THE CONCEPT OF CARBON CREDITS IN AGRICULTURE: A REVIEW OF LITERATURE

Constantin Dragoş DUMITRAŞ [1], Alexandru Sorin TUDORAN [1], Gavril ŞTEFAN [1],

e-mail: dragos.dumitras@iuls.ro

Abstract

One of the major concerns of the 21st century is climate change, which has a significant impact on sustainable development strategies and the global economy. In this regard, the carbon credit market has become a key tool in efforts to reduce greenhouse gas emissions and accelerate the shift towards a low-carbon economy.
This work presents a literature study that emphasizes the discrepancies in the current understanding of carbon credits in agriculture. The approach will focus on a detailed analysis of the relevant terms and concepts, highlighting the connections and interdependencies among them and emphasizing their importance within the carbon market framework. Thus, carbon credits are primarily intended to provide businesses with a financial motivation to implement strategies to reduce greenhouse gas (GHG) emissions and to switch to environmentally friendly and more sustainable operations in industries like manufacturing and agriculture.
The paper's findings highlight the three key areas of study for experts in the field of carbon credits: carbon trading, carbon markets, and carbon sequestration.

Keywords: GES, carbon sequestration, carbon credits, regenerative agriculture

As global warming intensifies, climate change mitigation has transitioned from a prospective necessity to an immediate imperative. The rise in anthropogenic CO_2 emissions represents a primary driver of global warming, thereby prompting increased scholarly and policy attention toward the pursuit of carbon neutrality.

Agriculture, as a sector essential to food security, makes a significant contribution to global greenhouse gas (GHG) emissions, thereby necessitating the establishment of robust methodologies for the estimation and monitoring of these emissions, along with efficient and transparent reporting systems (Ken EG, *et al.,* 2021).

The growing awareness of climate change and global warming acknowledges CO_2 emissions and other greenhouse gases as potential drivers contributing to climate change, which poses significant risks to individuals, economies, and livelihoods. The Paris Agreement, in force since 2016, aims to limit global warming to 1.5 degrees Celsius in order to achieve a climate-neutral world by the middle of the century.

Agriculture is the economic sector capable of sequestering greenhouse gases from the environment while simultaneously maintaining productivity. Within agriculture, conditions can be created that foster synergies between mitigation and adaptation strategies. (Vershuuren J., 2018)

Within the suite of financial instruments designed to reduce carbon emissions—including credits, bonds, insurance schemes, and trading mechanisms—carbon trading emerges as the most pivotal in terms of investment and financing. In the landscape of the construction and functioning of the global carbon market, the European Union (EU) carbon market stands out as the most successful in terms of institutionalization, the development of mechanisms, and the achievement of multiple objectives, including the monitoring of performance in reducing carbon emissions. Its experience in efficient operation and governance constitutes a benchmark and reference framework for other jurisdictions and organizations engaged in climate change mitigation efforts. (Z. Rui, 2017)

In 1968, the American economist J.H. Dales outlined the concept of emission rights in his monograph *Pollution, Property and Prices*, building upon Ronald Coase's theory of property rights. This proposal emerged as the outcome of an in-depth theoretical exploration. The fundamental idea expressed in this work asserts that the government, as the representative of public

[1] Ion Ionescu de la Brad Iasi University of Life Sciences, Iasi, Romania

interests and custodian of environmental resources, may trade emission rights for certain pollutants, such as stocks, to the highest interested bidder. This approach is grounded in the principle that the efficient allocation of emission rights can establish a market mechanism that incentivizes pollution reduction and fosters a more efficient use of natural resources, in line with the principles of a market economy. (J.H. Dales, 2002)

The relationship between climate change and carbon credits is fundamental to understanding how this global challenge is addressed. Carbon credits constitute a powerful instrument for incentivizing the reduction of greenhouse gas emissions and for financing sustainable development initiatives.

As early as 2012, Ștefan G. emphasized in his article that the economy was at the outset of a stage of structural transformations, a development that gave rise to the emergence of new economic theories. (Stefan, 2012)

Accelerated economic development, unprecedented population growth, and rapid industrialization have exerted significant pressure on the global ecosystem through the depletion of limited renewable resources and the introduction of inadequate, toxic, and non-recyclable products, thereby undermining the environment's capacity to sustain the ecological balance essential for the survival of species, including humans.

