Greenhouse gasses emissions during maize growing for energy purposes

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Abstract: Due to the increasing energy consumption and depletion of fossil fuels, alternative energy sources are becoming an increasingly important topic. One of the most important renewable energy sources is the energy from phytomass. Recently, also in the conditions of the Czech Republic, there has been a significant development of production of energy crops as raw material for the biogas production in biogas plants (BGP). However, farming and particularly technical processes associated with it participate in the anthropogenic emission production. This article presents the results of monitoring of emission load resulting from the cultivation of maize (*Zea mays* L.) for energy purposes. As a tool for emission load measuring (expressed in CO_2e where $CO_2e = 1x\ CO_2 + 23x\ CH_4 + 298x\ N_2O$), the simplified LCA method, respectively its climate impact category, was used. For calculation, the SIMA Pro software and the Recipe Midpoint (H) method was used. From the results, it is obvious that the cultivation of maize for energy purposes produces the greatest amount of CO_2e emissions within nitrate fertilization (0.052455 kg $CO_2e.1kg^{-1}$ of dry matter) and field emissions (0.050359 kg $CO_2e.1kg^{-1}$ of dry matter). Maize cultivation for energy purposes shows a higher emission load as compared for example with energy grasses.

Key words: maize, greenhouse gases emissions, Life Cycle Assessment, crop production

Introduction

The current situation and trends indicate the probability of irreversible effects on the world economy and particularly on the global climate. Energy demand will be growing constantly and it will drain especially irreplaceable fossil energy sources. It is an undeniable fact that fossil fuels are limited and it is necessary to look for other sources. We could say that in case of the economical land use, there will be biomass constantly available [13]. One of the possibilities is its transformation into biogas through anaerobic fermentation in biogas plants (BGP) [21]. In 2012, there were about 320 biogas plants in the Czech Republic. There will have been about 720 of them by 2020 [9]. With the increasing number of biogas plants, also the demand for suitable substrates increases while we could assume that the maize silage will still predominate. Also the current biogas production in BGP is based predominantly on the usage of maize. However, recently, there have been certain problems relating to its cultivation [23]. In terms of biomass energy utilization (in our case, specifically grown maize), it is necessary to deal with not only issues related to economic and social topics, but also environmental issues [26]. In terms of GHG emission production (in the Czech Republic, mainly N_2O, CH_4 and CO_2), it is also an important producer within agriculture, in addition to energetics and industry [18]. For example, according to Svendsen [29], this contributes by 9.2% to the total GHG emissions within the European Union. Within the trend of sustainability, however, also the agriculture should contribute to reduction of the emission load. In the literature, there is often a question of the impacts of agricultural alternative forms on reduction of environmental load discussed [11, 12]. For example, there are very often different crops, etc. compared which brings not always relevant results [28]. Therefore, for the energy crop cultivation, there is necessary to find possibilities of emission savings elsewhere than in changing of the entire farming system. To monitor specific emission load in different farming systems, The LCA (Life Cycle Assessment) analysis can be used [10]. It evaluates the environmental impact of a product based on the assessment of the impact of material and energy flows that are exchanged by the monitored system with the environment [8]. LCA is a transparent scientific tool [30] which evaluates the environmental impact on the basis of inputs and outputs within the production system [7]. On the basis of this study, it is possible to make a model of the established production system, to identify the strongest sources of emissions from particular energy flows and to determine the total emission load within the maize cultivation.

Material and methods

The aim of this study was to develop a model of technological process of cultivation of maize and wheat and to determine the impact of the emission load on the environment through it. As a tool for calculation of the emission load, the simplified Life Cycle Assessment (LCA) method was used. It is defined by international standards - ČSN EN ISO 14 040 (CNI, 2006a) and ČSN EN ISO 14 044 (CNI, 2006b). The results of the study were related to the Climate change impact category expressed as an indicator of carbon dioxide equivalent (CO_2e = 1x CO_2 + 23x CH_4 + 298x N_2O). For calculation, the SIMA Pro software with the Recipe Midpoint (H) integrated method was used. The functional unit of the system was 1 kg of the final product (1 kg of dry matter). Technological process of cultivation of silage maize for biogas production in BGP was compiled on the basis of primary data (direct information from farmers) and secondary data (obtained from the Ecoinvent database, specialized literature and agricultural production technology standards). The database uses data geographically related to Central Europe. The range of time horizons for the primary data collection was between the years 2012 - 2014 and the years 2000 - 2014 for the secondary data. Data selected for modelling are based on the average of commonly applied technologies. To the model system, there were agrotechnical operations from seedbed preparation, seed quantity, the use of plant protection products, the production and application of fertilizers, etc., to the harvest of the main product included. In addition to the emissions resulting from the above inputs, there are so called filed emission (N_2O) released after the application of nitrogen fertilizers produced. For their quantification, the IPCC (Intergovernmental Panel on Climate Change) methodology is used [3].

