IOP Conference Series: Earth and Environmental Science

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IOP Conf. Series: Earth and Environmental Science **263** (2019) 012025 doi:10.1088/1755-1315/263/1/012025

Monitoring of agricultural lands in Arkhangelsk region

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Abstract. The article presents the specific features of the agricultural lands monitoring system in Arkhangelsk, aimed to create a database on up-to-date conditions of agricultural soil cover. Data is presented on the regional soil status and the scale of lands withdrawn from agricultural use. Among the area's plough lands, plots with neutral soils with higher content of organic matter, phosphorus, and potassium prevail. Plough lands are considered ecologically clean. Further, the arctic presents the results of the time-ordered monitoring of abandoned lands (over 60 test plots) in the most fertile floodplain soils (Primorsky Municipality) and azonal carbonate soils (Kargopol Municipality). The study has found that cost-effective rehabilitation of the abandoned lands is possible provided that their abandonment does not exceed 40 years.

1. Introduction

The monitoring of agricultural lands in Arkhangelsk Region is the responsibility of the Agrochemical Station "Arkhangelskaya", subordinate to the RF Ministry of Agriculture and established in 1965. All agricultural lands shall be examined every 7 years with parallel analysis of reference plots. According to the State Register (Rosreestr) for Arkhangelsk Region and Nenets Autonomous Okrug, presently (as of January 1, 2018) 2313.2 K hectares of the area's lands are classified as rural lands, with 631.2 K ha among them classified as agricultural lands (ploughlands, haylands, and grazing lands).

One of the tasks pursued by the monitoring system is to create a database of agricultural soil cover conditions. Especially important to consider is the period of extensive agriculture, caused by the change in the social and economic conditions in the 1990s, when huge areas of ploughlands became abandoned and overgrown by coniferous and foliage trees. Most prominent are the changes in derelict ploughlands, as their arable layer had caused changes not only in the soil profile, but also vegetation [1]. Plans to bring them back into use should be guided by the quality of their soils [2].

The large-scale use of organic and mineral fertilizers, and the regular application of lime in the Soviet time had resulted in high fertility of ploughlands. In half of Arkhangelsk municipalities, neutral soils prevail (49%). Acid soils prevail only in the northern municipalities (Leshukonsky, Mezen). Commonly occurring are ploughlands with high content of organic matter, phosphorus (101-250 mg/kg), and potassium (81-170 mg/kg of soil). The ploughlands of the North are considered ecologically clean. Copper and zinc content in the soils of Arkhangelsk Region is significantly lower than their maximum permissible concentrations (MPC) [3].

However, in 2016 only 77.0 K ha of ploughlands (27.2%) were sown. Most intensely used are the ploughland of Velsk (with 50%-60% of ploughland not in use) and Kargopol (61%-70%), whereas in the rest of the municipalities, over 70%-80% of ploughlands remain abandoned.

Among the abandoned agricultural lands are the ploughlands with most fertile soils – floodplain, azonal calcareous, and soddy-podzolic/residually calcareous (differentiated in respect of soil structure). Their monitoring during out-of-use period and putting into active use is of high priority.

In the analysis of self-regenerating successions, Russia makes use of the approaches similar to those in other countries: the monitoring of soil properties and vegetation cover relies on the studies into different developmental stages. In Russia, however, land abandonment occurred almost spontaneously, while in the European countries the system for regular observations is in place which monitors the lands withdrawn from agricultural use intentionally, building on various agreements intended to maintain, among others, biological diversity [4]. Compared to abandoned arable lands in boreal zones, the abandoned hay fields and pastures have been explored to a greater degree. At the same time, demutation processes are more pronounced in the abandoned arable lands, as the plough-layer is known to change soil cover on the entire landscape. Challenges as community rehabilitation and demutation successions in vegetation and soil properties, have not been addressed adequately [6]. The history of soil formation may be critical for restoration of the post-agrogenic vegetation to its original conditions.

2. Materials and methods

Our analysis of covered the abandoned fields (a total of 60 test plots) on floodplains (Primorsky Municipality) and azonal soils (Kargopol Municipality), which were analysed for chronological sequence of formation. Based on land-use and agrochemical maps dating back to the 1980s ("Arkhangelskaya" Agrochemical Station), we selected lands of different age. For each land plot, agrochemical data on soil properties was obtained from the maps, based on which it became possible evaluate the progress of agrogenic soil development in the period of intensive land use. Within each test plot, a soil profile was described and classified according to the Russian classification system and also according to the WRB. The following parameters were determined: actual soil acidity (pH of soil-water extract) and exchanged soil acidity (pH_{KCl}) using the potentiometer test; hydrolytic soil acidity using the Kappen method; and also total absorption. Then, case exchange capacity and base saturation percentage were calculated. The organic content was calculated using the Tyurin method, while mobile phosphorus and potassium compounds were detected using the Kirsanov method.

