Monitoring of Statistical Data on GHG Emissions using GIS: A Review

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The aim of this work is to analyse greenhouse gases (GHGs), their emissions in the agricultural sector, and the possibility of monitoring them through remote sensing (RS), and data-driven solutions. In this paper using GIS software analysed the GHG emission reports of 43 member countries that are regularly submitted to the Secretariat of the United Nations Framework Convention on Climate Change. The analysis highlighted Sweden's leadership in the energy sector, where up to 66% of its electricity comes from renewable sources. New Zealand also stood out in the context of all countries, with very high methane (CH_4) emissions due to the country's large livestock population and poor emission controls in the agricultural sector. The article also provided an overview of the satellites currently available on the market for monitoring GHG emissions and a partial analysis of their characteristics. Future work is planned to further investigate the applicability of satellites for monitoring GHG emissions, to provide a detailed analysis of the characteristics of public, commercial, and hybrid satellites, to carry out practical applications of satellite data for the determination of agricultural emissions, and to develop a methodology for continuous emissions monitoring.

CCS CONCEPTS

CCS • Greenhouse gases data collection • GIS and Remote Sensing for GHG monitoring • Emission in the agriculture section

Keywords: GHG, Remote sensing, GIS, Agriculture, CO_2, CH_4, N_2O

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1 INTRODUCTION

Climate change and GHG emissions are one of the biggest challenges of the 21st century. It plays an important role in the control of local air pollution and climate change. Various international organizations and dictionaries interpret the concept of GHG very similarly and state that these are gases that have the property of absorbing infrared radiation (even heat energy) emitted from Earth's surface and reradiating it back to Earth's surface, thus contributing to the greenhouse effect, that basically, we can say that these are gases that trap heat in the atmosphere [1]–[6].

GHG and carbon dioxide (CO_2) have been talked about for a long time. The first scientific article about GHG was printed as early as 1896 [7]. Arrhenius' work is the first to quantify the contribution of CO_2 to the greenhouse effect and to speculate whether changes in atmospheric CO_2 concentrations are contributing to long-term climate change. Throughout this work, Arrhenius refers to CO_2 as "carbonic acid" in keeping with the convention at the time he wrote. In this paper, the author does not explicitly state that the burning of fossil fuels will cause global warming, although it is clear that he was aware that fossil fuels are a potentially significant source of CO_2.

Although the atmosphere contains a wide variety of gases, the global consensus on greenhouse gases in Annex A of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is that only CO_2, CH_4, nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3) are GHG. HFCs, PFCs, SF_6 and NF_3 are collectively known as fluorinated gases. These gases, all of them, are classified as GHGs because their levels in the atmosphere are increasing rapidly due to human activities [8].

These gases must be reported annually by member countries to the UNFCCC. The UNFCCC Secretariat (UN Climate Change) is the United Nations organisation tasked with supporting the global response to the threat of climate change. The UNFCCC stands for the United Nations Framework Convention on Climate Change. The Convention is nearly universal (198 countries) and is the main treaty of the 2015 Paris Agreement. The main objective of the Paris Agreement is to keep the global average temperature rise this century as close as possible to 1.5 degrees Celsius above pre-industrial levels. The UNFCCC is also the main treaty of the 1997 Kyoto Protocol. The ultimate goal of all three agreements under the UNFCCC is to stabilise GHG concentrations in the atmosphere to a level that avoids dangerous human interference with the climate system, over a period of time that allows ecosystems to adapt naturally and allows for sustainable development. The Secretariat provides technical expertise and assistance in analysing and reviewing information submitted by countries on climate change and in implementing the Kyoto mechanisms. It also maintains the Nationally Determined Contributions (NDCs) registry established under the Paris Agreement, which is a key aspect of the implementation of the Paris Agreement [9].

In 2022, the official United Nations Climate Change (UNCC) website lists the climate change targets for 43 countries around the world and the Union (Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, the European Union (EU), Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Japan, Kazakhstan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey Ukraine, the United Kingdom, the United States of America) reports on GHG emissions by sources and removals from sinks for 2020. All countries use the same unit of measurement for GHG emissions - CO_2 equivalent (kt) - in their reports, which makes it easy to compare the results between countries or to carry out additional comparative analytical calculations and avoids possible inaccuracies or errors in the conversion of values.

