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How do 28 European Union Member States perform in agricultural greenhouse gas emissions? It depends on what we look at: Application of the multi-criteria analysis

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ABSTRACT

European Union (EU) Member States have agreed to limit their greenhouse gas (GHG) emissions from sectors not covered by the EU Emissions Trading Scheme, including emissions from agricultural sector. The aggregated GHG emission rate (i.e. t CO_2 eq. from agricultural sector per country) is commonly used to measure the overall size of agriculture's influence on climate. And indeed, since 2005, EU has managed to decrease its aggregated GHG emissions by 3.1%. However, the question is—does that mean that EU's agriculture has become less emission intensive? This paper answers the question by providing a different perspective for the assessment and comparison of the agricultural GHG emissions in 28 EU Member States. It is done by applying three different approaches, including creation of derived indicators and application of multi-criteria analysis (TOPSIS), which is a novel approach for comparison of agricultural GHG emission mitigation performance. The results show that each EU Member State performs very differently in emission intensities. Even more, the emission intensity results show an alarming tendency of increase in most of the EU Member States, which indicates that the measured changes in aggregate agricultural GHG emission rates are misleading. Therefore, the paper suggests reconsidering the policy targets for GHG emission limits.

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1. Introduction

Agriculture is directly associated with climate change issues on environmental, economic and social dimensions. Climate influences agricultural productivity, whereas agricultural activities contribute to greenhouse gas (GHG) emissions, while functioning as a carbon sink under certain management practices. Thus, complex linkages exist between climate change and agriculture, frequently difficult to define or measure.

In 2010, the annual global non-CO_2 GHG emissions from agriculture were estimated to be 5.2–5.8 Gt CO_2 eq. (IPCC, 2014). That comprised about 10–12% of the total global anthropogenic emissions (IPCC, 2014). 0.442 Gt CO_2 eq. were produced by the European Union's (EU) agriculture sector, also around 10% of the total EU emissions for that year. EU Member States (MS) have agreed to limit their GHG emissions from sectors not covered by the EU Emissions Trading Scheme (non-ETS) on average by −10% in 2020 as compared to the emissions in 2005 (EC, 2009). That includes also emissions from the agricultural sector. In addition, Europe's ambition to move towards low-carbon economy by 2050 (EC, 2013) implies that by 2030 the non-ETS GHG emissions would have to be reduced by 30%, compared to 2005 levels (EC, 2014).

The IPCC has established a methodology for assessment of GHG emissions from various industry sectors, including agriculture (IPCC, 2006). Even more, IPCC has achieved that governments recognize and involve into climate change mitigation (Dace et al., 2015). Each year EU MS submit their national emission inventory reports to the United Nations Framework Convention on Climate Change (UNFCCC), thus facilitating the follow up of the trends and success achieved in the aggregated emission mitigation. By 2013, the EU has managed to reduce its agricultural GHG emissions by 3.1% as compared to 2005. The reduction has been achieved mainly due to the decrease in livestock numbers, i.e. through reduced agricultural activity and output. The emission reduction does not readily mean that EU would have become more efficient by reducing emission intensity (i.e. emitting less per unit of production).

Abbreviations: EU, European Union; EU28, 28 European Union Member States; GHG, greenhouse gas; LSU, livestock unit; MS, Member State; non-ETS, GHG emissions from sectors not covered by the EU Emissions Trading Scheme; TOPSIS, technique for order preference by similarity to ideal solution; UAA, utilized area of agricultural land.

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Import of food into the EU has increased significantly, thus the EU's emission reduction most likely has been achieved by dislocating production outside EU.

Since the 1990s, numerous agri-environmental indicators and indicator-based methods have been developed for assessing impacts of agriculture and agricultural systems on environment and sustainable development (Bockstaller et al., 2008). According to the definition provided by the Organization for Economic Co-operation and Development (OECD, 2001) an agri-environmental indicator is a "summary measure, combining raw data, used to describe the state of the environment, a risk to the environment, a change in the environment, or a driving force behind such a change, that can be attributed wholly or in part to an agricultural activity or activities". Thus, the analytical framework of Driving forces – Pressures and risks – State and impact – Response or DPSIR model is applied for indicator development to detect all stages of impact effects. In the EU, a set of 28 agri-environmental indicators is used (EC, 2006). The indicator 'GHG emissions' is used to indicate pollution in the "Pressures and risks" domain and show the aggregated annual emissions from agriculture. The aggregated GHG emission rate (i.e. t CO_2 eq. from agricultural sector per country) is the most frequently used measure for the overall size of agriculture's influence on climate, while derived indicators, such as GHG emissions per utilized area of agricultural land (UAA) (in t CO_2 $ha_{UAA}{}^{-1}$) or GHG emissions per livestock unit (LSU) (in t CO_2 LSU^{-1}) that would characterize the emission intensity of the agricultural sector, are not so commonly used in the policy design process.

