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RESEARCH ON THE MANAGEMENT OF CARBON DIOXIDE EMISSIONS AND SEQUESTRATION BY DIFFERENT CROPS, DEPENDING ON THE AGRICULTURAL TECHNOLOGIES APPLIED

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Abstract

The carbon footprint calculation was carried out based on the technological data of each crop sown 2023 and 2024 in 3 farms: Terra Nostra Farm Băilești - organic technology, Trăistaru Farm Băilești - conventional technology and Sonnenhof Farm Wolpertshausen - Germany - Demeter organic technology. At Terra Nostra Farm, the calculation was carried out for corn, wheat, soybean and alfalfa crops. At Trăistaru Farm, corn, wheat and sunflower crops were analyzed. Lentil + camelina, spelt wheat, mustard, coriander, alfalfa crops were studied at the Farm in Germany. The carbon emitted through works and inputs from the crops at the Farm in Germany were grouped as follows: lentils + camelina, eco mustard, coriander - values around 500 kg CO_2/ha and eco spelt and eco alfalfa - values around 1000 kg CO_2/ha. There were no differences in the carbon sequestered by corn depending on the technology applied. In wheat, a yield of 3000 kg/ha obtained at the Terra Nostra Farm sequestered a much smaller amount of carbon than the 5500-6000 kg/ha yields from the German Farm.

Key words: *carbon footprint; conventional technology; organic technology Demeter; carbon dioxide emissions; carbon sequestered.*

INTRODUCTION

Climate change resulting in global warming stems, in part, from the accumulation of greenhouse gases in the atmosphere, mainly from anthropogenic emissions and land use change (IPCC, 2013). The most important greenhouse gas, carbon dioxide, contributes approximately 60% of the total greenhouse gas effect on global warming (Rastogi et al., 2002), thus the consequences on the atmosphere show an increase from 280 ppm in the pre-industrial period to 400 ppm in the year 2013 (Rastogi et al., 2002; Rapp, 2014). A forecast of various international studies has shown that, depending on the calculation methods used, it can be considered that by the year 2100, CO_2 could increase between 490-1370 ppm (Keidel et al., 2015).

Human-produced greenhouse gas emissions must be reduced to limit global warming.

The most important greenhouse gases (GHGs) were established by the Kyoto Protocol (Japan), following the International Conference on Climate Change in 1997. The first mandatory period was 2005-2012, and the second was 2013-2020. In 2021, the Paris Climate Conference organized by the UNO took place, which continued the foundations laid in Kyoto with the objective of limiting global warming to below 2°C with a target of 1.5°C.

The most important greenhouse gases, according to the Kyoto Protocol, are: CH_4 - methane; CO_2 - carbon dioxide; PFC - perfluorinated carbon dioxide; HFC - hydrogen-containing fluorocarbons; NF_3 - nitrogen trifluoride; SF_6 - sulphur hexafluoride; N_2O - nitrous oxide.

The impact of all the gases mentioned above on the climate is reflected in the greenhouse effect, which influences global climate change. Soil organic carbon is of particular importance for ecosystems (Batjes, 1996; Nadelhoffer, 2004). It is known globally that soils, especially in forest areas, contain three times more carbon than exists in the atmosphere, but compared to the total terrestrial reserve in the biosphere, soils contain four and a half times more (Lajtha et al., 2014), which represents a higher carbon content than the atmosphere and plants combined (Jobbagy et al., 2000).

The flow of carbon dioxide from the soil of ecosystems plays a special role, carbon dioxide being released from the soil through the process of respiration or the so-called movement of carbon dioxide in the soil (Raich and Schlesinger, 1992; Lu et al., 2017). An important part of soil respiration is represented by autotrophic respiration (FCO_2) through roots and mycorrhizae, which is strongly reflected in plant metabolism (Berger et al., 2010). Autotrophic respiration shows interannual and intra-annually differences and the type of vegetation, climatic conditions and soil characteristics are factors that determine the variability of autotrophic respiration (Epron et al., 2012). The amount of CO_2 produced by root respiration is determined by the biomass of the roots and their respiration rate (Epron et al., 2001).