Due to their different radiative properties and atmospheric residence times, GHG differ in their heating effect (positive radiative forcing) on the Earth's climate system (Table 1) [2], [10]–[12]. These effects can be expressed in a common measure based on the radiative forcing associated with the CO_2 increase. The impact of economic activities on climate change is conveniently expressed in terms of CO_2 equivalent [12]. CO_2 equivalent emissions are a reference value and a useful proxy for comparing emissions of different GHGs. CO_2 equivalent abbreviated as CO_2-eq., is a metric used to compare the emissions of different GHG in terms of their global warming potential (GWP), converting the amounts of other gases into an equivalent amount of CO_2 with the same global warming potential. CO_2 equivalents are usually expressed in millions of metric tons of CO_2-eq., abbreviated MMTCDE [13]. CO_2-eq. for a gas is calculated by multiplying the tons of gas by the corresponding GWP:

$$MMTCDE = (million\,metric\,tonnes\,of\,\,gas) \cdot (GWP\,of\,\,gas) \qquad (1)$$

For example, CH_4 has a GWP of 25 and N_2O 298. This means that emissions of 1 million metric tons of CH_4 and N_2O are equivalent to emissions of 25 and 298 million metric tons of carbon dioxide [13].

Table 1: Properties of GHGs

Chemical formula	Lifetime in Atmosphere	Global Warming Potential (100 years)
CH_4	12 y	25
CO_2	Atmospheric CO_2 is part of the global carbon cycle, and therefore its fate is a complex function of geochemical and biological processes. Some of the excess carbon dioxide will be absorbed quickly (for example, by the ocean surface), but some will remain in the atmosphere for thousands of years, due in part to the very slow process by which carbon is transferred to ocean sediments.	1
N_2O	114 y	298
HFCs	up to 270 y	up to 14800
PFCs	2600-50000 y	up to 12200
NF3	740 y	17200
SF6	3200	22800

The aim of this work is to analyze GHGs in general, their emissions in the agricultural sector, and the possibility to continuously monitor them through RS and solutions based on their data.

2 MATERIALS AND METHODS

2.1 GHG data collection

Data of GHG for the all 43 countries from the UNCC website lists [9] collected and converted to the Figure 1. Data were collected and visualized using GIS software.

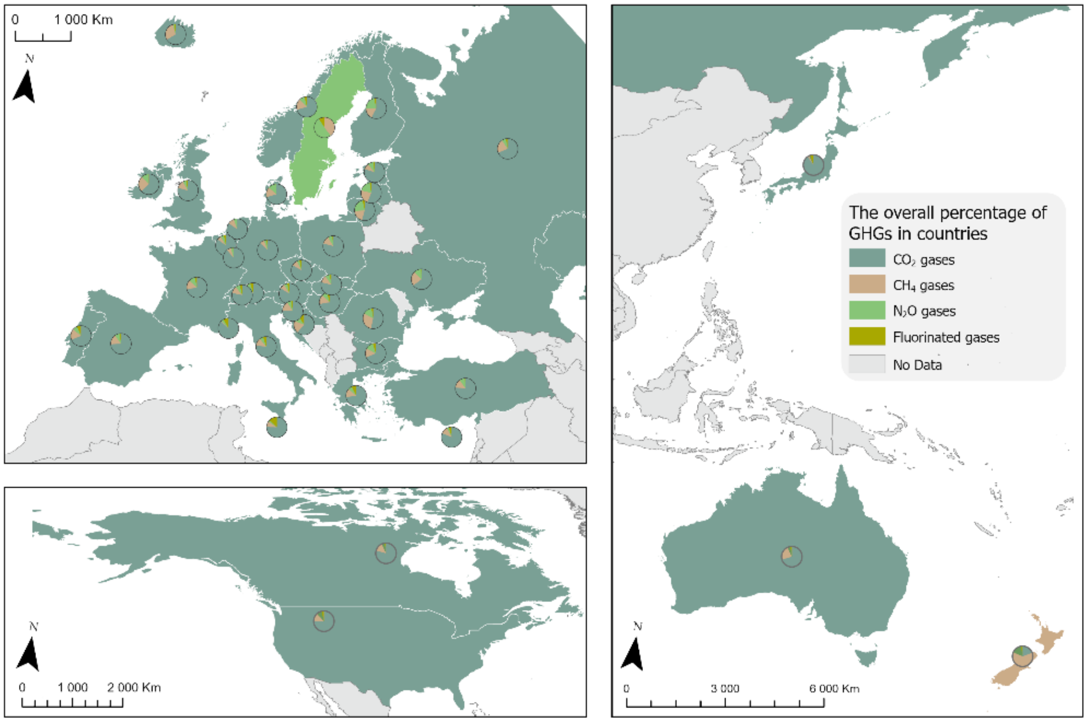

Figure 1: Overall percentage of GHG in countries (source: the authors)

A comparison of the estimates provided by all 43 countries shows that, except for Sweden and New Zealand, CO_2 and CH_4 gases are the main contributors to atmospheric emissions in most countries, while N_2O and fluorinated gases often account for less than 20% of the total GHG emissions (Fig. 1).