Addressing climate change, driven by the accumulation of atmospheric pollutants, is an essential endeavor that requires translating global policy imperatives into applicable solutions across all economic sectors. (N. Lokuge, 2022)

CARBON CREDITS AND MECHANISMS OF IMPLEMENTATION IN AGRICULTURE

The justification for a carbon certificate is straightforward. A company that is unable to halt its CO_2 emissions, yet wishes or needs to continue its activities, must purchase carbon certificates from the carbon market, thereby enabling another entity (a project developer) to undertake CO_2 emission reductions. In this scenario, although a company continues to emit CO_2, the overall global concentration of carbon in the atmosphere decreases.

Speculative investors, such as brokers, dealers, and exchanges, participate in the carbon market by acquiring carbon emission certificates as intermediaries. Final buyers may obtain carbon permits either directly from them or from project developers. The revenues generated from the sale of certificates provide financial support to the projects that produce them, thereby fostering new emission reduction initiatives.

Consequently, they are essential to climate change mitigation initiatives, providing economic incentives for emission reductions and facilitating the transition toward a low-carbon economy. They are frequently employed by businesses and nations to meet emission reduction targets, comply with regulations, or demonstrate environmental responsibility.

By promoting the reduction of greenhouse gas emissions in an economically viable manner, carbon credits play a pivotal role in the global transition toward a low-carbon economy, while at the same time providing a flexible and adaptable framework for companies and governments in their efforts to combat climate change.

THE EXTENT OF CARBON SEQUESTRATION THROUGH SUSTAINABLE AGRICULTURAL TECHNOLOGIES

The most accurate method for determining changes in soil carbon content within a given area is the collection of physical samples and the quantification of carbon levels before and after the change in practice.

Financial intermediaries employ mathematical models to forecast the amount of soil organic carbon generated by specific changes in agricultural land management practices. The predictive capabilities of these models are still in the testing phase. Thus, the scientific literature highlights the relationships between agricultural systems and the amount of carbon sequestered in soils (*table 1, table 2, table 3, and table 4).*

Tabel 1

Algorithms for quantifying practices across three tillage systems in wheat crop

Indicator	What does it represent?	Intervals		
		Conventional Tillage System	Minimum Tillage System	No-Tillage System
Dry matter fraction of the product	Proportion of the product (seeds/grains) without water	0.85 – 0.90	0.85 – 0.90	0.85 – 0.90
Harvest index	Proportion of grains/seeds in the total aboveground biomass	0.40 – 0.50	0.40 – 0.50	0.40 – 0.50
Root-to-shoot ratio	Root mass relative to aboveground mass at harvest	0.18 – 0.23	0.18 – 0.23	0.18 – 0.23

Carbon fraction of the product	%C in the dry mass of seeds/grains	0.42 – 0.47	0.42 – 0.47	0.42 – 0.47
Carbon fraction of aboveground residues	%C in the dry mass of straw/stover/stems	0.42 – 0.45	0.42 – 0.45	0.42 – 0.45
Carbon fraction of roots	%C in the dry mass of roots	0.38 – 0.45	0.38 – 0.45	0.38 – 0.45
Fraction of residues retained on the field	Portion of residues left in the field (not removed/burned)	0.50 – 0.90	0.80 – 1.00	0.90 – 1.00
Stabilized fraction of C from residues	Proportion of residue-derived C retained long-term in soil	0.11 – 0.15	0.13 – 0.17	0.15 – 0.18
Stabilized fraction of C from roots + rhizosphere	Proportion of root-derived C retained long-term in soil	0.20 – 0.24	0.23 – 0.29	0.26 – 0.32

Tabel 2

Algorithms for quantifying practices across three tillage systems in maize crop

Indicator	What does it represent?	Intervals		
		Conventional Tillage System	Minimum Tillage System	No-Tillage System
Dry matter fraction of the product	Proportion of the product (seeds/grains) without water	0.85 – 0.88	0.85 – 0.88	0.85 – 0.88
Harvest index	Proportion of grains/seeds in the total aboveground biomass	0.48 – 0.58	0.48 – 0.58	0.48 – 0.58
Root-to-shoot ratio	Root mass relative to aboveground mass at harvest	0.15 – 0.22	0.15 – 0.22	0.15 – 0.22
Carbon fraction of the product	%C in the dry mass of seeds/grains	0.42 – 0.47	0.42 – 0.47	0.42 – 0.47
Carbon fraction of aboveground residues	%C in the dry mass of straw/stover/stems	0.42 – 0.45	0.42 – 0.45	0.42 – 0.45
Carbon fraction of roots	%C in the dry mass of roots	0.38 – 0.45	0.38 – 0.45	0.38 – 0.45
Fraction of residues retained on the field	Portion of residues left in the field (not removed/burned)	0.50 – 0.90	0.80 – 1.00	0.90 – 1.00
Stabilized fraction of C from residues	Proportion of residue-derived C retained long-term in soil	0.11 – 0.15	0.13 – 0.17	0.15 – 0.18
Stabilized fraction of C from roots + rhizosphere	Proportion of root-derived C retained long-term in soil	0.20 – 0.24	0.23 – 0.29	0.26 – 0.32

