

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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RESEARCH AND ASSESSMENT
OF THE TOTAL CARBON CONTENT
AND CARBON DIOXIDE EMISSIONS
FROM SOILS OF DIFFERENT LAND-USE
PURPOSE

SUMMARY OF DOCTORAL DISSERTATION
TECHNOLOGICAL SCIENCES,
ENVIRONMENTAL ENGINEERING (04T)

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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Introduction

Topicality of the problem

Soil holds the largest coal reserve in the world (1500 gigaton). Its functions performed directly affect human and wildlife. These functions must be protected because of their social and economic importance and environmental importance. However, due to human activities, soil degradation, which affects the carbon and carbon dioxide emissions changes.

From all climate warming gases about 57% is the CO₂ gas. 20% of total CO₂ emissions into the atmosphere emit soils, and the soils have a significant impact on the CO₂ balance. It is estimated that the intensive use of land during the period between 1850 and 1998 soil organic matter losses in the balance sheet of one-third (26±9 Gt) was the loss of soil erosion, and about two-thirds (52±8 Gt) of mineralization. Currently estimated that the carbon (element) loss from the cultivated soils to 78 Mt per year. This is occurring in the best light textured soils and wetlands drained.

The evaluation of carbon dioxide emissions worldwide and summarized studies performed in various countries shows that there is a lack of short-term from several hours to several days, and (or) months and long-term data on a country's carbon dioxide emissions. Neither short nor long term data on the scale of CO₂ emissions in Lithuania is not available.

It is necessary to assess the quantities of carbon in the soil to prevent soil degradation, preserving soil fertility and biodiversity, and ensuring favorable living conditions. Imposition of carbon in the soil and carbon dioxide emission levels, it is possible to adopt measures to reduce or preventing further degradation.

The Kyoto Protocol states that the soil is a major carbon reserve, which must be protected and increased where possible. Seeking and applying new farming methods, which could allow agricultural soils to absorb and store carbon (carbon sequestration). Investigations evaluating the traditional tillage system in nonarable and how it affects the content of carbon in the soil. 10 years ago in Lithuania Dotnuva region started the first field tests in order to comprehensively investigate the different tillage systems. As a result, the estimate of soil degradation. However, such studies are carried out only for the definite test fields. Aggregated data on CO₂ emissions Lithuanian agricultural and forestry sector is also lacking. And the world's attention is increasingly shifting to the current state of the soil in order to assess their impact on climate change, and vice versa.

Object of the work

The total carbon content in soils of different land-use purpose and carbon dioxide emissions from soils.

Aim and tasks of the work

Aim. Research on the total carbon content in soils of different land-use purpose and carbon dioxide emissions from them. To achieve the aim these **tasks** were formulating:

1. To carry out investigations of the total carbon content in soils of different land-use purpose and carbon dioxide emissions from them.
2. To evaluate the regularities of carbon dioxide emissions from soil by linking them with the total carbon content.
3. To evaluate, through employment of modelling, changes in the total carbon content and prognosticated contents of carbon dioxide emissions as well as dependencies taking account of climatic indicators.

Methodology of research

The methods at soil sampling, and total carbon content, heavy metal and pH determination were applied in the work. A research method was developed for the investigation of carbon dioxide emissions. The dynamics of total carbon and carbon dioxide emission contents was analysed with the digital modelling programme DNDC.

Scientific novelty

Complex experimental investigations of the total carbon content in soil and carbon dioxide emissions from it and modelling of processes.

Practical value

The material accumulated in this work can be applied for further research on the total carbon in soil by expanding the scope of research. The accumulated data can be applied for a theoretical analysis based on the investigation of carbon dioxide emissions and modelling. The accumulated data can also be used for the assessment of carbon in soils of different land-use purpose and carbon dioxide emissions from them. The performed modelling work can be applied for the assessment of Lithuania's territorial soils according to the total carbon and carbon dioxide. The investigations of pH and heavy metals together with the total carbon can be assessed at the level of scientific investigations and, using additional data, to evaluate the influence of soil pollution on the content of the total carbon.

Defended propositions

1. The levels of heavy metal concentrations in the areas selected for carbon analysis in soil are similar to those in non-polluted (background) areas.
2. The largest average quantities of the total carbon were identified in the meadow soil of the supra-aquatic landscape (until 3.02%), followed by the meadow soil of the autonomous landscape (until 1.37%), the forest soil of the supra-aquatic soil (until 4.54%) and the autonomous landscape soil (until 1.39%), while the smallest in the arable soil (until 2.25%).

3. Investigations carried out under natural conditions showed the highest carbon emission in arable soils (until $0,263 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$), followed by meadow (until $0,149 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$) and forest soils (until $0,139 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$). Carbon emissions within soils reliably directly correlates with ambient air temperature ($r=0.6$) and its relative humidity ($r=-0.35$) as well as soil humidity ($r=-0.5$).
4. According the data of the model DNDC, the highest emission of carbon dioxide under the current conditions of the Lithuanian climate are generated by forest soils ($2.82 \text{ kgCO}_2/\text{ha}$ per day), followed by meadow ($2.67 \text{ kgCO}_2/\text{ha}$ per day) soils, while the lowest is produced by arable soils ($2.28 \text{ kgCO}_2/\text{m}^2$ per day); the biggest annual loss of carbon is incurred by arable soil (first year 830 kgC/ha , and after 10 years 452 kgC/ha) in meadow soil (first year 740 kgC/ha , but after 10 years to 542 kgC/ha) and grow in forest soils (first year 937 kgC/ha , after 10 year 565 kgC/ha).

Scope of the scientific work

The dissertation consists of 6 chapters whit final conclusions and recommendations, and list of references and author's publications. The total scope of the dissertation encompasses 154 pages, 74 figures, 5 tables and 6 formulas.

1. Soil investigations, classification and carbon circulation in soil

This chapter surveys information about the soil formation energy, the balance of materials and its impact on soil carbon accumulation or leaching out. It also surveys the ways of organic matter degradation in soil. The survey covers the typical properties of newly formed organic compounds and the possibilities of their transport and self-transport in soil. It presents information on the gaseous phase of soil. The chapter also analyses the factors which predetermine a soil air composition. It presents an evaluation of what predetermines the sorption properties of soil gas and the content of carbon dioxide emissions. It also discusses the models applied for the prognostication of the total carbon content and for the evaluation of changes in carbon dioxide emissions.

