ABANDONED LAND AS A FACTOR OF LANDSCAPES RESISTANCE TO ANTHROPOGENIC MERCURY DEPOSITION

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Abstract: we assessed the degree of reduction of landscapes' biogeochemical resistance in the European Russia centre regarding anthropogenic mercury load under the influence of agricultural land abandonment. We observed that chemical composition of vegetation encroached on abandoned agricultural fields may serve as an indicator of anthropogenic pollution.

An important factor for sustainable development is the geochemical carrying capacity of landscape, which can be characterized quantitatively by critical loads (CL) – the upper limit of pollutants' deposition without substantive harm to ecosystems and reduction of ecosystem functioning in a long run (Manual ..., 2004). There are three mechanisms of pollutants' sanation in the ecosystems: alienation with biomass $M_{upt,}$ removal by water M_{leach} and accumulation in soil $SD(M)_{an(acc)}$. At the same time the flow of pollutants into ecosystems from outside should be compensated by sanation process (Krivtsov et al., 2011):

$$CL = M_{upt} + M_{leach} + SD(M)_{an(acc)}.$$

Mercury (Hg) is one of the poorest understood elements with the undetermined percent of abundance in the landscape components. We studied the natural resistance capacity of agricultural and environmental landscapes regarding the load of mercury by looking at the case study area of approximately 1800 km ^{2} in the center of the Ryazan region, and which combines representative for Central Russia natural, anthropogenic, but also geochemical factors (Figure 1).

Agricultural land abandonment represents one of the factors, which can modify biological turnover of elements and influences the parameter M_{upt}. To maintain the geochemical stability it is important that the toxic elements alienation should be offset by the long-term accumulation in the wood biomass during the natural overgrowth on abandoned fields. However, such compensation often does not occur, since the process of natural vegetation encroachment on abandoned fields is rather slow and strongly depends on wind speed and wind direction. Abandoned areas are overgrowing only within the wind shadows of forests and wind protection forest belts (front and rear), that decrease ability for seed dispersal, and which should facilitate natural forest succession on abandoned lands (Figure 2). Thus, more than 90% of abandoned agricultural lands in study area has extremely low values of tree density approaching 0.001. When concentration of mercury in woody biomass are close to cultural plants, then low plants density defines 30-fold decrease of biogeochemical resistance of abandoned lands toward accumulation of Hg if to compare with agrocenoses and 5-fold decrease of biogeochemical resistance if to compare with forest recovery on burned forested areas in Meshchera lowlands (Table 1). Single trees on abandoned agricultural fields have better progress in development if to compare with the zonal forest ecosystems with the exception of local areas with very dense tree stands (study site III), but the average density factor is more important for natural resistance capacity rate of abandoned fields (Table 2).

