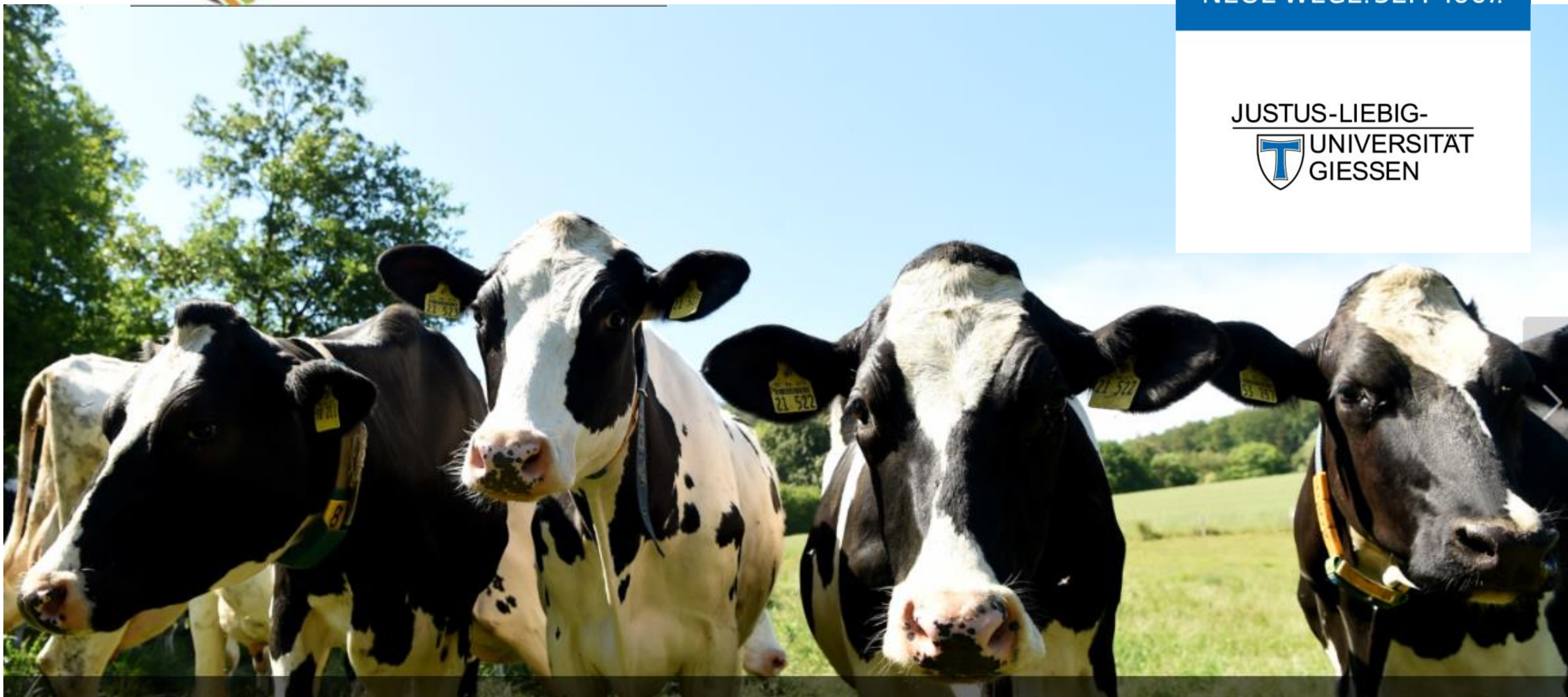
Green Dairy

ClieNFarms
Climate Neutral Farms

Dafa, 21.03.2023

JLU
NEUE WEGE. SEIT 1607.

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN



Carbon Farming – Synergien mit weiteren Nachhaltigkeitskriterien

Andreas Gattinger

andreas.gattinger@agrar.uni-giessen.de

European Commission | EN English | Search

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Carbon Farming

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The land sector is key for reaching a climate-neutral economy, because it can capture CO2 from the atmosphere. However, to encourage the agriculture and forestry sectors to deliver on climate action and contribute to the European Green Deal, it is necessary to create direct incentives for the adoption of climate-friendly practices, as currently there is no targeted policy tool to significantly incentivise the increase and protection of carbon sinks for land managers.

For this reason, in December 2021 the Commission adopted the Communication on Sustainable Carbon Cycles , as announced in the Farm to Fork Strategy (EN). The Communication sets out short- to medium-term actions aiming to address current challenges to carbon farming in order to upscale this green business model that rewards land managers for taking up practices leading to carbon sequestration, combined with strong benefits on biodiversity. These include:

- promoting carbon farming practices under the Common Agricultural Policy (CAP) and other EU programmes such as LIFE and Horizon Europe, in particular under the Mission “A Soil Deal for Europe”, and under public national financing;
- driving forward the standardisation of monitoring, reporting and verification methodologies to provide a clear and reliable framework for carbon farming;
- providing improved knowledge, data management and tailored advisory services to land managers.

https://ec.europa.eu/clima/eu-action/forests-and-agriculture/sustainable-carbon-cycles/carbon-farming_en

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Examples of effective carbon farming practices include:

- Afforestation and reforestation that respect ecological principles favourable to biodiversity and enhanced sustainable forest management, including biodiversity-friendly practices and adaptation of forests to climate change;
- Agroforestry and other forms of mixed farming combining woody vegetation (trees or shrubs) with crop and/or animal production systems on the same land;
- Use of catch crops, cover crops, conservation tillage and increasing landscape features: protecting soils, reducing soil loss by erosion and enhancing soil organic carbon on degraded arable land;
- Targeted conversion of cropland to fallow or of set-aside areas to permanent grassland;
- Restoration of peatlands and wetlands that reduces oxidation of the existing carbon stock and increases the potential for carbon sequestration.

https://ec.europa.eu/clima/eu-action/forests-and-agriculture/sustainable-carbon-cycles/carbon-farming_en

Carbon Farming – synergies with other sustainability criteria

1. A (brief) history of agricultural sustainability
2. Why Carbon Farming & other sustainability criteria together?
3. Carbon Farming + other sustainability – a must to have?

