SHORT TERM IMPACT OF APPLICATION OF DIFFERENT DOSES OF WOOD ASH ON GREENHOUSE GAS (GHG) EMISSIONS FROM PEAT

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Abstract. Wood ash contains most of the nutrients necessary for development of plants, as well as soil microorganisms. It is well studied that application of wood ash improves forest growth in peatlands and significantly increases biomass production in the forest floor; however, there is limited knowledge on the short-term impact on the soil GHG (CO_2, N_2O, CH_4) fluxes after application of wood ash, specifically, if different doses of the wood ash are applied. The scope of the study is to determine short term (2 months) effect of application of 2, 5 and 10 tons·ha^{-1} of hardened and fresh wood ash in peat from abandoned peatland – southern part of Kaigu mire (former raised bog). The study is implemented in controlled conditions (temperature and moisture) in a greenhouse. Peat from abandoned peatland is filled into 50 cm deep plastic boxes (area 50 x 70 cm) simulating 50 cm deep peat layer. The same amount of water is added regularly in all boxes to ensure that moisture level in peat remains close to natural conditions at the beginning of the experiment in control boxes. GHG fluxes are measured using Gasmet DX4040 FTIR analyser and opaque chambers. Measurement period 30 min. Measurements are repeated at least once per week. According to the study results directly after application of fresh wood ash peat acts as net sink of CO_2 due to consumption of CO_2 in chemical reactions; however, already in the second week after the application CO_2 emissions from soil increase, while carbon losses from treated boxes in average were smaller by 59% in comparison to control boxes. No significant effect of wood ash is found on CH_4 and N_2O emissions and no significant difference was found between hardened and fresh wood ash.

Keywords: GHG, emissions, wood ash, peat.

Introduction

Organic soils under the formation stage are net sinks for CO_2 and under certain moisture and temperature determined re-dox conditions, sources for CH_4 and N_2O. Drained organic soils can emit more CO_2 and N_2O due to enhanced decomposition of the organic matter caused by increased oxygen (O_2) availability in soil. The presence of O_2 also inhibits CH_4 emissions and may turn soil into net sink of CH_4 removals [1; 2].

Wood ash is residue remaining after the combustion of wood in a household furnace or an industrial power plant. It principally consists of calcium compounds with other non-combustible trace elements in wood. Many studies have been carried out on the chemical composition of wood ash, and the results are very different. Calcium carbonate ($CaCO_3$) is the main component at temperatures below 750 ºC, the main component at temperatures above 750 ºC (large furnace) is calcium oxide (CaO) [3]. Wood ash contains several mineral elements necessary for plants, primarily potassium, phosphorus and calcium. For example, the content of potassium and calcium in ash formed after burning plant residues can reach 30%, and phosphorus – 8%. The use of wood ash can replace artificial fertilizers and increases the concentration of nutrients in the soil. Wood ash can be used to neutralize soil acidification and improve nutrient balance in nutrient-poor forest areas [4-6].

Wood ash has been used to reduce nutrient deficiencies and acidification in boreal forest soils. However, ash may affect microbial processes producing or consuming greenhouse gases: methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) [7]. Ash can stimulate nitrification and denitrification and, therefore, increase N_2O emission and suppress CH_4 uptake rate [7]. Ash can also stimulate microbial respiration, thereby increasing CO_2 emissions [7]. The aim of this study is to determine the effect of various ash doses on greenhouse gas (GHG) emissions from peat, depending on the ash dose and type of hardened or fresh ash. Greenhouse gases are gases in the atmosphere that transmit sunlight and at the same time block the thermal (infrared) radiation emitted from the Earth's surface. This process causes the so-called greenhouse effect because these gases allow the sun rays to warm the Earth, but do not allow this heat to escape from our atmosphere into space. The primary greenhouse gases in the Earth's atmosphere are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). There are many ways to measure GHG emissions: in laboratory with a gas chromatograph, with the portable EGM-5, CO_2 emissions can be measured in situ. In this work GHG gases were measured

with FTIR technology. We hypothesized that wood ash stimulates microbial respiration, nitrification and denitrification, so N_2O and CO_2 emissions can increase after application of wood ash.

