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EVOLUTION AND DEGRADATION OF THE DRAIN LANDSCAPES AND SOILS OF THE BYELORUSSIAN POLESYE REGION

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Abstract. A complex monitoring research of the drained landscapes and soils in the Byelorussian Polesye has been carried out on the permanent sites and soil geo-morphological profiles from 1971. The research period with the leveling of surface, soil cartography, sampling of soils, water and vegetation in the permanent sites and their analysis allowed to determine the main regularities in the changes of the drained landscapes and soils. The evolution models of the drained soils were worked out and the prognosis was compiled. Evolution and degrading of the drained landscapes and soils evolved towards less productive non-marshy soils.

Keywords: monitoring, drained landscapes, soils, evolution, degrading

INTRODUCTION

Monitoring research and observations are scientific basis for the use of natural resources and environment protection. Complex monitoring of the natural environment makes it possible to obtain objective data and to trace ecological situation, evolution and degradation of natural complexes and negative and extreme processes. Until 1970-ies were drained in Byelorussia about 1 million ha of the swampy and marshy landscapes. Then a negative effect of the draining became visible. Numerous publications on the above issue were released. There was a need to carry out a permanent monitoring of drained landscapes and soils. Under the leadership and due to the initiative and insistence and with the help of the board of the Byelorussian State University. from 1971 such a work has been research conducted at the Research Laboratory of Landscape Ecology on the initiative of the corresponding member of the National Academy of Sciences of Byelorussia, professor Medvedev together with the Board of the Byelorussian State University.

The formation of marshy landscapes and soils on the regional level is conditioned by the hydrological regime. It is to the depth of soil and subsoil waters a great extent is related. Drained landscapes and soils are ecologically unstable and are subject to abrupt changes and evolution towards non-marshy soils.

In the process of increasing both scientific and practical efficiency of monitoring, the choice of study objects and assessment of their ecological condition and role in the environment are of prime importance. Drained landscapes and soils became such objects selected for research.

OBJECTS OF STUDY AND METHODS

The present research was carried out throughout all territory of the Republic of Byelorussia at 30 permanent sites and on 15 geo-morphological soil profiles (transects). Attention was paid to research in the Byelorussian Polesye. The sites were constructed in the main natural territorial complexes (PTK) at a level of landscape forests. Permanent geo-morphological soil profiles (transects) with an instrumental survey and fixation of the soil surface and subsoil water level were prepared for the monitoring. Such a combination of research at sites and geo-morphological soil profiles is well-grounded and allows to research a great variety of natural complexes. The monitoring research concentrated on big drained objects with developed infrastructure helpful for the carrying out of comprehensive research, with available hydrological ranges, water balance stations, meteorological stations and meteorological sites, hydrological checkpoints etc., that allow to get necessary additional pices of information.

The largest composite permanent site at which monitoring of the soil-landscape, geo-botanical, microbiological features were carried, is the Yaselda Riverhead situated in the pit valley of the river Yaselda, a tributary of the river Pripiat (the Black Sea basin), and a tributary of the river Lesnaia (the Baltic Sea basin) which shares borders with the Belovezha Forest national reserve. In this meliorated object, there are 12 permanent sites, three of which are in the woodland and three are in the undrained swamp. Three sites are dedicated to meteorological stations in the drained territory, in the zone of drainage influence and in the undrained swamp. All sites are located at boring wells near hydrological ranges. Beside the above sites, in the "Yaselda Riverhead" meliorated object there are three geo-morphological soil profiles in the hydrological ranges that cross the melioration object and the adjacent territory.

The Polesye Experimental Melioration Station, located in the central part of the river Pripiat flood land area, has five permanent sites and one soil geo-morphological soil profile. It also contains the Swampy meteorological station crossed by the Vulka hydrological range and a wide net of hydrological bored wells. Two of the permanent sites studied are located near the swamp meteorological station, and one near a hydrological range.

In the melioration sites founded in 1920s in the Luban district, there are three permanent sites and two geo-morphological soil profiles in the farms "Polesye" and "Kalinovka" farms. The melioration object "Mochka (the Malorita district, Brest province) constructed in the beginning of 1970s, the monitoring research was carried out on three permanent sites and one geo-morphological profile. Permanent monitoring research was carried out also in the Bereza, Pinsk, Oktiabrski and other districts of the Polesye region.