Carbon Farming – synergies with other sustainability criteria

1. **A (brief) history of agricultural sustainability**
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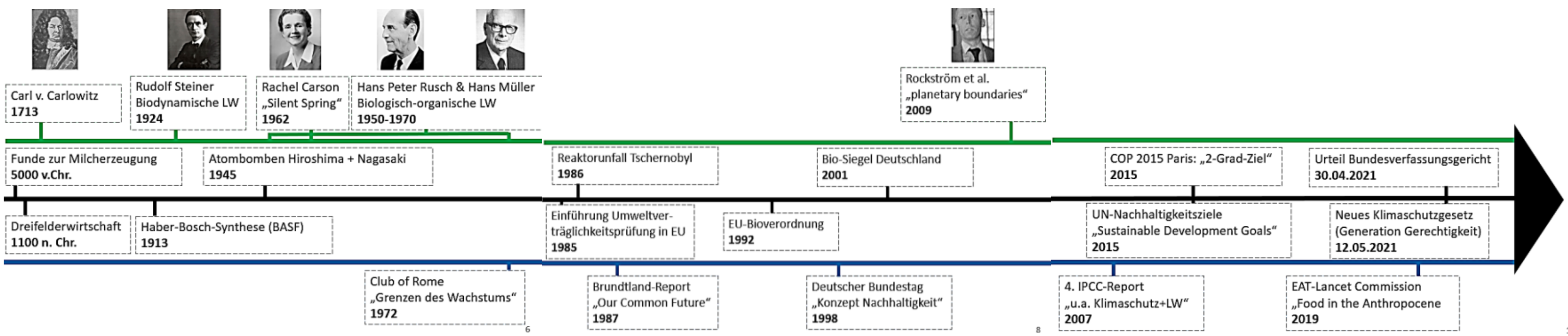
(Kurz-)Geschichte der Nachhaltigkeit in Landwirtschaft und Ernährung

Personen
Wichtige Ereignisse
Wegweisende Institutionen



(Kurz-)Geschichte der Nachhaltigkeit in Landwirtschaft und Ernährung

Personen
Wichtige Ereignisse
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Rockström et al.
„planetary boundaries“
2009

Reaktorunfall Tschernobyl
1986

Bio-Siegel Deutschland
2001

Einführung Umweltverträglichkeitsprüfung in EU
1985

EU-Bioverordnung
1992

Brundtland-Report
„Our Common Future“
1987

Rio-Konferenz
1992

Kyoto Protokoll
1997

Deutscher Bundestag
„Konzept Nachhaltigkeit“
1998

The Rio Conventions

The Interconnected Challenges of **Climate Change**, **Desertification** and **Biodiversity Loss**

Climate change, desertification and biodiversity loss are heavily interlinked and pose existential challenges to humanity. In response to these challenges, governments founded three sister "Rio Conventions" at the 1992 Earth Summit in Rio de Janeiro, Brazil.

These are:

- the United Nations Framework Convention on Climate Change (UNFCCC, also known as UN Climate Change) (founded in 1996)
- the Convention on Biological Diversity (CBD, also known as UN Biodiversity)
- the United Nations Convention to Combat Desertification (UNCCD)

The three Rio Conventions are the result of concerns over similar environmental and development issues and have sustainable development at their hearts. The **Rio Conventions work closely together**, with the overlaps in their work becoming ever stronger as the challenges related to **climate change**, **desertification** and **biodiversity** loss grow and cross-cutting solutions are developed.

United Nations
Framework Convention on
Climate Change

Convention on
Biological Diversity

United Nations
Convention to Combat
Desertification

https://unfccc.int/process-and-meetings/the-rio-conventions

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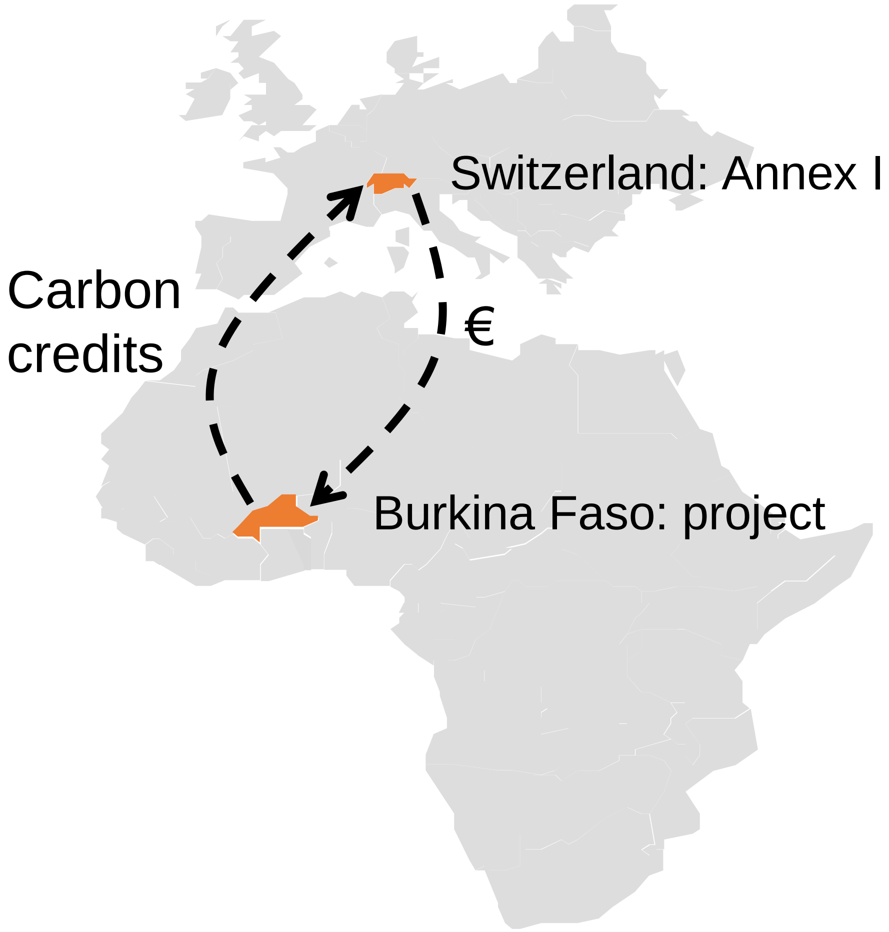
1998

The CDM or the double goal of GHG mitigation : **GHG mitigation + sustainable development**

- **CDM (Clean Development Mechanism),** was the first official program for carbon offset activities (Gattinger, 2023) **is the compensation scheme designed** under the **Kyoto-Protocol** as one of its flexibility mechanisms to allow for more efficient project based mitigation actions. The **CDM** as defined in **Article 12** of the **Kyoto-Protocol** (UNFCCC 1998) has the purpose: "[…] to assist Parties not included in Annex I in achieving **sustainable development** and in contributing to the ultimate objective of the convention, and to assist parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3."
- The **CDM** allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol.
- The **CDM** is the **main source of income for the UNFCCC Adaptation Fund**, which was established to **finance adaptation projects and programmes in developing country Parties** to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change. The Adaptation Fund is financed by a 2% levy on CERs issued by the CDM.

https://unfccc.int/process-and-meetings/the-rio-conventions

Carbon credits can be traded internationally, enabling sustainable development elsewhere (Clean development mechanism, CDM)