2. Natural investigations and assessment of the total carbon content in soils of different land-use purpose

Soil samples in the Neris Regional Park were taken with a special drill every 10 centimetres up to a depth of 30 centimetres. A total of 297 soil samples were taken and analysed.

Composite samples in the localities of Užpaliai and Paliepis were taken every 10 cm at three depths, while the samples of unbroken structure were taken every 5 cm at a depth of up to 25 cm. A total of 72 samples were taken and analysed.

Investigations were carried out in the Neris Regional Park and the localities of Paluknis and Užpaliai. The investigations were carried out with the aim of setting up a database which could subsequently be used for the modelling and analysis of the change of the total carbon content in soils of different land-use purpose. Soil samples were taken from meadow, arable and forest soils.

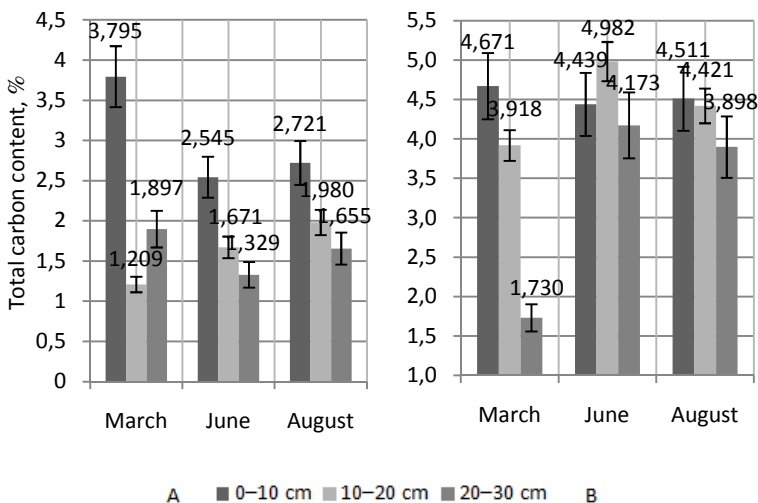


Fig. 1. The total carbon content in: meadow soil (A), forest soil (B)

The summed up results obtained from investigations in the Neris Regional Park show the following total carbon contents at all depths in March: 5.79% in forest soil, 4.33% in arable soil, 4.33% in meadow soil, and 3.89% in water-meadow soil. Upon summing up the total carbon contents recorded in June the following results were obtained: 8.79% in forest soil, 5.58% in arable soil, 4.44% in meadow soil, and 7.39% in water-meadow soil. The following results were obtained after summing up the total carbon contents in August: 7.31% in forest soil, 5.55% in arable soil, 4.82% in meadow soil, and 7.1% in water-meadow soil (Fig. 1, 2).

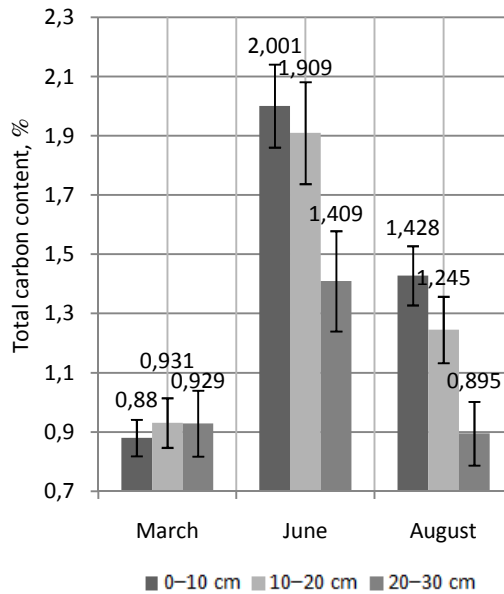


Fig. 2. The total carbon content in arable soil

As the performed investigations of the total carbon content in forest soil show, the average content of the total carbon varied from 1.1 to 3%. The biggest average content of the total carbon was identified in June, up to 2.943%, at a depth of 0–10 cm. The performed data analysis showed that relief had a major impact on the total carbon content. As determined during investigations performed in a super-aqual landscape, the total carbon content varied from 1.7 to 5%. It has also been determined that intensive leaching of the total carbon took place at a depth of 20–30 cm during the investigations of the supraqual landscape carried out in March.

A comparison of data from the autonomous landscape of arable soil and from meadow and forest soils showed the lowest content of the total carbon in this soil. The average values of the total carbon in arable soil in March were by 1.5 times lower than in forest and by 1.2 times lower than in meadow soil. In June, the total carbon quantities in arable soil increased, but were by 1.2 times lower than in forest and meadow soils. In August, the total carbon content in arable soil was by 1.1 times lower than in forest and by 1.2 times lower than in meadow soil.

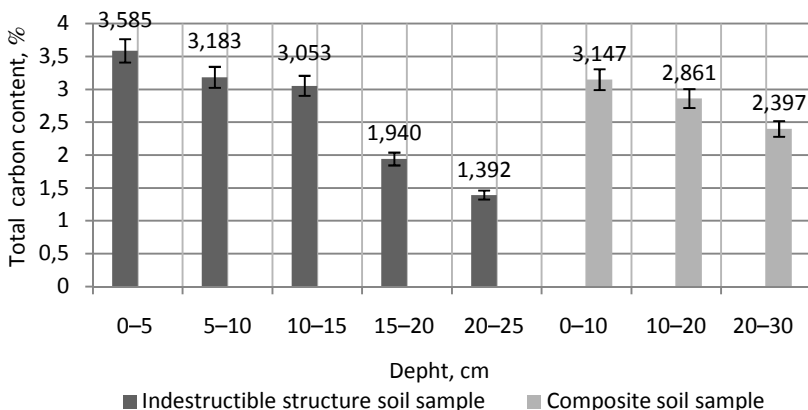


Fig. 3. The total carbon content in Užpaliai meadow research

As the investigations of the total carbon content carried out in the localities of Užpaliai and Paluknis show carbon content at deeper layer was by 1.26 higher in arable soil and 1.09 times bigger in composite samples. When compared to forest soil, the total carbon content in the samples taken from deeper layers was by 1.08 times bigger in arable soil and by 1.09 times bigger in composite samples (Fig. 3).

