Impact of Biochar on Soil Temperature During 2 Year Field Experiment

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Abstract. The aim of this paper was to investigate the relation of temperature of the soil surface to a biochar dose used in the field cultivation. Material from observations in a vegetation season of 2018 and 2019 was used in the studies. Based on the research that was carried out it was reported that the strongest relations of the temperature of air with the temperature of soil occurred for all biochar doses. In summer, relations of biochar to the soil temperature were stable and statistically significant.

1. Introduction

Soil is the link between the circulation of organic matter and the energy that feeds biological changes in the environment [1]. Soil temperature is one of the most important indicators of energy transformation and is an indicator of climate change, evapotranspiration, etc. Soil temperature is an indicator of the degree of energy exchange between the atmosphere and the pedosphere [2-7].

Knowledge of thermal conditions of the soil surface is significant for the proper cultivation process. The temperature of soil has a significant impact on the dates when biological processes in environment begin and end. It decides on the intensity of respiration processes and biochemical changes, that are particularly material in the vegetation period. Water content of soil depends on the soil temperature, which decides inter alia, on the speed of germination and health of plants. M.Molga made a thorough analysis of thermal and moisture conditions of soil [8-10]. He carried out, inter alia, a detailed characteristic of thermal properties of soil as well as factors that influence distribution of temperature including specificity of the ground layer of air.

Temperature strongly influences the soil freeze and thaw states [11], seed sowing dates [12], crop growth and development [13], yield [2], and the rate of plant diseases and insect pests. In addition, it also influences infiltration [14], evapotranspiration [15] and hence, soil water content [4-7, 16].

The objective of the article is to determine the relation of the temperature course in the superficial layer of soil in relation to the applied biochar dose in two year field experiment.
2. Material and methods
The studies presented in this article were made on the experimental field that belongs to the University of Agriculture in Kraków. Soil used for research is brown soil made of Jurassic limestone. 11 experimental fields with dimensions of 1.2x1.2 m were distributed on an experimental field. They were fertilised with biochar in the amount of 0, 1, 5, 10, 20, 30, 40, 50, 60, 80 and 100 Mg ha$^{-1}$. Before measurements were initiated, probes were conditioned in an incubator. Read outs on experimental fields were made every 48 hours from May to September 2018 and 2019. The analysis of variance in the scheme of repeated measurements that constituted extension of the analysis of the t-Student test for dependent tests were used for statistical assessment of the results of measurements. In the t-Student test were compared only two measurements and in the analysis of variance were compared two or more measurements of the same group of fields depending on the biochar dose.

3. Results and discussions
Figures 1 and 2 present the results of soil temperature measurements in 2018 and 2019. In 2018, after application of biochar in May, there was no statistically significant difference in temperature between the biochar plots and the control plot. In subsequent months (June-August) a statistically significant effect of biochar was observed on the change in soil temperature, which increased up to 3°C relative to the control sample. In September-November period, a negative impact of biochar on soil temperature was observed. At the analyzed biochar doses, there was a decrease in soil temperature up to 5°C relative to the control. The study conducted for 2018 also showed that in July, August and November there were no significant differences in soil temperature relative to the biochar dose. The temperature tests continued in 2019 were carried out for the same period as in 2018. The conducted temperature measurements showed gradual equalization of soil temperature irrespective of the biochar dose. In the months of May and June an increase in soil temperature with the addition of biochar was observed relative to the control plot (up to 3.5°C). In July and August, a process of soil temperature leveling and decline was observed, which progressed with the increase in biochar dose. Soil temperature equilibration occurred in September and October were not statistically significant. Research conducted in November confirmed the negative impact of biochar on soil temperature in winter period.

Figure 3 shows the variability of soil temperature with the addition of biochar to the control plot. The largest differences in soil temperature occurred in the months August-October reaching close to 12°C. Analyzing the temperature variability in each month, it can be concluded that after the first season of biocarbon soil conditioning, a statistically significant difference for biochar doses of 40-100 Mg ha$^{-1}$ disappears. In June and July, statistically significant variability was observed between soil and biocarbon temperatures depending on the dose. In May, negative temperature values occurred, which is due to the difference in the degree of use of plots - in 2018 the soil was intensively mixed with biocarbon while in 2019 this process did not occur. Taking into account the absolute values of temperature variation in May, one can observe a lack of statistically significant temperature variability relative to the biochar dose.
Figure 1. Average value of soil temperature in relation to biochar dose (Mg∙ha$^{-1}$) and month of measurement in 2018.

Figure 2. Average value of soil temperature in relation to biochar dose (Mg∙ha$^{-1}$) and month of measurement in 2019.
Figure 3. Average temperature of soil difference between 2018 and 2019 in relation to biochar dose (Mg·ha⁻¹) and month of measurement.

4. Conclusions
A relation between a biochar dose and the temperature of soil was reported. It was concluded that with field doses of 5-8 and 100 Mg·ha⁻¹, temperature increasing or decreasing was at a similar level. In other cases, it was reported that the increase of the biochar dose by 10 Mg·ha⁻¹ causes the increase of the temperature of soil by average 0.5-1.0°C.

