Author: *Chaire BEA*

Contributing authors: *Amandine Rave, Nathalie Vassal, Paul Villate*

Graphics: *Noÿa Broise*

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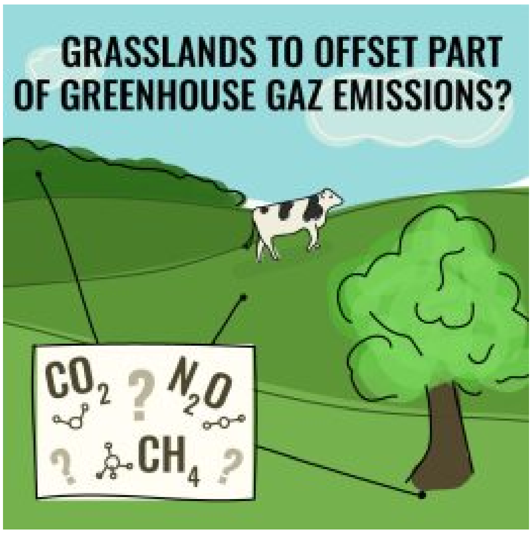
https://chaire-bea.vetagro-sup.fr/en/



October 2024

Grasslands help offset part of cows' greenhouse gas emissions, TRUE or FALSE?

TRUE

Grasslands are carbon sinks, which help offset some of the greenhouse gas emissions from cattle. Good soil management and livestock practices (such as rotational grazing) can increase the carbon storage capacity of grasslands. However, this capacity diminishes over time.

KEEP IN MIND

- GHG emissions from cattle account for 62% of GHG emissions attributed to livestock production globally.
- Grasslands help offset some of the carbon emissions from livestock farming by storing carbon.
- Good livestock and soil management practices can help maintain or even increase the carbon stock of grasslands.

The image of agriculture has gradually deteriorated due to various crises[1] and the questioning of certain livestock or cultivation practices (such as the excessive use of inputs), put in place to meet production needs. While polls show that the majority of French people have maintained a high level of support for farmers since 1999[2], some citizens are critical of the impacts of agriculture on health and the environment, in the short, medium and long term.

Criticism frequently singles out the breeding of ruminants and cattle, particularly with regard to its emissions of methane, a powerful greenhouse gas (GHG) which contributes to climate change. Indeed, in its report published in December 2023[3], the Food and Agriculture Organization of the United Nations (FAO) highlights that livestock farming is responsible for 12% of global GHG emissions (20.5% in France) caused by humans; methane accounts for a little more than half of these emissions (54%).

However, as early as 2009, the FAO has argued that « with better management practices, the livestock sector can also contribute significantly to mitigating the effects of climate change [...]. Increasing grazing systems for animal feed, particularly through effective rotational grazing is potentially the most cost-effective way to reduce and offset greenhouse gas emissions. The regeneration of vegetation cover and soil organic matter enhances carbon sequestration, while the incorporation of high-quality forage in animal feed contributes to the reduction of methane emissions per unit of animal product »[4].

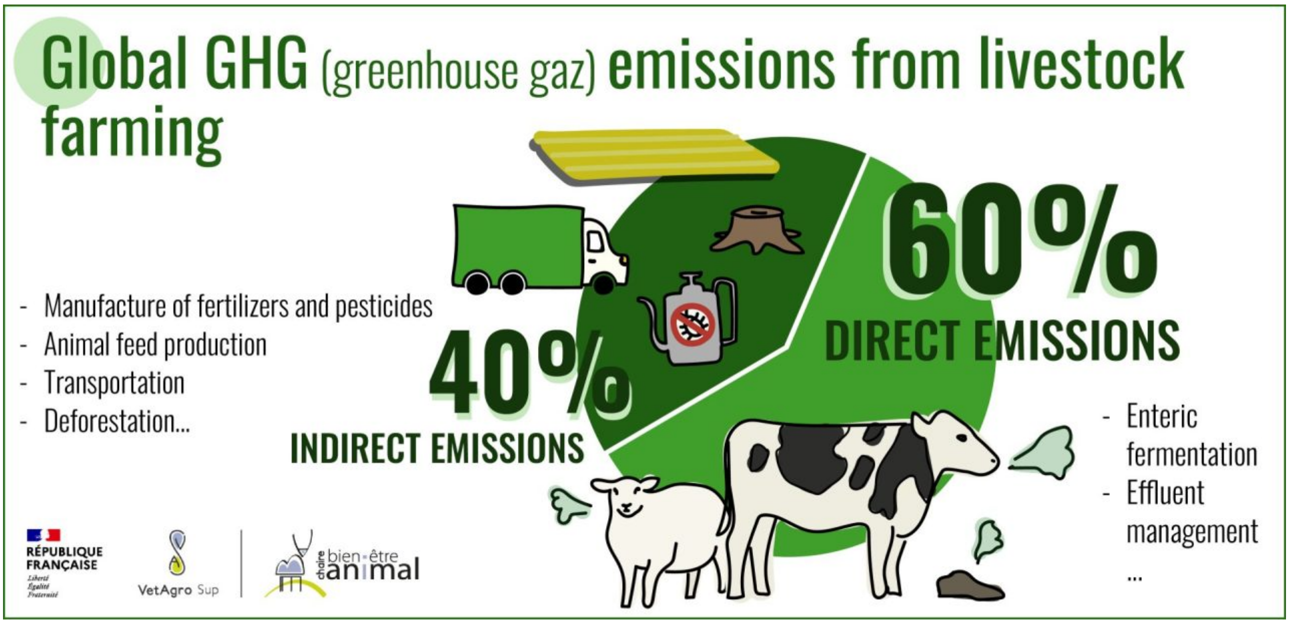
Let us take a closer look at the latest scientific data: can grasslands help to partially offset livestock GHG emissions?