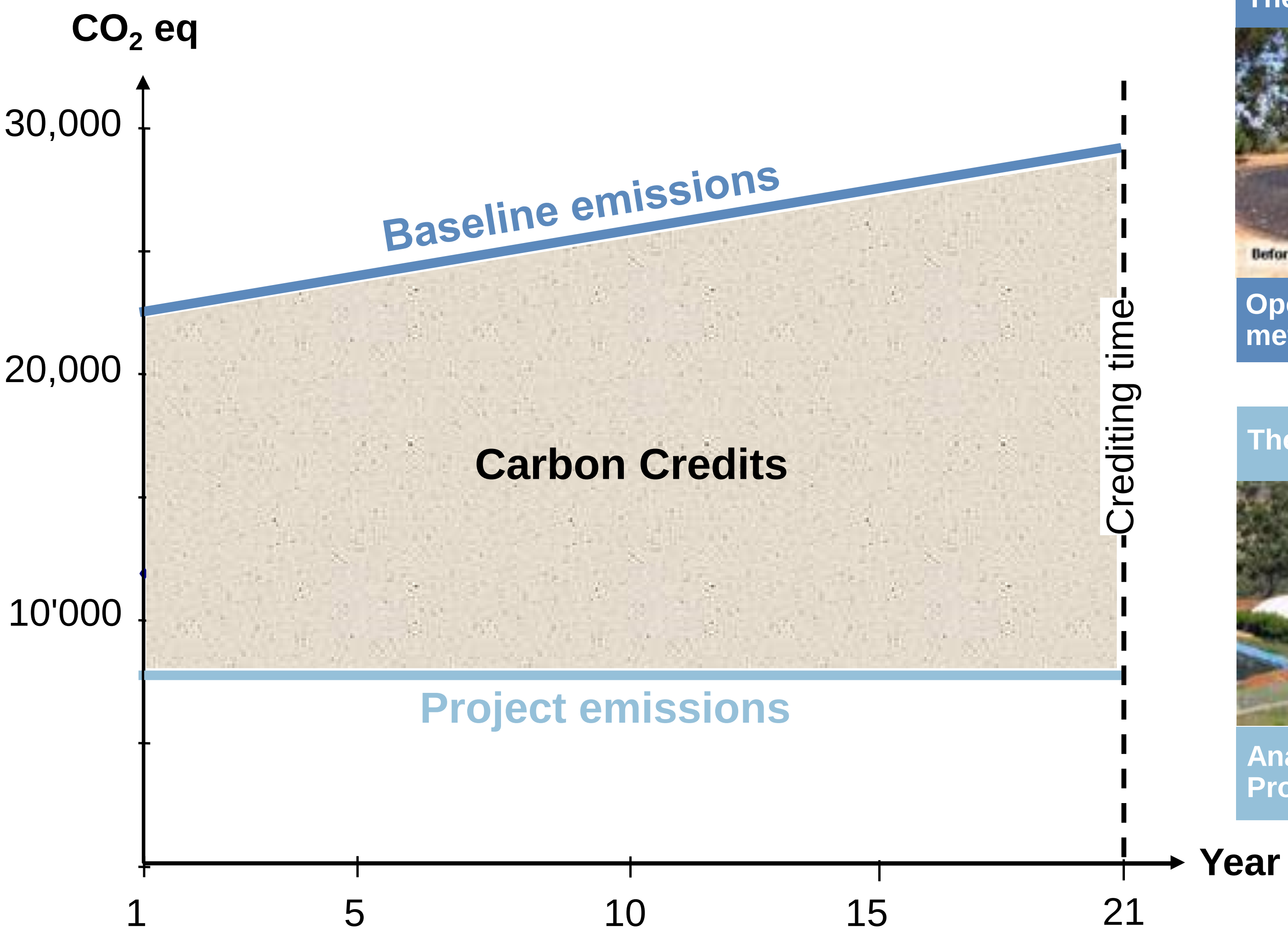
Example

- **Switzerland needs to reduce its emissions** to comply with the KP
- **Burkina Faso** has no emission limits
- **In Burkina many emission reduction opportunities exist** and some are realized
- **Carbon credits are sold** from Burkina Faso to Switzerland

Siehe auch: www.youtube.com/watch?v=mRWEgVALITA&feature=emb_title

South Pole, Zürich, 2010

Mode of action of carbon credits (a case study)



Business as usual:
The “baseline” scenario

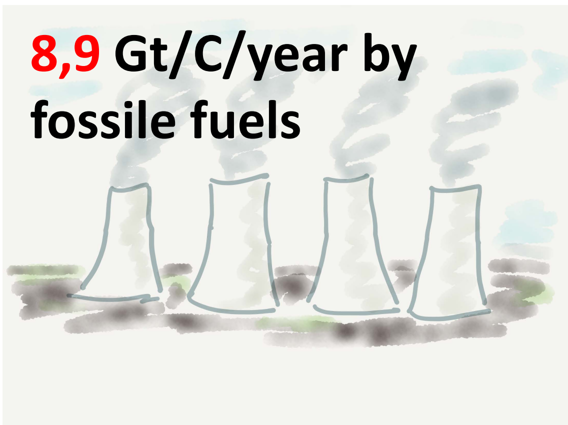
Open lagoons emitting methane

The CDM project

Anaerobic digesters that Produce electricity/heat

South Pole, Zürich, 2010

4 ‰ C Initiative



8,9 / 2400

4 ‰ (0,4 %) Increase of the organic carbon in the soil is necessary to compensate for the annual emissions of 8.9 Gt.

Important: No specific goal for the enrichment of organic soil carbon in agricultural soils, but a theoretical value that generally emphasizes the importance of changes in the supply of organic soil matter in the context of climate change and agricultural sustainability!

www.4p1000.org

French Ministry of Agriculture, 2015

> MILESTONES

- **16 September 2015** International Conference on "*Agriculture and agricultural soils facing climate change and food security challenges: public policies and practices*" at the OECD
- **12-15 October 2015** Committee on Food Security in Rome - FAO
- **12-23 October 2015** UNCCD COP12 Desertification in Ankara
- **1 December 2015** COP21 in Paris : official launch of the "*4‰ Initiative : soils for food security and climate*" by signing a joint declaration between all stakeholders

Key figures

24 % of global soils are degraded at various levels, including 50 % of agricultural soils [source: Bai et al., 2013]

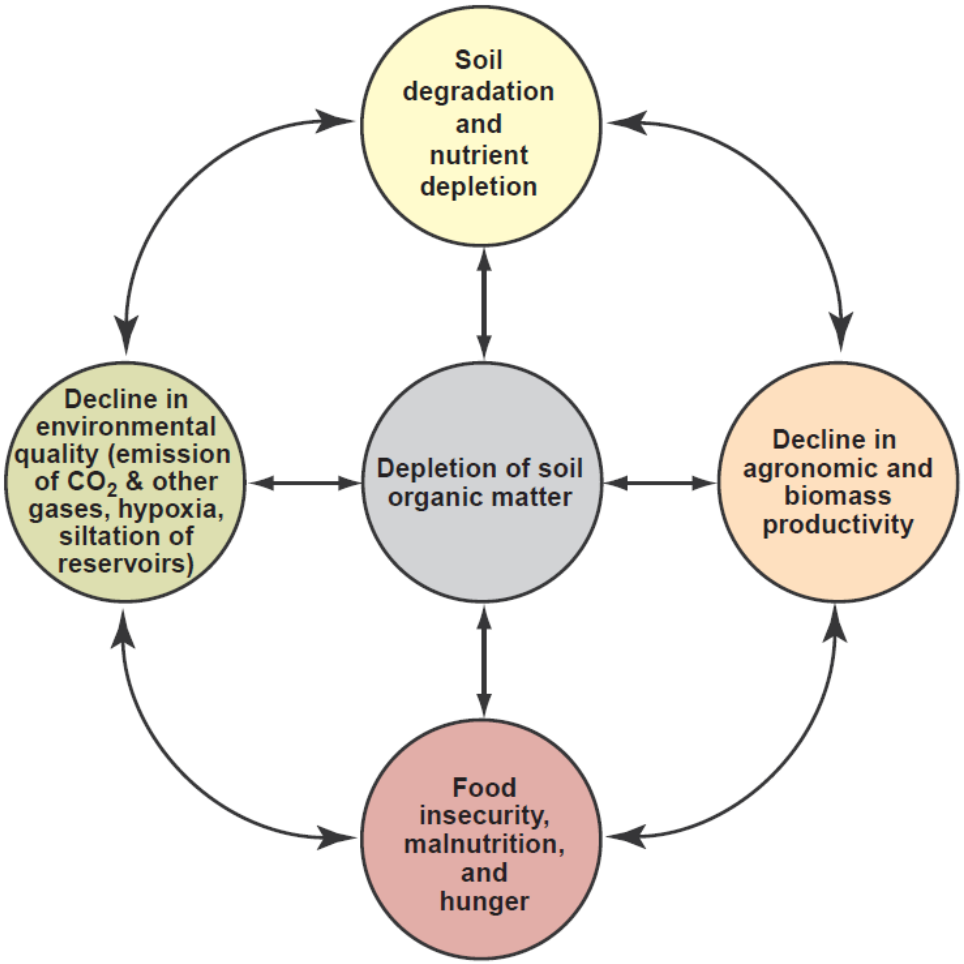
1 500 billion tonnes of carbon are stocked in soil organic matter, which is twice more carbon than atmospheric CO_2 [source : IPCC, 2013]

