CARBON DIOXIDE EMISSIONS. HISTORY AND METHODS OF THEIR REDUCTION THROUGH DIFFERENTIAL AGRICULTURAL TECHNOLOGIES

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Abstract

Human (anthropogenic) influence, mostly generalized industry, intensive conventional agriculture, traffic and others, causes the increase of concentration of greenhouse gases to a level by which significantly more heat is radiated back to the earth than it was in the initial state. This is how climate warming occurs. At the international level, periodic inventories are carried out that show the fact that the biosphere absorbs, approximately, half of the anthropogenic CO_2 emissions, and at the terrestrial level, the carbon source and reserve is given by the northern hemisphere.
This study presents some results from the literature regarding the methods of C emissions reduction and its sequestration per surface unit, i.e. per hectare of agricultural crops, to increase the contribution of agriculture to environmental depollution. The used methods included searching of databases, such as Web of Science or Google Scholar, in order to identify some relevant results.
Reducing CO2 emissions can be achieved through biological, chemical and technological options, either by reducing or sequestering them.
Key words**: **carbon dioxide, emissions, reduction, agricultural technologies

INTRODUCTION

Climate change and global warming originate, on the one hand, from the accumulation of greenhouse gases in the atmosphere, especially from anthropogenic emissions and land use change (https://www.europarl.europa.eu/climate-change-the-greenhouse).

The most important greenhouse gas, carbon dioxide, contributes about 60% of the total greenhouse gas effect on global warming (Rastogi et al., 2002), so the atmospheric consequences show an increase from 280 ppm in the pre-industrial period, to 400 ppm in the year 2013 (Filonchyk et al., 2024; Rastogi et al., 2002). A forecast of various international studies showed that, depending on the calculation methods followed, it can be considered that by the year 2100, CO_2 could increase between 490-1370 ppm (Keidel et al., 2015).

Greenhouse gases are a natural component of the Earth's atmosphere. By storing geothermal heat, the air temperature is heated to an average of 33°C, compared to the earth's unobstructed thermal radiation into space. The effect is similar to the natural greenhouse effect, which prevents geothermal heat from escaping directly into space. Thus, part of the heat emitted on the ground is absorbed, it being radiated back (Schulze et al., 2002).

The absence of greenhouse gases would lead to the drastic cooling of the earth, so that human life would be almost impossible. Alongside climate impact, a range of regional and global political and economic factors intensify long term vulnerability in certain regions. Climate change in recent years, with extreme weather events, has had a negative influence on the agricultural production (Rosculete et al., 2019, 2021).

Modern biotechnology has a significant potential to contribute to food security and sustainable development (De Souza and Bonciu, 2022 a,b).

Understanding the complex interactions between genotype, the environmental conditions, and the specific agronomic and management conditions is crucial for the success of crop improvement programs (Dihoru et al., 2023; Rosculete et al., 2023; Iacob et al., 2023). Mitigating climate change means reducing the flow of heat-trapping greenhouse gases into the atmosphere (Bonciu, 2023a,b).

The agricultural sector is a significant contributor to global carbon emissions through the production and use of agricultural machinery, crop protection chemicals such as herbicides, insecticides, fungicides, and fertilizers. The proportion of the nation's global carbon footprint due to agriculture is approximately 8%, of which 75% is directly related to fertilizer use (Choudrie et al., 2008).

It is known that approximately three quarters of anthropogenic greenhouse gases are represented by carbon dioxide, which indicates that the reduction of CO_2 emissions plays a decisive role in climate protection. It is noted that carbon dioxide is naturally present in the air, humans and animals exhale it, while for trees and plants it is vital, through absorption, they in turn transform CO_2 into oxygen which is vital for mankind, humans and animals inhale the oxygen. This results in a circular cycle. The CO_2 problem consists in the fact that people, through their activities, generate CO_2 more and more rapidly and increasing, for example by burning oil, coal or natural gas, through generalized, multilateral industrialization, which disrupts the natural cycle.

MATERIALS AND METHODS

The main goal of this review was the presentation of some results from the literature regarding the methods of C emissions reduction and its sequestration per surface unit, i.e. per hectare of agricultural crops, to increase the contribution of agriculture to environmental depollution. The used methods included searching of databases like Web of Science or Google Scholar, in order to identify relevant results.