3. Total soil carbon content, pH and heavy metals in situ studies of the Neris Regional Park and the data analysis

The aim of research was to determine total carbon quantities by evaluating the technogenic pollution of soil. A comparison of carbon quantities in different soils showed the highest quantities in meadow soil. The average value of the total carbon in deep samples stood at 7.45%, while that in composite samples – 7.27%. Deep samples were taken at a depth of up to 1 m., while composite samples – at a depth of up to 30 cm. A comparison of the identified quantities with those in other analysed types of soil showed that the carbon content in deep samples from the trans-eluvial meadow soil was by 1.35 times lesser, and in composite soil samples was by 1.45 times smaller than in the meadow soil of the super-aqual landscape. In forest soil the total carbon content was 1.45% lower than in trans-eluvial meadow soil and 0.86% higher than the deep samples of the meadow soil of the super-aqual landscape. The quantities of the total carbon in the deep samples of arable soil varied from 0.12 to 1.49%, while in composite samples from 0.14 to 1.2% (Fig. 4).

The investigation evaluated the concentration of the heavy metals Zn, Cu and Pb in soil. The metals were selected taking account of their mobility in soil. The heavy metals such as Mn, Zn, Cu are mobile metals. Depending on their respective pH values, these metals can be leached towards deeper soil layers. In the meantime lead was selected as the least mobile metal.

As determined during the analysis of forest soil, the highest concentrations of copper and zinc were identified when soil pH was 6.39 reaching 36.1 and 98.5 mg/l, respectively. The highest concentration of lead was determined when pH stood at 5.34–292 mg/l.

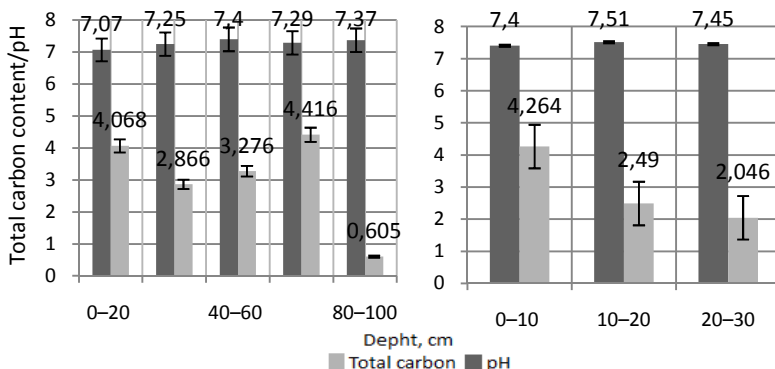


Fig. 4. Soil pH and the general carbon Neris Regional Park grassland soil:
A – a geological sample B – a composite sample

The distribution of heavy metals in arable soil is impacted by the mechanical cultivation of soil. In this soil the maxima of the highest concentrations for mobile metals were determined at the following values of pH: 6.43 (96,5 mg/l) for zinc, 6.43 (37.9 mg/l). The highest concentration of lead was identified when pH value reached 6.53 (17.7 mg/l).

In meadow soil the highest concentrations of heavy metals were determined at the following values of pH: 6 (67.7 mg/l) for zinc, 6.2 (39.7 mg/l) for copper. The highest content of lead, varying from 14.6 to 16.5 mg/l, was determined when pH values varied between 6.2 and 6.6.

It has been proven by investigations that the soils selected for carbon analysis belong to the soils of non-polluted (background) areas according to the concentrations of heavy metals.

As the vertical differentiation of elements in forest soils showed, zinc and copper, which are distinguished by better solubility and mobility in acid (pH =

5.3–6.5) forest soils, are mainly de-alkalified and eliminated from parent rocks ($K_{rd}^i < 1$) by parent rock processes. (Fig. 5(A)).

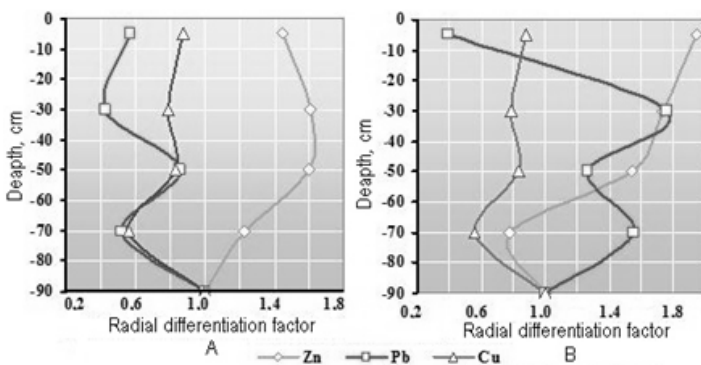


Fig. 5. Heavy metals in forest soil profile differentiation (A), supraqual landscape meadow soil profile (B)

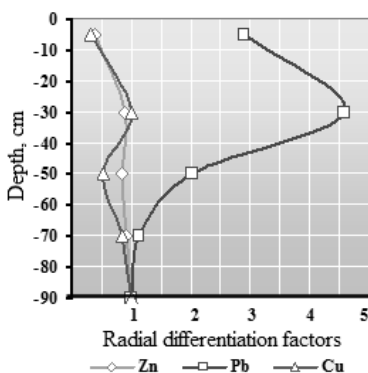


Fig. 6. Heavy metals differentiation transelluvial landscape meadow soil profile

It is common knowledge that supraqual water migration landscapes of class H^+ are normally described as the place of accumulation of the chemical elements that are de-alkalified and leached from eluvial and trans-eluvial landscape soils. This is favourably influenced by the general geochemical situation in them: the mechanical hydrodynamic and sorptive (related to the accumulation of clay minerals and humus) geochemical barriers become stronger, steady surface and intra-soil inflow of water-soluble metal compounds, increased thickness of soil and an active geochemical barrier of

filtration in it (Fig. 6.). Thus, the content of the total carbon in superficial soil horizons up to a depth of 35–40 cm exceeds its respective concentration by 2.9 to 3.3 times in the trans-eluvial meadow landscape position and by as many as 18.2 times in the illuvial horizon B.

