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Monitoring of Soil Fertility (Agroecological Monitoring)

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ZUSAMMENFASSUNG/SUMMARY

Monitoring the ecological status of agricultural land in trials with different inputs of fertilizers is focused on analyzing soil fertility indicators and their impact on productivity. Some of these experiments are long-term and part of international networks. Their results are of fundamental importance for monitoring, modeling, and controlling the status of soils. In a regular survey, we found tendencies toward decreasing soil fertility in some regions.

SCHLÜSSELWORTE/ Keywords:
Agriculture, Soil, Fertilization, Soil fertility, Experiments, Russia, Monitoring

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EINLEITUNG/ INTRODUCTION

The preservation of natural systems and maintain the appropriate quality of the natural environment is the basis of food security and sustainable development of the agricultural sector of countrys.
In Russia ways and means for implementing the state policy in agriculture, environment and natural resources is determined by the State program of development of agriculture and regulation of markets of agricultural products (2013-2020) (State program 2013-2020) and the environmental doctrine of the Russian Federation (Environmental doctrine, 2002).
It includes development of the state management system for nature conservation and nature use; monitoring of all environmental components, including agricultural lands; scientific support for nature management.
In the Russian Federation, the Ministry of agriculture is responsible for monitoring network of soil fertility (agro-chemical and agro-ecological soil condition of agricultural land). The system of agroecological monitoring in Russia. has been developed and operated by the Pryanishnikov Institute of Agrochemistry in Moscow.
The analysis of the experience of systems of monitoring of soils in different countries has allowed to improve the Russian system of agroecological monitoring of soils and to develop criteria for the adequacy and accuracy of the information obtained in the course of the monitoring for the solution of management problems.
Requirements for soil monitoring may be different depending on priorities, but organizational and methodological principles of monitoring remain unchanged: planned observations and the standardization of methods of data processing and analysis (Sychev and Romanenkov 2009).
In Russia there is no uniform monitoring system of agricultural lands. Local monitoring on the reference plots, test areas, and plots of long-term field experiments ran by the Geographical

Network, as well as the periodical agrochemical soil survey of agricultural lands and models of soil fertility, are complementary methods within the integral approach to assess the effect of economic activities and natural factors on the agricultural soils.

DATEN und DATENBEARBEITUNG/ DATABASE AND DATA PROCESSING

The modern system of data storage and processing based on the electronic format of the regional databases with the reference sampling points and field borders. A national database maintained by the portal of the Central computer centre in the Ministry of agriculture with access to data lines for data providers and automated integration and processing of planned updates. The system was launched in 1998-2003.

Georeferenced information can be combined with large amounts of data depending on the use of land, soil type or a group of indicators and can be used to make policy decisions at the local, regional or national levels, for example, in calculating the soil fertility index to allocate subsidies in the territorial entities of the Russian Federation, introduced in 2013.

Local monitoring data makes it possible to integrate an expanded set of indicators with data sets obtained during a soil survey. Additional information on acid-base parameters, the dynamics of nitrates and the atmospheric entry of acid, heavy and trace metals, aggregated by soil type, usually appears in the reference charts.

Data storage requires a unified database format for practical data management at the local level (the European format for Russian long-term experiments (Smidi et al., 2001) or at the regional level (Sychev et al., 2008).The database of long-term experiments can be an indispensable tool for integrating with geographic information systems (GIS), modeling tools, and developing analytical methods.

However, a satisfactory data flow from local monitoring for regular reporting and decision-making still has to be developed. At the moment, all analysis and trends are the subject of scientific research and not updated on a regular basis, and we currently have much better opportunities for manipulating data using excellent techniques, such as modeling, for forecasting, prediction, and scenario analysis (Sychev et al. 2011).

In order to make the soil information collected relevant for different categories of end users, the following activities may be helpful:

- Giving users access to archived information through regular reports and websites.
- Regularly comparing the soil survey and local monitoring data.
- Performing statistical analysis to obtain confidence limits for interpretation.
- Integrating data sets obtained from other environmental monitoring networks, including remote sensing domains, into our monitoring system.
- Widening the utilization of georeferencing information and spatial analytical tools to identify “hot spot” areas.

EREBNISSE/ RESULTS

Soil organic matter (SOM):

Soil organic matter and humus (its component) are important parameters, determining the genesis and potential feitility of soils. The reserves of soil organic matter play a decisive role in the reproduction of soil fertility. Monitoring data of agricultural soils based on regular surveys indicates that a decrease in the area of ploughland with a low humus content was observed during the years of intensive chemicalization (1975-1990). Since the 1990s, an inverse process has been observed (an increase in the area of ploughland with a low humus content, especially in the southern natural-agricultural zones). The results of the survey and data from local agroecological monitoring show that the weighted average content of organic matter in arable soils is 4.1 % for the entire Russian Federation. Arable soils with an average organic matter content of 2-4 and 4-6 % are predominant (39.1 and 28.9 % of the surveyed area, respectively). Arable lands containing less than 2.0 % prevail in the Northwestern (21.4 %) and Central (22.6 %) federal districts, where most ploughland is located in the zone of podzolic and soddy-podzolic soils.

A significant increase in the area of ploughland with a low humus content has been noted during the past 25 years. Especially, significant changes occurred in the dry-steppe zone, where their increase exceeded 20 %.

