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ASSESSING SOIL ORGANIC MATTER DYNAMIC IN LONG-TERM EXPERIMENT USING ROTH C 26.3 MODEL

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Abstract

Soil organic matter (SOM) has many environmental functions and it can be a considered as important indicator of soil quality. The changes in soil organic carbon (SOC) stock can occur following land use or land management change or with climatic change. RothC model is one of the most used model for the prediction of changes in SOC stock on agricultural soils. The efficiency of RothC model was tested to predict the dynamic of SOC stock during 20-year period (1991-2010) on a long term experiment. The obtained results showed 10% in SOC stock loss both on the fertilizer and unfertilized plots, and 30%-45% loss compared with 1940-50, respectively. The RothC model was found sufficiently sensitive to the parameters of long-term experiment and can be successfully used in similar agroecological conditions.

Keywords: *Soil organic matter, Roth C model, crop residues, RMSE*

Introduction

Soil organic matter (SOM) is the most often reported characteristic of a long–term experiments and can be identified as an valuable indicator of agroecosystem development within the specific agroecological conditions and agricultural practice (Körschens, 2004). Therefore, evaluation of SOM may provide crucial information for sustaining soil quality and agroecosystem health (Birkás, 2008). The maintenance of site–specific SOM content is a prerequisite for a protection of soil function and can be identified as a most important attribute of agroecosystem agronomic sustainability (Reeves, 1997). Likewise it is important to indentify vulnerable areas exposed to serious SOM loss due to intensive agriculture or natural causes. Numerous studies showed decline in organic matter content with tillage, insufficient fertilization and crop residue removal and burning (Dalal and Mayer, 1986; Manojlović et al., 2008). The changes of SOM in Serbia were observed both on the national level (Ličina et al., 2011) and also in Vojvodina Province (Sekulić et al., 2010). Preservation of SOM is a long-term process and includes both monitoring and predicting changes of SOM trends. The assessment of SOM change in the future was recognized as important tasks in the process of SOM protection. There are several types of models for the estimation of SOC stock (SOMM, ITE, Verberne, RothC, CANDY, DNDC, CENTURY, DAISY, NCSOIL). RothC and CENTURY are two of the most widely used and tested SOM models. RothC 26.3 (Colleman and Jenkinson, 2005) was originally developed and parameterised to model the turnover of organic C in arable topsoils from the Rothamsted Experiments. RothC-26.3 was tested in long term experiments on a range of soils and climatic conditions in Western and Central Europe, with detailed descriptions of the sites conditions and treatments (Coleman et al. 1997; Falloon and Smith 2002) The aim of this paper was to evaluate SOM content in the top soil after winter wheat at the long–term experiment on Chernozem, and examine RothC 26.3 model in prediction of SOM change in continuous cropping under conventional tillage practice.

Material and methods

The present study was performed on a long–term experiment (LTE) "Plodoredi" carried out at the Rimski Šančevi Experimental Field of the Institute of Field and Vegetable Crops in Novi Sad. The trial was located at the southern border of Chrenozem zone of the Panonian basin. For the purpose of this study SOM was accessed in the winter wheat based cropping systems. The study treatments were as follows: fertilized 3–year crop rotation (wheat–maize–soybean) D3; fertilized 2–year crop rotation (wheat–maize) D2; fertilized wheat monoculture MO; unfertilized 3–year rotation (wheat–maize–soybean), N3 and unfertilized 2–year rotation (wheat–maize) N2. The unfertilized treatments were established 1946/47, and fertilized in 1969/70. Conventional tillage practice including moldboard plough, harrow disc, and cultivator was performed every year. Harvest residues were incorporated by ploughing after 1988. Winter wheat sowing was done in October (20–30. X) with seeding rate of 250–270 kg ha^{-1}. During the observed period leading wheat and soyabean varieties and maize hybrids were grown and dital description of the trail can be found in Milošev (2000). The amount of crop residue was calculated according to obtained yield (Bolinder et al., 2007).