Analysis of the data used in the paper confirmed the regularity that the scope of daily changes of superficial layers of soil is higher than the range of air temperature changes [17]. It is important, however, to include the temperature of soil delay in relation to the air temperature which is emphasised by inter alia [18,19].

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References
[1] D. Fangueiro, P. S. Kidd, P. Alvarenga, L. Beesley, A. de Varennes, „Strategies for soil protection and remediation”. [In:] A. C. Duarte, A. Cachada, T. Rocha-Santos, eds., „Soil Pollution”. Academic Press, USA. pp. 251–281, 2018.
[2] D. Hillel, „Environmental Soil Physics”. Academic Press, USA. pp. 309–334, 1998.
[3] Q. Hu, S. Feng, „A daily soil temperature dataset and soil temperature climatology of the contiguous United States”. Journal of Applied Meteorology, vol. 42, pp. 1139–1156, 2003.
[4] J. Sikora, M. Gliniak, U. Sadowska, A. Klimek-Kopyra, A. Latawiec, „Time-domain reflectometry (TDR) in mapping soil temperature and humidity”. [in:] 22nd International Scientific Conference on Progress of Mechanical Engineering Supported by Information Technology, POLSITA 2019, Czajowice, Poland. 2019.
[5] M. Gliniak, J. Sikora, U. Sadowska, A. Klimek-Kopyra, A. Latawiec, M. Kuboń, „Impact of Biochar on Soil Temperature”. IOP Conference Series: Earth and Environmental Science, vol. 362(1), 012045, 2019.
[6] M. Gliniak, W. Sobczyk, „Content of toxic metals in soils on postproduction sites”. Przemysł Chemiczny, vol. 96(10), pp. 2055-2059, 2017.
[7] M. Gliniak, M. Betlej, A. Mitura, „The Application of the PAN Reclamation Model on the Example of Former Landfills Cracow Soda Works "Solvay". Inzynieria Mineralna-Journal Of The Polish Mineral Engineering Society, pp. 131-136, 2015.
[8] M. Molga, “O klimacie gleby,” Gazeta Obserwatora PIHM, vol. 4, pp. 9–13, 1953.
[9] M. Molga, “Meteorologia rolnicza,” PWRiL, Warszawa, 1958.
[10] M. Molga, “Siła ssąca gleby,” Gazeta Obserwatora PIHM, vol. 12, pp. 3–6, 1959.
[11] F. Shati, S. Prakash, H. Norouzi, R. Blake, „Assessment of differences between near-surface air and soil temperatures for reliable detection of high-latitude freeze and thaw states”. Cold Regions Science and Technology, vol. 145, pp. 86–92, 2018.
[12] A. Araghi, M. Mousavi-Baygi, J. Adamowski, “Detecting soil temperature trends in Northeast Iran from 1993 to 2016”. Soil & Tillage Research, vol. 174, pp. 177–192, 2017.
[13] R. Huang, C. Zhang, J. X. Huang, D. H. Zhu, L. M. Wang, J. Liu, Mapping of daily mean air temperature in agricultural regions using daytime and nighttime land surface temperatures derived from TERRA and AQUA MODIS data. Remote Sensing, vol. 7, pp. 8728–8756, 2015.
[14] A. S. Jebamalar, S. A. T. Raja, S. J. S. Bai, “Prediction of annual and seasonal soil temperature variation using artificial neural network”. Indian Journal of Radio and Space Physics, vol. 41, pp. 48–57, 2012.
[15] M. S. Moran, R. L. Scott, T. O. Keefer, G. S. Nearing, G. B. Paige, M. H. Cosh, P. E. O’Neill, “Partitioning evapotranspiration in semiarid grassland and shrubland ecosystems using time series of soil surface temperature”. Agricultural and Forest Meteorology, 149, pp. 59–72, 2009.
[16] A. Tabbagh, R. Guérin, B. Cheviron, H. Henine. “Seasonal monitoring of soil water content and infiltration using soil temperature measurements”. [in:] Proceedings of the Near Surface Geoscience, 22nd European Meeting of Environmental and Engineering Geophysics, Barcelona, Spain, 2016.
[17] J. Kossowski, „Związek amplitud dobowych temperatury gleby w warstwie przypowierzchniowej z amplitudami temperatury powietrza i innymi elementami meteorologicznymi,” Acta Agrophys., vol. 5, pp. 657–667, 2005.
[18] B. Michalska, and J. Nidzgorska-Lencewicz, „Dobowa zmienność temperatury w profilu gleby porośniętej w stacji meteorologicznej w Ostoi,” Folia Pomer. Univ. Technol. Agric., vol. 279, pp. 63–72, 2010.
[19] D. Ciaranek, „Wpływ warunków pogodowych na przebieg temperatury gleby w ogrodzie botanicznym Uniwersytetu Jagiellońskiego w Krakowie,” Zeszyty Naukowe UJ, Prace Geograficzne, vol. 133, pp. 77–99, 2013.