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. Organic farming has a positive impact on the environment, because it promotes the responsible and sustainable use of energy and natural resources and preserving biodiversity (Bonciu, 2022; 2023; Bonciu et al., 2022; De Souza, 2022; Paunescu et al., 2023).

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).

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

Carbon sequestration in the terrestrial ecosystem, in our case in agroecosystems, begins with a priority of refraining from creating and releasing as few CO_2 emissions into the atmosphere as possible and, if possible, reducing them completely (Topham, 2011; Pietantozzi, 2003).

The first measure is to retain CO_2 in the soil and cultivated plants. For this, we take into account that by reducing work with agricultural machinery, we will reduce emissions. Burning 1 litre of diesel leads to emissions of 2.7-2.9 kg of CO_2. With the classic soil work system, a minimum of 70 litres of diesel/ha = 203 kg of CO_2/ha is consumed. If the conservative work system is used, consumption is reduced to 40 litres = 120 kg of CO_2. If the "No-tillage" system is applied, consumption is reduced only during sowing = 20 l/ha, i.e. a maximum of 60 kg of CO_2/ha, 3 times less than in the first case. About 180 kg of CO_2 remained in the soil CO_2 pool.

Studies on carbon sequestration in different crops have been carried out by numerous researchers and the results have been very different (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 residues of 1.95 t/ha; Ferreira (2012) at a production of 8.90 t/ha established a carbon input brought with biological residues of 4.40 t/ha; Freitas (2014) at a production of 5.50 t/ha established a carbon input 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. In soybean, at productions of 2.27 t/ha, 3.22 t/ha and 4.52 t/ha, the carbon brought through biological residues was 1.02 t/ha (Jarechi and Lal, 2010), 1.23 t/ha (Ferreira et al., 2012), respectively 4.3 t/ha (Freitas et al., 2014). In sunflower, at a production of 3.14 t/ha, the carbon from plant residues was 1.10 t/ha (Freitas et al., 2014).

INRA published in July 2019 a summary on carbon sequestration. The main conclusions stated were: the transition to direct sowing remains a topic "still controversial" in the carbon issue. If we consider the entire soil profile, the transition from ploughing to direct sowing would have no effect on the total C stock in the soil. There is, however, a positive result because organic matter is often transformed into stable humus on "poor" C soil. The net gain is an average of +59 kg C/ha/year. Since 1 t of dry matter represents between 400 and 500 kg of carbon on average, the increase in production has a significant quantitative carbon capture effect (Hypolite, 2021).

The choice of crops will influence the carbon emission (peas < sunflower < winter cereals < maize) but also their productive performance.

MATERIALS AND METHODS

Based on the technological sheets for each crop, from each farm analysed (Terra Nostra Ecoland organic-biodynamic Demeter Farm Băilești, Trăistaru Conventional Farm and Sonnenhof organic-biodynamic Demeter Farm), the tables with the work performed and diesel consumption were completed according to the model presented by Berca (Berca, 2021).

Based on the biomass (sample taken from each crop), the harvest index but also the defining parameters of the stored carbon, the carbon sequestered by the crops studied in 2023 and 2024 was calculated (Table 1).

Table 1. Defining parameters of carbon stored by different crops, in different parts of the plant (crop). Biomass and carbon stocks, excluding storable crops

No. Crt.	Crops	Number of tests performed	Biomass (t/ha)				Carbon stock (t/ha)				Substance Organic Carbon SOC (humus C) t/ha
			Total plant	Roots (R)	Overground (S)	R/S	Total plant	Roots (R)	Overground (S)	R/S	
1	Perennial herbs	29	19.80	10.70	9.10	1.17	6.80	3.60	3.20	1.12	50
2	Maize	60	11.20	5.20	6.00	0.87	6.30	2.56	3.74	0.68	80 (asol. soybean)
3	Sorghum	26	9.50	1.90	7.60	0.25	4.20	1.10	3.10	0.35	40
4	Autumn wheat	57	9.40	2.10	7.30	0.29	2.40	0.80	1.60	0.50	40
5	Triticale	3	9.60	3.20	6.40	0.50	-	-	-	0.58	-
6	Soybean	52	4.10	1.10	3.00	0.37	3.00	1.10	1.90	0.58	80 (asol. maize)
7	Peas	18	3.80	1.50	2.30	0.65	1.10	0.30	0.80	0.38	38
8	Sunflower	8	3.90	1.50	2.40	0.63	1.20	0.40	0.80	0.50	30
9	Rapeseed	12	4.20	1.20	3.00	0.40	1.80	0.30	1.50	0.20	30

Source: Mathew I. et al., 2017 - What crop type for atmospheric carbon sequestration: Results from a global data analysis. Agriculture, Ecosystems & Environment, 243: 34-46.