Understanding greenhouse gas emissions from livestock farming

Agriculture mainly generates three greenhouse gases: carbon dioxide, methane, and nitrous oxide. Their contribution to the greenhouse effect varies depending on the gas. For example, methane, although having a shorter lifespan, has a warming potential more than 80 times greater than carbon dioxide[5].

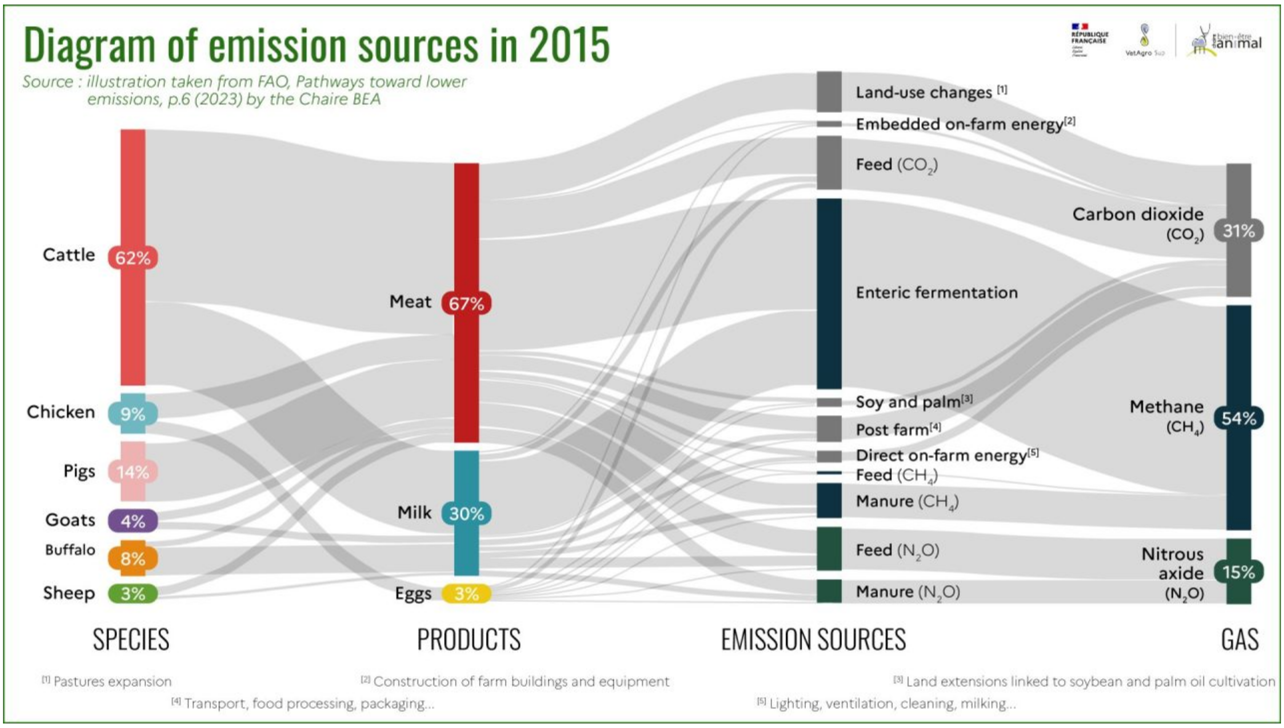
According to the latest FAO report in 2023, GHG emissions from livestock farming worldwide are distributed as follows:

- 60% direct GHG emissions: this mainly concerns methane from enteric fermentation (digestion process in ruminants) and nitrous oxide generated by the management of effluents (manure, slurry).
- 40% indirect emissions: this corresponds to the manufacture of fertilizers and pesticides, the production of animal feed, the manufacture of food concentrates, the transport and packaging of animal products or even the necessary deforestation for animal feed (such as soy).