1,2 billion tonnes of carbon could be stocked every year in agricultural soils which represents an annual rate of 4‰ compared to the surface soil horizon [source : IPCC, 2014]

Every years crop production in Africa, Asia and South America could increase by **24/40** millions, by increasing soil organic matter by 1 tonne/ha [Lal , 2006]

1,2 billion USD is the economic loss in crop production due to soil degradation [FAO, 2006]

Vicious cycle of humus loss - Decrease in crop yield - Food insecurity



Prof. Rattan Lal
Ohio State University, USA

An increase of 1 ton of soil carbon pool of degraded cropland soils may increase crop yield by 20 to 40 kilograms per hectare (kg/ha) for wheat, 10 to 20 kg/ha for maize, and 0.5 to 1 kg/ha for cowpeas.

As well as enhancing food security, carbon sequestration has the potential to offset fossil fuel emissions by 0.4 to 1.2 gigatons of carbon per year, or 5 to 15% of the global fossil-fuel emissions.

https://www.youtube.com/watch?v=4zA8F1Q8P4U

https://www.youtube.com/watch?v=Uh0TwQyw37A

Lal, 2004, Science

Relation between soil organic matter and yield levels of non-legume crops in organic and conventional farming systems (results from 7 farming system trials)

Farming system	Dependent: Y_{Nleg}							
	SOM-C-based regression, independent variables				SOM-N-based regression, independent variables			
	C_{org}		Y_{Leg}		N_t		Y_{Leg}	
	b	*p*	b	*p*	b	*p*	b	*p*
CON	0.28	*0.18*	0.35	*0.11*	0.34	*0.15*	0.34	*0.11*
ORG_{dc}	0.55	*< 0.001*	0.49	*0.002*	0.42	*0.021*	0.46	*0.01*
ORG_{all}	0.27	*0.02*	0.50	*< 0.001*	0.34	*0.008*	0.48	*< 0.001*

- **Yield levels of non-legume crops were positively correlated with SOM levels**, but the correlation was significant only under conditions of organic farming, and not with conventional farming treatments.
- Under conventional management, the agronomic relevance of SOM with regard to nutrient supply is much lower than under organic management.
- However, it has to be considered that we excluded other possible benefits of SOM in our survey that may be highly relevant for conventional farming as well.

Brock et al., JPNSS, 2011

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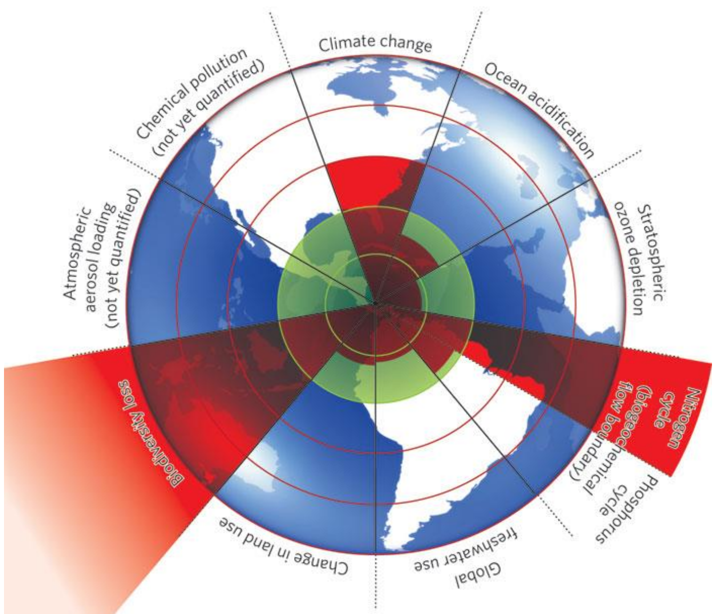
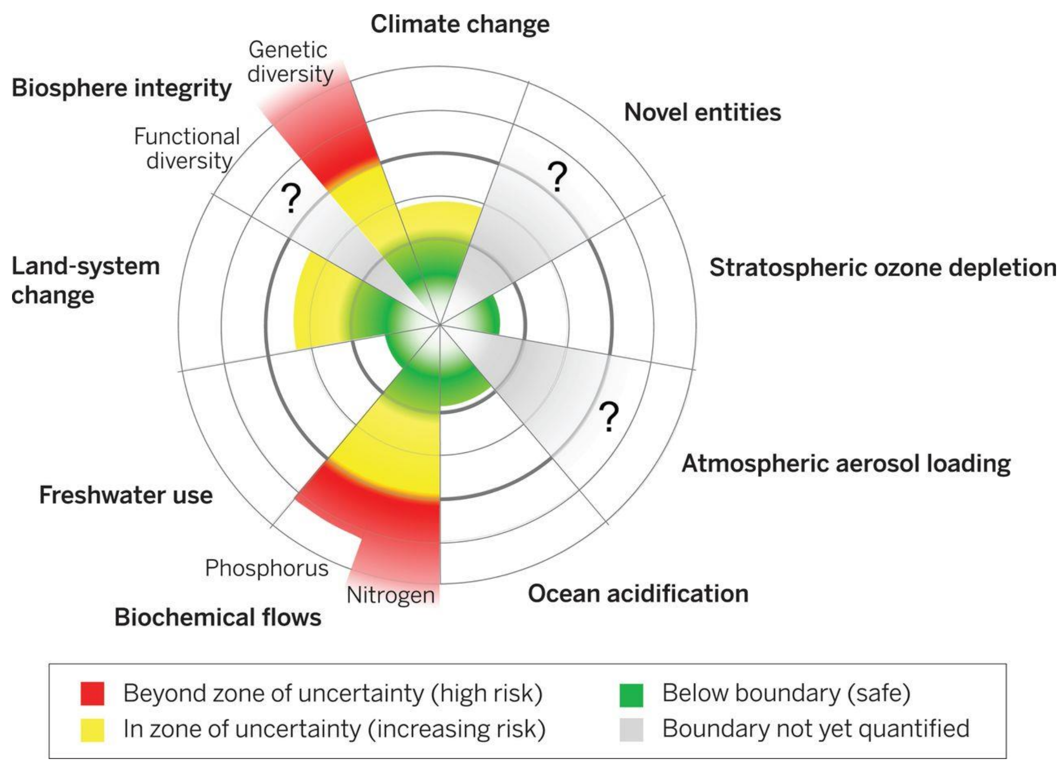
3. Carbon Farming + other sustainability criteria – a must to have?