Starting from the values obtained for each of the calculated indicators, a graphic representation was made for the carbon footprint of the crops on each farm and then a comparison was made between farms for the common crops.

The calculations were made for: carbon emitted from field operations and from inputs, carbon emitted through burned diesel, carbon sequestered by the crop, carbon fixed from the atmosphere, the amount of humus C brought into the soil.

For the Terra Nostra Ecoland organic-biodynamic Demeter Farm in Băilești, the calculation was made for maize, wheat, soybean and alfalfa crops, they were treated with Demeter products.

At the Trăistaru Conventional Farm, maize, wheat and sunflower crops were analysed.

The crops of lentils + camelina, spelt wheat, mustard, coriander, alfalfa crops were studied at the organic-biodynamic Demeter Farm in Wolpertshausen - Germany, they were treated with Demeter products.

For each crop, the following scheme was followed according to the Berca model (2021):

K=0.2 - coefficient calculated for agricultural crops

1. Carbon emitted by field operations = (carbon emitted by field operations + carbon emitted by field operations) x k = carbon emitted x t harvest = carbon emitted by field operations.

TOTAL CARBON EMITTED (kg/ha) = carbon emitted by field operations + carbon emitted by inputs.

Calculated in CO_2 (kg/ha) = TOTAL CARBON EMITTED x 3.67 (transformation coefficient) = kg equivalent CO_2 /ha.

The carbon emitted depending on the inputs used was that established by Lal (2004) and mentioned by Hillier et al. (2009):

- for nitrogen fertilizers - 2.96 kg carbon emitted/ha;

- for potassium fertilizers - 0.2 kg carbon emitted/ha;
- for plant protection with herbicides - 6.3 kg carbon emitted/ha;
- for plant protection with insecticides - 0.36 kg carbon emitted/ha;
- for plant protection with fungicides - 3.16 kg carbon emitted/ha.

2. Calculation by the amount of diesel burned/ha
TOTAL CO_2 Kg/ha = TOTAL DIESEL BURNED * 2.7 (transformation coefficient)
TOTAL CO_2 (kg/ha): carbon emitted through inputs x 3.67 (multiplication coefficient) = kg/ha + TOTAL CO_2 by the amount of diesel burned = kg CO_2 equivalent/ha

3. CARBON SEQUESTERED BY CROP (according to Mathew et al., 2017) – the biomass is established by the sample taken from the field and is calculated according to the defining parameters of the carbon deposited by different crops, in different parts of the plant (crops). Biomass and carbon stocks, excluding storable crops.

4. CARBON FIXED IN THE AIR:
To calculate the carbon fixed in the atmosphere, we started from the biomass production (overground and underground part):

➢ t grains x 0.45 (45% carbon) = t C (stored quantity removed from the system);
➢ t straw, stalks, stems, grasses x 0.44 (44% carbon) = t C;
➢ t roots x 0.43 (43% carbon) = t C.

TOTAL : t residual biomass (straw, etc. + roots) = t C.
30% of this carbon is returned to the atmosphere through respiratory processes and other losses.
Knowing that 1 t C = 0.34 t humus C, it is shown that 1 ha of crop brings a net quantity of t humus C to the soil.

RESULTS AND DISCUSSIONS

At the organic-biodynamic Demeter Băilești farm, on average over the 2 years, the highest amount of CO_2, expressed in kg/ha, was recorded by the alfalfa crop at an average production of 8500 kg/ha and the lowest by soybean at an average production of 1000 kg/ha, the amplitude being 306.99 kg/ha CO_2 (Figure 1). Very close to the maximum value of CO_2 was the amount of carbon dioxide emitted by the maize crop.
The amount of CO_2 emitted by the burned diesel is very close in value regardless of the crop, which suggests that the field operations do not differ much and the consumption is very close. Also, from the comparison with the carbon emitted by field operations and inputs, it was observed that the latter is quantitatively higher in maize and alfalfa compared to wheat and soybean (Figure 2).