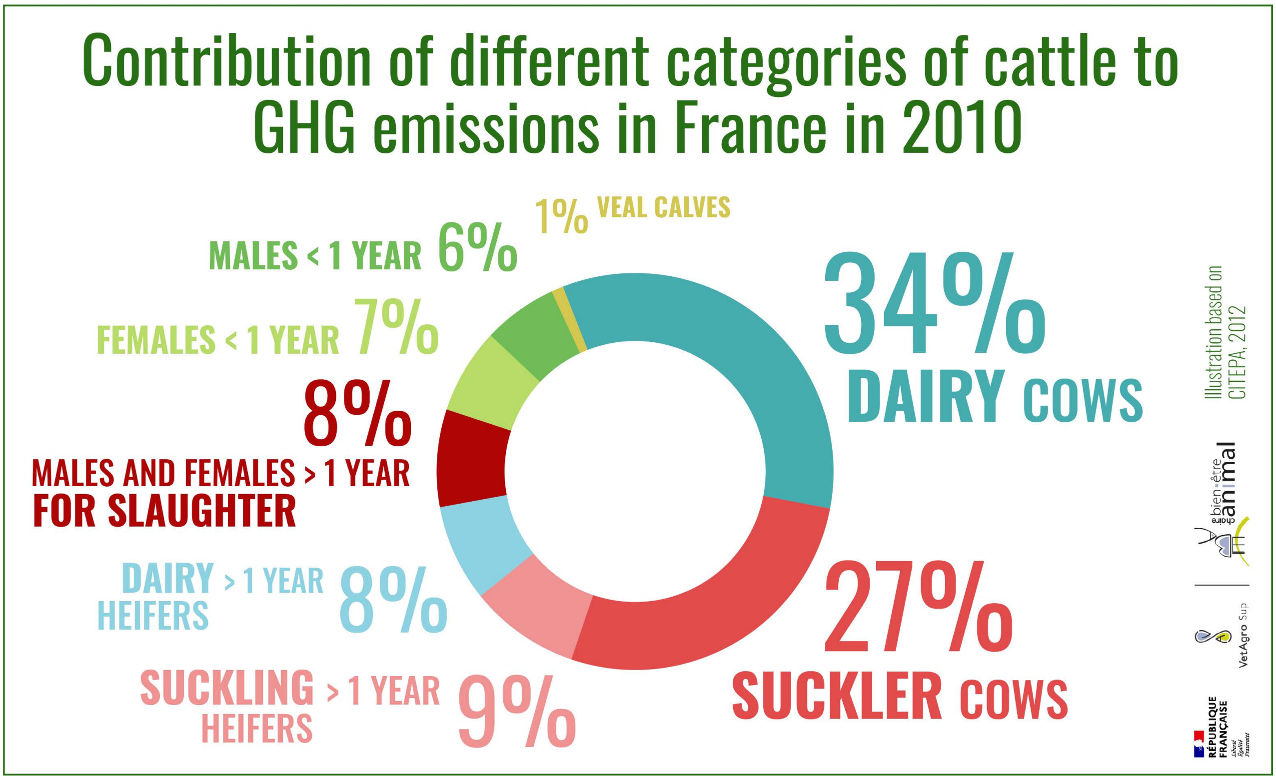


The weight of GHG emissions depends on species. According to the FAO (2023), cattle farming accounts for 62% of livestock farming's GHG emissions at the global level, far exceeding other species'. This is due to their total biomass, which is higher than that of other livestock, but also to their specific digestion process[6].

The illustration below shows the distribution of GHG emissions from different livestock farms and animal products (meat, milk, eggs), their origin (emissions linked to crop extensions, feed, feces, etc.) and their nature (carbon dioxide, methane or nitrous oxide).



Furthermore, the contribution to GHGs is different depending on cattle age and type. For example, since there are more dairy cows in France than suckler cows, it follows that dairy cows account for the majority of cattle GHG emissions.



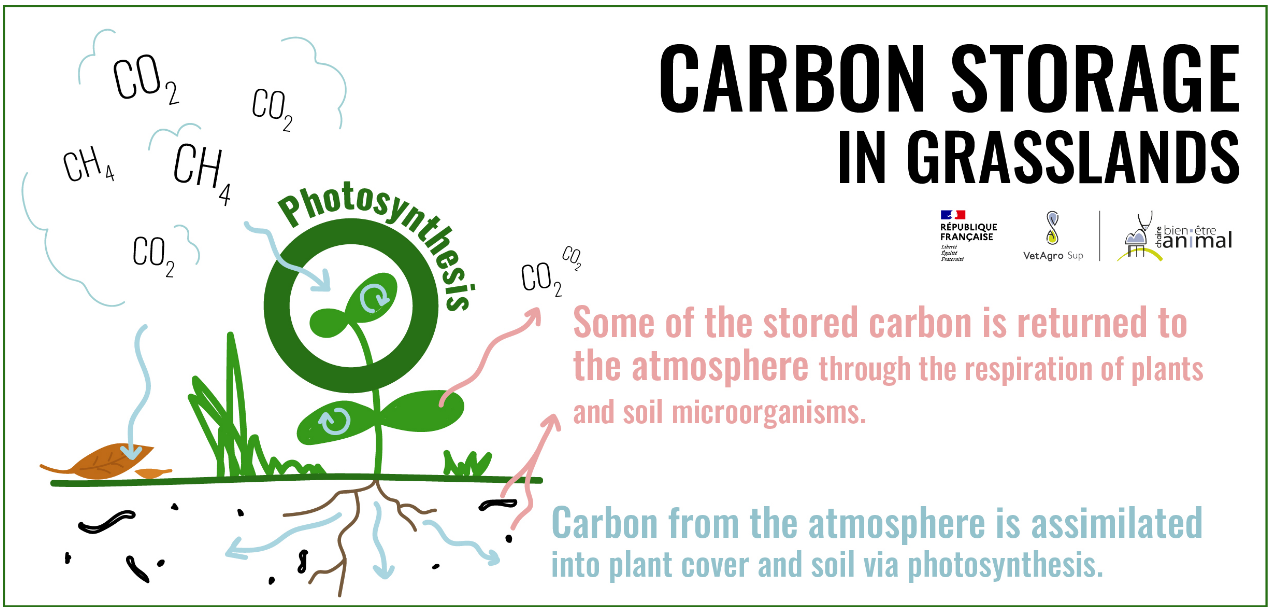
Livestock farming is not only a source of GHG: grasslands, which in France represents the bulk of cattle feed, allow carbon to be stored.

How do grasslands store carbon?

Ungrazed grasslands

Carbon sequestration by grasslands is a natural process. In the atmosphere, carbon is present mainly in the form of carbon dioxide (CO_2) and methane (CH_4).

Through photosynthesis, carbon is naturally fixed by plants as their metabolism includes it in the constitution of different molecules and plant tissues.



This carbon will be allocated to the soil via the residues of aerial parts (leaves, stems) and roots, but also via root exudates[7], and will add to the stock of organic matter. Part of the carbon is therefore stored in the soil's organic matter as well as in the plant's aerial parts, and will possibly be returned to the atmosphere in the form of CO_2 via the respiration of plants and soil microorganisms.

Several scientific studies have shown that temperate grasslands in Europe are "carbon sinks": they capture and store more carbon than they release into the atmosphere[8].

Grazed grasslands

A study by Senapati et al. (2014) compared the carbon storage capacities of a young sown and mown grassland (without animal grazing) and a young sown and grazed grassland, in France. This study allowed to measure the carbon fluxes between the different compartments of the system.