RESULTS AND DISCUSSIONS

History of carbon dioxide emissions

The most important greenhouse gases (GHG) were established by the Kyoto Protocol (Japan), following the International Conference with an impact on the international contracts concluded for climate protection in 1997 (the first mandatory period 2005-2012, and the second 2013-2020). Since 2021, the Paris Climate Conference has been held at the UN, which continued the foundations laid in Kyoto and aims to propose that global warming be below 2°C with a target of 1.5°C.

The most important greenhouse gases, according to the Kyoto protocol:

• CH_4 – Methane;
• CO_2 - Carbon dioxide;
• PFC - Perfluorinated carbon dioxide;
• HFC - Fluorocarbons containing hydrogen;

• NF_3 - Nitrogen trifluoride;
• SF_6 - Sulfur hexafluoride;
• N_2O - Nitrogen protoxide.

The most important greenhouse gas, carbon dioxide, contributes about 60% of the total greenhouse gas effect on global warming (Rastogi et al., 2002). A forecast of various international studies showed that, depending on the calculation methods followed, it can be considered that by the year 2100, CO_2 could increase between 490-1370 ppm (Keidel et al., 2015).

An iconic figure that represents global carbon dioxide emissions from 1850 to 2022 is enough to disturb our existence and to wonder where we will end up if no measures are taken (Vigna et al., 2024). Emissions increased in 2022 compared to 1850, by 182 times (Figure 1).

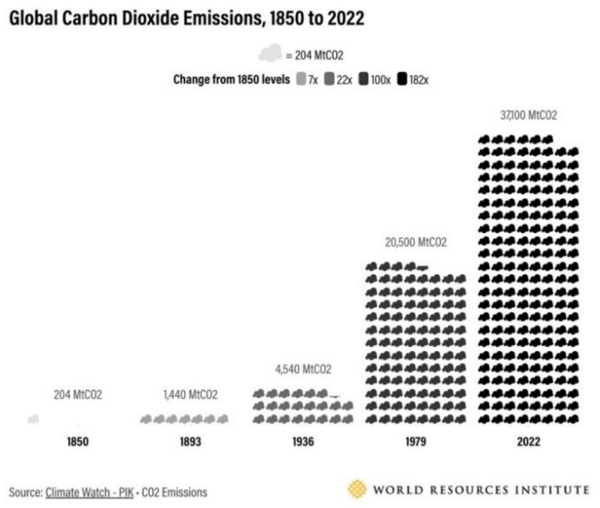

Figure 1. Global carbon dioxide emissions (1850-2022) (Climate Watch, by Vigna et al., 2024)

In 1850, the UK emitted the highest emissions. Coming to our days, it stands out as the country with the most significant CO_2 emissions - China followed by the USA, India, Russia and Japan. However, the USA has the highest amount of CO_2 emitted/person, being double the value of China and 8 times higher than India (Vigna et al., 2024). Reducing human-made greenhouse gas emissions has the effect of limiting global warming.

The absence of greenhouse gases would lead to the drastic cooling of the earth, so that human life would be almost impossible. Using Climate Watch – PIK (2024) as a source, the country ranking shows that the USA ranks first (794.5 Mt CO_2) followed by the UK (424.9 Mt CO_2) and Germany (348.7 Mt CO_2). In the top are also France, Poland, Belgium, Russia, Czech Republic and Austria, in that order.

Kanemoto et al. (2016) found that for most developed countries the carbon footprint has increased: for example, since 1970 the US carbon footprint has increased by 23% in land-based terms and by 38% in consumption-based terms, but by nearly 200% in spatial dimension (i.e., the minimum surface area required to contain 90% of emissions). In contrast, the rapidly growing carbon footprint of China and India show no such spatial expansion of their consumption footprints, despite their growing participation in the world economy. In their case, urbanization concentrates domestic pollution and this offsets the increasing importance of imports.

Variation between conventional, integrated and organic farming practices is used to explore alternative management factor combinations (Bonciu, 2022; Paunescu et al., 2023, 2021).

The main factors influencing the flow of carbon dioxide from the soil are:
- soil temperature
- soil moisture
- nitrogen in the soil
- soil reaction
- biotic factors
- the type of vegetation: in addition to the climate, the vegetation influences the carbon cycle through the process of photosynthesis and through the below- and

above-ground production of biomass (Raich and Schlesinger, 1992).