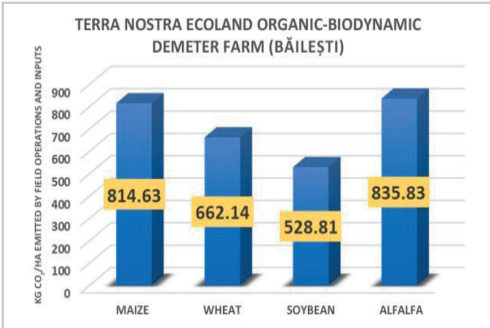

Figure 1. Carbon emitted through field operations and inputs to crops at Terra Nostra Ecoland organic-biodynamic Demeter Farm (Băilești) - average for 2023+2024

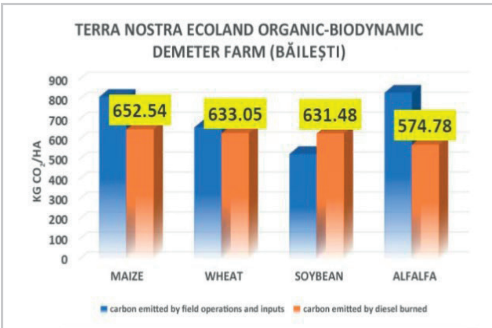

Figure 2. Carbon emitted through field operations and inputs compared to that emitted through diesel burned in crops at Terra Nostra Ecoland organic-biodynamic Demeter Farm (Băilești) - average for 2023+2024

Based on the analysis of global data on atmospheric carbon sequestration carried out by Mathew and his collaborators in 2017, starting from biomass samples and the harvest index calculated for each crop, the carbon sequestered by them was established (Figure 3).

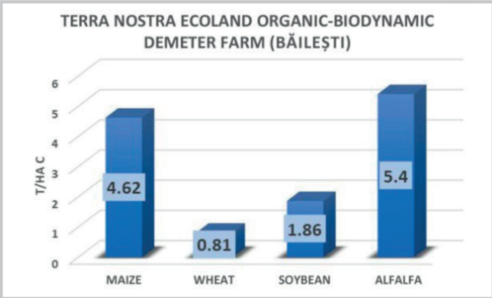

Figure 3. Carbon sequestered by crops at Terra Nostra Ecoland organic-biodynamic Demeter Farm (Băilești) - average for 2023+2024

For maize, the harvest index was 0.50, for wheat 0.55 and for soybean 0.38. On average, over the two years, organic - biodynamic Demeter maize had the highest amount of carbon sequestered, followed by alfalfa, wheat and soybean.

After the crop is stored and removed from the system, carbon fixed from the atmosphere by the aboveground and underground parts remains. Of this, 30% is lost to the air through respiration processes. Logically, the values of carbon lost through respiration are proportional to the amount of carbon fixed by each crop (Figure 4).

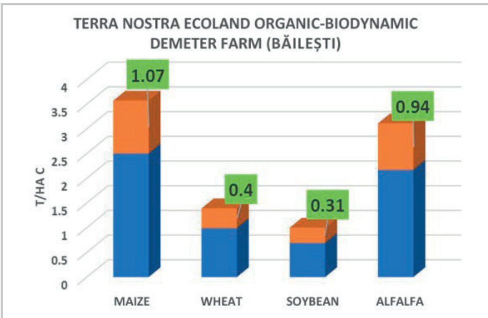

Figure 4. Carbon fixed from the atmosphere by crops at Terra Nostra Ecoland organic-biodynamic Demeter Farm (Băilești) / carbon released through respiration - average for 2023+2024

At the Trăistaru Conventional Farm, also located in Băilești, the carbon emitted through field operations and inputs had the highest values for maize and wheat compared to that emitted at the other farms studied. Also, the differences between the first two crops (maize and wheat) were insignificant.