1) apparenty **Climate Change** is not the only and (maybe) not the biggest problem!

Planetary Boundaries



Rockström et al. 2009



Steffen et al. 2015

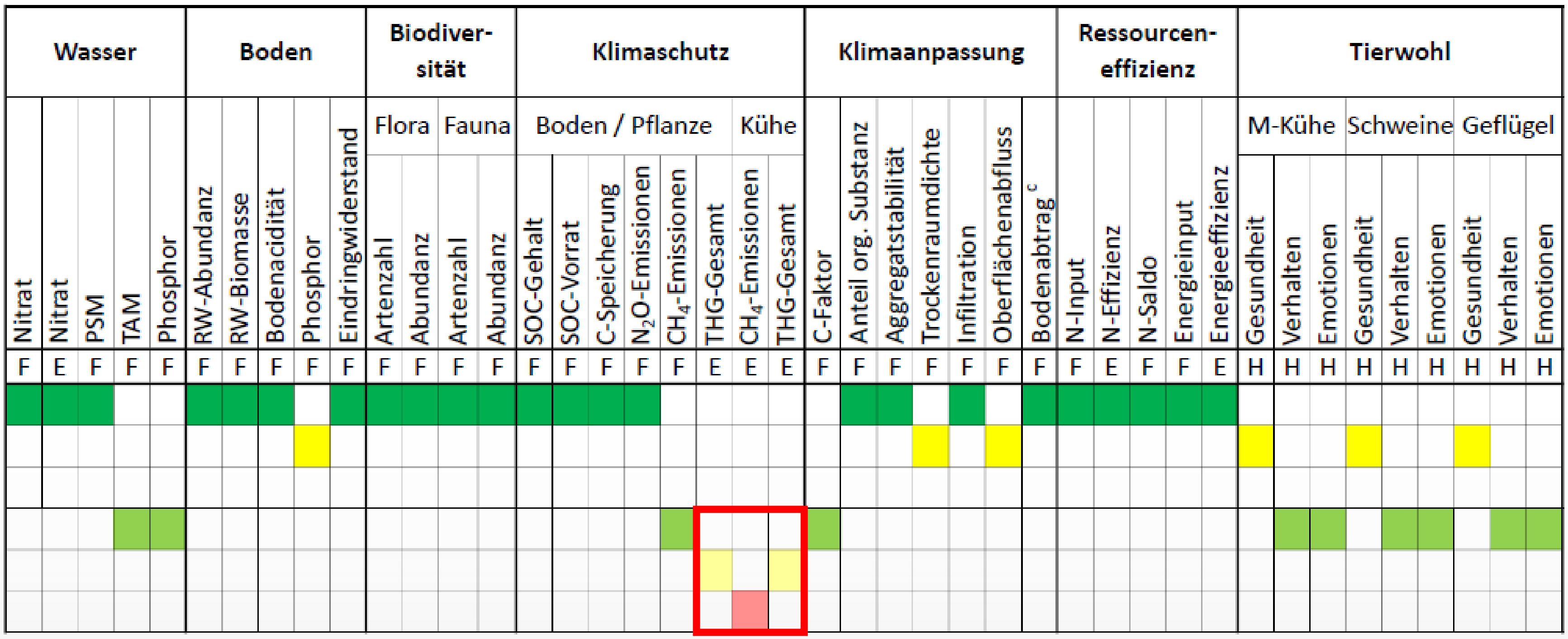
2) GHG mitigation and climate change adaption in agriculture needs to go hand in hand

Significant erosion impacts at Research Farm Gladbacherhof (Villmar-Aumenau) after extreme rain event (110L/h on 5.7.2018) despite > 35 years of organic farming and a mean sequestration rate of 0.3 t C per ha and year)

Privataufnahmen: Franz Schulz, 2018

3) **Promoting systemic changes (Organic Agriculture, Agroecology),** where other benefits are expectedly much larger than the related uncertainties in emission reductions….

Water - Soil - Biodiversity – Climate Protection – Climate Adaptation – Ressource Efficiency – Animal Welfare



Quantitative Auswertung der Literatur
- Ökolandbau erbringt eindeutig höhere Leistungen
- Ökolandbau erbringt eindeutig vergleichbare Leistungen
- Ökolandbau erbringt eindeutig niedrigere Leistungen

Qualitative Auswertung der Literatur
- Ökolandbau erbringt erwartbar höhere Leistungen
- Ökolandbau erbringt erwartbar vergl. Leistungen
- Ökolandbau erbringt erwartbar niedrigere Leistungen

In Studien gewählte Bezugsgrösse
- F Fläche
- E Ertrag
- H Herde

Sanders and Hess, 2019

3) Aktionsprogramm Natürlicher Klimaschutz (ANK)

Entwurf vom 14.02.2023

Bundesministerium
für Umwelt, Naturschutz, nukleare Sicherheit
und Verbraucherschutz

Aktionsprogramm Natürlicher Klimaschutz

Inhalt

1 von 75 | www.bmuv.de

Intakte Ökosysteme sind natürliche Klimaschützer. Wälder und Auen, Böden und Moore, Meere und Gewässer, naturnahe Grünflächen in der Stadt und auf dem Land binden Kohlendioxid aus der Atmosphäre und speichern es langfristig. Sie wirken zudem als Puffer gegen Klimafolgen, indem sie Hochwasser aufnehmen und bei Hitze für Abkühlung sorgen. Und schließlich erhalten sie unsere Lebensgrundlagen, bieten wichtige Lebensräume für Tiere und Pflanzen, speichern Wasser und sind Rückzugsorte für Menschen. Mit dem Aktionsprogramm Natürlicher Klimaschutz (ANK) machen wir deshalb Ökosysteme stark und verbinden Klimaschutz mit Naturschutz.

https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Naturschutz/aktionsprogramm_natuerlicher_klimaschutz_2023_bf.pdf

Carbon Farming – synergies with other sustainability criteria

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1) **Less important** for technical mitigation measures in agriculture

Table VI-2. **Methodology Categorization other Sectors** (continued)