RothC 26.3 (Colleman and Jenkinson, 2005) was originally develop from Rothamsted Long Term Field experiments data. The RothC 26.3 model was previously tested in the agroecological area of long-term experiment. The study period was from 1991 to 2010, subsequent to experiment was subjected to changes in cropping technology. The model requires three types of data: (a) Climatic data – monthly rainfall (mm), evapotranspiration (mm) and average monthly mean air temperature (°C); (b) Soil data – clay content (%), inert organic carbon (IOM), initial SOC stock (t C ha^{-1}), depth of the soil layer considered (cm) c) Land use and land management data – soil cover, monthly input of plant residues (t C ha^{-1}), monthly input of farmyard manure (FYM) (t C ha^{-1}), residue quality factor (DPM/RPM ratio) and d) climatic data. Model performance was evaluated using the following indices: Root mean square error (RMSE), Coefficient of correlation (r), Mean difference (M) and Relative error (E). After Loague and Green (1991), the total difference between the simulated (predicted) and the measured values were calculated as the RMSE. The statistical significance of RMSE was assessed by comparing to the value obtained assuming a deviation corresponding to the 95% confidence interval of the measurements: where: $t_{(n-2)95\%}$ is Student's t distribution with n-2 degrees of freedom and a two-tailed P-value of 0.05. To assess whether simulated values follow the same pattern as measured values, the sample r was calculated. Mean difference or difference between means of predicted and measured values expresses the total simulation bias; t of M (student's t-test of M): if the t of M is lower than the critical two-tailed 2.5% t-value means that the model bias is not significant.

Results and discussion

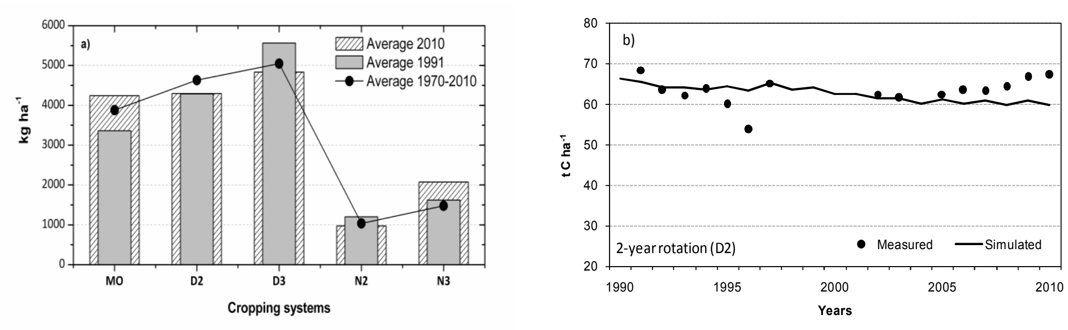
The analysis of the achieved yield of wheat points to a significant difference between fertilized and unfertilized variants. The highest grain yields was achieved on the D3, followed in most of the years by D2. When comparing the fertilized rotations, MO had the lowest yield. However, despite the unfavourable crop rotation, it was shown that MO in most years can achieve the yield between 3000 and 4000 kg ha^{-1}. The lowest yield was obtained on average at the N2 (1000 kg ha^{-1}) and N3 (1500 kg ha^{-1}), respectively. By analyzing the long-term yields it was found that there is certain stability in yields at some level and relatively small annual variations (Milošev, 2000; Šeremešić, 2007; Milošev et al., 2010). The crop yield analysis is important for the estimation of residue that could be transformed into SOM. Additionally, it is necessary for parameterization of belowground and aboveground net primary production used in RothC model calculation. In accordance with this higher potential for SOM preservation was found at D3 plot (Beauchamps and Voroney, 1994; Seremesic et al., 2011).

