Applied Soil Ecology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Review

Development and application of humus form concept for soil classification, mapping and dynamic modelling in Russia

Oleg Chertov[a,*], Marina Nadporozhskaya[b]

[a] Bingen University of Applied Sciences, Berlin Str. 109, Bingen, 55411, Germany
[b] St. Petersburg State University, Oranienbaumskoe 2, St. Petersburg, 198904, Russia

ARTICLE INFO

Keywords:
Russia
Humus form
Classification
Description
Forest types
Soil mapping
SOM modelling

ABSTRACT

In Russia, humus form concept has been known and used in forest science since the end of the 19th century. The scientific development of humus form physicochemical characterisation started in the 1940s. Later, classification with a field key of humus forms in forest soils of European taiga forests was elaborated for soil mapping. Twelve humus forms were identified in xeric and mesic soils, five in hydric, and six in histic soils. From the fractionation of soil organic matter (SOM), it was found that in topsoil, C and especially N concentrated mostly in fulvic acids in Mor, in humic acids in Moder and in non-hydrolysable fraction ("humin") – in Mull. A correlation humus forms with forest types and stand productivity in Russian European taiga forests was also found. The classification of humus forms was implemented for soil and forest site mapping at forest inventory on the Russian North West totally on the area of 300,000 ha. The study of humus forms led to the understanding that consistent eutrophication of an edaphic environment is a general trend of soil development at primary ecological successions, and to the formulation of a principle "ecogenesis repeats evolution". Recently, the humus form concept was used as a theoretical background for the simulation of SOM dynamics with compilation of ROMUL and Romul_Hum models. The idea of the existence of three main functional groups of soil biota corresponding to Mor, Moder and Mull with their specific role in SOM formation was used to elaborate these models.

1. Historical introduction

The concept of humus form was known in Russian soil and forest science since the publication of P.E. M & ller's book in German in 1887. This concept was used for the characterisation of forest types in the first Russian forest classification by Kruedener (1916; A. von Krüdener was a leader and participant of the first forest studies on Russian North in 19 century) and by a founder of scientific forest science in Russia Morozov (1920, cit. 1971).

However, the real start of humus form study in Russia was entered by two outstanding soil scientists, Turin and Ponomareva (1940), who confirmed importance of humus form concept by a comprehensive biochemical investigation of soil organic matter. They proposed to extend the humus form concept to the "humus profile type". The concept of humus form was included in the soil science textbook by Rode (1956) and in many forestry manuals (see Chertov, 1981). Then Blagovidov and Burkov (1959) developed the humus form classification, compiled a key for field diagnostics and linkage of humus forms with forest sites (Waldstandorten) and soil classification for mapping in Russian North-western forests. Here, we briefly describe the further development and application of humus form concept in Russia.

2. The Russian classification of humus forms

The general morphological pattern of a Mor humus form to be found in taiga Scots pine forests of Russian European Northwest is represented in Fig. 1.

The work of Blagovidov and Burkov (1959) was the basis for the development of humus form research in the second part of the 20th century. The number of Humus forms was expanded by new taxons in the cource of field studies (Chertov, 1966 and many others) with the creation of a regional classification for the Russian European Northwest (Fig. 2; Chertov, 1981). At that time, the word "humus form" was changed to "humus types" under influence of the contacts with and works of Wilde (1958, 1971). The field diagnostic of humus forms was based on the morphological patterns of organic layer (mostly forest floor) and organo-mineral Ah/AhE horizons and their thickness. Among a set of physical and chemical parameters, there is a leading role of a C:N ratio for humus form diagnostics. The general units of the humus form classification are shown in Fig. 2. A key for field diagnostics of

* Corresponding author.
E-mail address: oleg_chertov@hotmail.com (O. Chertov).

http://dx.doi.org/10.1016/j.apsoil.2017.04.006
Received 16 November 2016; Received in revised form 28 March 2017; Accepted 18 April 2017

Fig. 1. Typical Mor (Hemimor according to Zanella et al., 2010) of sandy Carbic Podzol, Scots pine stands (*Pinetum myrtillosum*) at the Russian European Northwest.

Humus forms was also published (Chertov, 1974).

Starting from the work of Turin and Ponomareva (1940), the names of humus forms in Russia were used as a grammar adjective to a soil taxonomic name. The names of three main Humus forms were represented by a direct translation from German.

At that time, the study of humic substances in the main humus forms revealed that a) there is a consistent increase of humic acids from L to H sub-horizons in the forest floor of any humus form, and b) in organo-mineral horizons, C and especially N concentrated in fulvic acids in Mor, in humic acids in Moder and mostly in the non-hydrolysable fraction ("humin") – in Mull (Chertov, 1966, 1981).