Materials and methods

Measurements were done *in vitro* conditions at room temperature by filling peat from Kaigu bog (former peat extraction site) into 21 plastic boxes (50 x 70 cm). Depth of the peat layer in the boxes is 50 cm. Peat in the boxes is compacted to ensure the same volume as in the field, where peat was collected. Wood ash was applied at a top and mixed into 3-5 cm topsoil layer. Applied dosage – equal to 2, 5 and 10 tons·ha^{-1} of wood ash (dry mass). Hardened (saturated with water about 2 months before application) and fresh wood ash from Salaspils city boiler plant is used. Coarse particles (D > 1 cm) are separated from the applied ash or crushed (hardened wood ash). During the study equal amount water is regularly added to ensure that relative moisture at a topsoil level in the control box is 50-60%. Temperature during the experiment is 11-27 ºC.

GHG fluxes are measured using opaque chambers with surface area 527 cm^2 and volume 12648 cm^3. One measurement is done each time per box. GHG gas fluxes are measured by FTIR technology using Gasmet DX4040 portable analyser. Measurements are done directly after positioning of the chamber and in 10, 20 and 30 minutes after positioning of the chamber. Duration of the measurement period – 2 minutes. Measurements are repeated at least once per week for 2 months period. In total 9 measurement series. An FTIR analyser can detect and calculate each gas in the sample based on the absorption characteristic. Advantages of this method achieved by simultaneously measuring of the entire infrared spectrum at once.

R^2 of the linear regression of the CO_2 concentration changes is used to ensure that outliers are excluded from the flux calculation. Only data series with $R^2 \geq 0.95$ for CO_2 content changes are used in the calculation. Other gases are not additionally controlled, since their fluxes (concentration changes) often were close to the uncertainty range of the equipment and R^2 is significantly smaller. GHG fluxes are calculated using the following equation [8]:

$$CO_2 - C\left[\mu gC \cdot m^{-2} \cdot h^{-1}\right] = \frac{M\left[g \cdot mol^{-1}\right] * P[Pa] * V\left[m^3\right] * \delta v\left[ppm \cdot h^{-1}\right] * f_1}{R\left[m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}\right] * T[K] * t[h] * A\left[m^2\right]},$$

where P – air pressure in the chamber, assumed constant 101300 Pa);
V – chamber volume, 0.012648 m^3;
δv – slope of regression representing gas concentration changes per hour;
R – universal gas constant (8.3143 m³·Pa·K⁻¹·mol⁻¹);
T – soil temperature, K;
t – measurement time, hours;
M – molar mass of measured gases, 44.01 CO_2, g mol^{-1}; 16.04 CH_4, g mol^{-1}; 44.01 N_2O, g mol^{-1};
A – chamber surface area (ground surface), 0.0527 m^2;
f_1 – recalculation coefficients (CO_2 0.27; CH_4 0.75; N_2O 0.64).

Further data analysis was done in LibreOffice Calc software using ANOVA, correlation and regression analysis. Effect of temperature, soil moisture, type and dosage of wood ash and the period between wood ash application and measurement is evaluated. Ttest is used to compare the difference.

Results and discussion

In total 756 measurements are done within the scope of the study. Average carbon dioxide (CO_2) emissions from soil are 119.69 ± 62.81 mg (CO_2-C) m^{-2}·h^{-1}; methane (CH_4) emissions from soil – 0.0012 ± 0.0027 mg (CH_4-C) m^{-2}·h^{-1}; nitrous oxide (N_2O) emissions from soil – 0.40 ± 0.34 mg (N_2O-N) m^{-2}·h^{-1}. The biggest CO_2 emissions are from control boxes and boxes with the smallest wood ash dosage (2 tons·ha^{-1}). Average CO_2 emissions from the boxes where dosages equal to 5 and 10 tons·ha^{-1} were applied are smaller in comparison to other variants (Fig. 1). No significant difference is found if hardened or fresh wood ash is applied; however, average CO_2 emissions from boxes, where hardened wood ash is applied, are significantly smaller than from other boxes. The reason for that is not explained in the study. CH_4 emissions are negligible (Fig. 1), which might be associated with saturation

of soil with oxygen during filling boxes and improved aeration of soil. No regularities are found depending on the dosage and type of wood ash. N_2O emissions are characterized with high uncertainty and no significant difference is found between the variants; however, in all cases peat is the source of N_2O emissions.