For sunflower, we did not have a comparison period, but we can mention that this is a more environmentally friendly crop, the amount of carbon emitted being less than half of the other two crops (Figure 5).

It was observed that the burned diesel emits carbon close to the level emitted by the field operations and inputs to the conventional technology applied to this Farm (Figure 6).

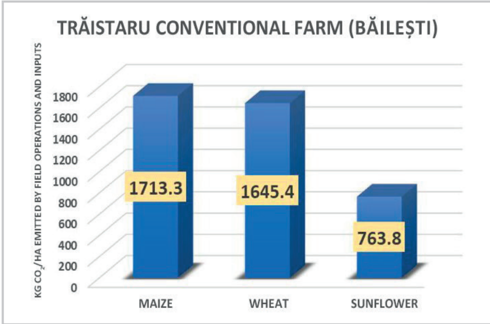

Figure 5. Carbon emitted through field operations and inputs to crops at the Trăistaru conventional Farm (Băilești) - average for 2023+2024

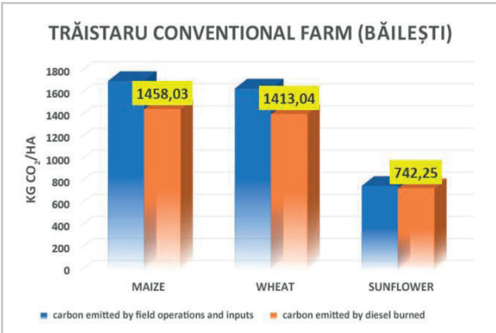

Figure 6. Carbon emitted through field operations and inputs compared to that emitted through diesel burned in crops at the Trăistaru Conventional Farm (Băilești) - average for 2023+2024

The carbon emitted in large quantities when conventional technology is applied is mainly due to the inputs that are very large and diverse (NP fertilizers, fungicides, herbicides, insecticides, foliar fertilizers). While in conventional the carbon emitted by these has values around 330 kg/ha, in organic-biodynamic Demeter the values are almost identical - 126 kg/ha.

The carbon sequestered by crops is high in maize, especially due to biomass (Figure 7). According to data from Mathew et al. (2017), at a biomass of 11.2 t/ha, the carbon stock is 6.3 t/ha. In our case, at a biomass of 7.69 t/ha, the carbon stock

was 4.32 t/ha. Biomass does not include storable crops.
Carbon lost through respiration on conventional farms is approximately equal in maize and wheat, but almost halved in sunflowers (Figure 8).

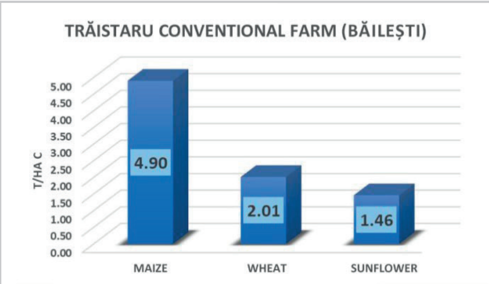

Figure 7. Carbon sequestered by crops at Trăistaru conventional Farm (Băilești) - average for 2023+2024

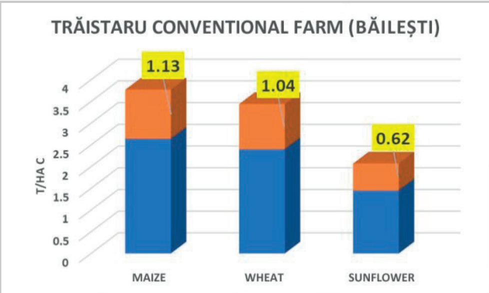

Figure 8. Carbon fixed from the atmosphere by crops at the Trăistaru conventional Farm (Băilești) / carbon released through respiration - average for 2023+2024

The carbon emitted through field operations and inputs (only organic-biodynamic Demeter products) from the crops sown at the Farm in Germany were grouped as follows: organic-biodynamic Demeter lentils + camelina, organic-biodynamic Demeter mustard, organic-biodynamic Demeter coriander – values around 500 kg CO_2/ha and for organic-biodynamic Demeter spelt wheat and organic-biodynamic Demeter alfalfa – values around 1000 kg CO_2/ha. This is due to the much higher average productions of wheat (5750 kg/ha) and alfalfa (9250 kg/ha), the transport of the production to these requiring a higher consumption of diesel (Figure 9).
With the exception of alfalfa, all crops had a similar diesel consumption and implicitly the carbon emitted by its combustion was practically equal (Figure 10).