When grasslands are grazed by ruminants, the same processes apply as with mowing: the carbon present in the atmosphere in the form of CO_2 and CH_4 is fixed by the plants in the form of organic carbon. Part of this carbon is stored in the organic matter of the soil and in the plants. Part is returned to the atmosphere via the respiration of plants and soil microorganisms, but also via the respiration of ruminants. Cattle also release CH_4 into the atmosphere through the enteric fermentation process of their digestive system. Cattle therefore release both CO2 and CH4 into the atmosphere. Thus, the overall respiration of the system (1510gCm^{-2} year^{-1}) is higher than in a grassland without animals (1244gCm^{-2} year^{-1}).

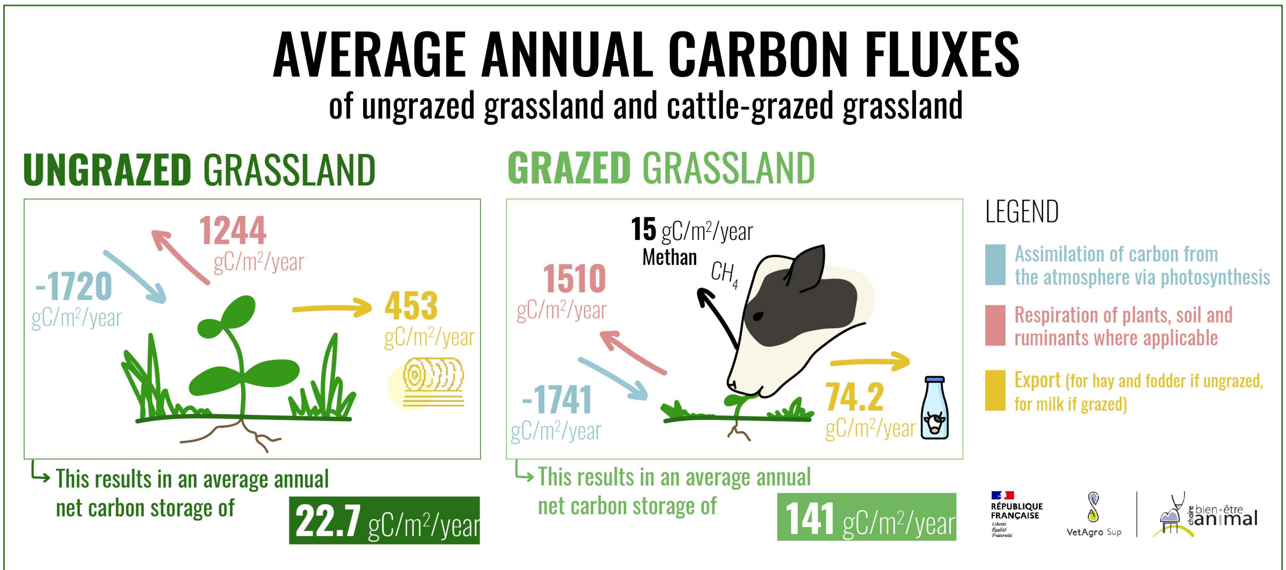


Illustration based on the diagram « Net carbon storage measured in a mowed and grazed temperate sown grassland shows potential for carbon sequestration under grazed system » de Senapati N., Chabbi A., Gastal F., Smith P., Mascher N., Loubet B., Cellier P., Naisse C., 2014.

However, the study by Senapati et al.(2014) shows that the net carbon balance of a grazed grassland is higher than that of an ungrazed grassland. This is mainly due to the fact that in the case of a grazed grassland, a large proportion of forage is directly recycled on site by the feeding animals (allowing the organic carbon contained in the grass to be allocated to grassland soil), whereas in an ungrazed grassland, most of the organic carbon contained in the grass (95%) leaves the system in the form of hay/forage and is not recycled on site. In a grazed grassland, around 25-40% of the organic carbon contained in the grass ingested by the animals returns to the soil via the animals' faeces. A small proportion of the organic carbon contained in the grass ingested is exported via milk and meat produced by the animals.

Did you know?

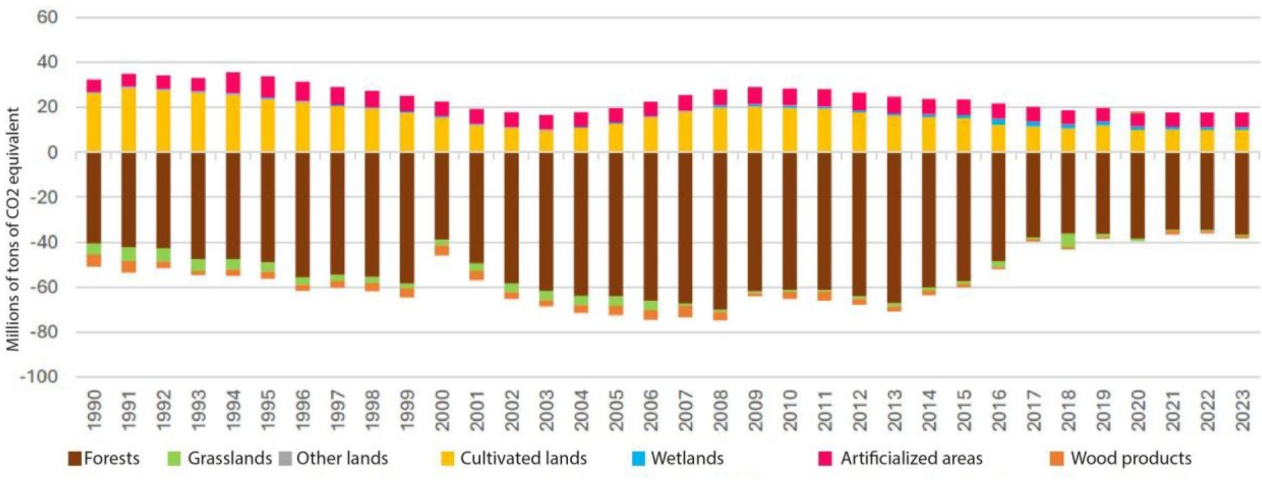
Soil is the most important natural carbon sink on continental surfaces. Soils store, in the form of organic carbon, approximately three times more carbon than the atmosphere[9].