The basic method for calculating GHG emissions is to multiply the activity level or rate (A) by its corresponding emissions factor (EF) [14], [15]:

$$GHG\ emissions = Activity\ (A) \cdot EmissionsFactor\ (EF) \qquad (2)$$

Activity data is the level or rate of a specific action that produces emissions. For an accurate calculation, the activity data that you use should be as exact and specific as possible. Emissions factors represents the rate or quantity of GHG emissions that are released because of a specific activity. Emissions factors are offered by a variety of sources, so it may be challenging to know which one to use [15].

In the remainder of this paper, Section 2.2 provides a review of all GHG from agricultural sector.

2.2 GHG emissions in Agriculture sector

The agricultural sector emits CO_2, CH_4 and N_2O gases. The figure 2 below shows that CO_2 gases account for only a very small proportion of total emissions in the agricultural sector, while Monaco has no accounting for this sector at all, with 0 emissions from agriculture. The presentation of statistical data on the map highlights the dominance of different gases in countries. Figure 2 shows that Europe is split in half according to the dominant type of GHG gas. In Western Europe, the agricultural sector emits more CH_4 gas, while in Eastern Europe - N_2O gas.

EU agricultural GHG emissions have changed very little between 2005 and 2019 and are expected to remain on this trend, with Member States projecting those agricultural emissions will only decrease by a marginal 2% by 2030. While agricultural GHG emissions at EU level have changed very little between 2005 and 2020, trends at national level have varied considerably, with 14 Member States increasing emissions and 13 Member States decreasing them. For example, emissions decreased by more than 10% in Croatia, Greece and Malta, while they increased by more than 10% in Bulgaria, Estonia, Hungary, Latvia and Luxembourg [16].

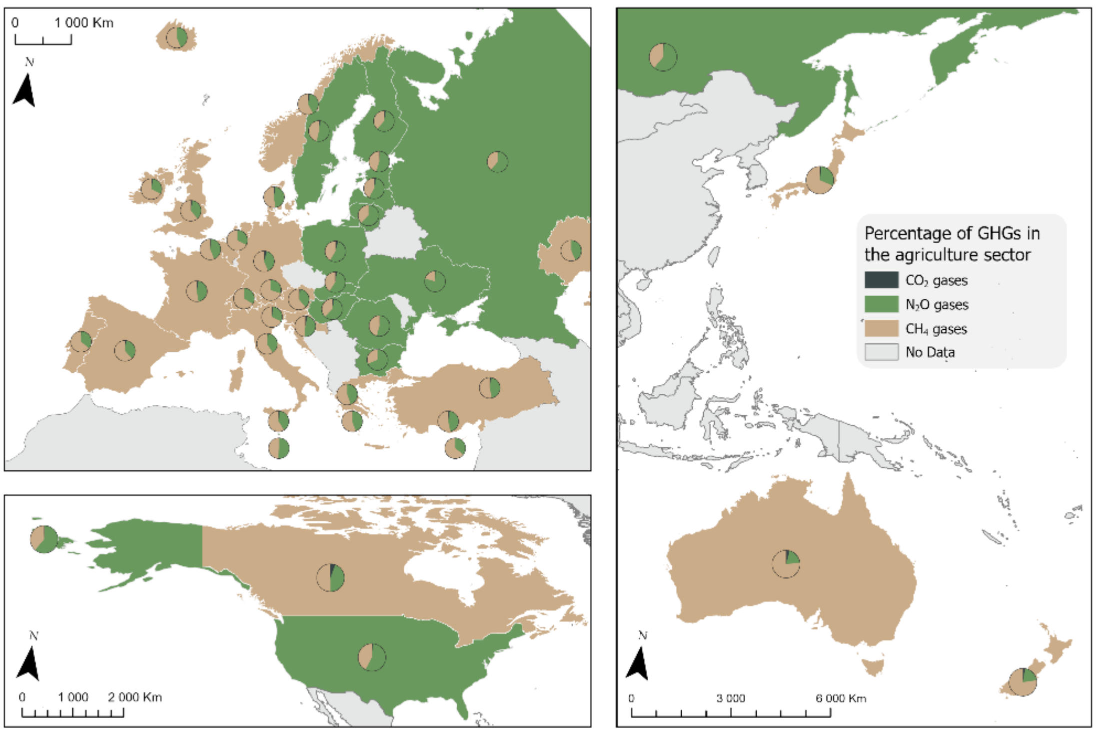

Figure 2: Percentage of GHG in Agriculture sector (source: the authors)