At the Sonnenhof organic-biodynamic Demeter farm, the largest amount of carbon sequestered was in the alfalfa crop, which also recorded a high production compared to the other crops, with a value practically 4 times higher (Figure 11).
In descending order, it was followed by organic-biodynamic Demeter coriander, lentils+camelina, mustard and spelt wheat, also in organic-biodynamic Demeter system.

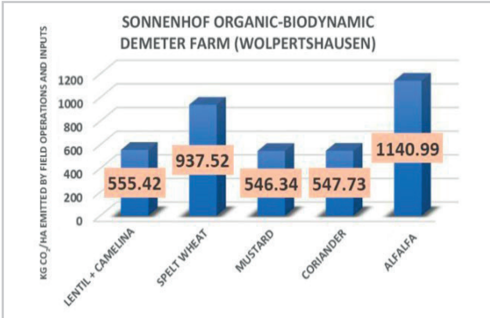

Figure 9. Carbon emitted through field operations and inputs to crops at Sonnenhof organic-biodynamic Demeter Farm Wolpertshausen - average for 2023+2024

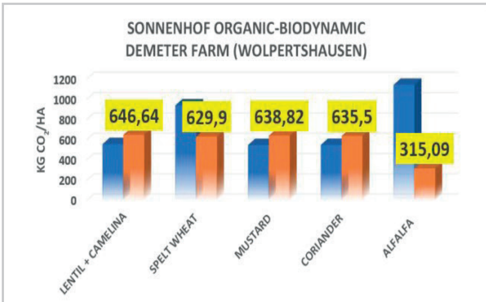

Figure 10. Carbon emitted through field operations and inputs compared to that emitted through diesel burned at Sonnenhof organic-biodynamic Demeter Farm Wolpertshausen crops - average for 2023+2024

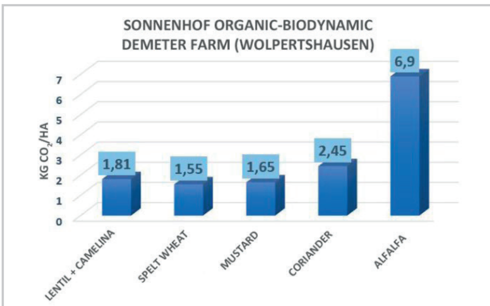

Figure 11. Carbon sequestered by crops at Sonnenhof

organic-biodynamic Demeter Farm Germany - average for 2023+2024

The carbon released through respiration, representing 30% of that fixed in the atmosphere, presents a decreasing sequence modified from the previous one, mustard being the last (Figure 12).

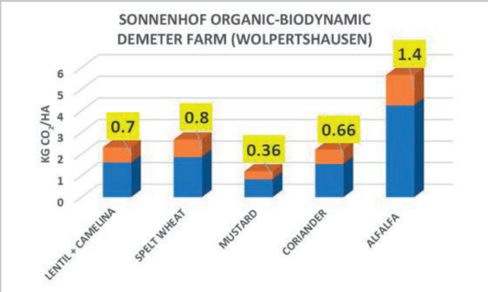

Figure 12. Carbon fixed from the atmosphere by crops at Sonnenhof organic-biodynamic Demeter Farm Germany / carbon released through respiration - average for 2023+2024

Comparatively, the carbon emitted through field operations and inputs to the maize crop, between the organic-biodynamic - technology applied at the Terra Nostra Ecoland Farm in Băilești and the conventional technology applied at the Claudiu Trăistaru Farm also located in Băilești, shows us that in the latter, the amount is practically double. In the wheat crop, in the conventional system, the carbon emitted is almost triple compared to the organic-biodynamic Demeter technology applied at Băilești and represents approximately 70% of the carbon emitted in the spelt wheat cultivated in the organic-biodynamic Demeter system at the Farm in Wolpertshausen - Germany (Figure 13).