No despite that metals are especially intensely accumulated and sorbed by humus from soil solutions under such conditions. As Fig. 5(B) shows, zinc and lead are more actively accumulated, in particular in a humous soil horizon.

4. Natural investigations of carbon dioxide emissions from Neris Regional park soils

Investigations were carried out in August and September. During measurements the ambient air temperature varied from 8.7 to 18.6 degrees. The analysis covered sand soils and podzolic soils.

The performed analysis of the quantities of carbon dioxide emissions from soils of different land-use purpose showed changes in carbon dioxide emissions. The obtained data show that the biggest carbon dioxide emissions are from arable soil – $0.263 \text{ g CO}_2 \text{ m}^{-2} \text{ h}^{-1}$, followed by 0.149 from meadow soil and $0.139 \text{ g CO}_2 \text{ m}^{-2} \text{ h}^{-1}$ from forest soil. The investigations were carried out under identical atmospheric conditions and in the same locations of total carbon investigation (Fig. 7).

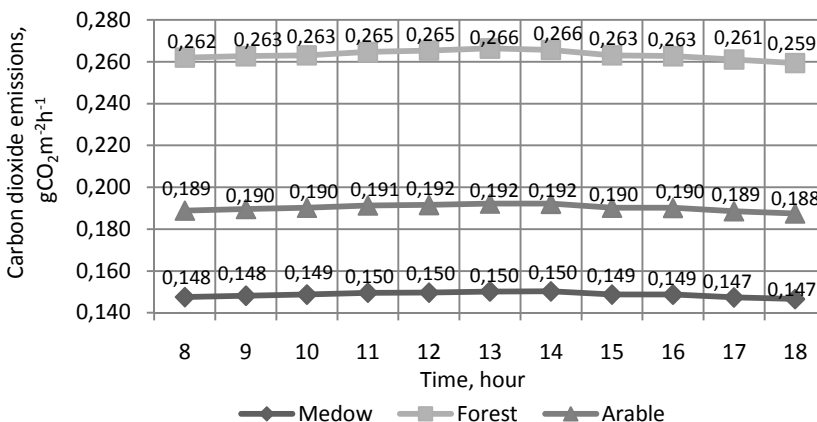


Fig. 7. The average carbon dioxide emissions from Neris regional park soils of different land-use purpose

Carbon dioxide emissions from soil are directly dependent on ambient air temperature. Investigations determined the following carbon dioxide emissions at a temperature of 12–18.6 °C: 0.162 g CO₂ m⁻²h⁻¹ in meadow soil, 0.307 g CO₂ m⁻²h⁻¹ in arable soil and 0.263 g CO₂ m⁻²h⁻¹ in forest soil. The respective results obtained in a temperature range of 9.2 to 9.9°C are: 0.146 g CO₂ m⁻²h⁻¹ in meadow soil, 0.306 g CO₂ m⁻²h⁻¹ in arable soil and 0.162 g CO₂ m⁻²h⁻¹ in forest soil. As the data obtained from the performed investigations show, carbon dioxide emissions decreased from 1.1 to 1.6 times.

The investigations of carbon dioxide emissions from soils of different types of land-use determined that carbon dioxide emissions could be lower due to soil humidity. As determined during the investigations, when soil humidity in meadow soil increased by 1.1 times, carbon dioxide emissions decreased by 1.2 times. When the humidity of arable soil rose by 1.4 times, carbon dioxide emissions fell by 1.7 times. When the humidity of forest soil increased by 1.4 times, carbon dioxide emissions fell by 1.8 times.

After the carbon dioxide emissions in grassland soil, simulations showed that the content of daily emissions ranged from 0.06 to 4.9 kg CO₂/m². Arable soil carbon dioxide emissions during the past year ranged from 0.18 to 17.87 kg CO₂/m². Simulated forest soil carbon dioxide emissions varied from 0.19 to 7.71 kg CO₂/m². The average carbon dioxide emission is 2.15 kg CO₂/m². Compared to the arable soil carbon dioxide emissions, the average forest soils emit 2.6 times lower in the grassland soil was 1.6 times higher (Fig. 7).

5. Total carbon and carbon dioxide emissions modeling change in soils of different land-use purpose

Soil modeling was carried out using the modelling programme DNDC, which is widely applied for the assessment of the total carbon quantities in soil as well as greenhouse emissions. The assessment covered soils of three different types of land-use. The aim of modelling was to identify the content of carbon dioxide emissions, to evaluate its dynamics within a year considering climate change and to make a comparison with investigation results. The assessment used the data received from an analysis of the total carbon quantities in soil in the Neris Regional Park. Data for the assessment of carbon dioxide emission were obtained upon carrying out investigations in autumn in the same locations where the total carbon quantity was determined.

The model evaluated sand soils. The model indicated the main physical parameters of soil and evaluated the average annual quantity of the total carbon. The average total carbon quantity in forest soil at a depth of 0–10 cm was equal

to 0.041 kgC/kg, in arable soil – 0.017 kgC/kg, while in meadow soil – 0.036 kgC/kg.

The model allowed an evaluation of the annual daily content of carbon dioxide emissions and the total carbon. Figure 8 presents the data produced by modelling in arable soil. Within a year, the total carbon content in this soil varied due to mechanical processing and artificial fertilisation of soil not only under the impact of climate conditions but also human activities.

The results received from the model showed total carbon variations from 87394 to 86564 kgC/ha in arable soil (Fig. 8). Within a year the content decreased to 830 kgC/ha. During harvesting part of organic matter returns back to soil supplementing it with carbon. The aeration qualities of soil are also improved. But carbon dioxide emissions show themselves belatedly as some time is necessary for the mineralisation of organic matter that has accessed soil.