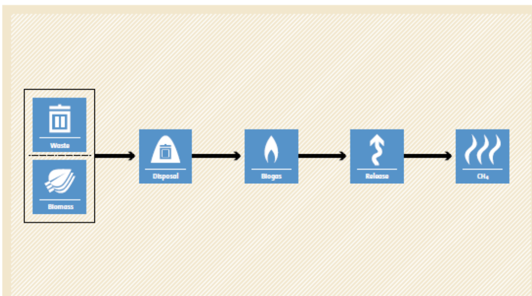
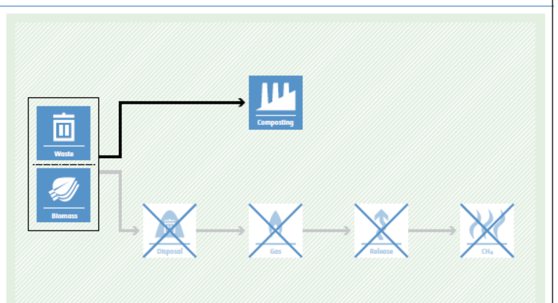
Sectoral scope	Renewable energy	Energy Efficiency	GHG destruction	GHG emission avoidance	Fuel/Feedstock Switch	GHG removal by sinks	Displacement of a more-GHG-intensive output
13 Waste handling and disposal	ACM0022 AM0112 AMS-III.BJ.	AMS-III.AJ. AMS-III.BA.	AM0073 ACM0001 ACM0010 ACM0014 AMS-III.G. AMS-III.H. AMS-III.AX.	AM0057 AM0080 AM0083 AM0093 AM0112 ACM0022 AMS-III.E. AMS-III.F. AMS-III.I. AMS-III.Y. AMS-III.AF. AMS-III.AO. AMS-III.BE.			
14 Afforestation and reforestation						AR-AM0014 AR-ACM0003 AR-AMS0003 AR-AMS0007	
15 Agriculture			AM0073 ACM0010 AMS-III.D. AMS-III.R.	AMS-III.A. AMS-III.AU. AMS-III.BE. AMS-III.BF. AMS-III.BK.	AMS-III.R.		

United Nations CDM Methodology Booklet December 2021 (up to EB 112)

1) **Less important** for technical mitigation measures in agriculture….

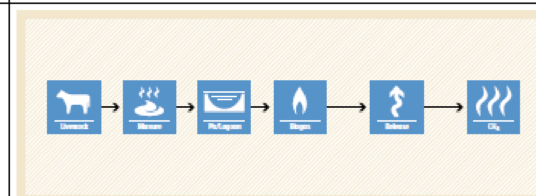
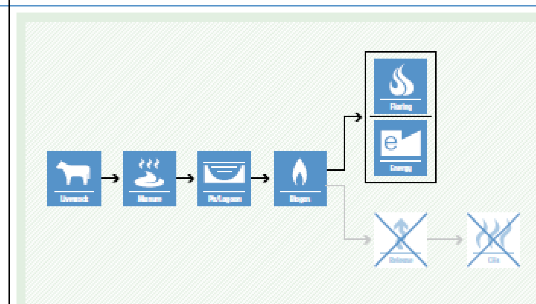
United Nations Framework Convention on Climate Change | CDM Methodology Booklet December 2021 (up to EB 112) | AMS-III.F.

AMS-III.F. Avoidance of methane emissions through composting

Typical project(s)	Controlled biological treatment of biomass or other organic matter is introduced through aerobic treatment by composting and proper soil application of the compost.
Type of GHG emissions mitigation action	• GHG emission avoidance. Avoidance of GHG emissions by alternative treatment process.
Important conditions under which the methodology is applicable	• Recovery and combustion of landfill gas is not eligible; • Identified landfill(s) should be able to accommodate the waste to be used for the project for the duration of the crediting period; or it is common practice in the region to dispose of the waste in solid waste disposal sites (landfills).
Important parameters	Monitored: • Quantity of waste biologically treated and its composition through representative sampling; • When project includes co-treating of wastewater, the volume of co-treated wastewater and its COD content through representative sampling; • Annual amount of fossil fuel or electricity used to operate the facilities or auxiliary equipment.
BASELINE SCENARIO Biomass and other organic matter (including manure where applicable) are left to decay and methane is emitted into the atmosphere.	
PROJECT SCENARIO Methane emissions are avoided through composting.	

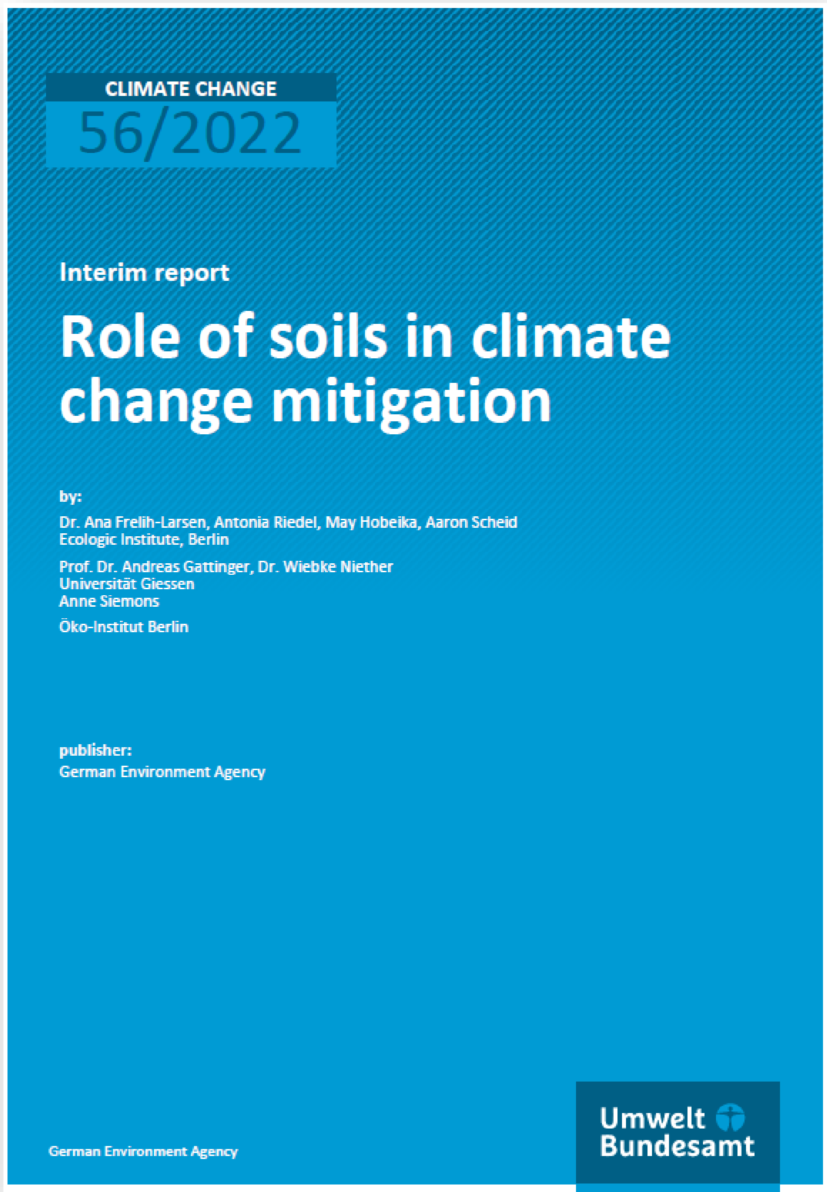
United Nations Framework Convention on Climate Change | CDM Methodology Booklet December 2021 (up to EB 112) | AMS-III.D.