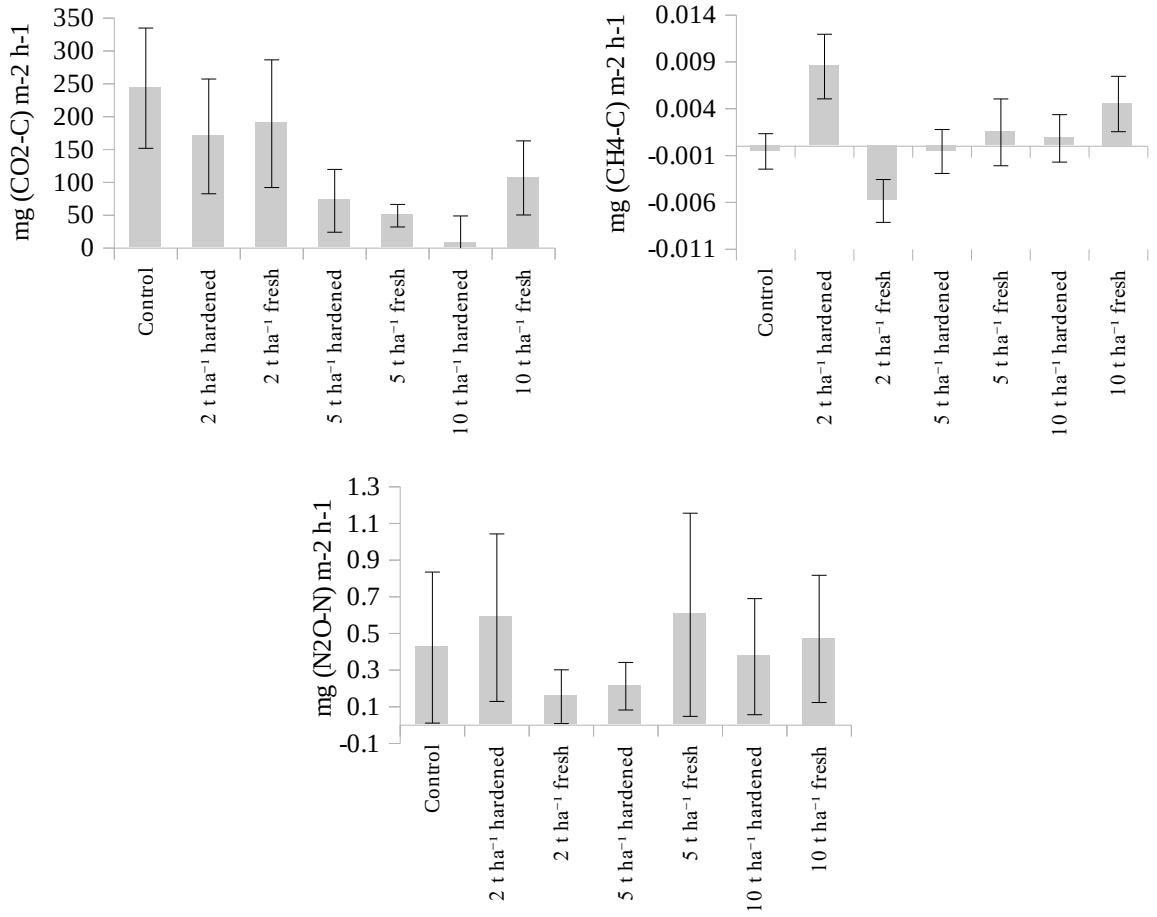

Fig. 1. **Average fluxes during the measurement period**

Average soil temperature during the measurement period is 16.3 ºC and average relative soil moisture – 59%. Despite adding of equal amount of water and similar conditions, soil moisture differs in different boxes, which might be associated with diversity of peat properties collected in the field.

CO_2 emissions are considerably bigger in control boxes in comparison to fertilized boxes during the whole measurement period (Fig. 2). Reduction of the fluxes may be associated with preparation of soil layers resulting in better aeration and higher emissions during the first week. CH_4 emissions do not demonstrate regular changes during the measurement period; no impact of wood ash on the CH_4 emissions is found in the study. N_2O fluxes significantly differ from other fluxes; significant N_2O emissions were observed only during the first week of the observations, returning to close to zero level during the rest of the period. Considering that the same trend is found in the control and fertilized boxes, the increase of N_2O fluxes is associated with preparation of soil boxes. If the first week is excluded from the evaluation (lower right chart in Fig. 2), no significant changes or significant N_2O emissions are found. Hardening of wood ash does not significantly affect the GHG emissions from peat, except CO_2 uptake during the first days after application of fresh wood ash.