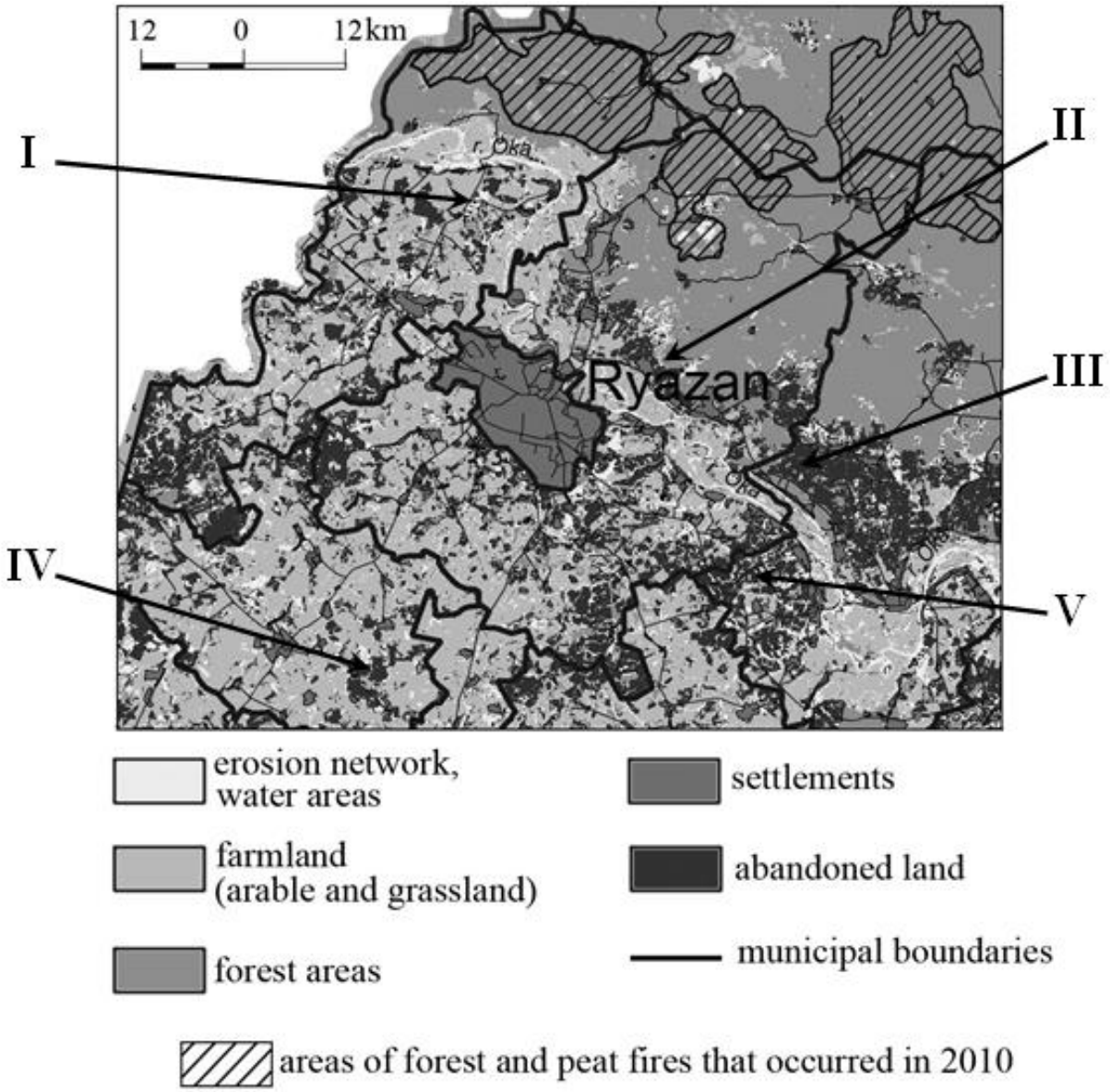
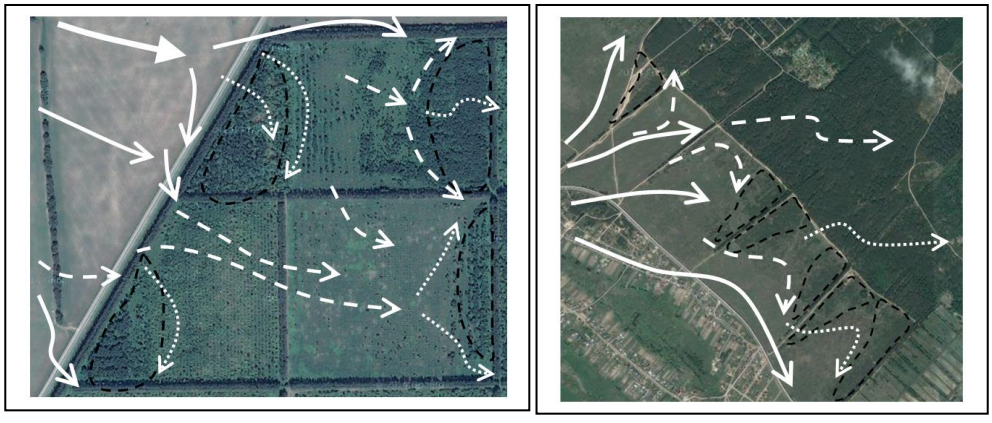