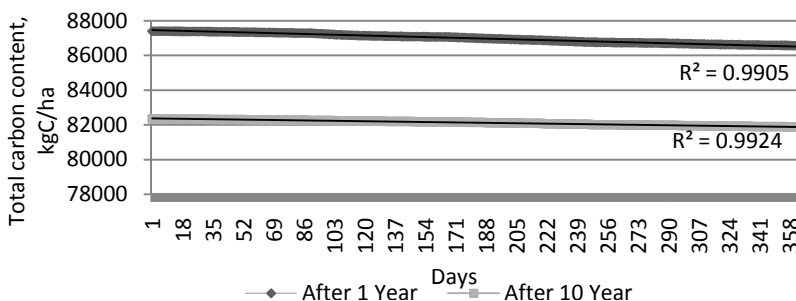


Fig. 8. The single carbon change in arable soils to evaluate climate change effects

The total carbon content in meadow soil varied from 116008 to 116534 kgC/ha. It has been determined that the total carbon content in soil was changing in a gradually decreasing manner. As part of the grown biomass is not removed from a meadow, the entire accumulated quantity of the total carbon may be influenced only by environmental factors. Within a year the total carbon content in meadow soil decreased by 740 kgC/ha, the total carbon content in forest soil was also changing but in ascending order. The annual growth in this soil contented to 937 kgC/ha. The average annual carbon dioxide emissions in forest soil like in meadow soil depended on the existing total carbon quantity in soil and were equal to 2.67 and 2.82 kgCO₂/ha per day, respectively. The average annual carbon dioxide emission in arable soil reached 2.28 kgCO₂/ha per day (Fig. 9).

A comparison of the obtained data and the data of investigation showed up to 4.5% higher content of the total carbon in arable soil, in meadow – 3.36% and in forest soil 1.44%.

According to the performed modelling of carbon dioxide emissions and their comparison with investigations results, 24% lower emissions were determined in meadow soil, 26% lower in arable soil and 27% lower in forest soil.

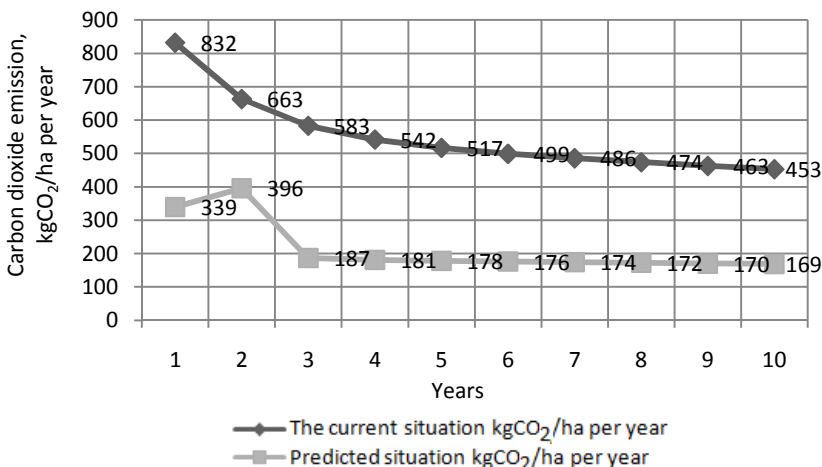


Fig. 9. Carbon dioxide emissions Neris Regional Park arable soil in 2009

The assessment of the impact of climate change on the total carbon content was based on literature forecasting a 3 °C increase. Upon the entry of meteorological data into the model, an increase in the average annual temperature from 8 °C to 11 °C for Vilnius country was taking into account.

6. Engineering technical solutions

The device was proposed for soil sampling. This drill is distinguished by a unique quality – a soil sample can be taken from a certain depth excluding top layers. Another peculiarity of the drill is that a sample is taken into a special cylinder which can be used as a sample vessel facilitating sample transportation. When transporting soil samples it is important to preserve their structure and therefore the taking of samples into sample cylinders can receive a wide application.

General conclusions

1. An analysis of literature has shown that the content of carbon in soil is continuously decreasing. The most affected soils are those of light granulometric composition. This has also been proved by international investigations. The main problems causing the decrease of carbon contents in soil are soil erosion, irrational farming and felling. It has also been revealed that investigations of carbon dioxide emissions are either insufficient or carried out by using outdated methods.
2. Field research found that the overall carbon content is highly influenced by relief. Therefore, studies were carried out by sampling in different elevation heights. Forest soil carbon in the maximum single autonomous landscape was 1.5%. Super-aqual landscaping general carbon was 5%. Grassland soil, the maximum contents of carbon single autonomous landscape was 1.6%, and landscaping super-aqual - 3.8%.
3. After investigation of the total carbon in soils Neris regional park the annual of the average quantities of forest soil total carbon was 2.4%, the total carbon content in meadow soil was 1.9% and arable soil, the total carbon quantity was 1.7%.
4. The performed comparison of data received from arable soil and other analysed soils showed the largest content of the total carbon compared to the autonomous landscapes of other soils. The average values of the total carbon in arable soil in March were by 1.5 times lower than in forest soil and by 1.2 times lower than in meadow soil. In June, the total carbon quantities in arable soil increased, but were by 1.2 times lower than in forest and meadow soils. In August, the total carbon content in arable soil was by 1.1 times lower than in forest soil and by 1.2 times lower than in meadow soil.
5. It has been determined that the total carbon content in the samples of unbroken structure from forest soil in soil profiles, up to 25 cm deep, varied from 2.4% to 3.7%, while in composite samples from up to 30 cm deep profiles varied from 1.3% to 1.9%. The total carbon quantities in meadow soil profiles vary from 6.9% to 16.5%, while in composite samples from 3.9% to 8.5%.
6. The illuvial (clayey) horizon, distinguished by the accumulation of humus and heavy metals of soils, is acting their combined geochemical barrier (filtration+sorption).
7. The performed analysis of the quantities of carbon dioxide emissions from soils of different use showed changes in carbon dioxide

emissions. As the obtained data show, the highest emission of carbon dioxide was produced by arable soil $0.263 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$, followed by meadow soil, $0.149 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$, and forest soil, $0.139 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$.

