USSR (Snakin et al., 1996). Maps of the various soil degradation processes in the region have been made (e.g. Sobolev, 1968; Bazilevich and Pankova, 1976) and results were incorporated in the global GLASOD study (Oldeman et al., 1991). Results of this study were questioned because they reflected expert-opinion rather than objective measured criteria (Sonneveld and Dent, 2009).

The search for expert-independent criteria has led to the idea to use the dynamics of productivity of vegetation as an indicator of land degradation. For instance NDVI (normalized difference vegetation index) has been used for estimating the long term bio-productivity trends using remote sensing data and after correction for climatic variations as an indicator for land degradation (Bai et al., 2008). In a further development, the previous approach was combined with global datasets on natural resource and models for estimating the global status and trends of land degradation processes (Nachtergaele et al., 2011). The analysis of NDVI also encouraged Le et al. (2014) to make a global estimation of land productivity for the assessment of the economic effect of land degradation.

For making reliable assessment of the state and rate of land degradation in Russia we decided to revise the existing national and international inventories and maps and estimate the credibility and accuracy of the data in these sources. The following criteria were used to confirm the credibility of the products: 1) the results have been obtained by direct observation and measurement, either in the field or using remote sensing data, 2) the number of observations has been big enough for making extrapolation of the point observations to the entire area of the region, 3) the results obtained using one method have been validated or extended using another method, e.g. field studies on key polygons have been extrapolated with the help of satellite images. The aim of the study was to outline the gaps and the ways forward in the land degradation studies in Northern Eurasia in order to improve the quality of estimations of the economic cost of land degradation.

## 2. Results

The list of the maps that have been produced in Russia and earlier in the Soviet Union is presented in Table 1. In this table the major mapping products are listed in chronological order. For better understanding of the results, the national assessments of soil degradation in Northern Eurasia are presented separately from the results of this territory in global or regional maps, except of the GIS of soil degradation in Russia (Stolbovoi et al., 1999), which is discussed together with international maps, because it used the same methodology as GLASOD (Oldeman et al., 1991) and corresponding regional maps.

### *2.1. The assessment of particular soil degradation phenomena*

In the Soviet Union, the first reliable assessments of soil degradation were made in the 1960s and 1970s (Sobolev, 1968; Bazilevich and Pankova, 1976). The basic information for these maps was obtained by a systematic survey of the agricultural lands of the country, which occupy less than 14% of the total national territory. These maps intended to inventory in particular soil erosion and salinization that were considered the most important phenomena of soil degradation in the country. The accuracy of these maps was limited by two conditions: (i) the intensity of the surveys undertaken was not uniform throughout the country: in places the study sites were densely sampled, and in places the results were extrapolated using so-called "key plots" (see Omuto et al., 2013); (ii) the spatial extension of the degradation phenomena was not controlled by remote sensing data, although in places aerial photographs were used for estimating gulley erosion and strong salinization (salt crusts at the soil surface) (Pankova and Mazikov, 1985). Actually the assessment and monitoring of soil degradation is done by two governmental institutions: the Agrochemical Survey of the Ministry of Agriculture and the Federal Survey for State Registration, Cadastre and Cartography of the Ministry of Economic Development of Russian Federation. The Agrochemical Survey makes regular agrochemical inventories of the agricultural lands of the country, and theoretically should also document soil degradation. The Federal Survey for Land Registration among other activities makes detailed studies on soil degradation on few key polygons, and then extrapolates the results to the national territory using remote sensing data. The efficiency of these surveys and the gaps in their activities will be discussed further.

#### *2.1.1. Soil erosion assessment*

Soil erosion is the most widespread aspect of soil degradation, especially in the mountains and in the areas with sparse vegetative cover (Ravi et al., 2010). In the first national assessment of soil erosion in the USSR (Sobolev, 1968) the evaluation of the rate of soil erosion was mainly empirical, as no models like USLE have been used for quantification the potential soil runoff. The main criteria for soil erosion assessment were the visible loss of topsoil layers and the decrease in the content of organic carbon. For strongly eroded soils the criteria worked well, as the disturbance of soil profile was evident. However, for weak erosion in the absence of morphological evidence the logic was somewhat circular: the soils with lower organic carbon content were considered to be eroded and then this fact was used to prove that mainly erosion was responsible for the loss of carbon. The fact that natural variation of organic carbon content is soils is high and depends on multiple factors was neglected. In some maps all the soils located on moderate slopes were shown as weakly eroded, independently of the real loss of soil material due to water erosion. This approach led to the overestimation of sheet soil erosion and thus complicated the identification of the real hotspots for action. This does not imply that the menace of potential soil runoff was exaggerated everywhere.

The status of soil erosion in the Soviet Union was shown on a map at the scale 1:4 million, prepared by a big collective of authors coordinated by the Dokuchaev Soil Institute (1992). This map summarized the results of long-term studies of water and wind erosion in the Soviet