Results and discussion

Climate changes are a key topic of these days. Production of greenhouse gases in the world needs to be constantly monitored and it is necessary to look for ways how to reduce their most important resources at the same time. For example, emissions from agriculture represent about 10 - 12% of the total produced GHG emissions (CO_2e) in the world representing 5.1 to 6.1 billions tones of CO_2e [20]. Within the EU-27, the total share of emissions from agriculture in total production of CO_2e is estimated at 10.1% [22] and in the Czech Republic, this share is 6.3% [6].

As stated before, results of the study were related to the *Climate change* impact category expressed as an indicator of carbon dioxide equivalent (CO_2e = 1x CO_2 + 23x CH_4 + 298x N_2O). The same concentration of different greenhouse gases has very different consequences for increasing absorption of long-wave radiation, so the certain greenhouse gases are more effective than others [19]. Nitrous dioxide (N_2O) is the most effective greenhouse gas produced by agriculture [15]. One kilogram of this gas has the same greenhouse effect as 289 kg of CO_2 [27, 15]. In addition, these gases (CO_2, N_2O, CH_4) are characterized as greenhouse gases with a direct impact on climate [14].

This paper evaluates the current model of a technological progress within the cultivation of maize for the production of biogas. Results show the amount of emission impact on the environment. Table 1 shows the values of particular system processes while the highest emission load is associated with agrotechnical operations (0.020346 kg $CO_2e.kg^{-1}$ of dry matter), N fertilizer application (0.052455 kg $CO_2e.kg^{-1}$ of dry matter) and production of N_2O field emissions released after the application of N fertilizers (0.050359 kg CO_2e.kg-1 of dry matter). Also Barros [1] states that the greatest amount of GHG emissions released into the atmosphere comes mainly from N fertilizers. Zou et al. [31] and Mori et al. [16] also state that fertilizer usage has an effect on increasing N_2O emissions from the soil.

Table 1 Production of emissions within particular system processes, own source - Bernas et al., 2014

System subprocesses	**kg $CO_2e.kg^{-1}$ of maize dry matter**
Organic fertilizers	0.003607
Mineral fertilizers N	0.052455
Mineral fertilizers P	0.007475
Mineral fertilizers K	0.002661
Total fertilizers	***0.066198***
Seed consumption	0.003203
Chemical protection	0.000763
Agrotechnical operations	0.020346
N_2O field emissions (converted to CO_2e) generating after the application of N fertilizers.	0.050359
Total production	***0.140870***

The highest CO_2e emission load comes from nitrogen fertilizer application (0.052455 kg CO_2e.kg^{-1} of dry matter) and production of N_2O field emissions released after the application of N fertilizers (0.050359 kg CO_2e.kg^{-1} of dry matter). On the contrary, the lowest amount of CO_2e emissions results from the use of chemical plant protection products (0.000763 kg CO_2e.kg^{-1} of dry matter). This is contrary to the statement of Fott [5] who states that emissions from agricultural activities come mainly from the usage of nitrogen fertilizers and pesticides precisely. Graph 1 shows a comparison of two strongest emission sources also expressed in CO_2e.kg^{-1} of maize dry matter with the emission load resulting from the remaining system processes altogether.

If we think of CO_2e production reduction within the chosen cultivation process, it is necessary to focus on the two most powerful sources (N fertilizer application and field emission arising from the application of N fertilizer). In this respect, we often deal with the question regarding reducing the dose of fertilizer and the total change of the agricultural system [4, 17]. Another way how to reduce emissions of greenhouse gases is the replacement of maize by another energy plant. Also Bellarby [2] proposes the cultivation of less loading plants as a way how to reduce (namely mitigate) GHG emissions. These may be, for example, energy grasses. These have prerequisites to lower CO_2e production during their life cycle thanks to the character of perennial plants and generally lower fertilization requirements.

Fig. 1 Network of energy flows, own source (SIMA Pro) - Bernas et al., 2014.