A comparison of the total humus content with different SOC fractions reveals the role of organic matter as a factor connected with crop productivity and soil functions. Generalization results of this kind of study in arable and native Leached Chernozems from the forest-steppe zone of the Novosibirsk Ob' region showed that the decrease in the soil organic carbon pool under long-term use as ploughland is due to the predominant loss of detritus (nonhumified fraction of organic matter) and easily mineralizable organic matter. The contents of detritus, labile C, and total organic C in native and abandoned soils were 3.8, 1.2, and 1.1 times higher than those in the old arable soil, respectively.

Soil acidity: In most of European Russia, soil acidity (low pH) is the main factor limiting the obtainment of high crop yields. In the 1960s, natural soils with an acid reaction comprised up to 80 % of the area in northern European Russia and up to 45 % in the central part. During the period of intensive chemicalization, the area of soils with a pH <5.0 decreased to 20 % due to periodical liming. However, the volume of liming has now decreased by more than 20 times. Therefore, soil acidification has become an urgent problem in some regions. The highest portion of acid soils (more than 70.0 %) is observed in the Komi Republic; Orel, Kirov, Tambov, and Penza Oblasts; and Perm Krai. More than half of arable soils have an acid reaction in some regions of the Russian Federation: 58.4 % in Adygeya, 60.6 % in Karelia, 68.8 % in Mordovia, 54.7 % in Vologda Oblast, 55.5 % in Yaroslavl Oblast, 63.2 % in Smolensk Oblast, 65.7 % in Lipetsk Oblast, 65.4 % in Kostroma Oblast, 69.6 % in Tula Oblast, 69.2 % in Ryazan Oblast, and 68.3 % in Nizhni Novgorod Oblast.

In the past 25 years, the area of acid arable soils in the Tambov Oblast (zone of chernozemic soils) has increased by 27.8 %, with the annual increase exceeding 1.1 %. The weighted average pH value decreased from 5.7 in 1971 to 5.4 in 2009. Same processes are taking place in other regions of the Central Chernozemic zone (Penza, Lipetsk and Belgorod Oblasts).

At the same time, the generalized data for the Non-Chemozemic zone of Russia obtained during 30 years of monitoring observations indicate that agriculture is significantly efficient when acidic conditions are optimized in both light- and heavy-textured soils.

Plant-available nutrients: Under natural conditions, most ploughland has an insufficient content of available phosphorus. Until 1990, the areas of soils with a low phosphorus content decreased by 2-3 times due to the application of significant amounts of phosphorus-containing fertilizers. However, this is due to the removal of low-productivity lands from agricultural use rather than to the long-term after-effect of phosphorus fertilizers. Presently, the percentage of arable soils of Russia with medium and increased phosphorus availability is 57.0 % of the area.

In some regions of the Russian Federation, the reduction of the ploughland area with a high phosphorus availability is accompanied by an increase in the areas of soils with a very low or low phosphorus content. In total, the area of arable soils with a low phosphorus availability has increased by 478.7 thousand ha. In the Republic of Kalmykia and the Lipetsk and Tambov Oblasts, the area of these soils has increased significantly (from 10 to 20 thousand ha); in three regions, the areas of arable soils with a low phosphorus availability have increased by more than 40 thousand ha: by 47.2, 43.0, and 49.7 thousand ha in Stavropol Krai, Orel Oblast, and Volgograd Oblast, respectively. In Rostov Oblast, the area of ploughland with very low phosphorus availability has increased by 56.3 thousand ha.

The results of the agrochemical survey of agricultural soils, local agroecological monitoring, and long-term field experiments of the Geographical Network revealed two main tendencies of changes in soil fertility:

• a slow but permanent decrease in the contents of humus and available phosphorus and potassium (the rates of these processes vary among the regions, but negative tendencies are observed everywhere);

• movement of the boundary of acid soils to the south, to the zone of Chernozems, the most valuable soils.

To preserve and reproduce soil feitility, the contents not only of major mineral nutrients, but also of microelements, should be considered. Data on soil fertility monitoring indicate that the soils of all agricultural lands are insufficiently supplied with mobile forms of essential microelements (B, Mo, Zn, Cu, Mn, Co). The area of soils where microfertilizer application is necessary is increasing. Presently, the microelement deficit needs to be made up for in almost all natural-agricultural zones of Russia: by 26.8 % for boron, by 84.5 % for molybdenum, by 96.9 % for zinc, by 71.6 % for copper, by 74.5 % for manganese, and by 92.6 % for cobalt.

SCHLUSSFOLGERUNGEN/ CONCLUSION

- Agroecological monitoring is an efficient tool for solving problems in the maintenance of soil fertility, as well as for preventing and controlling the negative anthropogenic impact on agroecosystems.
- Local monitoring on the reference plots, test areas, and plots of long-term field experiments of the Geographical Network, as well as the periodical agrochemical soil survey of agricultural lands and models of soil fertility, are complementary methods within the integral approach to assess the effect of economic activities and natural factors on the agricultural soils.
- Long-term field experiments can be used to determine environmentally optimal fertilizing systems and assess the role of separate practices in the positive and negative environmental impacts; they are an indispensable tool for integration with GIS and developing analytical records.
- Local monitoring data are still underrepresented in regular reports and decision making, including those of Siberia and the Far East, and a satisfactory data flow from local monitoring still has to be developed.
- There is some ongoing work to integrate new modern monitoring methods and information systems into the already successful running monitoring program.

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