Measuring soil carbon stock is challenging due to its variability over time. The process of carbon storage typically experiences exponential growth during the initial 30-40 years (assuming consistent practices, which is rare), after which it slows and approaches a state of equilibrium where carbon inputs and outputs in the soil balance out over time[10]. Once sequestered, carbon can persist in the soil for thousands of years, particularly in deeper soil layers.

In any case, plant biomass production allows carbon to be stored and increases the carbon content of the soil (as well as its potential to store it). Thus, forests, peat bogs and even grasslands are particularly interesting for storing carbon.

As with other types of soil, the carbon storage capacity of grasslands changes over time: it follows an exponential growth for the first 30-40 years, then slows down and tends towards an equilibrium where carbon inputs and outputs tend to cancel each other out. Beyond the first 30-40 years, the carbon stock contained in the grassland soil is significant but the emissions linked to the animals that enhance the grassland (carbon flux) are therefore no longer offset via this mechanism.

In its latest report 2024, CITEPA (Interprofessional Technical Center for the Study of Atmospheric Pollution) shows the evolution of the role of grasslands in France in terms of absorption of CO_2 equivalent over the last thirty years: this decreasing role is explained in particular by the “aging” of French grasslands[11].



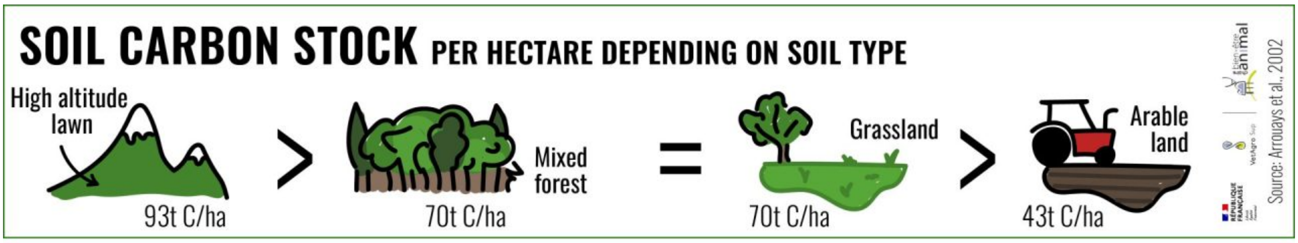
Distribution of CO_2 emissions and absorptions in France (Metropolitan France and Overseas EU)
Source: CITEPA 2024

Factors influencing soil carbon storage capacity

Soil carbon storage capacity depends on a number of criteria, including soil characteristics and climate, as well as human factors such as plant cover management, fertilization and farming practices.

Land use

As seen previously, ungrazed mown grasslands and grazed grasslands do not have the same annual net carbon balance. In the same way, not all soils have the same characteristics and carbon stocks depending on plant cover. Scientific studies show that a soil under annual crops has a much smaller stock than a grassland or a forest.



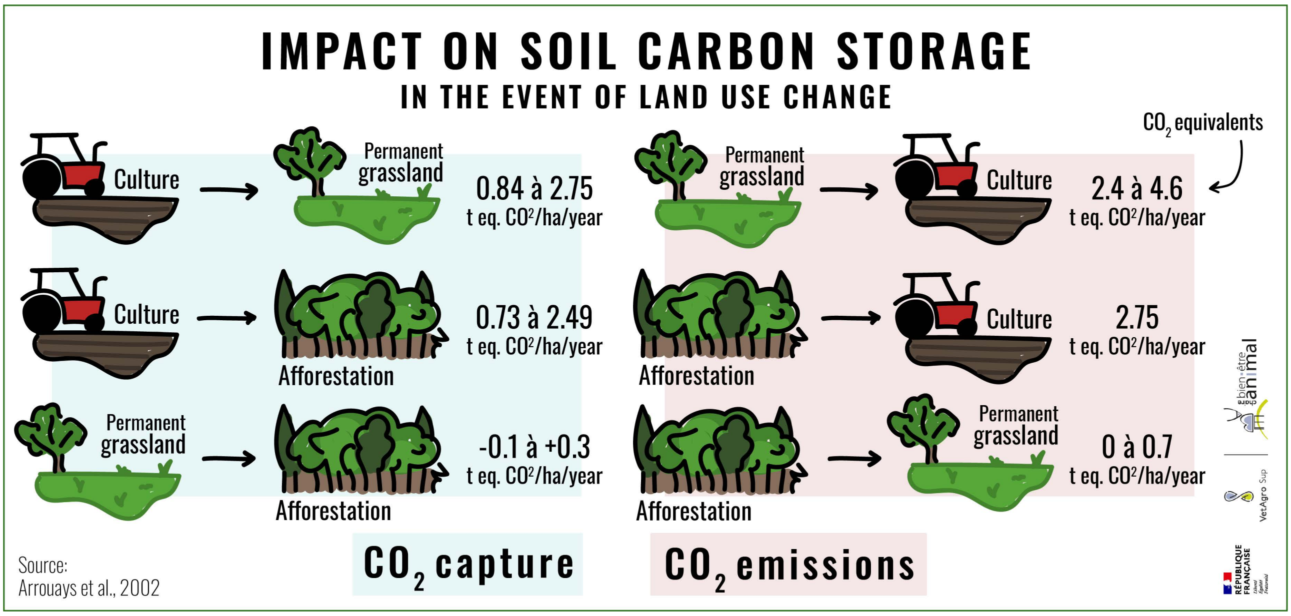
According to the FAO 2023 report, land devoted to pasture represents 26% of global land surface, forests 30.3% and arable land 10.8%. It is therefore important to not only protect grasslands and forests in order to store carbon, but also to expand these areas.