Food and agriculture organization of the United Nations (FAOUN) carry about emissions due to agriculture global, regional and countries trends. The FAOSTAT emissions database provides a comprehensive picture of CH_4, N_2O and also CO_2 emissions and removals from agriculture production and associated land use activities. It has the analytical brief focuses on overall trends over the past period 2000–2018 [17].

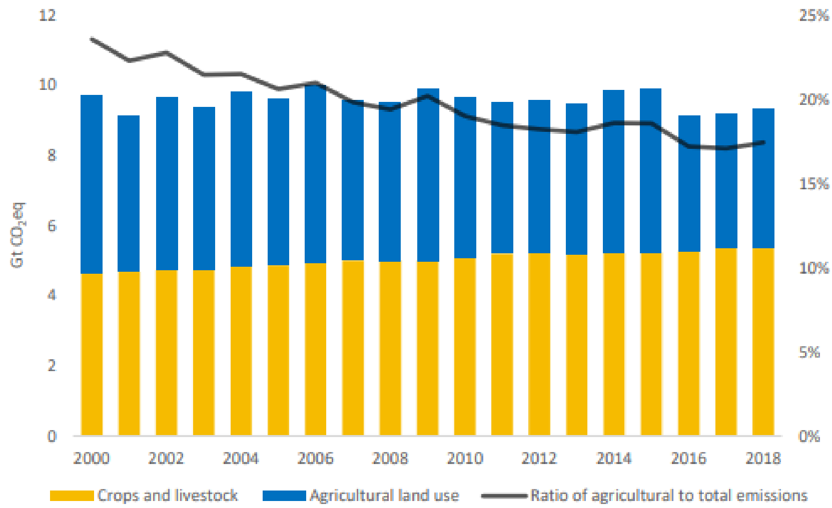

Figure 3: Yearly emissions from crops and livestock and related land use, and share of agriculture in global GHG emissions from all sectors, 2000–2018 (source: [17])

The total agriculture and related land use emissions reached 9.3 billion tons of CO_2 equivalent (Gt CO_2-eq.). Crop and livestock activities within the farm gate generated more than half of this total (5.3 Gt CO_2-eq.), with land use and land use change activities responsible for nearly 4 Gt CO_2-eq. in 2018. It is 14 % larger than 2000. We have trend growth. The reason is land deforestation and conversion it to agricultural land [17].

2.3 GIS and Remote Sensing for GHG monitoring

Despite the fact that GHG emissions from the agricultural sector in the EU have been steadily declining in recent years [18], this is still an area that cannot be neglected, and there is a need to develop user-friendly monitoring processes that allow for rapid and continuous access to the state of play. Monitoring is one of the most important tools in the fight against climate change. Monitoring is needed for many reasons: to report emissions to the UNFCCC, to determine where to focus reduction efforts and to track the success of policy interventions.

GIS software is needed to perform spatial calculations or to analyze derived products, such as classified satellite images or LiDAR data. Analyzing statistical data, it is important to carry out monitoring not only in tables, but also to map those tables geographically using GIS software. Such linking of statistical data with GIS data highlights not only local but also regional or even national problems. By combining remote sensing information with GIS, it is possible to track, model, and monitor GHG trends across the earth's surface.

Satellite imagery is increasingly being used worldwide to monitor GHG emissions. Of course, satellites cannot yet fully replace our current emission reporting systems, but satellite systems are nevertheless constantly improving and becoming more adaptable. According to Jane Burston [19], the first satellite to detect atmospheric GHG from space was Europe's Envisat satellite, which took its first im-age in 2002. Today, the number of satellites dedicated to monitoring GHG emissions is much larger and growing.

A total of 33 relevant satellite missions and instruments both in orbit and in planning funded by public, private and not-for-profit entities were identified in the data-base of GHG monitoring capabilities from space underpinning the analysis. These missions have a potential to contribute to National GHG Inventories, focusing on the three major gases listed under the Paris Agreement for reporting purposes by Parties – CO_2, CH_4, N_2O [20].