Tabel 3

Algorithms for quantifying practices across three tillage systems in sunflower crop

Indicator	What does it represent?	Intervals		
		Conventional Tillage System	Minimum Tillage System	No-Tillage System
Dry matter fraction of the product	Proportion of the product (seeds/grains) without water	0.90 – 0.92	0.90 – 0.92	0.90 – 0.92
Harvest index	Proportion of grains/seeds in the total aboveground biomass	0.25 – 0.35	0.25 – 0.35	0.25 – 0.35
Root-to-shoot ratio	Root mass relative to aboveground mass at harvest	0.05 – 0.08	0.05 – 0.08	0.05 – 0.08
Carbon fraction of the product	%C in the dry mass of seeds/grains	0.42 – 0.47	0.42 – 0.47	0.42 – 0.47
Carbon fraction of aboveground residues	%C in the dry mass of straw/stover/stems	0.42 – 0.45	0.42 – 0.45	0.42 – 0.45
Carbon fraction of roots	%C in the dry mass of roots	0.38 – 0.45	0.38 – 0.45	0.38 – 0.45
Fraction of residues retained on the field	Portion of residues left in the field (not removed/burned)	0.50 – 0.90	0.80 – 1.00	0.90 – 1.00
Stabilized fraction of C from residues	Proportion of residue-derived C retained long-term in soil	0.11 – 0.15	0.13 – 0.17	0.15 – 0.18
Stabilized fraction of C from roots + rhizosphere	Proportion of root-derived C retained long-term in soil	0.20 – 0.24	0.23 – 0.29	0.26 – 0.32

Tabel 4

Algorithms for quantifying practices across three tillage systems in rapeseed crop

Indicator	What does it represent?	Intervals		
		Conventional Tillage System	Minimum Tillage System	No-Tillage System
Dry matter fraction of the product	Proportion of the product (seeds/grains) without water	0.90 – 0.92	0.90 – 0.92	0.90 – 0.92

Harvest index	Proportion of grains/seeds in the total aboveground biomass	0.28 – 0.40	0.28 – 0.40	0.28 – 0.40
Root-to-shoot ratio	Root mass relative to aboveground mass at harvest	0.20 – 0.28	0.20 – 0.28	0.20 – 0.28
Carbon fraction of the product	%C in the dry mass of seeds/grains	0.42 – 0.47	0.42 – 0.47	0.42 – 0.47
Carbon fraction of aboveground residues	%C in the dry mass of straw/stover/stems	0.42 – 0.45	0.42 – 0.45	0.42 – 0.45
Carbon fraction of roots	%C in the dry mass of roots	0.38 – 0.45	0.38 – 0.45	0.38 – 0.45
Fraction of residues retained on the field	Portion of residues left in the field (not removed/burned)	0.50 – 0.90	0.80 – 1.00	0.90 – 1.00
Stabilized fraction of C from residues	Proportion of residue-derived C retained long-term in soil	0.12 – 0.15	0.14 – 0.17	0.16 – 0.18
Stabilized fraction of C from roots + rhizosphere	Proportion of root-derived C retained long-term in soil	0.20 – 0.24	0.23 – 0.29	0.24 – 0.30

The tables above present the calculation algorithms of sequestered carbon according to the soil tillage system (conventional, minimum tillage, and no tillage) for the following crops: wheat, maize, sunflower, and rapeseed.

Since the specialized literature primarily employs metric tons of CO_2 (carbon dioxide equivalent) to discuss carbon sequestration quantities, all measurements were converted into this unit of measure.

The reduction of greenhouse gas emissions, the adaptation of production methods to climate change, and the steep increase in global food demand driven by population growth are the three interconnected challenges facing the agricultural sector.

Research indicates that greenhouse gas (GHG) emissions from agricultural activities are minimal compared to industrial emissions. Globally, the energy and industrial sectors represent the main source of GHG emissions, contributing approximately 73% of the total.