On a global scale, soil respiration rates are positively correlated with mean annual air temperatures and mean annual precipitation. There is a close correlation between mean annual net primary productivity of different vegetation biomes and their mean annual soil respiration rates, with soil respiration averaging 24% higher than mean annual net primary productivity. This difference represents a minimum estimate of the contribution of root respiration to the total soil CO_2 efflux (Raich and Schlesinger, 1992).

CO_2 capture and storage is gaining attention as an option for limiting CO_2 emissions from fossil fuel use. CO_2 capture is based on safe long-term storage in geological formations.

Carbon neutrality can be achieved by balancing carbon dioxide emissions with carbon removal, often achieved through carbon offsetting.

The importance of greenhouse gases in agriculture

In agriculture, several greenhouse gases are very important:

●Carbon dioxide: CO_2

The carbon dioxide molecule is based on the chemical formula CO2, which consists of one carbon atom and two oxygen atoms (wikipedia.org/wiki/Dioxid_de_carbon).

Carbon dioxide gas is known to be colourless, highly soluble in water, non-flammable, odourless and non-toxic. In addition to nitrogen, oxygen and the so-called noble gases, it is a natural component of air and is one of the most important greenhouse gases.

CO_2 emissions from agriculture come from the burning of fossil fuels for cars and transport, the use of synthetic fertilizers and the conversion of forest areas to agricultural land. Land management has a very important role in CO_2 release.

The flow of carbon dioxide from the soil or its movement through a complex and variable process of release is encountered in various specialized studies under the name of soil respiration (Abramoff et al., 2018; Beegum et al., 2023). Soil respiration is seen on a global scale as the second flux of CO_2 between the atmosphere and the terrestrial biosphere (Adachi et al., 2017).

Both regionally and globally, the flux of carbon dioxide is of particular importance in regulating the carbon cycle. Some results suggests that climate-driven losses of soil carbon are currently occurring across many ecosystems, with a detectable and sustained trend emerging at the global scale (Bond-Lamberty et al., 2018). A special significance that can significantly contribute to changes in the composition of CO_2 in the atmosphere is the minor changes in the rate of CO_2 flows from the soil, originating from climate changes (Rodrigues et al., 2023).

● Methane: CH_4

Methane emissions come from enteric fermentation (digestion by ruminants) and from the storage of organic materials such as manure.

It should be noted that conventional industrialized agriculture can also have a remarkable impact, although methane is not a particularly strong greenhouse gas.

● Nitrogen protoxide: N_2O

Nitrous oxide emissions come from agricultural sources that overuse nitrogen fertilizers, from organic fertilizers or even from sewage treatment plants, as well as other sources.

● Carbon monoxide (CO) and volatile organic compounds (VOC)

These gases can result from the burning of biomass and waste in agriculture, such as field burning or charcoal production.

Carbon sequestration

Sequestration of atmospheric carbon dioxide is necessary due to its increased concentration. The increase in atmospheric CO_2 emissions, along with global warming and environmental degradation, are driven by global energy demand (EPA Final Report, 2008). Compared to the emission of 300 Pg C between 1850 and 2000, the total emission during the 21st century is estimated to be 950 to 2195 Pg, with an annual emission rate of 20 to 35 Pg C y^{-1}. Reducing CO_2 emissions can be achieved through biological, chemical and technological options, either by reducing or sequestering them (Lal, 2008).

The interest remains predominantly towards carbon sequestration models in agricultural ecosystems, where we have greater possibilities of intervention (Berca, 2021).

The first measure is the retention of CO_2 in the soil and cultivated plants. For this we take into account that by reducing the work with agricultural machinery, we will reduce emissions. Burning 1 liter of diesel leads to emissions of 2.7-2.9 kg of CO_2. Through the classic soil work system, a minimum of 70 liters of diesel fuel/ha = 203 kg CO_2/ha is consumed. If the conservative works system is used, the consumption is reduced to 40 liters = 120 kg CO_2. If the "No-tillage" system is applied, consumption is reduced only at sowing = 20 l/ha, i.e. a maximum of 60 kg CO_2/ha, 3 times less than in the first case.

Through the degradation of soils, through erosion or humus burning, desertification can be reached. Combating them is also a factor in retaining C in the soil.

Afforestation, reforestation, greening - are just as many methods of processing CO_2 from the air and directing it to the soil.