Of these 33 identified missions, most are driven by public entities (21, of which 13 in orbit and operational). In addition, there are 7 commercial missions (of which 1 in orbit and operational, and 1 in its final trial period before being fully operation-al in orbit) and 5 hybrid missions (all in development) with proposed launch dates until the 2040s. Aiming to provide a comprehensive overview, the database features specific mission information on the country or region where the mission is based, the contributing or coordinating organizations, the mission name and the related instrument, the mission status (in orbit, in development, end of mission), the mission goal and application, GHG data monitored directly (CO_2, CH_4, N_2O), potential policy-relevant application (point-source, national, and global level), and data access.

Despite the wide choice of technologies [21], GHG are hard to measure: there are multiple natural and anthropogenic sources at all scales which are unpredictably distributed in space and time [19]. One of the RS approaches for GHG monitoring is the use of unmanned aircraft. This method is most suitable for monitoring small and specific areas, as it can otherwise be very costly in terms of time, logistics and finances. In the industrial sector, for example, pipelines can be tens of thousands of kilometers long and some facilities are in very remote locations, so accessibility to such sites can be a real challenge and emissions can be sporadic, depending on non-permanent processes. In the agricultural sector, the main sources of emissions are often livestock and their manure, which are relatively small, geographically dispersed sources, or rice paddies, which are spread over a large area and emit GHGs in a highly variable and erratic manner depending on the season and weather.

On the one hand, satellites seem to be able to solve some of the difficulties encountered: a single sensor can provide data from a large coverage area, measurements are consistent and stable, and hard-to-reach areas are also covered. However, the use of satellites poses other problems.

Satellite imagery for GHG monitoring is available in three types - public, commercial and hybrid. Public satellites are free for all to use, but usually have a rather poor spatial resolution. This means that such satellites are not suitable for monitoring small objects, such as livestock emissions or gas leaks in pipelines. While satellites have indeed improved considerably, such as the Envisat satellite's sensor with a 30 km x 60 km instantaneous field of view [22], [23], the image with such an array is only suitable for studying the regional or global atmospheric distribution of gases, whereas the Sentinel-5P satellite already has a 7 km x 7 km instantaneous field of view [24]. Commercial satellites may have an even smaller array, but their data are paid for and not publicly available.

Another downside is that the satellites are so far equipped with passive sensors, which means they rely on sunlight and cannot "see" in the dark or through clouds. This problem is particularly acute in tropical regions, which are major sources and sinks of GHGs due to expanding wetlands, abundant rice paddies, and extensive burning of forests to make farming possible [19].

Satellites have a consistent and steady coverage of the same area, but this means that by the time they reach an area of interest to the user, the weather conditions may be poor, or the gases may have dissipated, or the observation of a particular object may be less frequent than the user would like or require. For example, a pipeline accident at a particular site may have been repaired before the satellite can reach the site, in which case ground-based measurement techniques or unmanned aircraft must be used to estimate the amount of GHG gases.

Global direct quantification of emissions using public satellite data is currently not reliable or detailed enough to directly measure greenhouse gas emissions and contribute to UNFCCC reporting. Further analysis of the characteristics of commercial and hybrid satellites is therefore needed, as well as the employment of sample data for monitoring specific sites, in this case related to agricultural GHG emission sources.

3 MATERIALS AND METHODS

3.1 CO_2 emissions

As mentioned above and shown in Figure 1, most countries emit mainly CO_2 gases, so climate change may often be associated with CO_2 gases, but these gases are not in themselves the cause of climate change. CO_2 is an important component of the natural cycle, necessary to sustain plant and animal life [25]. The cause of climate change is not the presence of this component in the atmosphere, but rather an overly rapid increase in its quantity.

CO_2 is released into the atmosphere from the combustion of fossil fuels (coal, natural gas and oil), solid waste, trees and other biological material, and from certain chemical reactions (e. g. in cement production). CO_2 is removed from the atmosphere (or 'sequestered') when it is absorbed by plants as part of the biological carbon cycle [2]. Human activities alter the carbon cycle, both by adding more CO_2 to the atmosphere and by affecting the ability of natural sinks such as forests and soils to remove and store CO_2 from the atmosphere.

In the agricultural sector, CO_2 gases are accounted for from liming and urea ap-plication activities and account for a very small proportion of total emissions from the agricultural sector.

