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# A COMPARISON OF THE FIELD AND LABORATORY METHODS OF MEASURING $CO_2$ EMISSIONS RELEASED FROM SOIL TO THE ATMOSPHERE

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***Abstract:*** In the context of global climate changes the attention of the research is focused on the soil tillage technologies. Soil tillage significantly affects the amount of carbon dioxide ($CO_2$) released from soil to the atmosphere. Research of the soil emissions is usually conducted in field conditions. The aim of this study is to increase efficiency of the research by substitution of the field method by laboratory method of measuring $CO_2$ emissions released from soil. The INNOVA measuring devices equipped with the photoacoustic infrared detection sensor was used. The field method measurement is conducted directly in the field conditions. The laboratory method consists of collecting soil samples from the field by sampling probes and their subsequent analysis in laboratory. Soil conditions where the soil samples were taken: haplic luvisol with slightly alkaline soil reaction and medium content of humus. Measurements were conducted nine days after soil tillage by power harrow PÖTTINGER LION 301. Means of the measured values of $CO_2$ emissions released from soil ranged from 455.580 ppm to 459.392 ppm. There were not found a statistically significant difference between field and laboratory method at 99.9% confidence level.

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The $CO_2$ emissions in the surrounding air were significantly lower, mean 403.125 ppm. It means that it is possible to use soil sampling laboratory method to measure $CO_2$ emissions released from soil to the atmosphere. Used laboratory method allows to measure $CO_2$ emissions released from soil at the same time in 12 points and creates the possibility for long-term complex monitoring.

***Key words***: *soil emissions, carbon dioxide, soil sampling, measuring methods*

## INTRODUCTION

Global climate change is a phenomenon that undermines and threatens all humanity. In this context, carbon dioxide ($CO_2$) is generally the most mentioned gas. Agriculture is one from the major $CO_2$ producers. Emissions released from the soil into the atmosphere when compared with other sources are relatively small, but the total area of agricultural land is a source of a huge amount of emissions. Intensification of agriculture, continued upward pressure on food production in sufficient quantity and adequate quality causes removal of environmental aspects sidelined. The primary way to release $CO_2$ from the soil is diffusion. The main reasons for creating $CO_2$ in the soil are a breathing roots of cultivated plants and soil organisms and decomposition of organic matter [1]. The main factors affecting the amount of generated emissions include temperature, atmospheric pressure [2], soil type [3], soil organic matter content [4], fertilizers [5-8], the oppressed land [9] and tillage [10]. Moisture and precipitation distribution [1, 11] also significantly affect the release of $CO_2$. The biggest problem of measuring emissions from soil is deficiency of equipment.

Research on the release of $CO_2$ from the soil into the atmosphere is mostly implemented by a number of field methods, which are classified into the following groups: absorption, gazometric, and micrometeorological gradient method [12].

The aim of this study is to increase efficiency of the research by substitution of the field method by laboratory method of measuring $CO_2$ emissions released from soil.

## MATERIAL AND METHODS

Experimental measurement were carried out at the experimental field near Dražovce village, district Nitra. Experiments started 9 days after soil tillage provided by power harrow PÖTTINGER LION 301 when soil has been cultivated to the depth 100 mm.

Measurement of $CO_2$ emissions released from the soil to the atmosphere were conducted by two methods: laboratory method and field method. During the experiment the soil samples were collected in order to provide pedological analysis.

### Soil properties

Soil type was Haplic luvisol with content of clay, silt and sand for 37.70, 39.43 and 22.87 %, respectively. Soil moisture content were measured by gravimetric method and 26-28 % and pH were 7.78 and 6.87 for $H_2O$ and KCl, respectively. Humus content was 2.799 % and Cox was 1.624 %.

Soil properties were analyzed at the Department of Soil Science a Geology at Slovak University of Agriculture in Nitra, Slovakia.

## Soil tillage

Soil tillage was provided by power harrow PÖTTINGER LION 301 (Fig. 1). Basic parameters and standard equipments are shown in Tab. 1 and Tab. 2 [13].

*Table 1. Basic parameters of power harrow PÖTTINGER LION 301*

| *Parameter* | *Unit* | *Value* |
|---|---|---|
| *Working width* | *m* | *3* |
| *Rotor* | *pcs.* | *10* |
| *PTO speed* | *rpm* | *1000* |
| *Rotor speed* | *rpm* | *342* |
| *Tine dimensions* | *mm* | *18 x 320* |
| *Power requirements up to* | *hp* | *180* |
| *Transport width* | *m* | *3* |
| *Weight with bar cage roller ø 420 mm* | *kg* | *1089* |
| *Weight with packing roller 420 mm* | *kg* | *1259* |
| *Weight with packing roller 500 mm* | *kg* | *1419* |


*Figure 1. Power harrow PÖTTINGER LION 301*

## Material equipments

The INNOVA devices (LumaSense Technologies, Inc., Denmark) consist of INNOVA 1412, INNOVA 1309 and notebook [14, 15].