A net of the permanent sites and transects tested coverd the full soil and landscape variety of the Byelorussian Polesye drained territories.

A permanent monitoring research was also carried out at the meliorated objects constructed in period of time and with varied agricultural use (from 1 year to 30-50 years), with various methods of melioration (net of canals, combination of open canals and ceramic drainage, polder drainage etc.). Soils of various genesis and degree of drainage from sod-podzolic marshy soils to peat soils of various depth (un-drained, drained and located in the drain area), non-marshy lands of watershed territories were studied. Anthropogenic mineral soils that emerged in the place of recessed peat soils were also studied [3-5,11,14].

The study of the drained soils was carried out on the permanent installations (sites) with an area from 2 to 100 ha and permanent geo-morphological soil profiles with a length of 0.2 to 0.5 km and 4 to 5 km. They were installed in the areas with characteristic geo-morphological soil conditions for a given landscape. The research, as a rule, covered drained territories and territories adjacent to them. The permanent sites were mostly located at the hydrological watersheds and meteorological and water balance sites.

The permanent sites included:

- sites for a precise initial and follow-up soil cartography by a vertical survey: for the study of changes in the soil surface structure, agrochemical qualities, meso- and micro-relief and vegetation biocenoses;
- sites of 20x20 m and 3x3 m in the geo-morphologic soil profiles in respect of peat loss and changes in the meso- and microrelief by the method of leveling the squares corners with an edge length of 1 to 2 m;

- permanent support profiles on the characteristic soils of the sites.

The soil cartography was carried out through the pegging out open test pits every 20 to 25 m; from each test peat 25 to 100 mixed samples were taken from each arable (humus) level from 5 points around the test peat. To obtain reliable data for the study of soil characteristics from the basic profiles of the soil horizon, the mixed samples were taken following genetic horizons, from genetic horizons and arable (humus) horizons. Additional samples were taken from peat soils to study peat losses.

At the permanent sites with well-defined coordinates, initial and repeated research of soil morphology, surface structure and also peat losses were carried out in with respect to the changes depth and volume, and in model experiments. Changes in the soil natural vegetation and agrocenoses were also studied.

The following issues were studied at the permanent sites:

- hydro-physical properties and dynamics of soil humidity according to the pattern of months of the vegetation periods and years;
- agrochemical properties, overall chemical composition of the soils;
- content of organic matter and humus, fractional group content of organic matter;
- content of microelements in the soils, water and plants;
- biological activity of soils;
- soil fauna;
- chemical content of subsoil and surface waters;
- chemical content of vegetation;
- microrelief and relief.

During the initial and repeated studies on soils, water and vegetation, analyses were made according to a uniform methodology. Data were mathematically processed.

The permanent site "Brestskaia" may serve as an example of our monitoring research at the sites.

RESULTS

Results of the monitoring research at the "Brestskaia" site, constructed at the Brest grade-testing facility, have been given below in a form of maps, graphs, charts and tables (Table 1). An additional advantage of using a grade-testing facility is a high level of agricultural processes and strict control of crops and of fertilizer application.

The first stage of the monitoring research was carried out at the permanent site in 1972 and repeated in 1976, 1979, 1988 and 1994. The site had a shape of a pral-

Table 1. Changes in the soil cover and their forecast at the "Brestskaia" permanent site, Kamenets region, Brest oblast