Figure 1 – Structure of land fund for the case-study area – center of Ryazan region (I-V – detailed study sites for biogeochemical sampling on abandoned agricultural lands)



а) Study site I б) Study site II

Figure 2 - The weakening and deviation of surface air flow by woody vegetation, as a factor, which affects woody vegetation encroachment on abandoned fields (black dashed line delineates wind shadows)

Table 1 - The role of the various land categories regarding biogeochemical fluxes of mercury

Land categories	Share of study area, %	G_{an}, t/km^2/year	C_{Hg}, mkg/kg	Average density degree	Hg_{upt}, gr/km^2/year	Share of total biogeochemical sanation of mercury, %
Forests	24.0	145.6	11.66	0.657	1.697	19.2
Forest recovery on forest burned areas	11.6	60.3	8.62	0.1-1.0	0.520	2.9
Abandoned agricultural lands	12.5	10.6	9.09*	0.038	0.096*	0.6*
Cultivated agricultural lands	49.5	459.4	6.99	-	3.211	76.8

Note: G_{an} – an integral part of biological products, which provides landscapes' biogeochemical resistance: for forest ecosystems and their derivatives such as an anthropogenic felling, human induced forest burns – a growth of wood and bark; for agrocenoses – general harvest and byproducts of marketable goods; C_{Hg} – average concentration of mercury in G_{an}; Hg_{upt} – degree of annual immobilization of mercury in woody biomass and alienation with the products from agro-ecosystems. * Excluding data from study site V.

Table 2 – The ratio of productivity of trees overgrown on abandoned agricultural fields in comparison to the average growth of corresponding species observed in the zonal forest ecosystems of Central Russia

Study site	Tree type	Age	Density	Relationship of the annual rate of productivity growth to the average zonal productivity for corresponding tree species, calculated based on the following indicators:	
				trunk diameter	height
V	Birch (*Betulla verrucosa*)	9	0.015	2.7	1.24
		6	0.115	2.26	1.42
III		15	0.850	0.76	0.92
II	Pine (*Pinus sylvestris*)	6	0.503	2.97	3.25

Note: The calculations were performed using the database of standards for growth of tree species in zonal forest ecosystems of Central Russia (Usoltsev, 2002).

However, the share of biotic component of sustainability for Hg is not more than 5% of the total critical load, since abiotic mechanisms of sanation are dominated. However, the barrier mechanisms, which prevent biological absorption of mercury, are not always effective. As an example, several abandoned fields, which were 25 km south-east of Ryazan (study site V in Figure 1), and which were located following the direction of prevailing wind and major transfer of industrial emissions from regional capital Ryazan, experienced intensive accumulation of mercury in birch species of age 3-9 years in all fractions of phytomass (from 268 to 2,481 mg / kg, or 20 to 55 times higher than zonal average). Consequently, the extent of long-term Hg immobilization, even at average density less than 0.08, was 3 times higher than the average level of alienation with the harvest in agrocenoses for study region and in local areas with the density of 0.8-1.0 and reached level 80-100 gr / km^2/ year, which is higher than the regional average of mercury deposition from the atmosphere.

To summarize, the abandonment of arable land at least 30 times reduces the biogeochemical ecosystem resilience regarding accumulation of mercury. But, under certain conditions, namely

vegetation of abandoned lands can compensate accumulation of Hg from the atmosphere alone due to immobilization in trunks and branches. However, such growth of geochemical stability due to agricultural land abandonment seems to us a bit imaginary, mainly because, firstly, it has been tested for smaller area (on a few abandoned fields with a total area approximately 15 km^2), and secondly, it coincides with the trajectory of air emissions transport from the regional capital, where industries are concentrated. Third, it coincides with already described in the literature human-induced anomalies of lead, cadmium and nitrogen in soils, in sediments and natural waters (Krivtsov et al., 2011). Looking at the increase of Hg accumulation by vegetation on abandoned lands for study site V, we consider being one of the best examples of failure of regulatory mechanisms of geochemical cycles for toxic elements in ecosystems under anthropogenic pollution.

Literature

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