The Photo-acoustic Field Gas-Monitor – INNOVA 1412 is a highly accurate, reliable and stable quantitative gas monitoring system. It uses a measurement system based on the photo-acoustic infrared detection method. Gas selectivity is achieved through the use of optical filters. The detection limit is typically in ppb (parts per billion) region. The accuracy of these measurements is ensured by the 1412's ability to compensate for temperature and pressure fluctuations, water vapor interference and interference from other gases known to be present.

The Multipoint Sampler – INNOVA 1309 is a 12 channel multiplexer, enabling gas samples to be drawn from up to 12 different sampling locations and delivered to the gas monitor. In addition to this, up to six temperature transducers can be connected to the 1309, providing information about the environment at these specific points, extends the area monitoring capabilities of the gas monitors. Reliability is ensured by automatic self-tests of both hardware and software. Operating status can be read-out at any time. The model 1309 contains a pressure transducer that measures the atmospheric pressure surrounding the multiplexer.

Notebook – operation software is used for control and setup the analysis and is supplied by manufacturer.

*Table 2. Characteristic of seamless steel pipe*

| *Parameter* | *Unit* | *Value* |
|---|---|---|
| *Outer diameter* | *mm* | *114.3* |
| *Internal diameter* | *mm* | *106.3* |
| *Wall thickness* | *mm* | *4* |
| *Weight of one meter* | $kg \cdot m^{-1}$ | *10.88* |

Sampling probes were made from seamless steel pipe (Tab. 2).

For the experiment purposes there were made two variants of sampling probes:

- small sampling probes with length 170 mm for the field method,
- sampling probes with length 300 mm for the laboratory method.

Used cap were made from a combination of copper and steel. There were made two variants of cap, with or without the hole with 5 mm diameter due to the teflon suction hose introduction. Holes were drilled only on the caps used as a top cap for sampling probes of field and laboratory method. No drilled caps were used to close the sampling probes from the bottom.

Air pipes - each of twelve air pipes was consist of:

- teflon suction hose EN-2007 type AFO614,
- air filter EN-2026 type DS2306,
- fitting for air filter EN-2247 type UD-5041.

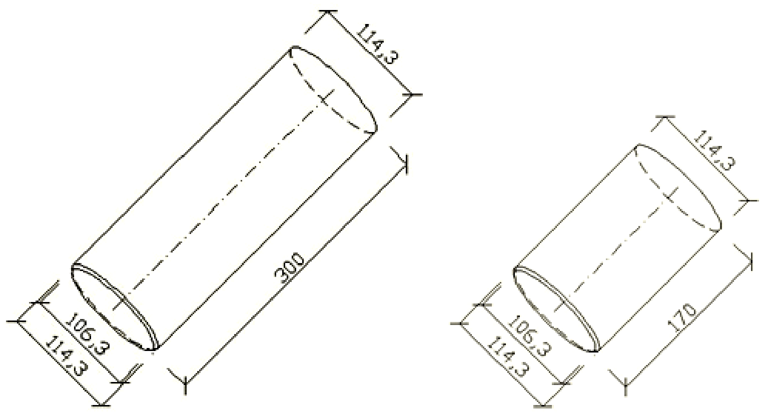


*Figure 2. Sampling probes, big (left) and small (right), dimensions in mm*

For soil samplings there were used additional tools: hammer, damping pad, spade, scarper and isolation tape. For easier penetration into the soil there was created outside bevel angle of 45° on the bottom of the each sampling probes.

## Measuring methods

For the measuring of concentration of carbon dioxide emissions released from soil to the atmosphere it is possible to create by two methods, field and laboratory. In order to exclude the effect of temperature, humidity and atmospheric pressure there were used both methods for measuring carbon dioxide emissions conducted directly on the field. Experiment was carried nine days after soil tillage. Air column in both methods was 150 mm.

### *Laboratory method*

The laboratory method consists of collecting soil samples from field and their subsequent analysis in laboratory. Big sampling probes were incorporated to 150 mm depth into the soil, surrounding soil has been removed and the sampling probes were closed up from the bottom. For this case the big sampling probes were left directly on the field with a goal to eliminate nature effects (pressure, air humidity, temperature).

### *Field method*

The field method measurement was used directly on the field. Small sampling probes were incorporated to 20 mm depth into the soil surface.