An analysis of the data provided to the UNFCCC Secretariat (Fig. 1) shows that Sweden stands out in the context of all countries, with more CO_2 removed by land use, land use change and forestry than produced by the energy, industry, agriculture and waste sectors. The main reason for Sweden's low emission levels is the country's dependence on clean energy sources. Most of Sweden's electricity comes from hydroelectric and nuclear power, as well as wind power. Renewable sources now ac-count for more than 66% of Sweden's electricity [26].

3.2 CH_4 emissions

Figure 1 shows that CH_4 emissions as a percentage of total GHG emissions are so important. CH_4 is emitted during the production and transport of coal, natural gas and oil. CH_4 is also emitted from livestock and other agricultural activities, land use and the decay of organic waste in municipal solid waste landfills. CH_4 gases are also emitted from natural sources such as natural wetlands.

Data provided to the UNFCCC Secretariat show that in most countries, the agricultural sector is the largest contributor to CH_4 emissions, followed by the energy sector. Monaco stands out among all the countries, as it has no accounting for agriculture at all, and its methane emissions are entirely from the energy and waste sec-tors.

In the UNFCCC Secretariat's agriculture sector, CH_4 gases are accounted for in the areas of enteric fermentation, manure management, rice cultivation, agricultural soils, prescribed burning of savannas and field burning of agricultural residues. However, in an analysis of GHG emission reports submitted by 43 countries, no country reports CH_4 emissions in agricultural soils and prescribed burning of savannas, and most emissions are in enteric fermentation and manure management. More than 80% of all agricultural GHG emissions are due to CH_4 emissions from enteric fermentation and N_2O emissions from soil. CH_4 from manure management is the third most important source of emissions [18].

Analysis of the information presented in Figure 1 shows that New Zealand stands out strongly in terms of CH_4 emissions. New Zealand experts report that its CH_4 emissions come from two agricultural sources - the enteric fermentation of cattle and sheep and their manure management [27]. In 2020, New Zealand had 36.9 million livestock such as sheep, dairy cattle, beef cattle and deer. Experts agree that the agricultural sector plays an important role in New Zealand's economy, but poorly managed livestock and agricultural production has a significant impact on the environment [28].

3.3 N_2O emissions

N_2O gas is a powerful greenhouse gas produced by microbes living in the soil. One molecule of N_2O in the atmosphere contributes almost 300 times more to climate change than one molecule of CO_2. This means that although much less N_2O is produced from soil, it still plays an important role in climate change [29], [30].

Human activities such as agriculture, fuel combustion, wastewater treatment and industrial processes increase the amount of N_2O in the atmosphere. N_2O gases are also naturally present in the atmosphere as part of the Earth's nitrogen cycle and have a variety of natural sources. N_2O gas molecules remain in the atmosphere for an average of 114 years before they are destroyed by chemical reactions. Globally, about 40% of all N_2O emissions are due to human activities. N_2O emissions come from agriculture, land use, transport, industry and other activities [2].

The UNFCCC Secretariat accounts for N_2O emissions in the agricultural sector in the following areas: manure management, agricultural soils, prescribed burning of savannas, field burning of agricultural residues. Of all the areas accounted for, only manure management and especially agricultural soils account for a significant share.

Agricultural soils are currently the main anthropogenic source of N_2O, as synthetic nitrogen (N) fertilisers and manure have been used more in the last century. With-out efforts to reduce emissions, atmospheric N_2O will continue to increase with the demand for agricultural products, threatening our ability to mitigate climate change and ozone depletion. Accurate estimates of N_2O emissions from agricultural soils are therefore essential to understand the magnitude of anthropogenic N_2O emissions and to develop effective solutions. This topic is particularly relevant given the recent policy emphasis on climate change mitigation through soil management [31].

From the information in Figure 1, it appears that Sweden stands out from other countries in terms of N_2O emissions, but this is not the case. Sweden's national ac-counting actually shows the highest emissions of N_2O of all GHGs, most of which come from the agricultural sector. Comparing the absolute and per capita N_2O emissions in the Swedish report, Sweden is slightly above average in terms of N_2O emissions.

3.4 Country trend: monitoring and management of GHG emissions in Lithuania

Lithuania is also part of the global climate change mitigation process and is one of the 195 countries in the world that have ratified the UNFCCC. The UNFCCC entered into force on 21 March 1994. The Kyoto Protocol (KP) was signed in 1998 and ratified in 2002. Under the Kyoto Protocol, Lithuania committed to reduce its greenhouse gas (GHG) emissions by 8% below 1990 levels during the first commitment period 2008-2012 and has fulfilled its commitment to reduce its emissions by more than 55% during this period [32].