The aim of the paper is to compare the 28 EU Member States (EU28) for their agricultural GHG emissions from a different perspective than it is generally accepted, i.e. by creating derived indicators that characterize emission intensity of agricultural activities and conducting a multi-criteria analysis by which the weighted normalized emission intensity is obtained and assessed.

It is common to compare and evaluate the EU MS with respect to their progress towards agricultural development, environmental efficiency, emission mitigation, especially in various policy monitoring and progress reports (e.g. Leip et al., 2010; Domínguez et al., 2012). EU MS have been compared also in scientific studies. Godinot et al. (2016) have demonstrated the feasibility and utility of calculating nitrogen balance and efficiency indicators in 27 EU MS indicating that the rarely considered indicator of changes in soil nitrogen enables more valid comparisons between MS with different production methods and intensities, than the more commonly used indicators – nitrogen farm-gate balance or nitrogen use efficiency. Whereas, in the reviewed literature, application of the multi-criteria analysis for comparative assessment of EU MS' emission intensity of agricultural sector has not been reported. Hence, this paper shows the first attempt of such application.

2. Methodology

According to the UNFCCC emissions accounting framework (UNFCCC, 2008), the agricultural GHG emissions are categorized into 10 sources: enteric fermentation, manure management, agricultural soil management, rice cultivation, prescribed burning of savannahs, field burning of agricultural residues, liming, urea application, other carbon-containing fertilizers, and other agriculture emissions. In our study, we have used the data of EU MS on the agricultural emissions submitted to the UNFCCC, as well as the data on Common Agricultural Policy indicators—livestock units and utilized agricultural area, available on the *Eurostat* public database. We included all 28 EU Member States, and compared their performance with respect to the emission intensity of the agricultural sector in 2005, 2007, 2010, and 2013 (according to the frequency of scope and sample surveys of the Agricultural Census). In this context, we define emission intensity as the rate of GHG emissions, expressed in tons of CO_2 equivalent, generated per an agricultural activity characterizing unit – livestock unit (t CO_2 eq. LSU^{-1}) or hectare of utilized agricultural area (t CO_2 eq. $ha_{UAA}{}^{-1}$). The timescale of 2005–2013 has been selected, as, in EU decision and framework documents (EC, 2009; EC, 2014), 2005 serves as a reference year for the GHG reduction goals, while 2013 is the last year for which the national inventory reports have been submitted to UNFCCC.

Three approaches were selected for the comparison (see Fig. 1). In the first approach, we compared the EU MS by using the most frequently used indicator—total aggregated agricultural GHG emissions (t CO_2 eq.) and total aggregated agricultural GHG emissions per utilized agricultural area (t CO_2 eq. $ha_{UAA}{}^{-1}$). In the second approach, EU MS were compared by creating derived indicators. While, in the third approach, the EU MS were compared by conducting a multi-criteria analysis, where the derived indicators were used as criteria. The following subsections provide the description of the second and third approach in more detail.

2.1. Derived indicators

Bockstaller et al. (2008) have distinguished among three groups of indicators: (i) simple indicators based on the use of one type of variable obtained by survey, databases and not directly measured; (ii) indicators based on calculation and integrating more than one type of factors; and (iii) indicators based on one or several measurements. The indicators derived in our study would belong to the second group.

Three sources dominate in the agricultural GHG emission statistics. In EU28, about 42% of agricultural emissions are generated from enteric fermentation, 38% – from agricultural soil management, 16% – from manure management, and the remaining 4% – from all other sources (the percentage fluctuates slightly from year to year). Considering that, we have used only the dominating three emission sources for creating the derived indicators (see Fig. 1). The derived indicators are (i) emission rate from agricultural soil management per utilized agricultural area (t CO_2 eq. $ha_{UAA}{}^{-1}$); (ii) emission rate from enteric fermentation per livestock unit (t CO_2 eq. LSU^{-1}); and (iii) emission rate from manure management per livestock unit (t CO_2 eq. LSU^{-1}). Thus, the emissions are connected directly to the specific agricultural activity. The time scale used for all indicators is 1 year.

The area used for farming, including arable land, permanent grassland and crops, and other agricultural land such as kitchen gardens, is denoted by the UAA. The emission rate expressed per UAA shows the emission intensity of the overall agricultural activity or, as in our case of derived indicators – of the activity related to management of agricultural soil, i.e. soil fertilization, crop and feed production, grazing, etc. By applying the derived indicator, where emissions from soil management are expressed per hectare of UAA, we can compare performance of EU MS and identify those more and less successful.

LSU is selected as a reference unit of agricultural livestock farming activity, as it allows for aggregation of livestock from various species and age. We use the LSU, as defined by the Eurostat, i.e. 1 LSU is "the grazing equivalent of one adult dairy cow producing 3000 kg of milk annually, without additional concentrated foodstuffs" (Eurostat, 2016). The emission rate expressed per LSU allows for identification of emission intensity from a normalized livestock unit, hence facilitating comparison between countries, regions or even farming systems.

2.2. Multi-criteria analysis

In the present study, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used to compare the EU

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