8. As determined during the investigation, when soil humidity in meadow soil increased by 1.1 times carbon dioxide emissions decreased by 1.2 times. When the humidity of arable soil rose by 1.4 times, carbon dioxide emissions fell by 1.7 times. When the humidity of forest soil increased by 1.4 times, carbon dioxide emissions fell by 1.8 times.
9. Carbon dioxide emissions from soil are directly dependent on ambient air temperature. As the data of the performed investigation show, carbon dioxide emission decreased by from 1.1 to 1.6 times when temperature fell from 18.6 to 8.7°C .
10. After simulations of the carbon dioxide emissions in grassland soil, showed that the content of daily emissions ranged from 0.06 to $4.9 \text{ kg CO}_2/\text{m}^2$. Arable soil carbon dioxide emissions during the past year ranged from 0.18 to $17.87 \text{ kg CO}_2/\text{m}^2$. Forest soil carbon dioxide emissions varied from 0.19 to $7.71 \text{ kg CO}_2/\text{m}^2$. The average carbon dioxide emission is $2.15 \text{ kg CO}_2/\text{m}^2$. Compared to the arable soil carbon dioxide emissions, the average forest soils emit 2.6 times lower in the grassland soil was 1.6 times greater.

Recommendations

1. When analysing the contents of the total carbon account it is necessary to take into account the relief status and to evaluate the consequences of soil erosion for the contents of the total carbon. Where research is carried out in a hilly location it is advisable to take soil samples not only from an autonomous landscape but also from a super-aqual landscape.
2. When analysing carbon dioxide emissions account has to be taken of meteorological conditions, in particular rain. Where soil is heavily soaked, lower emissions of carbon dioxide are identified. It is recommended to carry out investigations after several days when soil humidity becomes stable.
3. For small changes in the boundaries between research and simulated data, this model can be used for further research.

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SKIRTINGOS ŽEMĖNAUDOS DIRVOŽEMIŲ BENDROSIOS ANGLIES KIEKIO IR ANGLIES DIOKSIDO EMISIJOS TYRIMAI BEI VERTINIMAS

Mokslų problemų aktualumas

Dirvožemyje yra didžiausios anglies atsargos pasaulyje (1500 gigatonų). Jo atliekamos funkcijos tiesiogiai įtakoja žmogų ir gyvąją gamtą. Todėl šias funkcijas reikia saugoti dėl jų socialinės bei ekonominės svarbos, ir dėl reikšmės aplinkai. Tačiau dėl žmogaus veiklos dirvožemiai degraduoja, o tai įtakoja anglies ir anglies dioksido emisijų pokyčius.

Iš visų klimato atšilimą skatinančių dujų net 57% priskiriami CO₂ dujoms. Apie 20% viso CO₂ kiekio, į atmosferą išskiria dirvožemiai, todėl dirvožemiai daro nemažą įtaką CO₂ balansui. Apskaičiuota, kad intensyvaus žemės naudojimo laikotarpiu tarp 1850 ir 1998 metų dirvožemio organinės medžiagos nuostolių balanse vieną trečdalį (26±9 Gt) sudarė nuostoliai dėl dirvožemio erozijos ir apie du trečdalius (52±8 Gt) dėl mineralizacijos. Apskaičiuota, kad anglies (elemento) nuostoliai iš Europos dirbamų dirvų siekia 78 Mt per metus. Ryškiausi pokyčiai pasireiškia lengvos granulometrinės sudėties dirvožemiuose ir nusausinamose pelkėse.

Įvertinus anglies dioksido emisiją pasauliniu mastu ir apibendrinus tyrimus atliktus įvairiose šalyse, matyti, kad dar labai trūksta trumpalaikių – nuo kelių valandų iki kelių dienų ir (ar) mėnesių – bei ilgalaikių duomenų apie konkrečios šalies anglies dioksido emisijas. Nei trumpalaikių, nei ilgalaikių tyrimų duomenų apie CO₂ emisijos mastą, Lietuvoje taip pat nėra.

Būtina vertinti anglies kiekius dirvožemyje, siekiant laiku užkirsti kelią dirvožemio degradacijai, išsaugant dirvožemių derlingumą ir užtikrinti biologinę įvairovę bei palankias gyvenimo sąlygas. Įvertinus dirvožemyje anglies kiekius ir dėl mineralizacijos procesų išsiskiriantį anglies dioksido emisijų dydį, įmanoma pritaikyti priemones, mažinančias arba užkertančias tolesnei dirvožemio degradacijai.

Kioto protokole pabrėžiama, kad dirvožemyje yra pagrindinės anglies atsargos, kurias reikia apsaugoti ir kiek įmanoma didinti. Atliekami tyrimai vertinant tradicinę žemės dirbimo sistemą į neiriamąją ir kaip tai įtakoja anglies kiekį dirvožemyje. Prieš 10 metų Dotnuvoje pradėti vieni iš pirmųjų Lietuvoje lauko bandymai, siekiant kompleksiskai ištirti skirtingas žemės dirbimo sistemas. Jų metu nustatyta dirvožemio degradavimo grėsmė. Tačiau, tokie tyrimai atliekami tik parengtuose bandymo laukuose. Apibendrintų duomenų apie CO₂ emisiją Lietuvos žemės ūkio ir miškų sektoriuje taip pat trūksta.

Pasaulyje vis dažniau dėmesys krypta į esamą dirvožemių būklę, siekiant įvertinti jų įtaką klimato kaitai ir atvirkščiai.

Tyrimų objektas – bendrosios anglies kiekio ir anglies dioksido emisijos Neries regioninio parko, Paluknio, Užpalių ir Pailiepio vietovių skirtingos panaudos dirvožemiuose.

Darbo tikslas ir uždaviniai

Tikslas – įvertinti bendrosios anglies kiekį ir anglies dioksido emisijas skirtingos žemėnaudos dirvožemiuose.