In December 2012, at the Doha Climate Change Conference, Lithuania, as an EU Member State, together with the other Parties to the UNFCCC Kyoto Protocol, adopted the Doha Amendment, which establishes the second commitment period of the Kyoto Protocol, starting on 1 January 2013 and ending on 31 December 2020. The Doha Amendment amends Annex B of the Kyoto Protocol, which sets out further legally binding mitigation commitments for the Parties listed in that Annex for the second commitment period, and amends and further establishes provisions for Parties to implement their mitigation commitments during the second commitment period. The Union and its Member States agreed at the Doha Climate Change Conference on a quantified emission reduction commitment that limits their average annual GHG emissions to 80% of their base year emissions during the second commitment period [32].

In December 2015, 195 countries adopted the first global legally binding climate agreement at the Paris Climate Conference (COP21). The agreement sets out a glob-al action plan to help the world avoid climate change by limiting global warming to well below 2°C [32].

Lithuania signed the Paris Agreement on 22 April 2016 and ratified it on 30 December 2016. Under the Paris Agreement, Lithuania, together with the EU and its Member States, has set a binding target to reduce the country's economic greenhouse gas emissions by at least 40% of 1990 levels by 2030, which was endorsed in the European Council conclusions of 23 and 24 October 2014 on the EU's 2030 climate and energy policy framework. On 6 March 2015, the Council endorsed this contribution by the Union and its Member States as the Intended Nationally Determined Contribution (INDC), which was submitted to the UNFCCC Secretariat. The target will be achieved through the implementation of the EU legislation on the 2030 cli-mate and energy targets in all sectors of the economy, with reductions of 43% and 30% respectively by 2030 in the ETS and non ETS sectors compared to 2005 [32].

Although Lithuania is not the worst performer in terms of GHG emissions in the overall country context, an analysis of the sectoral data submitted to the UNFCCC Secretariat shows that in the agriculture sector, Lithuania is the fifth worst perform-er in terms of the percentage of GHG emissions from the agriculture sector (Fig. 4). Despite a 49.2% decrease in GHG emissions in agriculture between 1990 and 2020 [32], it remains a sector where GHG emissions account for a significant share of total emissions. The comparatively low attention paid to GHG reductions in the agricultural sector was also stated by a researcher at Vilnius University in 2020: 'While the energy sector, the waste sector, and renovation in Lithuania are moving in the right direction, the transport and agricultural sectors have not seen any progress' [33]. He also argues that in agriculture, exemptions for 'green' and 'red' diesel should disappear, the use of smokeless technologies should be more widespread, and the use of chemical fertilisers reduced.