AMS-III.D. Methane recovery in animal manure management systems

Typical project(s)	Replacement or modification of existing anaerobic manure management systems in livestock farms, or treatment of manure collected from several farms in a centralized plant to achieve methane recovery and destruction by flaring/combustion or energetic use of the recovered methane.
Type of GHG emissions mitigation action	• GHG destruction. GHG destruction and displacement of more-GHG-intensive service.
Important conditions under which the methodology is applicable	• Manure or the streams obtained after treatment are not discharged into natural water resources (e.g. river or estuaries); • In the baseline scenario the retention time of manure waste in the anaerobic treatment system is greater than one month, and in case of anaerobic lagoons in the baseline, their depths are at least 1 m; • Final sludge must be handled aerobically; • The storage time of the manure after removal from the animal barns, including transportation, should not exceed 45 days before being fed into the anaerobic digester, unless it can be demonstrated that the dry matter content of the manure when removed from the animal barns is more than 20%.
Important parameters	Monitored: • Amount of biogas recovered and fuelled, flared or used gainfully; • The annual amount of fossil fuel or electricity used to operate the facility or auxiliary equipment; • Fraction of the manure handled in the manure management system; • Proper soil application (not resulting in methane emissions) of the final sludge must be monitored.
BASELINE SCENARIO Animal manure is left to decay anaerobically and methane is emitted into the atmosphere.	
PROJECT SCENARIO Methane is recovered and destructed or gainfully used due to replacement or modification of existing anaerobic manure management systems.	

United Nations CDM Methodology Booklet December 2021 (up to EB 112)

2) **Very important** for mitigation measures in agriculture working in/with agro-ecosystems….


CLIMATE CHANGE
56/2022

Interim report

Role of soils in climate change mitigation

by:
Dr. Ana Frelih-Larsen, Antonia Riedel, May Hobeika, Aaron Scheid
Ecologic Institute, Berlin

Prof. Dr. Andreas Gattinger, Dr. Wiebke Niether
Universität Giessen
Anne Siemons

Öko-Institut Berlin

publisher:
German Environment Agency

German Environment Agency

Umwelt Bundesamt

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

eco logic

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Frelih-Larsen et al. 2022

GHG mitigation measures based on Nature-based Solutions (NbS)

- Assessment of relevant climate friendly soil management options (Frelih-Larsen et al. 2022)*
- NbS are: "*locally appropriate, adaptive actions to protect, sustainably manage or restore natural or modified ecosystems in order to address targeted societal challenge(s) - such as climate change mitigation -, while simultaneously enhancing human well-being and providing biodiversity benefits*" (Reise et al. 2022).
- Detailed factsheets on 10 measures (in **bold**)

*Available at [www.umweltbundesamt.de/publikationen/Role-of-soils-in-climate-change-mitigation.](www.umweltbundesamt.de/publikationen/Role-of-soils-in-climate-change-mitigation)

Measure	Type of measure	NbS fit	SOC sequestration potential (t CO_2e/ha/year)	Co-benefits vs. Trade-offs
Conversion arable to grassland	LC	0	0.6 - 3.3	+++
Rewetting of organic soils	LC	++	1.5-1.6	++
Silvoarable agroforestry	LC, MC	++	0.8 – 7.3	+++
Silvopastoral agroforestry	LC, MC	+++	0.3 – 27	+++
Mixed crop-livestock systems	MC, LC	+++	0.1	++
Use of cover crops	MC	+++	0.3-1.1	+++
Crop rotations with forage legumes	MC	+++	2 - 2.4	++
Crop rotation with grain legumes	MC	+++	No data	++++
Permanent grassland management	MC	+++	0.2-1	++
Residue management	MC	+++	2.5	+
Mulching	MC	++	No data.	+
Applying manure / compost	MC	++	1.39	++
Prevention of land take	LC	++	10-66%	++
Improved crop rotation	MC	+++	0.2	++
Buffer strips	MC	+++	7.2- 9.3	++
Contour farming / terracing	MC	++	No data	++
Reduction of compaction	MC	+++	No data	+
Nitrification inhibitors (B/S)	MC	0	:	+
Precision farming	MC	+	No data	++
Low input grasslands	MC	+++	0.14	+
Organic farming	MC	+++	1.65	+++
Critical external inputs	MC	+++	1.38	++

2) **Very important** for mitigation measures in agriculture working in/with agro-ecosystems….

A.2 Silvoarable agroforestry (including hedgerows)

A.2.1 Measure definition

Agroforestry with cropland or silvoarable agroforestry is a system where woody perennials such as trees or hedges and agricultural, usually annual crops are grown on the same cropland in a specific spatial and/or temporal fashion (Cardinael et al. 2017; FAO and ICRAF 2019). This involves tree lines but may also involve the use of hedgerows, woodlots (small parcels of woodland), and scattered trees (Golicz et al. 2021).

In Europe, five main categories of trees occur in agroforestry systems: fruit trees, olive trees, timber trees, oaks and fodder trees (Eichhorn et al 2006). Depending on the systems, cereals, vegetables, sunflowers or fodder crops (e.g., legumes, alfalfa) can be intercropped with trees. Systems can vary in terms of the intensity of management, with some managed extensively and others relying on fertilisation and irrigation. Olive trees (dispersed or in rows), linear systems of hybrid poplars, and oak systems intercropped with cereals are some of the most widely adopted systems. Systems with timber trees may be more promising commercially because they face fewer constraints than fruit trees (fruit trees compete more with crops on the same area of land; market standards for fruit trees) (Eichhorn et al. 2006).

Some systems combine trees with both arable and grassland use (grazing, fodder cultivation) so that the term *agrosilvopastoral* is used. For example, in Spanish *dehesas*, the grazing component is dominant, but a small proportion of land may also be cultivated with crops such as cereals, sunflower or fodder crops (Eichhorn et al. 2006).

Agroforestry covers approximately 8.8% of the EU's utilised agricultural area and is concentrated in the Mediterranean and southeast Europe (Burgess et al. 2018). There is insufficient quality of data to be able to determine the share of silvoarable as opposed to silvopastoral or silvoarable-pastoral systems. However, pure silvoarable systems represent a minor share of agroforestry in the EU.

Geographical and biophysical applicability

- **Suitability to different biophysical conditions:** In Northern Europe silvoarable systems are limited by light availability due to higher latitudes (lower photon flux densities) which reduces the economic viability of crops under tree canopies (Eichhorn et al. 2006). In the Mediterranean, there is a greater diversity of silvoarable systems with the limiting factor here being water availability. Sloping land should not be kept exposed due to risk of soil erosion, so that silvoarable systems should also not be established here unless they use permanent soil cover (reduced or no-till organic systems that do not use herbicides).
- **Suitability in EU/German conditions:** Given the large diversity of potential combinations of trees and crops, silvoarable agroforestry systems can in principle be designed for and applied across Europe. They should not be established on rich organic soils due to emissions occurring during the planting phase of the trees and because this would limit rewetting of peatlands, which is a much more effective mitigation option.