### Statistical analysis

Data were analysed by using ANOVA after normality test by using Kolmogorov-Smirnov test and homogeneity of variance by using Levene's test. With ANOVA P-Value < 0.05 we continued in post-hoc LSD Test. We have used software STATGRAPHICS Centurion XVI.I (Statpoint Technologies, Inc.; Warrenton, Virginia, USA). Graphic processing of results was performed using software STATISTICA 7 (Statsoft, Inc.; Tulsa, Oklahoma, USA).

## RESULTS AND DISCUSSION

There were created two variants of experiment with three replications. As a first variant there was used field method with three big sampling probes FM1, FM2 and FM3 (**F**ield **M**ethod, number). In the second variant we have was used laboratory method with three small sampling probes LM1, LM2 and LM3 (**L**aboratory **M**ethod, number).

The measurement results were compared with the concentration of carbon dioxide in the atmosphere. Concentration carbon dioxide in the air atmosphere was measured at the level of 1 meter above the field surface A (**A**ir).

By using of Kolmogorov-Smirnov test we have found out a normal distribution for all tested sets of values. P-Value of Kolmogorov-Smirnov test for all samples - set of values determined normal distribution (all P-Value > 0.5). Next, Levene's test confirmed homogeneity of variance P-Value = 0.7538 (P > 0.5). ANOVA was used after the values verification. The P-value of the ANOVA is less than 0.05. There is a statistically significant difference between the means of the six variables at the 95.0 % confidence level (Tab. 3).

*Table 3. Analysis of variance for $CO_2$ emissions measurement*

| *Source* | *Sum of Squares* | *Df* | *Mean Square* | *F-Ratio* | *P-Value* |
|---|---|---|---|---|---|
| *Between groups* | *55370.0* | *6* | *9228.34* | *47.93* | *0.0000* |
| *Within groups* | *28301.7* | *147* | *192.529* | | |
| *Total (Corr.)* | *83671.8* | *153* | | | |

To determine which means are significantly different from which others, there were selected Multiple Range Tests – LSD Test at the 99.9 % confidence level (Tab. 4) and statistically significant differences (Tab. 5). Three homogenous groups were identified using columns of X's. Within each column, the levels containing X's form a group of means within which there are no statistically significant differences. Between the field and the laboratory methods there are not statistically significant differences at the 99.9% confidence level.

*Table 4. LSD Test at 99.9 % confidence level*

| *Sample* | *Count* | *Mean* | *Homogeneous Groups* | |
|---|---|---|---|---|
| *A* | *22* | *403.125* | *X* | |
| *FM1* | *22* | *455.580* | | *X* |
| *LM3* | *22* | *456.491* | | *X* |
| *FM3* | *22* | *456.805* | | *X* |
| *LM1* | *22* | *456.971* | | *X* |
| *FM2* | *22* | *458.063* | | *X* |
| *LM2* | *22* | *459.392* | | *X* |

*Table 5. Statisticaly significant difference at 99.9 % confidence level*

| Contrast | Sig. | Difference | +/- Limits |
|---|---|---|---|
| A - FM1 | * | -52,4547 | 14,0484 |
| A - FM2 | * | -54,9378 | 14,0484 |
| A - FM3 | * | -53,6798 | 14,0484 |
| A - LM1 | * | -53,8456 | 14,0484 |
| A - LM2 | * | -56,2671 | 14,0484 |
| A - LM3 | * | -53,3658 | 14,0484 |
| FM1 - FM2 | | -2,48312 | 14,0484 |
| FM1 - FM3 | | -1,22508 | 14,0484 |
| FM1 - LM1 | | -1,39092 | 14,0484 |
| FM1 - LM2 | | -3,81237 | 14,0484 |
| FM1 - LM3 | | -0,911068 | 14,0484 |
| FM2 - FM3 | | 1,25804 | 14,0484 |
| FM2 - LM1 | | 1,0922 | 14,0484 |
| FM2 - LM2 | | -1,32925 | 14,0484 |
| FM2 - LM3 | | 1,57205 | 14,0484 |
| FM3 - LM1 | | -0,165836 | 14,0484 |
| FM3 - LM2 | | -2,58729 | 14,0484 |
| FM3 - LM3 | | 0,314014 | 14,0484 |
| LM1 - LM2 | | -2,42145 | 14,0484 |
| LM1 - LM3 | | 0,47985 | 14,0484 |
| LM2 - LM3 | | 2,9013 | 14,0484 |

* denotes a statistically significant difference.