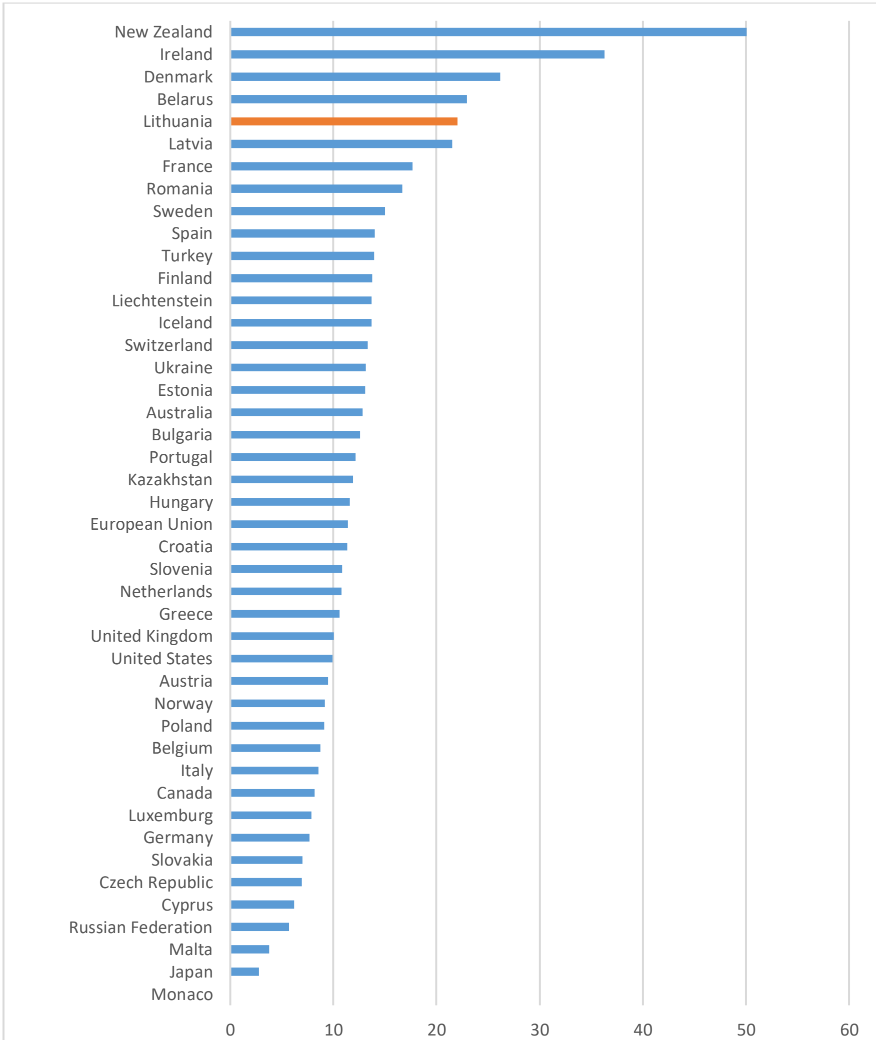

Figure 1. Percentage of GHGs in Agricultural sector (source: the authors)

In 2022, the Republic of Lithuania announced plans to implement measures to re-duce greenhouse gas emissions in the agricultural sector [34]. These measures cover 4 areas - thematic activities on land use and land use change, thematic activities on R&D and advisory services, thematic activities on livestock and thematic activities on forestry. Continuous monitoring is needed to ensure that the GHG emission reduction target is met in 2030 and that the measures have worked and contributed to GHG emission reductions.

4 CONCLUSIONS

This review article has helped us to understand what gases are considered GHG in general. The analysis of the reports submitted by Member States to the UNFCCC Secretariat clearly shows the sources of CO_2, CH_4, N_2O and fluorinated gases, which gases are relevant in which sectors, which are emitted most, and which should be given more attention or more frequent measurements in order to better understand the emission trends. It also highlighted some countries in the overall context as doing very well with emissions in certain sectors or vice versa, which should pay more attention to their national emissions. In this article, the presentation of statistical data on the map was especially useful, this way of visualizing the data very clearly highlights the regions that are statistically similar, and at the same time individual countries that have larger positive or negative deviations compared to other countries are also highlighted. As the future focus will be on the Lithuanian market and the proposed methodology for continuous monitoring of GHG emissions through the use of remote sensing, the analysis of the reports focused more on Lithuania. The analysis showed that Lithuania is not the worst performer in terms of GHG emissions in the overall context, but that the agricultural sector should receive more attention. As part of the country's response to this, it published in 2022 a list of measures that it hopes will help to reduce emissions from the agricultural sector over time.

Of course, the announcement of measures does not guarantee their effectiveness, so continuous monitoring of the situation is needed. Over the past few decades, the Earth Observation (EO) community has also provided significant support for monitoring GHG emissions. Governments and public bodies have strongly funded missions to monitor national and global GHG emissions using satellites. There are currently public, commercial or even hybrid satellites on the market for monitoring GHG emissions, but a broad analysis of all instruments is needed as most satellites have different characteristics. They may be designed to measure different gases, different regions, and the data obtained may have different accuracy and resolution. The analysis of satellite images in this work has shown that in many cases public satellites have too low a resolution and are not suitable for monitoring specific, relatively small objects. Also, satellites have passive sensors, which means that their data are suitable for further analysis if they are captured during the day and in un-cloudy weather, which can be problematic for a region like Lithuania, which has a large number of cloudy days per year.

Future work is planned to further investigate the characteristics and capabilities of the satellites available on the market, to clarify their applicability to the Lithuanian market and their suitability for continuous monitoring of the agricultural sector, and to develop a methodology for consistent and continuous monitoring of GHG emissions in the agricultural sector. It is crucial for policy makers to gain a full overview of existing and upcoming capabilities to improve GHG reporting and strengthen climate mitigation policy at all levels, with data from public and private satellite missions. Consistent and extensive research into existing technologies enables science-based decisions on emission mitigation at national and global level.

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