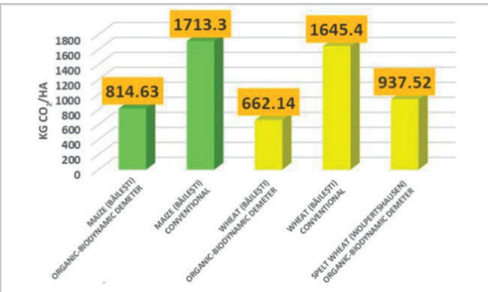

Figure 13. Carbon emitted through field operations and inputs to maize and wheat crops depending on the technology applied to the farms studied - average for 2023+2024

Regarding the carbon emitted calculated based on the burned diesel, the conventional amounts are equally high, the proportion being over 200% for both the maize and wheat crops. The only difference is that for the wheat crop, the carbon emitted at the Terra Nostra Ecoland Farm in Băilești - Romania and the Sonnenhof Farm in Wolpertshausen - Germany is practically equal in terms of quantity (Figure 14).

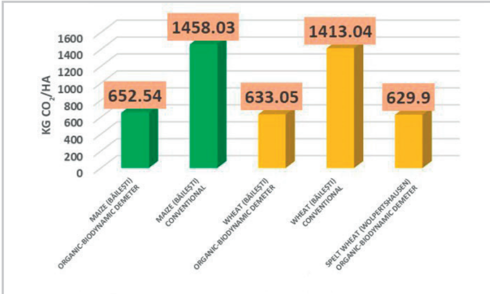

Figure 14. Carbon emitted through diesel burned in maize and wheat crops depending on the technology applied on the farms studied - average for 2023+2024

There were no differences in the carbon sequestered by maize crops depending on the technology applied, since the biomass was similar and the yields were equal – 5000 kg/ha. In contrast, for wheat, a crop with an average yield of 3000 kg/ha and the corresponding biomass obtained at Terra Nostra Ecoland Farm sequestered a much smaller amount of carbon than the crops from the conventional Traistaru farm and Sonnenhof German Farm where the yields were 5500 and 5750 kg/ha, respectively (Figure 15).

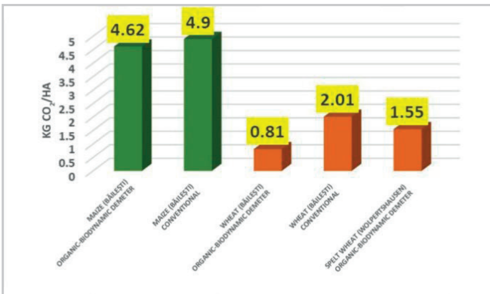

Figure 15. Carbon sequestered by maize and wheat crops on the studied farms - average for 2023+2024

CONCLUSIONS

By comparison, the carbon emitted through field operations and inputs to the maize crop, between the organic-biodynamic Demeter technology applied at the Terra Nostra Ecoland Farm in Băilești and the conventional technology applied at Claudiu Trăistaru Farm also located in Băilești, shows us that in the latter, the quantity is practically double.

In the wheat crop, in the conventional system, the carbon emitted is almost triple compared to the organic-biodynamic Demeter technology applied at Băilești and represents approximately 70% of the carbon emitted by the spelt wheat cultivated in the organic-biodynamic Demeter system at the Sonnenhof Farm in Germany. Regarding the carbon emitted calculated based on the burned diesel, in the conventional system the resulting quantities are equally high, the proportion being over 200% for both the maize crop and the wheat crop.

The only difference is that in the wheat crop, the carbon emitted at the Terra Nostra Ecoland Farm and the Sonnenhof Farm in Germany is practically equal in terms of quantity. There were no differences in the carbon sequestered by maize crops depending on the technology applied, because the biomass was similar and the yields were equal - 4750-5000 kg/ha.

In contrast, in wheat, a crop with a production of 3000 kg/ha and the corresponding biomass obtained at the Terra Nostra Ecoland Farm sequestered a much smaller amount of carbon than the crops from the conventional and from the Sonnenhof farm in Germany where the yields were 5500-5750 kg/ha.

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