Darbo tikslui pasiekti reikia spręsti šiuos **uždavinius**:

1. Atlikti bendrosios anglies kiekio ir anglies dioksido emisijos skirtingos žemėnaudos dirvožemiuose tyrimus.
2. Įvertinti anglies dioksido emisijos iš dirvožemio dėsninumus ir sąsają su bendrosios anglies kiekiu.
3. Modeliuojant įvertinti bendrosios anglies kiekio pokyčius ir anglies dioksido emisijos prognozes, taip pat priklausomybę nuo klimato rodiklių.

Tyrimo metodika

Darbe taikytos autoriaus patobulintos dirvožemio ėminių paėmimo ir bendrosios anglies kiekio tyrimo metodikos. Taip pat taikytos ISO standartais paremtos sunkiųjų metalų ir pH nustatymo metodikos. Autorius pritaikė anglies dioksido emisijos tyrimų metodiką. Dirvožemio bendrosios anglies kiekio ir anglies dioksido emisijos dinamika analizuota skaitinio modeliavimo programa DNDC.

Mokslinis darbo naujumas

Kompleksiniai eksperimentiniai dirvožemio bendrosios anglies kiekio bei anglies dioksido emisijos tyrimai ir kiekio pokyčių vertinimas modeliuojant.

Praktinė reikšmė

Darbe sukaupta medžiaga gali būti taikoma tolesniems dirvožemio bendrosios anglies tyrimams. Sukaupti duomenys gali būti taikomi teritorinei analizei įvertinti anglies dioksido emisijas bei modeliavimui. Taip pat sukaupti duomenys gali būti panaudoti anglies ir anglies dioksido emisijai vertinti skirtingos panaudos dirvožemiuose. Modeliavimo rezultatai gali būti taikomi Lietuvos teritorinius dirvožemius vertinant pagal bendrąją anglį ir anglies dioksidą.

Ginamieji teiginiai

1. Pasirinktų anglies tyrimams teritorijų dirvožemiai pagal sunkiųjų metalų koncentracijų lygį artimi neužterštų (foninių) teritorijų dirvožemiams.
2. Didžiausi vidutiniai bendrosios anglies kiekiai ištirti superakvalinio landšafto pievų dirvožemiuose (iki 3,02%), autonominio landšafto pievos dirvožemyje (iki 1,37%), miško dirvožemio superakvaliniame dirvožemyje

- (iki 4,54%), autonominio landšafto dirvožemyje (iki 1,39%), o mažiausi ariamame dirvožemyje (iki 2,25%).
3. Natūriniais tyrimais, kad didžiausia anglies emisija pasižymi ariamieji dirvožemiai (iki $0,263 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$) mažesne pievos (iki $0,149 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$) ir miško (iki $0,139 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$). Anglies dioksido emisija dirvožemiuose patikimai tiesiogiai koreliuoja su aplinkos oro temperatūra ($r=0,67$) ir jo santykinė drėgme ($r=0,51$) bei dirvožemio drėgnumu ($r=0,54$).
 4. Modelio DNDC duomenimis didžiausia anglies dioksido emisija Lietuvos klimato sąlygomis pasižymi miško dirvožemiai ($3,18 \text{ kgCO}_2/\text{m}^2$ per para), pievų ($2,83 \text{ kgCO}_2/\text{m}^2$ per para), mažiausia – ariamieji dirvožemiai ($2,11 \text{ kgCO}_2/\text{m}^2$ per para), per metus daugiausiai anglies prarandama ariamame dirvožemyje (per pirmus metus 830 kgC/ha , po 10 metų 452 kgC/ha), pievų dirvožemyje (per pirmus metus 740 kgC/ha , po 10 metų 542 kgC/ha), o miško dirvožemiuose padidės (per pirmus metus 937 kgC/ha , po 10 metų 565 kgC/ha).

Mokslinio darbo apimtis

Disertaciją sudaro 6 skyriai, bendrosios išvados ir rekomendacijos, literatūros ir autoriaus publikacijų sąrašas. Bendra disertacijos apimtis 154 lapai, 74 paveikslai, 5 lentelės ir 6 formulės.

Pirmasis skyrius skirtas literatūros analizei. Apžvelgiama informacija apie organinės medžiagos susidarymo ir skaidymosi kelius. Įvertinama, kas nulemia dirvožemio dujų sorbcines savybes ir anglies dioksido emisijos kiekį. Skyriaus pabaigoje formuluojamos išvados.

Antrajame skyriuje pateikti tyrimai, atlikti Neries regioniniame parke, Paluknio, Užpalių ir Paliepio vietovėse, taip pat atliktų tyrimų metodika. Pagrįsti pasirinkti tyrimo objektai ir suformuluotos išvados.

Trečiajame skyriuje analizuojami bendrosios anglies kiekiai, pH sunkieji metalai dirvožemyje.

Ketvirtajame skyriuje pateikiami anglies dioksido išskyrimo iš dirvožemio tyrimai, atlikti Neries regioniniame parke.

Penktajame pateikiami bendrosios anglies kiekio ir anglies dioksido emisijos prognoziniai modeliavimo rezultatai, atlikti DNDC modeliu.

Šeštame skyriuje pateikiamas išradimo patobulinimas, skirtas dirvožemio ėminiams imti.

Bendrosios išvados

1. Literatūros analizė atskleidė, kad anglies kiekis dirvožemiuose nuolatos mažėja. Labiausiai pažeidžiami yra lengvos granulimetrinės sudėties dirvožemiai. Pagrindinės problemos, sąlygojančios anglies kiekių mažėjimą dirvožemiuose, yra dirvožemio erozija, neracionalus ūkininkavimas, miškų kirtimas. Taip pat atskleista, kad nėra