Soil moisture is maintained by adding the same amount of water to retain the moisture level constant in the control boxes. The relative soil moisture in different boxes varied between 47% and 75%, providing opportunity to evaluate relationships between the soil moisture and GHG fluxes (Fig. 4). Positive trend between the soil moisture and CO_2 emissions is found in the control boxes, while adding of wood ash reduces this correlation. No relationship is found between the soil moisture and CH_4

emissions or N_2O fluxes; however, weak tendency of decrease of the N_2O emissions with increase of the soil moisture is found in several boxes containing wood ash.

Relationships between the GHG fluxes and soil temperature are evaluated in Fig. 3. The biggest correlation between the CO_2 emissions and soil temperature is found in boxes without ash and boxes with the smallest dosage of wood ash (2 tons·ha^{-1}). In the boxes where the amount of wood ash equal to 5 or 10 tons·ha^{-1} is applied no significant increase of the CO_2 emissions is detected, no difference was found between hardened and fresh wood ash. No relationships are found between the CH_4 emissions and soil temperature; however, in the most cases the slight increase of CH_4 emissions can be observed if the temperature increases. N_2O emissions increase if the soil temperature is higher; however, if the data sets acquired during the first week are excluded (lower right chart in Fig. 3), the positive correlation is not appearing anymore.