Fit with NbS definition

Silvoarable agroforestry serves carbon sequestration objectives and fulfil all aspects of nature-based solutions as in the working definition for this research project as defined by Reise et al. (2022) provided that: the arable components of the system are locally appropriate and protect soils and that agroforestry is not situated on rich organic soils, does not involve conversion from

A.8 Nitrification inhibitors: biological and synthetic

A.8.1 Measure definition

Nitrification inhibitors (NIs) are compounds that delay bacterial oxidation of NH_4^+ to NO_3^- (Nitrification) by depressing the enzymatic activities of nitrifiers (e.g. Nitrosomonas) in the soil (Subbarao et al. 2006). NIs were developed to prevent nitrate leaching by stopping bacteria in the soil from converting nitrogen from fertilisers or animal urine into nitrate. Inhibition of nitrification can improve the sustainable use of nitrogen by reducing nitrate leaching to groundwater (Qiao et al. 2015). Lower nitrate concentrations in soils also contribute to reduced nitrous oxide emissions.

Geographical and biophysical applicability

- **Suitability to different biophysical conditions:** They can be used in different cropping systems across various climatic regions (Subbarao et al. 2006). Because a wide geographical range of plant species possess nitrification inhibitory effect (Wang et al. 2021), BNIs can be locally applied in different geographical regions. SNIs are less effective in soils with heavy texture, high soil organic matter as this might cause sorption of the inhibiting compounds and affect its mobility (Subbarao et al. 2006). For example, in a plane loamy soil in Wisconsin, US, nitrap yearin completely inhibited nitrification in soils with 1% SOM and at higher pH whereas this was not effective in soils with 5% SOM (Hendrinkson and Keeney 1979). Also, in an arable soil in Germany, SNIs like DCD was found to perform better at reducing nitrate formation in sandy than in loam and clay soils (Barth et al. 2019). This is not surprising since their original application was to prevent nitrate leaching from sandy soils.
- **Suitability in EU/German conditions:** SNIs are widely used on conventional farms with livestock and/or biogas production, where ammonia-rich slurries prone to gases and dissolved nitrogen losses are regularly applied. They are also widely used by arable farms with light soils and urea-based fertilisation regimes. The further expansion of SNIs is limited because of the European and German goal to increase the share of organic agriculture to 30% and SNIs are per definition not compliant with the EU organic regulation.

Nitrification inhibitors can be either biological (BNI) or synthetic (SNI)[26] (Coskun et al. 2017).

Subbarao et al. (2006) listed 64 synthetic compounds which have been proposed as SNI. Most of these SNIs inhibit the first enzymatic step of nitrification (inhibition of the ammonia oxidase enzyme AMO) (Ruser and Schulz 2015). Commercially and widely utilized SNIs are nitrap yearin, dicyandiamide (DCD) and 3,4-dimethylp yearazole phosphate (DMPP) (Ruser and Schulz 2015; Subbarao et al. 2006). Nitrap yearin and dicyandiamide (DCD) belong to a large extent to the inhibition group of Cu chelators and the same mechanism of inhibition is also assumed for DMPP (Ruser and Schulz, 2015.), whereby a strict classification of SNIs in only one group of inhibitors is not possible. However, some SNIs also carry risks for soil health and biodiversity as they can be ecotoxic for terrestrial and aquatic organisms: in a study of two commercial NIs (Piadin and Vizura) and an active ingredient of another NI (dicyandiamide (DCD)), Piadin and Vizura showed ecotoxic effects in all experiments conducted (Kössler et al. 2019). Concerns have also been raised about risk to human health since the active ingredient, dicyandiamide (DCD), was found as a residue in milk (Ray et al. 2020). This underlines the importance of applying the precautionary principle and a comprehensive risk assessment.

[26] There are also urea inhibitors (UI). SNI and UI are often grouped together as "inhibitors", however they are chemically different and have different modes of action. This factsheet focuses on SNI and BNI.

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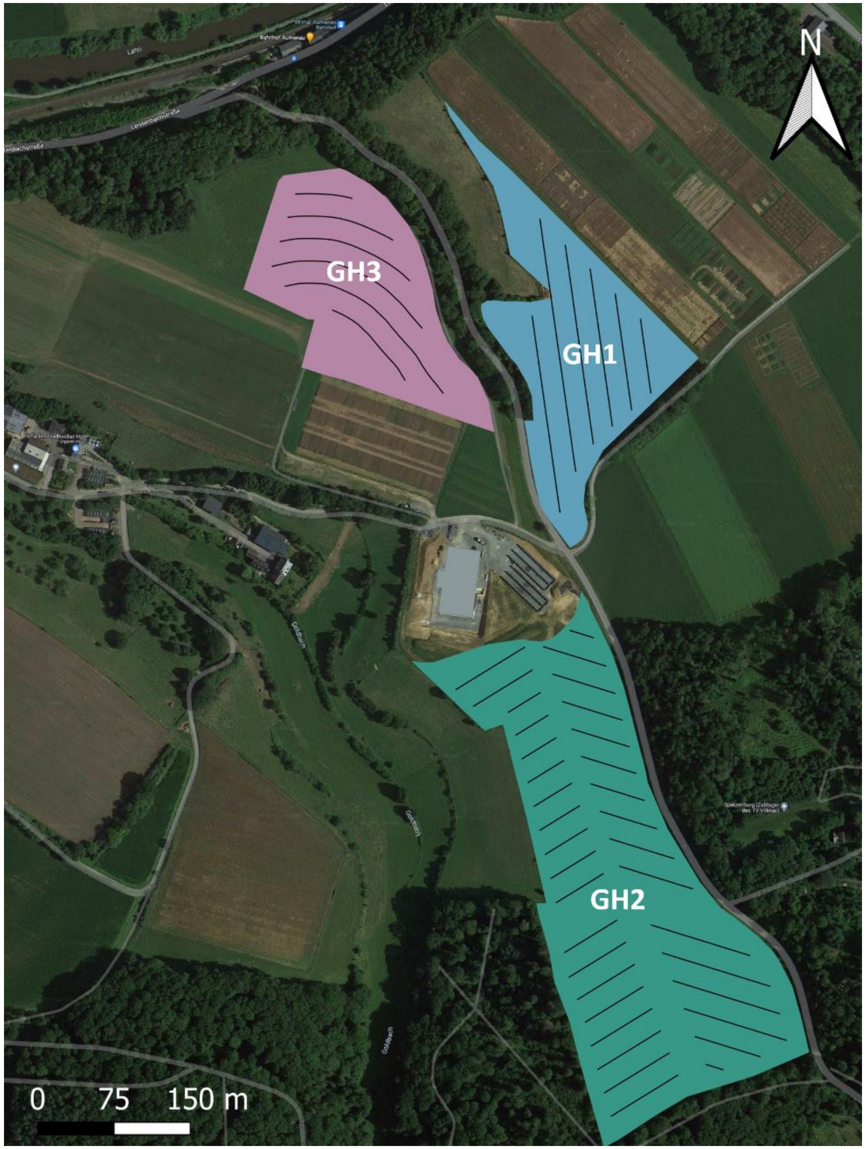

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