Two European projects (GreenGrass and CarboEurope) have studied the carbon storage capacity of 28 European grasslands and established an average net carbon storage capacity comparable to that of European forests. However, a large variability between grasslands was found during these studies, and these first results must be interpreted with caution. Furthermore, altough carbon storage capacities of permanent grassland[12] and forest are comparable, their respective ecosystem[13] may not be, each system playing a specific role in terms of biodiversity, impact on the water cycle, etc.

Land use conversion

The storage of organic carbon in soil is not irreversible. Thus, the conversion of land to other uses can promote the release of soil carbon stocks: in other words, soil can either be a carbon sink or source. For example, when a forest is converted to grassland or to crops (or vice versa), this is accompanied by a change in soil characteristics and in the processes operating at the organic matter level, disrupting soil carbon storage capacities[14].

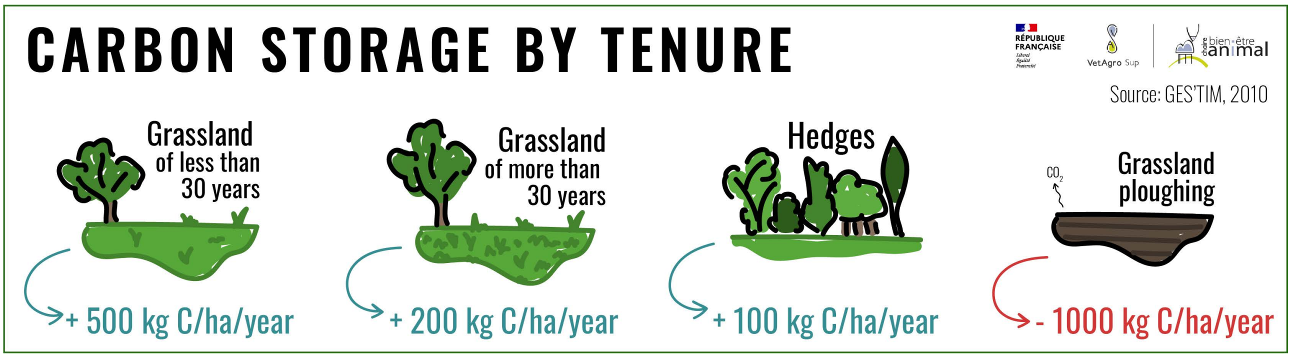
A study conducted by Arrouays et al. (2002) showed that the carbon storage potential of soils remains almost identical when a forest is transformed into permanent grassland, whereas the transition from a forest to cropland or from a permanent grassland to cropland leads to significant CO_2 emissions. (+2.4 to 4.6 t eq. CO_2/hectare/year). Thus, if permanent grasslands were replaced by cultivated areas (where possible, outside mountainous areas for example), this would result in carbon destocking and an increase in emissions.



Good soil management practices

Other factors can influence the carbon storage capacity of soils, regardless of their use: these include soil management practices.

Different soil management practices can increase carbon storage capacity. For instance, permanent grasslands store more carbon than temporary grasslands[15]. This is due to the absence of soil tillage, the increased production and restitution of biomass, which allow the soil carbon storage process to follow an exponential growth during the first 30-40 years. Thus, temporary grasslands subjected to a succession of crops and whose soil is worked do not offer the same storage capacities as permanent grasslands. Furthermore, the balanced supply of organic nitrogen via animal manure or via a nitrogen-rich plant cover such as legumes increases carbon sequestration. Conversely, a nitrogen deficit can cause carbon destocking[16].



Grazing intensity is also an impacting factor: overgrazing, which is an excessive exploitation of the vegetation of a forage area by cattle and other ruminants, can degrade the plant cover and reduce soil carbon storage capacity through reduced return of litter (decomposing plant debris) to the soil. Conversely, rotational grazing (including short rotations) makes it possible to avoid overgrazing, to stimulate biomass production while reducing the consumption of concentrated feed (cereals, soybeans, etc.). This also makes it possible to reduce GHG emissions linked to the management and storage of effluents, with a uniform distribution of nutrients on the plots[17].

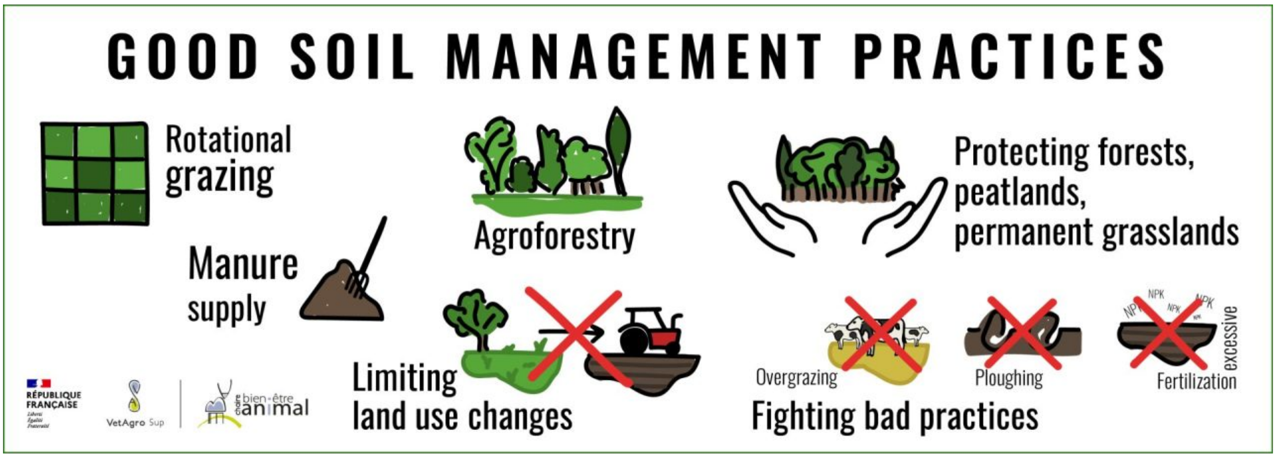
In addition, agroforestry or the presence of hedges in a grassland also makes it possible to increase carbon stocks.