In comparison, agriculture, forestry, and other land uses (AFOLU) account for approximately 18–22% of global emissions, of which agriculture alone (excluding land-use change) contributes 10–12% of the total (IPCC, 2021; FAO, 2021). In the European Union, the structure is similar: the agricultural sector is responsible for about 11% of total emissions, while energy and industry together exceed 70% (EEA, 2022).

Therefore, carbon credit systems in the agricultural sector have attracted considerable global attention with respect to achieving climate neutrality.

Table 5 presents the main measures and their impact on emissions. Financial incentives are needed to promote the adoption of these solutions by rewarding efforts to improve soil management, enhance fertilizer use efficiency, and implement effective irrigation practices.

Tabel 5

Agricultural Greenhouse Gas Mitigation Measures

Measure	**Examples**	**Effects on emissions**		
		CO_2	**CH_4**	**N_2O**
Cropland management	Fertilization	+		+
	Soil tillage	+		+/-
	Irrigation/Drainage	+/-		+
	Land-use change (set-aside/fallow)	+	+	+
Grassland management	Grazing intensity	+/-	+/-	+/-
	Fertilization	+		+/-
	Introduction of new species	+		+/-
Management of organic soils	Avoidance of wetland drainage	+	-	+/-
Restoration of degraded lands	Erosion control, organic amendments, fertilization	+		+/-
Livestock management	Improved feeding practices		+	+
	Additives and agents		+	
Manure management	Improved storage and handling		+	+/-
	Anaerobic digestion		+	+/-
Bioenergy	Energy crops	+	+/-	+/-

ECONOMIC AND ENVIRONMENTAL BENEFITS OF CARBON CREDIT SYSTEMS

The integration of carbon credits into agricultural practices presents significant economic opportunities for farmers. By adopting practices that sequester carbon, farmers can generate additional income through the sale of carbon credits. This financial incentive could drive the broader adoption of sustainable agricultural practices.

In addition to financial benefits, carbon credit systems may also promote secondary environmental gains, such as improved soil health, enhanced biodiversity, and better water management. However, the extent to which these benefits are realized depends on the specific practices adopted and the context in which they are implemented.

The advantages and disadvantages of the carbon credit system are essential for understanding the complexity and effectiveness of this environmental policy instrument in combating climate change. *Tables 6* and *7* present the identified advantages and disadvantages.

Tabel 6

Benefits of carbon credit systems

ADVANTAGES	JUSTIFICATION
Incentivizing Emission Reductions	Carbon credits encourage entities to reduce their GHG emissions, motivating them not only to adopt cleaner technologies in the short term but also to plan long-term sustainability strategies. This can lead to significant innovations in emission reduction technologies and the adoption of sustainable business practices.
Promoting Global Sustainability	By facilitating investments in environmental projects such as reforestation or renewable energy, carbon credits contribute to fostering sustainability at the global level. They represent a mechanism through which companies can play an active role in combating climate change.
Flexibility for Companies	The system provides companies facing difficulties in directly reducing their emissions with the option to purchase carbon credits. This mechanism offers flexibility and enables enterprises to comply with environmental regulations in a cost-effective manner.
International Cooperation	The trading of carbon credits can facilitate cooperation between industries and nations, bringing together a wide range of actors in the joint effort to reduce global GHG emissions.

Tabel 7

Challenges and limitations of carbon credit systems

CHALLENGES AND LIMITATIONS	JUSTIFICATION
Ethical Concerns and Effectiveness	There are ethical concerns regarding the actual effectiveness of offsetting emissions through the purchase of carbon credits. Critics argue that this system allows companies to evade responsibility for implementing real and lasting changes in their operations by effectively buying their way into compliance.
Risk of Greenwashing	Companies may use the purchase of carbon credits as a marketing strategy to enhance their public image without making significant investments in actual emission reductions. This can lead to misleading perceptions regarding the companies' genuine commitment to sustainability.
Economic Inequalities	The carbon credit market may favor larger and more profitable companies that can afford to purchase credits rather than invest in emission reductions. This dynamic can create inequalities among companies and hinder progress toward a low-carbon economy.
Implementation and Monitoring	The effective implementation and monitoring of the carbon credit system are significant challenges, requiring rigorous verification and reporting mechanisms to ensure the integrity and transparency of the process.

CONCLUSIONS

1. With agriculture responsible for 10–12% of global GHG emissions (~11% in the EU), carbon credit markets in this sector are justified.