Designations	Soils	1972		1976		1979		1988		1994		2015 forecast			
		in crop rotation with intertilled and grain crops, grasses										under grasses (I)		under grain and intertilled crops (II)	
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
1	Antropogenic deeply gleified low humus sandy	-	-	-	-	-	-	-	-	0.10	1.8	0.13	2.3	0.25	4.6
2	Anthropogenic gleyish medium humus sandy	-	-	-	-	-	-	-	-	0.88	15.7	0.63	11.4	4.46	8.2
3	Antropogenic gleyish strong humus sandy	-	-	-	-	-	-	0.39	6.9	0.34	6.1	0.05	0.9	0.62	11.0
4	Anthropogenic gleyish low peat sandy	-	-	-	-	-	-	0.61	10.9	0.08	1.4	0.27	4.8	0.53	9.5
5	Anthropogenic gleyish strong peat andy	0.22	3.9	0.29	5.2	0.45	8.0	0.37	6.6	0.15	2.7	0.69	12.3	0.85	15.2
6	Peatish gleyish	0.16	2.8	0.36	6.4	0.67	12.0	0.40	7.1	0.49	8.8	1.68	30.0	1.81	32.3
7	Peat gleyish	0.47	8.4	0.65	11.6	0.58	10.5	0.81	14.5	1.34	23.9	1.31	23.4	0.90	16.1
8	Peat weak	1.54	27.5	2.48	44.3	2.59	46.3	2.34	41.8	1.91	34.1	0.84	15.0	0.19	3.2
9	Peat medium	3.11	55.6	1.82	32.5	1.30	23.3	0.68	12.2	0.31	5.5	-	-	-	-
10	Peat strong	0.10	1.8	-	-	-	-	-	-	-	-	-	-	-	-
Overall		5.6	100.0							-					
Number of soil contours		12		11		12		16		17		14		15	
Average soil-site index points		69		67		64		60		56		50		44	

lelogram, with side leght of 208 m and 298 m. A cartographic survey was done with marking out ranging points on the axes of crop rotation fields every 40 m with a field width of 30 m. The number of points was 30. Additionally, the soils were studied at 31 more points. Each point had a test pit uncovering the depth of the peat horizon.

The permanent site had five crop rotation fields of the same size with an area of 1.04 ha. Before 1992, the crop rotation was in the following order: 1) ryegrass and perennial grasses, 2) perennial grasses, 3) winter crops, 4) potato, 5) spring crop. In the last several years, intertilled crops were completely excluded from crop rotation.

At the permanent site, the subsoil water level was regulated and kept at a depth from 50 to 120 cm. The permanent site differed from other monitoring sites in the Byelorussian Polesye primarily by the introduction of high doses (250 to 350 kg or more of active matter) of mineral fertilizers, mostly potassium and phosphorous, added in a stabilized manner during a period of more than 22 years of observations of the site. An exact record of yield was taken. Productivity during the latter period of time was 30-50 c/ha for crops, 160-350 c/ha for potatoes, 450-770 c/ha for the grass mass. Starting in 1992, agricultural control of the site was significantly weaker.

In 1972, an average peat depth at the site was 110.3 cm. After 22 years, it decreased by 50.8 cm and was 59.5 cm. The decrease of peat depth for the first 4 years was 4.8 cm a year, for the next 3 years – 2.3 cm, after 9 years peat loss decreased to 1.4 cm per year, and during the last 6 years it was 1.9 cm.

The area of the peat marshy lands at the permanent sites during the first series of research (1972) was 96.1% of the site, 3.9% was covered was anthropogenic-gley of strongly peatified sandy soils. During the first series of research, the medium-depth peat soils with a peat of depth 1 to 2 m covered 56% of the area, 22 years later the area decreased 10 times. The last research series (1994) revealed a new soil variety at the site: anthropogenic slightly humified soil (1.8%) and medium humified (15.7%) sandy soils. For 22 years, the area of mineral soils increased by more than 24% due to peat loss. The area of peat-gleyey soils the edge of turning into mineral soils, increased by 6%.

Since the bottom of peat deposits is not flat and due to differences in its depth after peat loss, there is a large number of soil varieties which leads to an increase in the contourn. Qualitative changes in the soils were reflected in the soil-site index grade, i.e.: 69 in 1972, 67 in 1976, 64 in 1979, 60 in 1988 and 56 in 1994.