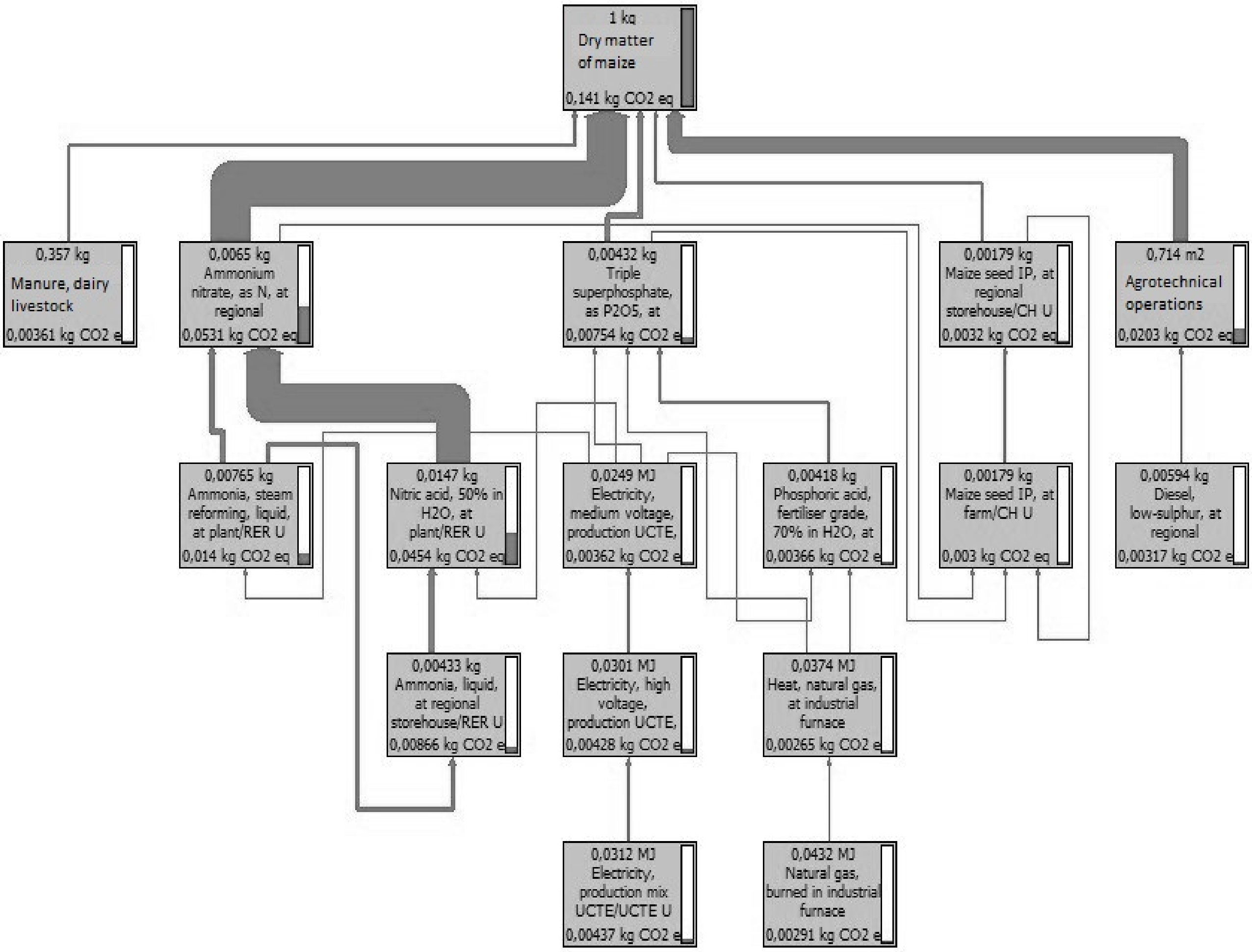
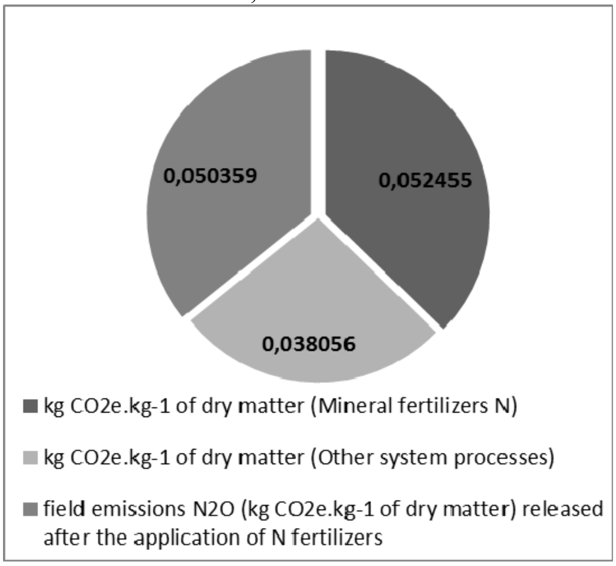


Figure 1 represents a network of particular energy flows involved in the production of 1 kg of maize dry matter. The strongest energy flow demonstrates the emission load due to the use of N fertilizers. One of the reasons why N fertilizers are the strongest producers of GHG emissions within agriculture is their constantly rising consumption. For example, Robertson and Vitoušek [25] stated that global consumption of N fertilizer increased tenfold in the period from 1950 to 2008.

Graph 1 Main sources of CO_2e emissions, own source - Bernas et al., 2014



** Among other system processes, an application of organic fertilizers, mineral P and K fertilizers, seed consumption, chemical plant protection and agrotechnical operations were included.*

Conclusion

The results show that the total emission load of the selected cultivation cycle of maize intended for biogas production represents 0.140870 kg $CO_2e.kg^{-1}$ of maize dry matter. From the system subprocesses, the largest emission load for the *Climate change* impact category is formed by nitrogen fertilizer application (0.052455 kg $CO_2e.kg^{-1}$ of dry matter) and N_2O field emission resulting after the application of N fertilizer (0.050359 kg $CO_2e.kg^{-1}$ of dry matter). The reduction of the amount of CO_2e produced within the cultivation of maize for biogas can be done by reducing the dose of fertilizer (probably at the cost of lower yields), changes of the cultivation technology or choosing another energy plants. When deciding on the introduction of another energy plants suitable for the production of biogas, it is also necessary to know the CO_2e emission load generated during its growing cycle. Based on this finding, it would be possible to carry out further evaluation and comparison.

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