Modeling SOM dynamic with Roth C model

According to studies conducted at the same experimental field an estimated carbon stock observed during 1940-50. period would be 95 t C ha^{-1} (Bogdanovic, 1955). To initiate the RothC model it is necessary to calculate the SOM equlibrium as an initial value for modeling C in soil (Coleman and Jankinson, 2005). For wheat MO, D2 and D3 equilibrium is done for the 1970 with C stock of 78 t C ha^{-1}. RothC calculation from that period takes into account input from the aboveground and belowground crop residue. Inputs are determined each year based on the yield quantity. For unfertilized rotation N2 and N3, the equilibrium C was established for 1947 (91.4 t C ha^{-1}). Until 1988 only averaged belowground residues of wheat, corn and soybeans were considered for the calculation, and afterwards all plant remains were included, based on crop yields.

Figure 1 (b, c, d, e and f) shows the values of C stock obtained using the Roth C model (line) and the measured values of SOC (dot) during the period 1991-2010. The results indicate pronounced downward trend in soil C content especially in the initial years which later slows. The amount of SOC reserves with RothC model at MO decresed from 72.7 to 64.19 t C ha^{-1} (-12% lower). Though, SOC stock reserves compared to other fertilized rotations, indicated that wheat growing in MO could preserve SOM. This can be explaind with better weed control during the growing season, reduced yields and nutrients removal. The SOC stock at D2 decresed from 66.2 to 59.7 t C ha^{-1} (-10%), and at D3 from 70.0 to 64.1 t C ha^{-1} (-9%). Compared with equilibrium created at 1970 the fertilized rotation lost 18% of C stock in topsoil (D3 and MO) and 25% at MO. However, the SOC loss is even bigger compared with stock C from 1940-1950 (30 % loss). Based on the model the current C reserves content in the unfertilized soil is about 50 t C ha^{-1} which is 10% lower than 1991 and 45% lower compared with equlibirum initiated 1940-50. Further on, a negative trend projected by the model will continue into the future resuting with the C reserve of about 44 t C ha^{-1} for the unfertilized plots and 50 t C ha^{-1} for fertilized plot by the 2030.

Continous SOC loss indicate that even with fertilization it would be difficult to preserve initial content in soil. RothC model data suggest that returning and properly manage all crops residue is crucial in the preservation of SOM (Barančíková et al., 2010). With lower yields, narrow rotation (without legumes) and projected climatic changes it would be a great chalange to maintain SOM level observed at 2010.



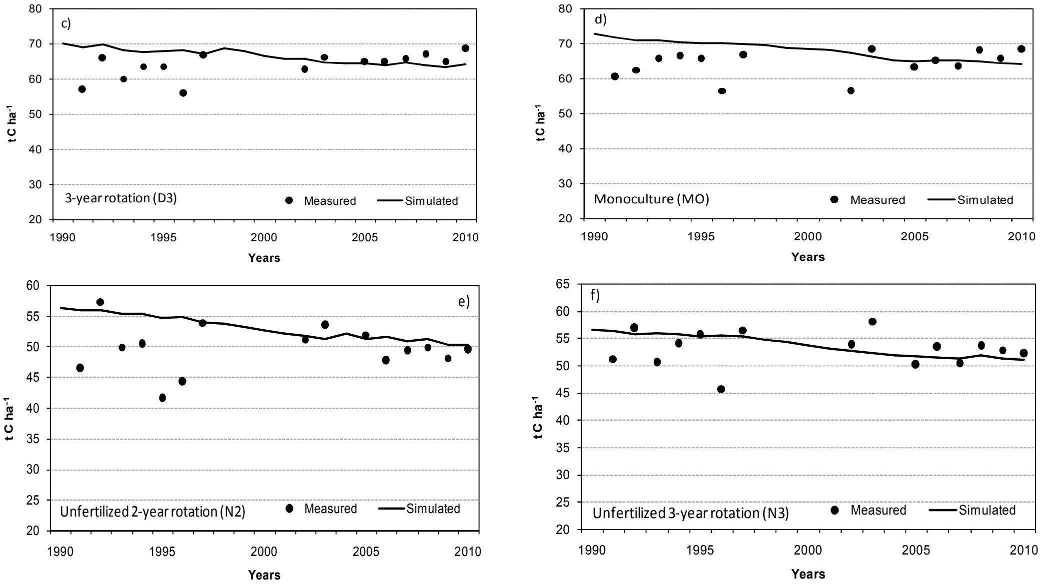


Figure 1. a) winter wheat grain yield, Roth C model and measured C (t ha^{-1}) for b) 2-year rotation, c) 3-year rotation, d) wheat monoculture, e) unfertilized 2-year rotation and f) unfertilized 2-year rotation