During the last series of research, 34.4% of the area was covered with the peat soils of low-depth, and other 3 peat soil varieties covered 38.2% and anthropogenic soils formed as a result of peat loss covered 27.7%. According to the forecast, in 2015, this ratio for the first variant (with an application of the optimal norms of drainage and use under perennial grasses) will be 13.1, 48.2 and 38.7% respectively. In the second variant (in the conditions of over-draining and usage for crop rotation with grain crops, intertilled crops and perennial grasses) – 3.8, 42.9 and 53.3% respectively (Table 1). There is a distinct, noticeable decrease of the peat soils area, especially the ones with a high peat depth. Maps forecasting peat loss were compiled. According to the forecast, peat will completely disappear in 2070 with the first variant of usage and in 2047 with the second variant. The main period of active peat disappearance should take place in the period from 2020 to 2060 in the first variant and from 2010 to 2040 in the second variant [6].

Thus, a decrease of organic matter content, disappearance of peat soils and their transformation into anthropogenic sandy soils as a result of peat loss and also deterioration of their hydro-physical and other properties has decreased. According to the forecast, it will further decrease potential fertility and average soil index grade (Table 1).

The monitoring research carried out for many years on a wide net of sites allow to draw conclusions on the changes in the properties of the drained soils, their evolution and degradation.

In relation to the lowering of the subsoil water level and changes in the water regime during draining the morphology of the soil profile undergoes changes [10]. Features of marshy soils in the sod-podzolic soils disappear. These features may take residual forms. The genetic horizons of these soils do not undergo any significant changes. More drastic changes are observed in the sod marshy soils, especially with sod granulometric content. The sub-arable gley horizon becomes lighter and close to podzole in colour. Sandy drained soils may completely lose the features of marshy soils after over-draining.

Peat soils with a depth of more than 1m after draining undergo dehydration and desiccation. Densification along the soil profile and quite a sharp differentiation into three horizons, i.e.: arable (ATd'), sub-arable above the subsoil water level (T_2) and a horizon in the subsoil zone of water level fluctuations (T_3) take place. The upper (arable) horizon is considered to be the most varied: it is mixed during plowing, remains of plants from peat become more fragmentated, and with time, the horizon becomes gradually pulverized.

Swift changes in the hydro-physical properties of the drained soils, i.e.: the humidity, full and capillary humid capacity, and resources of productive moisture, are reduced. Thus, in the 10-year period, at one of the permanent sites at the Yaselda Riverhead the mass volume increased from 0.15 to 0.21 g cm^{-3}, capillary humid capacity decreased from 522.2 to 366.1% and from 599.4 to 394.8%. Resources of productive moisture in the arable horizon decreased from 127 to 75 mm. In general, hydro-physical properties were deteriorating with the use of both peat and mineral soils. The most intensive changes of the soil hydro-physical properties appeared in the first 3-5 years after draining and development [7].

An appllication of quite high dozes of mineral phosphorous and potassium fertilizers provided these soils with the optimal levels of nutrients. The nitrogen content in the peat soils was decreasing. Its increase took place at the sites where high dozes of nitrogen fertilizers were applied.

At the sites where there was no soil liming, an decrease in the exchangeable forms of calcium and magnesium was observed. After liming their content in the soils increased.

The most important soil-generating process on the drained peat soils is peat loss. According to our data and data from literature, the linear peat loss is 0.5 to 11.0 cm per year. Most often peat loss is 1 to 3 cm per year. In the terms of weight, peat loss is 3 to 20 tons per ha and more. The mineral drained soils, with in frequent exceptions (after an application of high fertilizer doses) lose humus content.

The processes of decay and humidification in the low drained peat soils is going on all over the territory of Byelorussia. It depends on the air and water regime, botanic content and degree of peat decay.

The agricultural use of peat soils is related to a reduction of carbon content. The organic matter composition of peat and marshy soils agriculturally used is characterised by a reduction in the content of the most mobile 1a fraction of fulvoacids. In the organic matter of peat soils with a low level of decay, along with a general mineralization of organic matter, processes of humic acids accumulation and reduction of bitums and non-hydrolizing residue content develop. The non-hydrolizing residue in the reed-sedge and timber-sedge peat soils increased with the use of soil as the huminous acids accumulated because of mobile and coarse-dispersive fractions. The processes of accumulation of the biologically stable and biochemically inertious huminous matters develop in the drained peat soils during a drastic change in the water and air regime after draining. As a result of these processes, the fulvoacid and huminous acids content in the soils decreased and that of non-hydrolysable residue increased.