2. The European Union carbon market, responsible for managing over 70% of emissions from energy and industry, represents an opportunity for farmers to increase their income through the sale of sequestered carbon.

3. Conservation tillage practices (minimum and no-tillage) significantly enhance soil carbon sequestration. Under these systems, residue retention on the field reaches 90–100% (as opposed to 50–90% in conventional tillage), while the stabilized fraction of root-derived carbon increases to 26–32% (compared with 20–24%)."

4. Measures such as set-aside, irrigation /drainage, and grassland management simultaneously reduce CO_2, CH_4, and N_2O emissions, thereby contributing to climate neutrality.

5. Carbon credits generate additional income for farmers while delivering environmental benefits such as improved soil health, enhanced biodiversity, and a cleaner environment."

6. The system entails the risk of greenwashing (where polluters merely purchase carbon credits to offset their own emissions without making significant investments in clean technologies), as well as economic inequalities between small farms (which face scale-related barriers to accessing the carbon market) and large farms (which have easier access to the market).

ACKNOWLEGMENTS

This work was carried out within PNRR-DTEClimate/VeBDisease project no. 760008/30.12.2022.

REFERENCES

Dales J.H., a. 2002 - *Polluation, Property& Prices – An essay in policy-making and economics, printed and bound in Great Britain by Bookcraft (Bath*) Ltd., ISBN 1 84064 842 2

Hoffmann M.P., Jacobs A., Whitbread A.M., a. 2015, *Crop modelling based analysis of site-specific production limitations of winter oilseed rape in northern Germany*, Field Crops Research Volume 178, July 2015, Pages 49-62

Ken E.G., Renske H., Jens A.A., James S., a. 2021 - *Regenerative agriculture: an agronomic perspective*, SageJournals, Volume 50, https://doi.org/10.1177/00307270219980

Lokuge N., Anders S., a. 2022 - *Carbon-Credit Systems in Agriculture: A Review of Literature*, The School of Public Policy Publications, Volume 15:12

Raziel A. O., Sotirios V. A., Rafael M.-F., Jerry L. H., Emily E. W., Michael J. C., a. 2020, *Root to shoot and carbon to nitrogen ratios of maize and soybean crops in the US Midwest*, European Journal of Agronomy, Volume 120, 126130

Rui Z., a. 2017 - Building a national unified carbon market requires institutional innovation[N], China Financial News

Sanz-Sáez Á., Erice G., Aguirreolea J., Muñoz F., Sánchez-Diaz M., Irigoyen J.J., a. 2012 - *Alfalfa forage digestibility, quality and yield under future climate change scenarios vary with Sinorhizobium meliloti strain*. Journal of Plant Physiology, 169:782-788.

Stefan G., a. 2012, *Considerations on the theory of economic growth and development, Proceedings of World Conference on Business, Economics and Management (BEM-2012), vol 62, pp. 280-284, DOI10.1016/j.sbspro.2012.09.045*

Trepos R., Champolivier L., Dejoux J.-F., Al Bitar A., Casadebaig P., Debaeke P., a. 2020, *Forecasting Sunflower Grain Yield by Assimilating Leaf Area Index into a Crop Model*, Remote sensing

Verschuuren, J., a. 2018 - *Towards an EU regulatory framework for climate-smart agriculture: The example of soil carbon sequestration*, Transnational Environmental Law, 7 (2): 301-322

*** **Departament of Primary Industries, a. 2011** - Canola growth & development

*** **European Environment Agency, a. 2022 -** Annual European Union greenhouse gas inventory 1990–2020 and inventory report 2022. European Environment Agency, Report No 8/2022.

*** F**ood and Agriculture Organization, a. 2021 -** FAOSTAT Emissions Database. Food and Agriculture Organization of the United Nations.

*** **Intergovernmental Panel on Climate Change, a. 2006** - 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use, Cap. 4 Forest Land, pag. 4.48-4.49

*** **Intergovernmental Panel on Climate Change, a. 2021 -** Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

***** Ministerul Mediului, a. 2021 -** *"Evoluția emisiilor de gaze cu efect de seră în perioada 2007-2020"*.

*** **U.S. Department of Agriculture**, **a. 2024** - Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: METHODS FOR ENTITY-SCALE INVENTORY, Cap. 3 Quantifying Greenhouse Gas Sources and Sinks in Cropland and Grazing Land Systems, pag. 3-16 – 3-17