- pakankamai vykdomų anglies dioksido emisijų tyrimų arba jie atliekami pasenusiais metodais.
2. Natūriniais tyrimais nustatyta, kad bendrosios anglies kiekiui didelės įtakos turi reljefas. Todėl tyrimai atlikti imant ėminių įvairiuose reljefo aukščiuose. Miško dirvožemyje maksimalus bendrosios anglies kiekis autonominiame landšafte buvo iki 1,5%. Superakvaliniame landšafte bendrosios anglies kiekis buvo iki 5%. Pievos dirvožemyje maksimalūs bendrosios anglies kiekiai autonominiame landšafte siekė iki 1,6%, o superakvaliniame landšafte – iki 3,8%.
 3. Įvertinus Neries regioninio parko metinius vidutinius bendrosios anglies kiekius miško dirvožemyje rasta iki 2,4%, pievos dirvožemyje bendrosios anglies kiekis siekė iki 1,9%, o ariamajame dirvožemyje bendrosios anglies nustatyta iki 1,7%.
 4. Visais analizuojamais laikotarpiais ariamo dirvožemio bendrosios anglies kiekis buvo mažiausias. Palyginus su kitais analizuotais dirvožemiais nustatyta, kad bendrosios anglies kiekis buvo mažiausias lyginant su kitų dirvožemių autonominiais landštais. Kovo mėnesį vidutinės ariamo dirvožemio bendrosios anglies kiekio reikšmės buvo mažiausios už miško dirvožemio bendrosios anglies kiekį iki 1,5 karto, o už pievos dirvožemio iki 1,2 karto. Birželio mėnesį bendrosios anglies kiekiai ariamame dirvožemyje nežymiai didesni, tačiau jie buvo mažesni 1,2 karto nei miške ir pievoje. Rugpjūčio mėnesį bendrosios anglies kiekis ariamame dirvožemyje buvo mažiausias. Iki 1,1 karto mažesnis nei miško dirvožemyje ir 1,2 karto mažesnis nei pievos dirvožemyje.
 5. Nustatyta, kad dirvožemio profiliuose bendrosios anglies kiekis miško dirvožemyje, nesuardytos struktūros ėminiuose, kito nuo 2,4% iki 3,7%, o sudėtinių ėminių profiliuose gylyje iki 30 cm nuo 1,3% iki 1,9%. Pievos dirvožemio profiliuose bendrosios anglies kiekiai kinta nuo 6,9% iki 16,5%, o sudėtiniuose ėminiuose nuo 3,9% iki 8,5%. Atliktais tyrimais įvertinta, kad nesuardytos struktūros ėminiai pateikia detalesnę informaciją apie bendrosios anglies kiekius dirvožemyje. Todėl tolesniuose tyrimuose taikyti nesuardytos struktūros ėminių ėmimas.
 6. Kaip kombinuotais geocheminis barjeras (filtracinis+sorbcinis) dirvožemiuose veikia jų iliuvinis (moliuotais) horizontas, pasižymintis humuso ir sunkiųjų metalų akumuliacija.
 7. Analizuojant anglies dioksido emisijų kiekius skirtingos panaudos dirvožemiuose nustatytas anglies dioksido emisijų kitimas. Žvelgiant į gautus duomenis nustatyta, kad daugiausiai anglies dioksido išsiskiria

ariamame dirvožemyje $0,263 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$, o pievoje $0,149 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$ ir miške $0,139 \text{ g CO}_2 \text{ m}^{-2}\text{h}^{-1}$.

8. Nustatyta, kad dėl dirvožemio drėgmės anglies dioksido emisijos mažėja. Natūriniais tyrimais įrodyta, kad pievos dirvožemyje drėgniui padidėjus 1,1 karto anglies dioksido emisijos sumažėjo 1,2 karto. Ariamo dirvožemio drėgniui padidėjus 1,4 karto, anglies dioksido emisijos sumažėjo 1,7 karto. Miško dirvožemio drėgniui padidėjus 1,4 karto, anglies dioksido emisijos sumažėjo 1,8 karto.
9. Dirvožemio anglies dioksido emisijos turi tiesioginę priklausomybę nuo aplinkos oro temperatūros. Iš atliktų tyrimo rezultatų matyti, kad anglies dioksido emisijos sumažėjusios nuo 1,1 iki 1,6 kartų, nukritus temperatūrai nuo $18,6$ iki $8,7$ °C laipsnių.
10. Atlikus anglies dioksido emisijų modeliavimą pievos dirvožemyje nustatyta, kad emisijų dydis per parą kito nuo $0,06 \text{ kg CO}_2/\text{m}^2$ iki $4,9 \text{ kg CO}_2/\text{m}^2$. Ariamame dirvožemyje anglies dioksido emisijos metų bėgyje kito nuo $0,18$ iki $17,87 \text{ kg CO}_2/\text{m}^2$. Miško dirvožemyje sumodeliuotas anglies dioksido emisijų kiekis kito nuo $0,19$ iki $7,71 \text{ kg CO}_2/\text{m}^2$. Vidutinė anglies dioksido emisija yra $2,15 \text{ kg CO}_2/\text{m}^2$. Lyginant su ariamo dirvožemio anglies dioksido vidutinėmis emisijomis miško dirvožemis išmeta į atmosferą 2,6 karto mažiau, o su pievos dirvožemiu 1,6 karto daugiau.

Rekomendacijos

1. Analizuojant bendrosios anglies kiekius būtina atsižvelgti į reljefo padėtį, bei įvertinti dirvožemio erozijos padarinius bendrosios anglies kiekiams. Tyrinėjant kalvotas vietas patartina imti dirvožemio ėminių ne tik autonominiame landšafte, bet ir superakvaliniame.
2. Tyrinėjant anglies dioksido emisijas atsižvelgti į meteorologines sąlygas, o ypač į liūtų. Jei dirvožemis labai įmirkęs nustatytos anglies dioksido emisijos yra mažesnės. Tyrimus patartina atlikti po kelių dienų, kai normalizuojasi dirvožemio drėgnis.
3. Dėl mažų kitimo ribų tarp tyrimo ir sumodeliuotų duomenų, šį modelį galima taikyti tolesniems tyrimams.

Trumpos žinios apie autorių

Mantas Pranskevičius gimęs Šiauliuose 1982 metų spalio 3 dieną. 2004 metais įgijo aplinkos inžinerijos bakalauro laipsnį Šiaulių universiteto Technologijos fakultete. 2007 metais įgijo aplinkos inžinerijos magistro laipsnį Vilniaus Gedimino technikos universitete Aplinkos inžinerijos fakultete. Nuo 2007 dirba VGTU Aplinkos apsaugos institute. 2007–2011 metų Vilniaus Gedimino technikos universiteto doktorantas.