Significant changes occured also in the subsoil and surface waters after draining of the marshy landscapes. Drainage and use of the peat soils led to an increased mineralization of the soil-ground waters from 74 mg l^{-1} (in non-drained) to 285-450 mg l^{-1} (in the drained), chlorine-ion ratio increased 2.1-2.5 times, sulfate ions 1.3-1.5 times, potassium ions 4.5-4.8 times, sodium 2.2-2.4 times. The most intensive changes in the chemical composition of the drained soils occurred during the first 3-5 years after draining and agricultural use of the soils. An increased concentration of chemical components was related to the intensity of the mineralization processes and washing away by the down-pouring water as well as by the applying of fertilizers. The sulfate and chlorine-ion content in the soil-ground waters of the drained marshy soils after 11 years of their agricultural use increased, respectively, 7.8 and 4.4 times, and potassium and sodium ions – 2.7 times. The contaminated soil-ground waters and drained waters get into the hydrographic circuit and their contamination increased.

The study of the overall chemical content of the very deep and medium-deep peat soils showed that it changed little before its depth started to change to 0.5 m before evolution and degradation. But the most drastic changes took place at transformation of soils with peats at low depths into anthropogenic mineral soils. During the 16 year period the organic matter content in the arable horizon decreased from 84.3 to 27.5%, silicon oxide increased from 9.12 to 67.3%, the content of biogenic elements decreased from 2.52 to 1.93%.

The monitoring research on the perennial repetitive surveys revealed drastic changes in the micro- and meso-relief. Ideally flat marshy massifs turned into curbed ones with relative heights from 1.5 to 3.0 m and more. Soil variation with respect to moisture increased. Regulation of the soil water regime was more complex required costly flattening work.

Data from the monitoring research showed that changes in landscapes and soils under the influence of drainage and soil use were a regular process of soil transformation into new evolutionary stages of functioning. It leads to new kinds and types of soils that did not exist in the natural conditions. Such soils showed zoning features which proved genetic basis of their changes. The intensity of changes in the drained soils increased the extent of these processes in the natural soils. It led to their accelerated transformation (mostly towards degradation) and accelerated evolutionary stages until the initial features of peat soils disappeared completely. Duration of the evolutionary changes depended on the genetic features of the soils, their granulometric content, typical main soil parameters and subsoil water level. In the morphology of the drained soils, the first features which underwent changes was the main feature of the marshy level. In the sandy soils they often disappeared altogether. They became less marshy. In the drained peatified marshy soils a decrease of the peat depth was observed. The process of peat mineralization in the drained soils cannot be stopped. It can be only prolonged in time.

The fertility of soils formed after the disappearance of peat deposits depended on the granulometric content of the substrate mass and the character of water regime. The soil-site index of these soils decreased by 15-30 points, and their potential fertility also deteriorated. They became closer to the zonal sod-podzolic soils.

The soils that evolved after peat loss had a specific composition. In the top part of their profile there were spots of gleification; depth of humus 35 to 20 cm; colour light gray; a mixture of humified sand with peat residues. The humus content at the last stage of evolution was no more that 3%. When compared to peat-humus-sod soils, the above soils had less favorable water-physical qualities (low humidity and moisture reserves, high volume mass). They were low-acidic, with a low level of phosphorus, calcium and microelements [2,6-8,11,13].

Drainage and use of peat marshy soils caused changes in the soil surface structure, increased areas of mineral soils and low-depth peat soils. Thus, during the initial research of the permanent sites in the Polesye (1971-1973), peat marshy soils with peat depth of more than 50 cm covered on average 60.2%, and during the second series of research (1987-1990) they showed a decrease to 35.1%; the area of sod-humus-gleyey soils were reduced 10 times, and sod-gleyish 3 times. Together with changes in the structure of the soil cover towards deterioration, the parameters of structural elements also changed. The degree of contrast increased, and the area of soil varieties contours decreased; the separation ratio and the fractional index grew. Results of changes in the soil cover structure were the basis for the forecasting of the state of the drained soils [6-13]. On the basis of monitoring research, models of drained soils evolution were created. These soils change further to three variants: 1) at a positive balance of organic matter, 2) at the optimal norms of drainage and meadow use, 3) at the over-draining and use in crop rotations with intertilled and grain crops. It showed that the final stage of the drained peat soils evolution was anthropogenic mineral soil, close to sod-gleyish natural analogues. At over-drainage, evolution of such soils finished at the stage of anthropogenic mineral soils close in the features and fertility to the zonal sod-podzole soils [8,11].