Global trends and outlook

In its 2023 Global assessment of soil report carbon in grasslands: From curret stock estimates to sequestration potential, the FAO highlights that 54% of grassland soils worldwide have stable carbon storage capacities, thanks to sufficient organic inputs. This is all the more true for environments that are little or not exploited by humans[18].

However, grassland soils in certain geographical areas have a negative carbon balance due to soil degradation (linked to human activity and extreme climatic events such as water stress, intense and frequent fires, etc.): this is the case in East Asia, South America and Central Africa, and areas of Africa south of the equator. In these regions, current carbon stocks in grassland soils are also likely to decline due to increasing anthropogenic pressure and climatic conditions. FAO has also published a global soil map that tracks the status of carbon sequestration in soils.

Better soil management practices such as manure application (which provides organic matter to stimulate soil microorganisms), agroforestry, or rotational grazing offer opportunities to increase the carbon storage capacity of grassland soils in the short term. Limiting certain changes in use (such as converting permanent grassland to cropland) and combating poor soil management practices (overgrazing, systematic and deep ploughing, excessive fertilisation) also contribute to this effort. Finally, maintaining the carbon stocks already present in the soil is necessary, by protecting primary or old-growth forests, peatlands and permanent grasslands, which are carbon sinks and help to offset part of the carbon emissions linked to cattle farming.



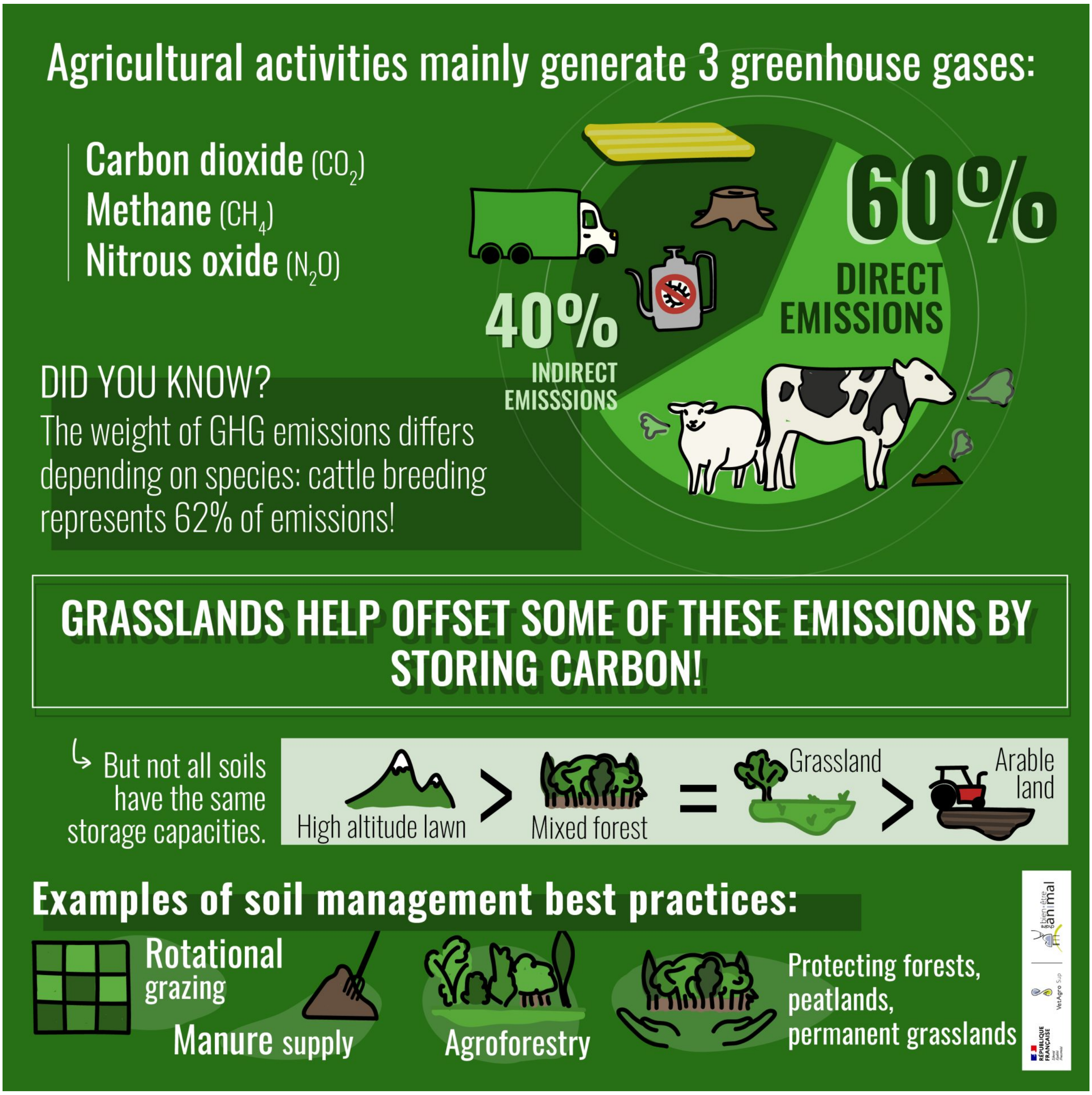
Such practices call for ambitious national and international agricultural policies, such as the French initiative “4 per 1000” launched in 2015 during COP21, highlighting the importance of preserving living soils.

Did you know?