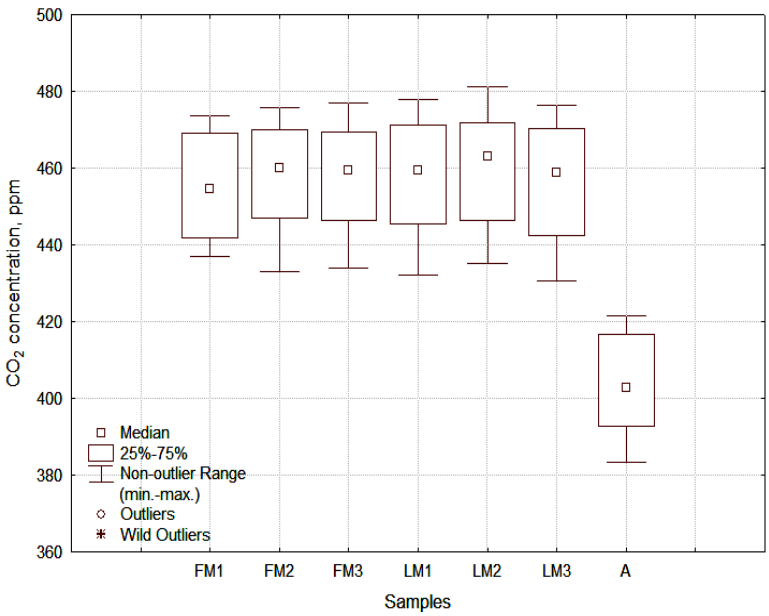


*Figure 3. Box-and-Whisker diagram of concentration $CO_2$*

Comparison measuring methods and practical verification of the laboratory method allows to use this method for measuring of carbon dioxide emission released from soil to the atmosphere. Used method allows to measure $CO_2$ soil emission simultaneously from 12 points at the same time and creates the possibility for long-term complex monitoring of the soil. For measuring carbon dioxide from soil to the atmosphere it is possible to use the Automated Soil $CO_2$ Exchange Station – ACE [16]. Major advantage for the use laboratory method by INNOVA devices over ACE is to use only one device for measuring 12 points at the same time. Measurement by one ACE allow to measure only one point at the same time.

## CONCLUSIONS

The aim of this paper was to compare the field and the laboratory methods for measuring of carbon dioxide emissions released from soil to the atmosphere by INNOVA devices. The results show the way to replace the field method by the laboratory method. By statistical processing of the data obtained there was not found statistically significant differences between the used methods at 99.9 % confidence level. Based on these findings, it was confirmed that the method does not affect the measurement results and thus it may be considered them to be interchangeable with each other. Anyway it is still necessary to verify this finding in the widest range of soil conditions to be sure about these findings.

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## UPOREDNA ANALIZA POLJSKIH I LABORATORIJSKIH METODA MERENJA EMISIJE $CO_2$ OSLOBOĐENOG IZ ZEMLJIŠTA U ATMOSFERU

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***Sažetak:*** U kontekstu globalnih kljimatskih promena, težište istraživanja je stavljeno na tehnologije obrade zemljišta. Obrada zemljišta značajno utiče na količinu ugljen-dioksida ($CO_2$) oslobođenog iz zemljišta u atmosveru. Istraživanje emisija iz zemljišta obično se izvodi u poljskim uslovima. Cilj ove studije je da unapredi efikasnost istraživanja zamenom poljskih metoda laboratorijskim metodama merenja emisija $CO_2$ oslobođenog iz zemljišta. Korišćeni su merni uređaji INNOVA, opremljeni senzorima za fotoakustičnu i infracrvenu detekciju. Merenje poljskim metodom izvođeno je direktno u poljskim uslovima. Laboratorijski metod sastoji se od sakupljanja zemljišnih uslova sa terena i njihova naknadna analiza u laboratoriji. Zemljišni uslovi na mestima uzorkovanja zemljišta: ilovasti černozem blago bazne reakcije sa srednjim sadržajem humusa. Merenja su sprovedena devet dana posle obrade mašinom PÖTTINGER LION 301. Srednje vrednosti izmerenih emisija $CO_2$ oslobođenog iz zemljišta iznosile su od 455.580 ppm do 459.392 ppm. Nije utvrđena statistički značajna razlika između poljskog i laboratorijskog metoda na nivou tačnosti 99.9%. Emisije $CO_2$ u okolni vazduh bile su značajno manje, sa srednjom vrednošću od 403.125 ppm. To znači da je moguće primeniti laboratorijski metod na uzorcima zemljišta za merenje emisija $CO_2$ oslobođenog iz zemljišta u atmosveru. Primenjeni laboratorijski metod dozvoljava merenje emisija $CO_2$ oslobođenog iz zemljišta istovremeno u 12 tačaka i omogućuje dugotrajno kompleksno praćenje.

***Ključne reči***: *emisije iz zemljišta, ugljen-dioksid, uzorkovanje zemljišta, merne metode*

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