Higher correlation of measured and modelled data was observed with D3, whearas other cropping systems showed no correlation (Table 1). The significant RMSE for investigated plots indicating that the simulations fell within the 95% confidence interval of the measured data (Coleman and Jankinson, 1996). The simulation biases expressed as M were all significant because all the values of t of M were less than the 2.5% critical two-tailed t-value. Values of M and E rank model bias similarly. A significant bias in a given simulation indicated by E for the no fertilization plots was -5.76 and -1.13, respectively for N2 and N3. For the fertilization plots E values was 1.27 for D2, -3.76 for D3 and -5.73 for MO. The close match between the simulation lines and the measured data was again reflected in low values for E which were all well below the respective E95% values, suggesting that there was no significant bias towards either over- or under-prediction by model.

Table 1. Statistics describing aspects of the performance of the RothC models when simulating data from long-term experiment at Rimski Šancevi

Statistics		**D2**	**D3**	**MO**	**N2**	**N3**
r = Correlation Coeff.		-0.09	-0.58	-0.34	0.01	0.01
Assuming no model parameters adj. k=1.						
	F = ((n-2) r^2) / (1-r^2)	0.12	6.48**	1.65	0.00	0.00
	F-value at (P=0.05)	4.67	4.67	4.67	4.67	4.67
RMSE	Model	6.48**	8.73**	10.03**	9.45**	7.04**
	95% Confidence limit	12.01	11.90	11.84	15.16	14.33
E	Model	1.27**	-3.76**	-5.73**	-5.76**	-1.13**
	E 95% Confidence Limit	10.33	10.23	10.18	13.03	12.32
M	Model	0.81**	-2.39**	-3.67**	-2.88**	-0.60**
	t = Student's t of M	0.75	-1.78	-2.59	-2.86	-0.61
	t-value (Crit. at 2.5% - 2-tailed)	2.16	2.16	2.16	2.16	2.16

r = Correlation Coeff; RMSE = Root mean square error of model; RMSE (95% Confidence Limit; E = Relative Error M = Mean Difference (t-value critical at 2.5% - 2-tailed =2.10)

Conclusion

The modelling SOM in soil approach represents one of the most promising methods for the estimation of the stock and changes of SOC. On the basis of our results, it can be concluded that RothC model is suitable for the estimation of SOC stock changes in agricultural soils and can be used for the modeling of SOC stock changes on the chernozem soils with similar agroecological conditions. Generally, the fertilized rotation in topsoil were lower in C stock by 10 % in comparison with 1991 by 18% (D3 and MO) or 25% (MO) compared with 1970 and by 30 % compared with 1940-50. The unfertilized plots were lower 10% lower than 1991 and 45% lower compared with 1940-50.

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References

Barančíková, G., Halás, J., Guteková, M., Makovníkova, M., Nováková, M., Skalsky, R., Tarasovičová, Z. (2010): Application of RothC Model to Predict Soil Organic Carbon Stock on Agricultural Soils of Slovakia. Soil and Water Research, 5(1), 1–9

Beauchamps, E.G., Voroney R. P. (1994). Crop carbon contribution to the soil with different cropping and livestock systems. Journal of Soil and Water Conservation, Vol. 49:2, 205–209.

Birkás, M. (2008). Environmentally–sound adaptable tillage. Akadémiai Kiadó Budapest, pp. 354.

Bogdanović, M. (1955). Odlike humusa u glavnim tipovima zemljišta NR Srbije. Doktorska disertacija. Poljoprivredni fakultet Zemun-Beograd.