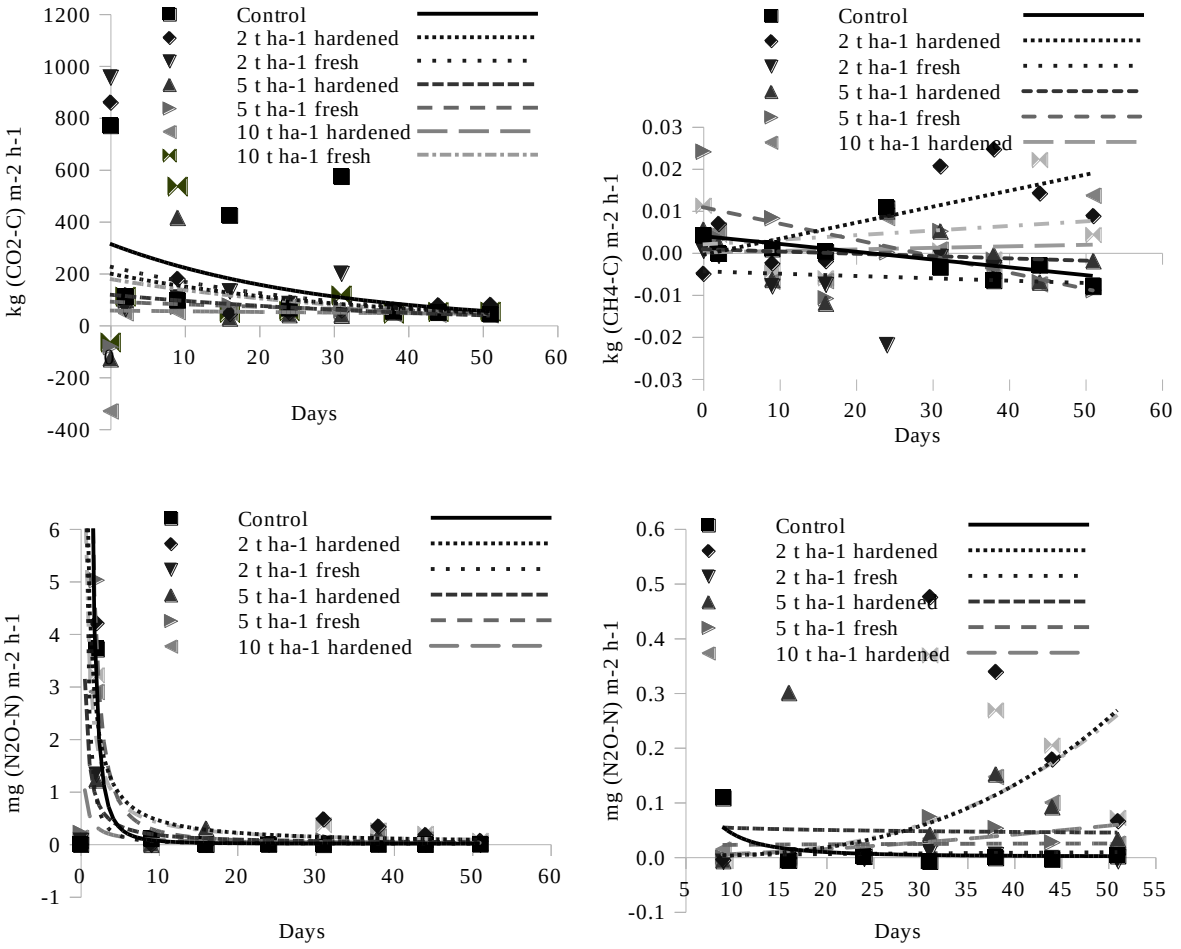

Fig. 2. **Relationship between GHG emissions and duration of measurements**

Considerable amount of potential outlier values is found in the study. Following to the IPCC recommendations [9], the potential outliers are not excluded from calculation of the GHG fluxes if R^2 value for CO_2 flux for the data set is at least 0.95. The reduction of CO_2 emissions from soil and no significant changes in CH_4 emissions after application of wood ash is in line with findings of other authors, e.g., [1; 10]; however, we did not observe significant reduction of N_2O emissions reported by these authors. No effect of wood ash applications on N_2O fluxes are reported also by other authors, e.g., [7], while CO_2 and CH_4 uptake increased significantly in short and long term. The effect on CO_2 emissions is explained by the short-term impact on the microbial community by short term reduction of total activity [2; 11]. Reasons for this effect are complex, changes of soil pH mentioned by above-listed authors aare not approved by studies comparing traditional liming materials and wood ash [12].