The monitoring research allowed to finish the main regularities in the changes of the drained soils used for the forecasting of changes. The following methods of forecasting were worked out as the basis for the research carried out: 1) calculational-cartographic, 2) calculation, 3) forecasting of changes in the landscapes and soils along landscape analogues. The prognosis charts of the soil changes for all permanent sites and agricultural units, including the Polesye experimental drain station (the Luninets region) were compiled. According to the forecast compiled for the year 2015, about 375.000 ha of peat soils will be transformed into anthropogenic mineral soils with low-fertility [2,6-9,11].

The results of observations on the nature and transformations of the drained peat soils were the basis for the developing of a classification of anthropogenic mineral soils that evolved in place of the peat loss-affected soils. These soils are united in one soil type of anthropogenic mineral soils after peat loss soils with four subdivisions depending on the content of organic matter, gleification degree, lixiviation and podzolification [9,11,13].

The use of some soil types is practically impossible because of a small contour area and complex configuration. Hence, a task to carry out cartographic surveys of the natural territorial complexes with a given soil structure relating to different monostructures, i.e., relief elements was assumed for their more productive use and counteracting their degradation.

On the basis of the cartographic survey and studies of the natural territorial complexes recommendations as to their ecological use were prepared for two agricultural units in the Liuban and Svislach regions as examples.

On the basis of the monitoring research and processing of a large amount of soil cartographic material from the drained objects and farms with vast areas drained soils, a classification of the drained territorial natural complexes was compiled. It reflects the structure of the soil cover, relief, peat ratio, degradation level, longevity of the peat soils, and direction of their changes.

Methodology was worked out for the cartographic survey of the drained territorial natural complexes together with recommendations for their ecologically safe use. The surveying methods for the drained territorial natural complexes are based on the structure of the soil cover and relation of these structures to certain morphostructures, and relief elements [1,12].

A large-scale surveying of the natural territorial complexes to a 1:10 000 scale is a good foundation for their ecologically safe use, evaluation of the drained lands and reconstruction of the melioration objects.

The permanent sites of the Byelorussian State University, subjected to long-term observations, on the evolution and degradation of drained soils, were included in the National system of environment monitoring of the Republic of Byelorussia. It will help increase the efficiency of the National system of environment monitoring.

CONCLUSION

Evolution and degradation of the drained swampy and marshy landscapes and hydromorphic soils of the Byelorussian Polesye region evolved towards less productive non-marshy soils.

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EWOLUCJA I DEGRADACJA ZMELIOROWANYCH KRAJOBRAZÓW I GLEB REGIONU POLESIA BIAŁORUSKIEGO

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Streszczenie. Przeprowadzono badania monitoringowe zdrenowanych krajobrazów i gleb Polesia Białoruskiego w wybranych glebowo-geomorfologicznych profilach – od 1971 roku. Przedstawiono specyficzne obiekty melioracyjne oraz metodę monitoringu. Wykazano kierunki ewolucji i degradacji zdrenowanych gleb prowadzące do obniżenia ich produktywności. Badania monitoringowe dały podstawę do stworzenia modeli ewolucji zdrenowanych gleb w różnych warunkach drenażu. Opracowano prognozę zmian gleb zdrenowanych do 2015 roku dla dużych gospodarstw i dla całego kraju, według której ok. 370.000 ha płytkich gleb torfowych Białorusi przekształci się w antropogeniczne gleby mineralne, głównie piaszczyste. Aktualnie opracowuje się klasyfikację tych gleb, metodę ich kartografii oraz rekomendację dla ich optymalnego użytkowania.

Słowa kluczowe: monitoring, krajobraz, gleby, ewolucja, degradacja