In the conditions in which it is desired to obtain bioenergy from biomass, it is preferable to cultivate plants that provide us with a large amount of biomass (corn silage, beets, etc.). A large amount of biofuel will be obtained and an equally large amount of CO_2 uptake from the atmosphere and its storage in the soil (Vleeshouwers and Verhogen, 2002).

The final effect of the above will lead to the revival of ecosystems, to the improvement of the services they offer, to the revival of environmental factors (water, air, biodiversity) of a vital quality, much improved and close to ancestral natural models.

Since 1 t of dry matter represents between 400 and 500 kg of carbon on average, increasing production has a significant quantitative carbon sequestration effect (Hypolite, 2021).

The choice of crops will have an impact (peas < sunflower < winter cereals < corn) but also their performance.

Studies on carbon sequestration in different crops have been carried out by numerous researchers and the results have been widely differentiated (Jarechi and Lal., 2010; Ferreira et al., 2012; Freitas et al., 2014). Thus, in maize, Jarechi and Lal (2010) at a production of 4.33 t/ha established a carbon input brought with biological remains of 1.95 t/ha; Ferreira (2012) at a production of 8.90 t/ha established a carbon input brought with biological remains of 4.40 t/ha; Freitas (2014) at a production of 5.50 t/ha established a carbon input brought with biological residues of 2.72 t/ha. In wheat, the carbon input highlighted at productions of 2.69 t/ha, 5.50 t/ha was 1.82 t/ha, respectively 2.35 in the conception of the first two authors. To soy, at productions of 2.27 t/ha, 3.22 t/ha and 4.52 t/ha, the carbon brought by biological residues was 1.02 t/ha, 1.23 t/ha, respectively 4.3 t/ ha by Jarechi and Lal, Ferreira and Freitas. In sunflower, at a production of 3.14 t/ha, the carbon in plant residues was 1.10 t/ha (Freitas, 2014).

Calculations regarding the sequestered carbon in plants and soil

The biosphere is made up of all living things on the Earth's surface. It is constantly dynamic and it is extremely difficult to have even a modest measurement of its number and mass. Biomass has in its composition a green sequence, plants, algae, some microorganisms, organized in different ecosystems and which, by absorbing the energy of the Sun, carbon dioxide and water, form the first organic molecule - glucose, with which the composition of organic matter begins on planet.

The applications regarding the sequestration of C per surface unit, i.e. per hectare of agricultural crop, are necessary for the purpose of undertaking efforts to increase the contribution of agriculture to depollution and possibly the compilation of carbon certificates which already in America and, even in Europe, it trades at $15/ton.

The denominator may vary between 3.65 and 3.67 - according to different authors (Berca, 2021). This parameter is especially requested in the calculation of the carbon balance at any level.

1 ton CO_2 is absorbed by 50 trees/year
By burning fuels, are obtained: 1 ton of coal = 2.86 t of CO_2 1 m3 natural gas = 1.90 t CO_2 1000 liters of diesel = 2,460 t CO_2 1000 liters of gasoline = 2,392 t CO_2 1 ton of oil = 2.87 t CO_2 1000 tons of oil = 2,226 t CO_2

1 ton of straw retains 220 kg CO_2 = 60 kg C 1 ton of corn cobs/sunflower stalks - 230 kg CO_2 = 60 kg C 4.54 kg straw - 1 kg CO_2 = 0.06 kg C

1 ton of humus = 400 kg C = 1468 kg CO2 = 6.7 tons of straw

Carbon fixation through photosynthesis is very different from one crop to another and from one area to another.

According to Cesar Moto et al. (2010), in the Murcia area of Spain, the amounts of C fixed annually were as follows, for several crops also present in Romania:

Oats - 4.0 t/ha C	Lettuce - 6.5 t/ha C
Maize - 5.1 t/ha C	Tomatoes - 8.5 t/ha C
Barley - 4.8 t/ha C	Peach - 8.0 t/ha C
Cauliflower -10.0 t/ha C	Grapes - 4.7 t/ha C

Carbon is synthesized at terrestrial level in the form of glucose, through the two forms of photosynthesis, which we also have in our country: C1 and C4. The former is characteristic of plants from colder areas, such as cereals, peas, other legumes, fodder, etc., and the latter is typical of plants originating from warmer areas, such as corn, sorghum, and the like. All plants in tropical areas activates in C4.

Offsetting CO_2 emissions

Carbon offsetting is an important first step. For the future of the sustainable climate environment, it is essential to understand how the functioning of the ecosystem is altered by irrigated agriculture, applied technology and overall with the focus towards a sustainable agriculture.