3. Results

In order to analyse the data on agroecological properties of abandoned fields, the test plots were grouped according to the period the lands remain out of use. It has been found that the period of 20 years after termination of ploughing on soddy-calcareous/residually calcareous soils was marked by compaction of the plough layer and retaining of the favorable, almost neutral, soil reaction due to earlier agrotechnical operations. The process of acidification begins in the old arable layer only 40 years later as the abandoned field becomes overgrown with wood (Table 1: the mean value with error of mean is indicated in the numerator of the fraction, the parameter values from minimum to maximum are indicated in the denominator of the fraction). Potentially, by the time 40 years lapse, the land remains highly fertile, judging by the high sum total of exchange bases (S-value), cation exchange capacity, and base saturation degree (over 80%). Based on their adsorption capacity, after 20-40 years of abandonment and natural overgrowth (with trees and shrubs), the soddy-calcareous/residually calcareous soils can still be classified as highly fertile, cultivated soils.

Table 1: Dynamics of agrochemical properties in arable horizon of post-agrogenic successions in Kargopol Municipality, Arkhangelsk Region, Russia.

Duration of abandonment (number of fields)	pH_{KCl}	Humus, %	P_2O_5mg $100g^{-1}$	K_2O mg $100g^{-1}$
Out of use	6.5±0.01	2.52±0.18	6.7±0.73	5.2±0.07
for 25 years (11)	6.4-6.7	1.29-3.59	3.0-18.8	4.7-5.9
Out of use	5.7±0.15	2.44±0.14	3.4±0.70	2.8±0.25
for 25-40 years (3)	4.9-6.5	2.12-3.00	1.8-6.6	4.5-7.1
Out of use	6.5±0.04	2.53±0.15	4.1±0.70	6.3±0.49
for 40-60 years (4)	6.6-6.7	2.13-3.12	1.7-7.6	3.9-9.1
Out of use	6.3±0.05	2.55±0,20	3.1±0.44	17.1±0.8
for 60-80 years (5)	6.1-6.6	1,99-3.32	2.9-3.5	9.3-23.5
Out of use	6.5±0.04	1.75±0.06	3.6±0.19	16.7±1.37
for 80 years (4)	6.5-6.8	1.57-1.95	3.4-4.0	5.9-29.6

In floodplain soil ecosystems, the fertile properties achieved during the previous agricultural use, remain for 20 years, meaning that their rehabilitation can be cost-effective only within this time period (Table 2).

Table 2: Dynamics of agrochemical properties in arable horizon of post-agrogenic successions in floodplain soil of Primorsky Municipality, Arkhangelsk Region, Russia.

Duration of abandonment (number of fields)	Humus, %	pH_{KCl}	P_2O_5mg $100g^{-1}$	K_2O mg $100g^{-1}$
Out of use	1.84±0.18	5.93±0.22	47.14±2.27	11.18±1.21
for 5 years (5)	1.19-2.43	5.32-6.54	41.9-55.2	8.3-15.8
Out of use	3.14±0.29	5.83±0.08	49.75±3.81	18.13±4.27
for 6-19 years (4)	2.40-4.01	5.66-6.08	42.7-62.6	8.6-31.7
Out of use	2.77±0.29	5.33±0.14	50.26±9.20	15.99±2.34
for 20-40 years (10)	1.82-4.70	4.56-6.03	5.8-107.4	8.0-30.5
Out of use	9.74±1.07	4.69±0.07	19.63±4.17	10.60±1.02
for 50 years (3)	8.17-2.35	4.58-4.86	13.7-29.8	8.3-12.6
Natural lands (8)	3.34±0.31	5.56±0.21	17.01±6.94	12.14±2.37
	2.13-5.37	4.70-6.33	3.0-65.0	5.9-27.8

4. Conclusion

After 40 years of abandonment, the properties of the plough layer reach those of natural floodplain soils. After longer abandonment, and aggravated by previously poor reclamation and overgrowing, eutrophication starts, making such lands inexpedient for resuming agricultural use.

This conclusion agrees with the regeneration model for soil ecosystems, which suggests that carbon content restores in soil within 40 years of overgrowing [6] and reestablishment of soil fertility takes place (in other words, soil rests). Critical to the process of selecting lands to be put back into agricultural use, are the criteria of soil quality and proximity to urban areas.

Acknowledgements

The studies have been supported by the RFFI and Grant № 17-44-290111 from Arkhangelsk Region Government.

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