CARBON BALANCE IN ABANDONED LANDS OF MOSCOW REGION IN RUSSIA

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ABSTRACT
Carbon balance of cultivated soil (loamy Phaeozems) under fallow was compared with that of soils abandoned 1, 5, 10, and 25 years converted naturally to permanent grassland (Moscow region, Russia). Carbon inflow or net primary production (NPP) was calculated as the sum of the above and below ground productivity of grassland ecosystems. The total C outflow was equal to the annual CO_2 fluxes from the soils and was estimated as CO_2 emission measured by the closed chamber method. Carbon balance (CB) was defined as the difference between respiration of heterotrophs and NPP. Botanical survey clearly showed that the vegetation of abandoned agricultural lands changed to permanent grasslands after 5 years of abandonment. Carbon inflow increased from 97 g C·m-2·yr^{-1} in the arable soils to 1100 g C·m-2·yr^{-1} in the 10-yr grassland. Total annual carbon losses from soils as CO_2 amounted to 347-845 g C·m-2·yr^{-1}. Heterotrophic respiration varied from 272 g C·m-2·yr^{-1} in cultivated soil to 411 g C·m-2·yr^{-1} in 25-yr grassland. Our estimations showed that 5, 10, and 25 yr grasslands act as carbon sink and their C balance constituted -217 g C·m-2·yr^{-1}, -778 g C·m-2·yr^{-1} and -473 g C·m-2·y^{-1}, respectively. Arable soils under the fallow act as CO_2 source (CB = +175 g C·m-2·yr^{-1}). Carbon balance of the one-year grassland was close to zero. Hence, after 5 years abandonment former arable lands converted to permanent grasslands become a stable C sink.

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INTRODUCTION
Since the early 1990s about 1/4 part of the agricultural land of Russian Federation has been abandoned due to the economic depression [*Pankova and Novikova*, 2000]. Abandonment of cultivated lands leads to the vegetation succession accompanied by the changes in carbon fluxes between atmosphere, plant, and soils. After abandonment soils may act as an important carbon sink according to the new ratio between carbon inflows and outflows [*Guo and Gufford*, 2002]. Besides, when cultivated lands are abandoned, they usually accumulate carbon and nitrogen, both in the vegetation and in the soil [*Paustian et al*., 2000; *Poulton et al*., 2003]. The present study was aimed (1) to determine the botanical composition and net primary production of abandoned lands of different age, and (2) to quantify the changes of carbon fluxes in soils after different duration of abandonment.

MATERIALS AND METHODS
Our investigations were carried out in 2004 on arable soil (loamy Phaeozem) under the fallow and soils abandoned 1, 5, 10 and 25 years ago after the change from crops to permanent grasslands (Moscow region, Russia, 54°50'N, 37°35'E). Carbon input, or NPP, was calculated as the sum of the above and below ground productivity of grassland ecosystems. The C losses were equivalent to the annual CO_2 fluxes from soils and were estimated on the basis of our previous long-term CO_2 emission measurements and models developed [*Kurganova et al*., 2003]. Carbon balance (CB) was defined as the difference between respiration of heterotrophs (estimated under controlled conditions in laboratory) and NPP.

RESULT AND DISCUSSION
Botanical survey clearly showed that the vegetation of abandoned agricultural lands changed to permanent grasslands after 5 years of abandonment. Aboveground productivity (AGP) varied from 31 g C·m-2·yr^{-1} in cultivated

land under the fallow to 356 g C·m-2·yr^{-1} in the 10-yr abandoned lands (Table 1). Below ground productivity (BGP) was calculated using the ratio AGP:BGP=1:2.1 [*Yermolaev and Shirshova*, 2000]. Net primary production increased from 97 g C·m-2·yr^{-1} in the arable lands to 1100 g C·m-2·yr^{-1} in the 10-yr grassland. Total annual carbon losses from soils as CO_2 amounted to 347-845 g C·m-2·yr^{-1}. It was found that the share of root respiration in total soil respiration of grasslands averaged 65% for the vegetation season (May-September) and 11% for the cold period (October-April). Heterotrophic respiration varied from 272 g C·m-2·yr^{-1} in cultivated soil to 411 g C·m-2·yr^{-1} in 25-yr grassland. The difference between NPP and heterotrophic respiration showed that 5, 10, and 25 yr grasslands act as carbon sink and their C balance constituted -217 g C·m-2·yr^{-1}, -778 g C·m-2·yr^{-1} and -473 g C·m-2·y^{-1}, respectively. Arable soils under the fallow act as CO_2 source (CB = +175 g C·m-2y^{-1}). Carbon balance of the one-year grassland was close to zero.

Table 1. Productivity, Carbon Losses, and Balance (gC m^{-2} yr^{-1}) in Abandoned Soils of Different Age

		Abandoned lands			Grassland,
	Fallow	1 year	5 years	10 years	25 years
Productivity:					
NPP, including:	97	330	499	1103	592
Aboveground (ANP)	31	106	161	356	191
Belowground (BNP)	66	223	338	747	401
CO2-C fluxes from soils:					
Total (TSR), including	347	613	580	671	845
Growing season*	156	460	435	503	632
Beyond the growing season	190	153	145	168	213
Heterotrophic (HR), including:	272	297	281	325	411
Growing season (May-September)	103	161	152	176	221
Beyond the growing season	169	136	129	149	190
Carbon balance, CB = HR- NPP	+175	-32	-217	-778	-181

* Growing season means the period from May to September, beyond the growing season means the period between October and April.

CONCLUSIONS

The conversion of arable soils to permanent grassland caused by decrease of agricultural production since early 1990s led to carbon sequestration in the vegetation and soil organic matter. After 5 years abandonment former arable lands converted to permanent grasslands become a stable C sink. Therefore, carbon sequestration in abandoned lands (both NPP and soils) should be included in calculation of the national C budget of Russia.

ACKNOWLEDGMENTS

This study was supported by Russian Foundation for Basic Researches, Program of Presidium of RAS N 13, and by International Bureau of Federal Ministry of Education and Research of Germany (RUS 03/A30).

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