Bolinder, M. A., Janzen, H.H., Gregorich, E.G., Angers, D.A., Vanden Bygaart, A.J. (2007). An approach for estimation net primary productivity and annual carbon inputs to soil for common agricultural crops in Canada. Agriculture, Ecosystems and Environment, Vol. 118, 29-42.

Coleman K., Jenkinson D.S. (2005): ROTHC-26.3 A model for the turnover of carbon in soil. Model description and windows users guide. Available at http://www.rothamsted.bbsrc.ac.uk/aen/carbon/mod26_3_win.pdf

Coleman K., Jenkinson D.S., Crocker G.J., Grace P.R., Klir J., Korschens M., Poulton P.R., Richter D.D. (1997): Simulating trends in soil organic carbon in long-term experiments using RothC-26.3. Geoderma, Vol. 81, 29–44.

Coleman, K., Jenkinson, D.S. (1996): RothC-26.3: a model for the turnover of carbon in soil. In: Evaluation of soil organic matter models using existing long-term datasets (eds D.S.Powlson, P.Smith & P.J.U.Smith), NATO ASI Series I, Vol. 38, pp. 237–246. Springer-Verlag, Heidelberg.

Dalal, R. C., Mayer, R. J. (1986): Long–term trends in fertility of soil under continuous cultivation and cereal cropping in Southern Queensland: I Overall changes in soil properties and trend in winter cereal yield. Australian Journal of Soil Research, Vol. 24, 265–279.

Falloon P., Smith P. (2003): Accounting for changes in soil carbon under the Kyoto Protocol: need for improved long-term data sets to reduce uncertainty in model projections. Soil Use and Management, Vol. 19, 265–269.

Körschens, M. (2004). Soil organic matter and environmental protection. Archives of Agronomy and Soil Science, Vol. 50, 3–9.

Ličina, V., Nešić, L., Belić, M., Hadžić, V., Sekulić, P., Vasin, J., Ninkov, J. (2011): Zemljišta Srbije i prisutni degradacioni procesi. Ratarstvo i povrtarstvo, Vol. 48(2), 285-290.

Loague K., Green E.E. (1991). Statistical and graphic methods for evaluating solute transport models: overwiev and application. Journal of Contaminant Hydrology, Vol. 7, 51–73.

Manojlović, M., Aćin, V., Šeremešić, S. (2008). Long–term effects of agronomic practices on the soil organic carbon sequestration in Chernozem. Archives of Agronomy and Soil Science, Vol. 54, 353–367.

Milošev, D. (2000). Selection of cropping systems for winter wheat. Monograph, Beograd, p. 163 (in Serbian)

Milosev, D., Seremesic, S., Djalovic, I., Kastori, R., Jockovic, M. (2010). Agro-ecosystem productivity and resilence in environmental conditions of the Southern Pannonian Basin. „9th Alps-Adria Scientific Workshop“, Špičak, 589-592.

Reeves, D. W. (1997). The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil and Tillage Research, 43: 131–167.

Sekulić, P., Ninkov, J., Hristov, N., Vasin, J., Šeremešić, S., Zeremski-Škorić, T. (2010): Sadržaj organske materije u zemljištima AP Vojvodine i mogućnost korišćenja žetvenih ostataka kao obnovljivog izvora energije. Ratarstvo i povrtarstvo, Vol. 47, 591-598.

Seremesic S., Milosev, D., Djalovic I., Zeremski, T., Ninkov J. (2011). Management of soil organic carbon in maintaining soil productivity and yield stability of winter wheat. Plant, Soil and Environment, 57(5), 216-221.

Šeremešić, S., Milošev, D., Jug, D., Đalović, I., Jaćimović, G. (2010). Changes in soil organic matter content as affected by crop rotation and fertilization at the long-term experiment. Proccedings of Alps-Adria Workshop, Opatija, 16-20 March, 643-647.

Šeremešić, S., Milošev, D., Manojlović, M. (2007). Soil organic matter status affected by crop rotation and fertilization at long–term experiment. Book of Abstracts „Practical Solutions for Managing Optimum C and N content in Soils IV, pp. 65.