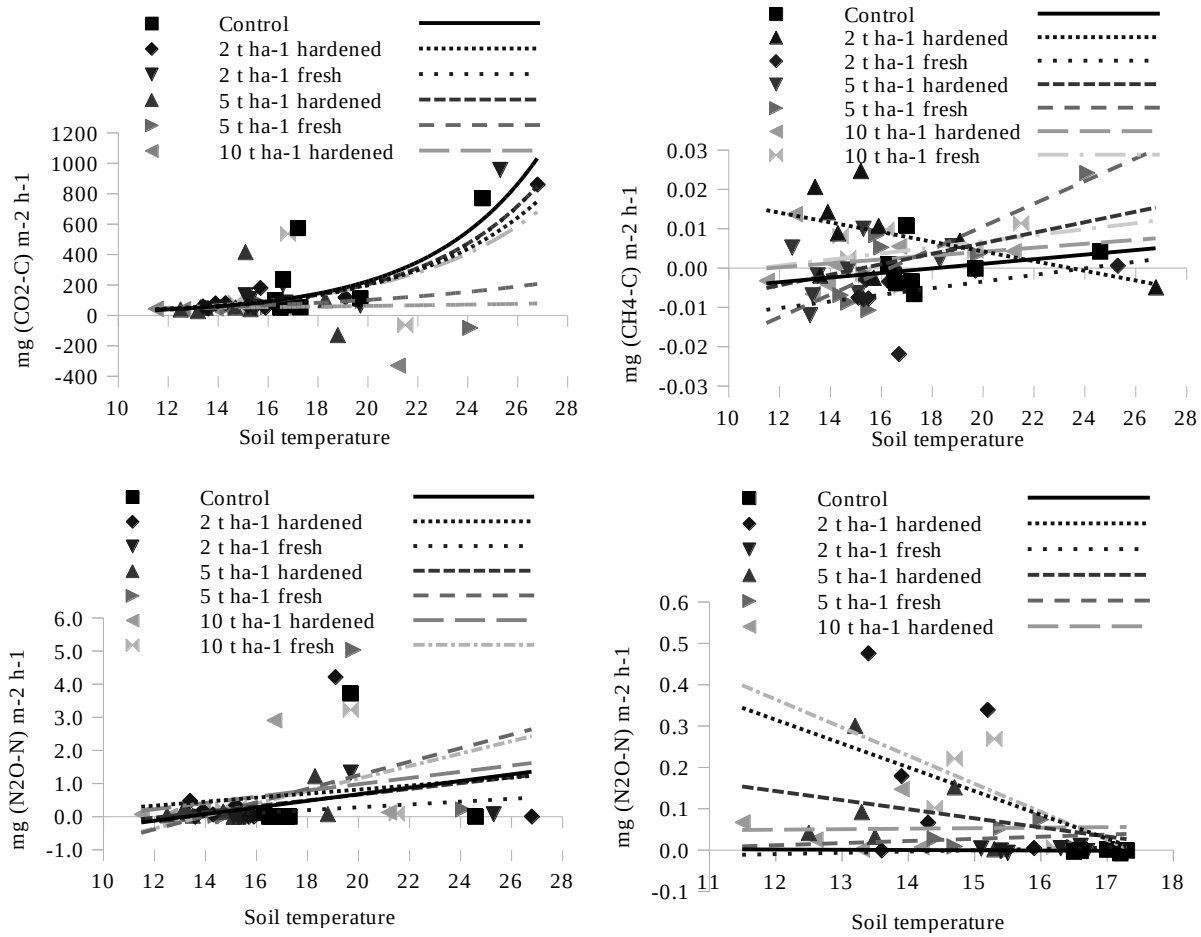

Fig. 3. **Relationship between GHG emissions and soil temperature**

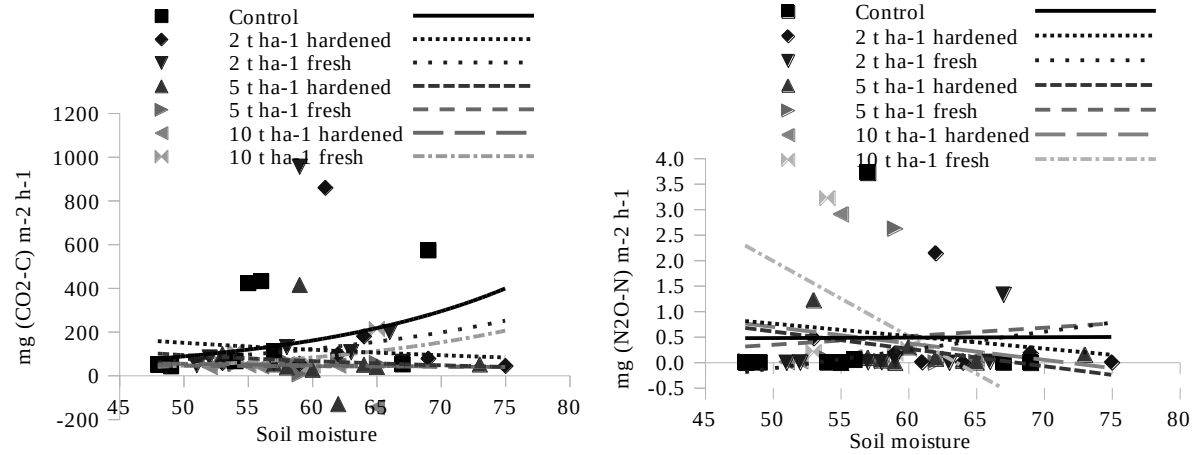

Fig. 4. **Relationship between GHG emissions and soil moisture**

Conclusions

1. Application of wood ash reduces CO2 emissions from soil by 59%; partially it is associated with the initial stage of the study and chemical consumption of CO2. Application of wood ash also reduces the growth of CO2 emissions with increase of the soil temperature and moisture.
2. No correlation is found between application of wood ash and CH4 emissions pointing out that the application of wood ash should not be considered as a source of CH4 emissions. Similarly, application of wood ash is not associated with increase of N2O fluxes (insignificant 5% reduction). Increase of N2O emissions after preparation of soil mixture quickly disappears after few days.

3. Wood ash is not increasing GHG emissions from soil in short term and this measure can be considered as the emissions' neutral; however, further studies are necessary to evaluate long term effect associated with increase of the proportion of fresh dead organic matter in fertilized plots.
4. Hardening of wood ash does not have significant effect on the GHG emissions, the emissions do not differ statistically significantly in case of application of fresh and hardened wood ash.

Acknowledgements

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