It is known that agriculture is a sector that contributes to the release of greenhouse gases directly, through methane and nitrous oxide, but also indirectly through carbon dioxide from energy-consuming processes and land use changes.

It is concluded that reducing emissions and promoting sustainable agriculture are important in reducing global warming from the agricultural sector. Politically, at the European level, this topic has become a big debate, but it is still not materialized in stages and complete rules. One of the causes that are still not legally imposed on these controls and certifications is the lack of data, research and experimentation in this field.

CO2 certificates

CO_2 certificates are identical to carbon certificates or greenhouse gas emission certificates which represent the amount of emissions for which financial responsibility is assumed by supporting climate protection projects. They have the right to trade. One certificate corresponds to one ton of greenhouse gases.

According to the European Union and the United Nations, the quantitative measurement can be expressed through carbon certificates. These at the EU level have the right to come from annual allocations that the European Commission distributes to countries, EUA type Certificate (Emission Unit Allowance) as well as certificates based on the decisions of the United Nations, with the aim of reducing global carbon dioxide emissions or of other greenhouse gases.

Carbon certificates should not be confused with green certificates, which refer to certificates obtained as a result of renewable or green energy production.

CO_2 emission certificates could be granted to farmers who implement sustainable agricultural practices, serving both to protect the environment and to sustain and sustain economic growth. With the generation of tradable CO_2 certificates or carbon credits and their commercialization according to principles oriented towards the common good, the transformation of agriculture towards a climate-positive economy or at least to support climate protection will be decisively promoted.

The motivation of farmers to reduce emissions through good agricultural practices, such as through an ecological farming system, using land sustainably and implementing sustainable practices through reforestation, soil protection, biodiversity conservation, animal protection, is an important and decisive aspect in researching the aspects regarding the criteria for the development of CO_2 emission certificates. At the same time, the aspect of protection and the possibility of working in traditional, sustainable agriculture must also be taken into account, which also takes into account the preservation of traditions, customs and social aspects of the community, which is an important and decisive aspect in the research of the aspects regarding the criteria for the elaboration of certificates of CO_2 emission.

The European Commission has launched and actively promotes low-carbon agriculture to really encourage farmers and foresters to adopt sustainable carbon storage and sequestration solutions and to recognize their key role in supporting climate ambition. Incentives can come from PAC funds (within strategic national plans), from other public funds or from private resources.

Romania's National Strategic Plan contains interventions specifically designed to stimulate such practices, for example part of the eco-schemes of Pillar I, and some agri-environmental commitments from Pillar II. The ecoscheme applicable in arable land provides obligations regarding the soil coverage during the most sensitive period of the year on at least 85% of the surface, the allocation of a percentage of at least 5% for nitrogen-fixing crops and, optionally, the practice of minimum soil work by half from the arable surface, diversifying crops or planting at least 2 trees/ha, with the aim of increasing biodiversity (https://forumulappr.ro/carbon).

Monitoring carbon uptake is challenging due to specific characteristics such as the impermanence of soil carbon and the uncertainty of measurements. To address these challenges, an initiative on carbon sequestration in agricultural soils and a framework for certification of carbon uptake is being worked on. These initiatives aim to harmonize the quantification of carbon sinks as a basis for effectively rewarding terrestrial climate actions.

CONCLUSIONS

At the international level, periodic inventories are carried out that highlight the fact that the biosphere absorbs, approximately, half of the anthropogenic CO_2 emissions.

The agricultural sector is a significant contributor to global carbon emissions through the production and use of agricultural machinery, crop protection chemicals such as herbicides, insecticides and fungicides, and fertilizers.

Due to the presence of greenhouse gas in large amount, plants cannot convert enough CO_2 and the rest remains in the atmosphere, which causes the danger of unnatural global warming, causing climate change. In conclusion, one can understand the major importance of reducing CO_2 and other greenhouse gases in the atmosphere.

Land management has a very important role in CO_2 release. Thus, land management practices aimed at (maintaining and) improving soil health on arable land (humus consolidation management measures) can increase soil carbon content and stimulate carbon sequestration. Such practices can be supported under the agri-environment and climate measure, with many Member States activating such support in their rural development programmes.

Reducing CO_2 emissions can be achieved through biological, chemical and technological options, either by reducing or sequestering them.

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