3. Correlation of humus forms with forest types, and their use in soil mapping

A close correlation of humus forms with forest stand composition and dynamics was found related to cutting and fires in Russian European taiga forests. Therefore, humus forms were used for the characterisation of forest site units' in the forest site classifications of the Russian Northwest (Chertov, 1981) and also of Vietnam (Chertov, 1985). The humus form was a core parameter in the evaluation of forest stands' productivity as well. For example, Dys-moder is a typical humus form for loamy Albeluvisols under Norway spruce forests (*Piceetum oxalidosum*) on forest sites of well drained moraine hills, while Rhyzo-oligo-mull develops here under secondary Silver birch stands (*Betuletum herbosum*) (Chertov, 1981). It is necessary to point out that humus forms are used as a main parameter for the soil characteristization in the comprehensive classification of forest ecosystems of the Russian Northwest (Fedorchuk et al., 2005).

The work on the humus form development was practically oriented for use in forest inventory and planning. Therefore humus forms were linked to the Russian soil classification at the lowest level (something as a "sub rank") that reflects a current state of soil productivity in relation to vegetation and anthropogenic impacts of every soil unit (Chertov, 1981). This approach was implemented in soil and forest site mapping for forest inventory in the Russian Northwest totally over 300,000 ha (15,000 ha in a scale 1:10,000; 70,000 ha in scale 1:25,000; the rest in scale 1:100,000).

4. Theoretical aspects

The concept of Humus form allowed some theoretical aspects in soil ecology to be determined. A study of vegetation dynamics gave a reason for the conclusion of a theoretical trend of soil development to the consistent eutrophication of edaphic environment at primary and secondary forest succession with the formation of humus forms from Mor to Mull on well drained soils in various landforms (Chertov and Razumovsky, 1980). Later on, this hypothesis was expanded to the principle of "ecogenesis repeats evolution" (Chertov, 1990), which can be demonstrated as the primary ecosystem succession on sandy dunes in boreal forests and on massive rocks if no severe disturbances take place. The micromorphological analysis of humus forms was also used by Romashkevich and Gerasimova (1982) for a study of 13 soil types along a meridian transect in East Europe.

It should be pointed out that there are two additional approaches for the evaluation of soil humus status in Russia. The first are numerous forest floor classifications with their latest interpretation as "detrito-profiles" (Bogatyrev et al., 2004). The second is the "organoprofile" concept (Grishina, 1986) with special reference to the chemistry of humic substances and without morphological and taxonomic aspects but clearly addressed to replace the humus form theory.

5. The use of humus form concept in modelling SOM dynamics

The humus form concept was a theoretical background to the creation of the model of soil organic matter dynamics ROMUL (ROhhumus MULl, Chertov and Komarov, 1997; Chertov et al., 2001;

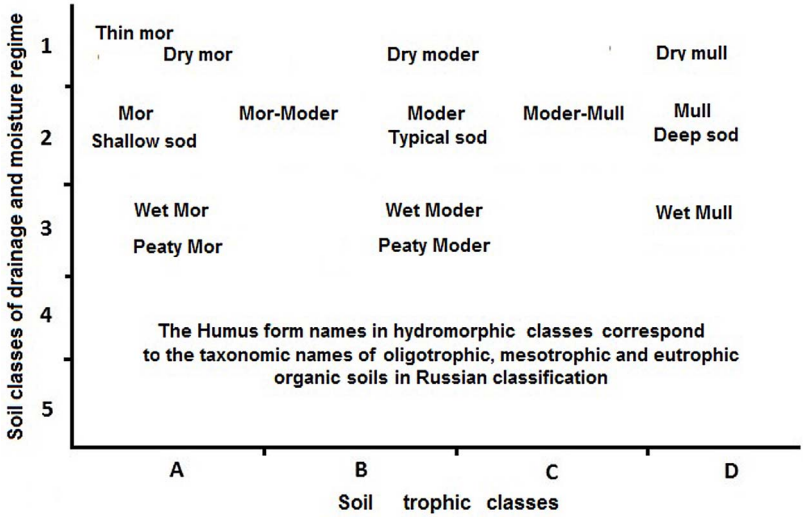

Fig. 2. Edaphic ordination of humus forms in the Russian European Northwest by scales of soil water regime and productivity. Water regime scale: 1–xeric, 2–mesic, 3–temporally hydric, 4–hydric, 5–permanently hydric (ground water table near the surface) with histic soils. Trophic scale: A – oligotrophic, B and C – mesotrophic, D – eutrophic.