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Modelling the impact of mulching the soil with plant remains on water regime formation, crop yield and energy costs in agricultural ecosystems

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The presented work considers the possibility of rational use of natural resources (water, soil, energy), which are interconnected, in particular, through food-water-energy nexus. One of non-traditional agricultural technologies which are developing during the last time in many countries and oriented on sustainable management, conservation of soil, energy and water resources, as well as protection of environment is mulching the soil, i.e. using plant remains after previous harvesting as soil cover. However, application of this agricultural technology was based mainly on an empirical approach without any theoretical basis including estimation of the efficiency of this method, which would allow us to systematize the obtained results and predict the implications of mulching. This raises the problem of developing a relatively universal technique for calculating an increase in water supply and potential yield of agroecosystems due to mulching as well as predicting the efficiency of mulching under different natural conditions. This work is devoted to the solution of this problem.

A model describing the formation of water regime in an agricultural field covered by a straw mulch (the MULCH model) has been developed. It simulates the dynamics of the water budget components in the rooting zone at daily time step from the beginning of snowmelt to the period with stable negative air temperatures. The model is intended for estimation of mulching efficiency in terms of increase in water supply and yield of crops under different climatic and soil conditions. The model was approbated while studying the mulching effect on some characteristics of the water regime and yield of spring wheat in specific sites located in semi-arid and arid regions of the steppe and forest-steppe zones situated in the eastern and southern parts of the East-European (Russian) plain. Here, the territory under consideration includes the south of the European part of Russia, the Crimea and the south-eastern part of Ukraine.

In addition, a technique for estimating the energetic efficiency of various agricultural technologies with accounting for the impact of the technologies on changes in soil energy, was developed. This technique was applied for estimation and intercomparison of efficiencies of four agricultural cultivation technologies which are usually used for wheat production in different areas of the steppe and forest-steppe zones of the European part of Russia: (1) mouldboard tillage of soil without irrigation, (2) mouldboard tillage of soil with irrigation, (3) reduced soil cultivation, (4) reduced soil cultivation with mulching soil with plant remains. Four Russian agrometeorological stations (Petrinka, Kamennaya Step', Bezenchuk, and Ershov) were taken for this study as representative sites. They are located in an active agriculture zone and differ by conditions of aridity and types of soil. The obtained estimates of the energetic efficiencies of the tillage modes allowed us to conclude that mulching the soil with plant remains in a combination with reduced cultivation is the most effective agricultural mode for the regions under study. This technology can be considered as the most promising for the development of agriculture at least in these regions of Russia.