The “4 per 1000 initiative " is based on the following observation: if the level of carbon stored by the soil in the first 30 to 40 centimeters increased by 0.4% (or 4‰) per year, the annual increase in carbon dioxide (CO_2) in the atmosphere would almost be offset.

However, such initiatives do not address all the GHG issues related to livestock farming. For offsetting carbon emissions, grasslands, with their margin for progress in terms of carbon storage, will not be sufficient. Other problems – such as nitrous oxide and ammonia ($NH3^+$) emissions related to livestock farming – are studied, and different avenues for their reduction are considered (such as, for example, the burial of effluents in the soil)[19]. In addition, the imperatives of economic profitability, productivity and food safety must also be taken into account. That being said, other levers for action also make it possible to reduce GHGs related to cattle farming, while being keen to preserve animal welfare: genetic selection, effluent management, feed, etc.[20] So many avenues to explore to reconcile cattle farming and environmental issues…

In short



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This article was modified on 14 October 2024 to integrate more recent scientific data.

References

[1] For example, rising production costs, environmental problems linked to the intensification of practices, a crisis of vocation linked to growing uncertainties such as climatic hazards or price volatility...

[2] On average, since 1999, 74.7% of French people surveyed by Ifop believe that consumers can trust farmers. Fougier, Eddy. 2019, L'hostilité des acteurs de la transition écologique à l'encontre des agriculteurs, Paysans & société, vol. 375, no. 3, pp. 32-38.

[3] FAO. 2023. Pathways towards lower emissions – A global assessment of the greenhouse gas emissions andmitigation options from livestock agrifood systems. Rome

[4] FAO, 2009, La situation mondiale de l'alimentation et de l'agriculture, pp.58 et 82

[5] Methane released into the atmosphere is 80 times more potent than CO2 over a 20-year period. The atmospheric lifetime of methane is 10 to 12 years, while that of carbon dioxide is about 100 years. Source: United Nations Environment Programme, 2021

[6] Llonch, P., Haskell, M.J., Dewhurst, R.J. & Turner, S.P. 2017, Current available strategies to mitigate greenhouse gas emissions in livestock systems: an animal welfare perspective. Animal, 11(2): 274–284. https://doi.org/10.1017/S1751731116001440

[7] Substances secreted by plant roots into the soil. These substances include a variety of chemical compounds that play essential roles in the interaction of plants with their environment (Pinton 2007).

[8] Senapati N., Chabbi A., Gastal F., Smith P., Mascher N., Loubet B., Cellier P., Naisse C., 2014. Net carbon storage measured in a mowed and grazed temperate sown grassland shows potential for carbon sequestration under grazed system. Carbon Management, 5:2, 131-144.

[9] Dignac, Marie-France & Derrien, Delphine & Barré, Pierre & Barot, Sébastien & Cécillon, Lauric & Chenu, Claire & Chevallier, Tiphaine & Freschet, Grégoire & Garnier, Patricia & Guenet, Bertrand & Hedde, Mickaël & Klumpp, Katja & Lashermes, Gwenaëlle & Maron, Pierre-Alain & Nunan, Naoise & Roumet, Catherine & Basile-Doelsch, Isabelle, 2017. Increasing soil carbon storage: mechanisms, effects of agricultural practices and proxies. A review. Agronomy for Sustainable Development. 37. 10.1007/s13593-017-0421-2. .

[10] Armelle Gac, Jean-Baptiste Dollé, André Le Gall, Katja Klumpp, Tiphaine Tallec, et al. 2010, Le stockage de carbone par les prairies : Une voie d'atténuation de l'impact de l'élevage herbivore sur l'effet de serre. Institut de l'Elevage – INRA, 12 p., Collection l'Essentiel. hal-02824535

[11] CITEPA 2024 report available on: https://www.citepa.org/fr/secten/

[12] According to the study by Arrouays et al.(2002), a permanent grassland is a natural grassland or one that was sown more than 6 years ago with no land use change intended.

[13] Ecosystem services are generally defined as the direct and indirect contributions of ecosystems to the benefit of human life. See https://www.millenniumassessment.org

[14] In a forest, a significant portion of the carbon stock is located in the wood of the trees, in addition to soil carbon. When the conversion of a forest to grassland or cropland results in the burning of trees, the carbon destocking is thus considerable.

[15] According to the study by Arrouays et al. (2002), a permanent grassland is a natural grassland or one that was sown more than 6 years ago with no land use change intended; a temporary grassland is less than 6 years old, alternating with crops.

[16] Gac et al. (2010)

[17] Mukherji, A., Arndt, C., Arango, J., Flintan, F., Derera, J., Francesconi, W., Jones, S, Loboguerrero, A.M., Merrey, D., Mockshell, J., Quintero, M., Mulat, D.G., Ringler, C., Ronchi, L., Sanchez, M, Sapkota, T. and Thilsted, S. 2023. Achieving agricultural breakthrough: A deep dive into seven technological areas. Montpellier, France: CGIAR System Organization

[18] Conversely, grasslands exploited by humans need greater organic inputs to maintain their carbon storage capacity. See Marta Dondini, Manuel Martin, Camillo De Camillis, Aimable Uwizeye, Jean-Francois Soussana, et al. 2023, Global assessment of soil carbon in grasslands: From curret stock estimates to sequestration potential. FAO Animal Production and Health Paper. 187, 978-92-5-137550-1 .

[19] See our article « Le CowToilet : des WC pour vaches pour réduire les émissions d'ammoniac et mieux valoriser l'azote ? » et ADEME, Guide des bonnes pratiques agricoles pour l'amélioration de la qualité de l'air, 2020, accessible https://librairie.ademe.fr/produire-autrement/4044-guide-des-bonnes-pratiques-agricoles-pour-l-amelioration-de-la-qualite-de-l-air.html

[20] Llonch et al. (2017)