CH11 - Key issues in developing robust carbon-neutral certification schemes for agriculture

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Carbon farming: standards, good agricultural practices, reporting and verification activities

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Summary

The carbon cycle has always been a crucial element of agri-food production. However, the rise in atmospheric CO_2 from around 280 parts per million (ppm) in 1780 pre-industrial revolution to 417 ppm in 2022 has led to focus on whether carbon farming to increase nature-based CO_2 sequestration can provide opportunities to halt and then reverse this trend. The aim of this chapter has been to consider carbon farming in terms of standards, practices, reporting and verification. Carbon codes, such as the UK Woodland Carbon Code and Peatland Carbon Code are emerging as integral components of carbon trading and play a critical role in quantifying and certifying the carbon sequestered through land use change. Such governance approaches allow carbon farmers to generate tradable carbon credit, contributing to efforts in mitigating climate change while also ensuring high environmental integrity and engaging with local communities in a transparent and collaborative manner.

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1. Introduction

Utilising algae, fungi and plants to sequester carbon dioxide (CO_2) from the atmosphere, via photosynthesis, to convert into simple and complex molecules has underpinned the food web within nature and food production for an ever-growing global human population. The carbon cycle has always been a crucial element of food gathering and later food production that emerged as a range of farming practices. However, the rise in atmospheric CO_2 from around 280 parts per million (ppm) in 1780 pre-industrial revolution to 417 ppm in 2022 (NOAA, 2023), has led to focus on whether carbon farming can increase CO_2 sequestration and then provide opportunities to halt and then reverse this trend. BS EN ISO 14064:2019 (p.2) define a greenhouse gas (GHG) as a "gaseous constituent of the atmosphere, both natural and anthropogenic [as a result of human activity], that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds." Atmospheric levels of three GHGs namely CO_2, methane (CH_4) at a mean mole fraction 1.9 ppm in 2022, and nitrous oxide (N_2O) at a mean mole fraction 0.3 ppm in 2022, and their contribution to climate change continue to give cause for concern (NOAA, 2023).

Carbon farming can be viewed from the sequestration aspect as a whole farm approach that optimises carbon capture (sequestration) by implementing practices that improve the rate of carbon dioxide (CO_2) removal from the atmosphere and storing the CO_2 in plant material and/or soil organic matter (CCI, 2023). Other definitions, e.g., in the European Parliament publication "Organic farming. Making agriculture fit for 2030," expand the definition of carbon farming to include both practices for sequestering atmospheric carbon and/or for reducing greenhouse gas emissions (GHGEs) at farm level (Dumbrell et al. 2016; McDonald et al. 2021). Thus, carbon farming is positioned as an important approach to mitigate GHGEs (Dumbrell et al. 2016). Thus, carbon farming refers to the farm management practices that aim to deliver climate mitigation through changing agricultural activities with a carbon benefit as a result.

Carbon farming involves: "the management of both land and livestock, all pools of carbon in soils, materials, and vegetation, plus fluxes of CO_2, CH_4, and N_2O… [including] carbon removal (sequestration and permanent storage of carbon in soils and biomass), avoided emissions (preventing the loss of already stored carbon), and emissions reductions i.e., reductions of GHGEs below current levels of farm emissions" (McDonald et al. 2021). Decarbonisation of farming activities can be achieved by either reducing the intensity of GHGEs per unit of output or alternatively, or in combination, offsetting GHGEs associated with the unit of output by equivalent GHGEs capture through another activity (Rogelj et al. 2018; Pearson et al. 2023).

The advantages of carbon farming are that it provides a multi-enterprise income source for farming businesses linking natural resources, food production and net GHGEs reduction; drives farmers to increase and optimise soil carbon and as a result improve soil health, which in turn improves climate resilience, reduces the risk of flooding through increasing water holding capacity and slows water-run-off from farms, reducing as a result diffuse pollution (e.g., of nutrients and crop protection products) and soil erosion risk, improves biodiversity and conservation air and water quality, optimise and improve human wellbeing (McDonald et al. 2021; Green, 2022). In this context, a natural resource can be considered as a part of nature that provides any benefits to humans or underpins human well-being (BS EN ISO 14008:2020). An ecosystem, "the dynamic complex of plant, animal and micro-organism communities and their non-living environment, interacting as a functional entity (BS EN ISO 14008:2020, p. 2), is depended on this natural cycles.

Why is carbon farming gaining so much attention? The United Nations Food and Agriculture Organisation (FAO) state that in 2018 global GHGEs due to agricultural activity (within farm gate and related land use/land use change), was 9.3 billion tonnes of CO_2eq or Carbon Dioxide Equivalent. Carbon Dioxide Equivalent (CO_2e or CO_2eq) is the standard unit of measure used in carbon calculations where the emissions of different gases can be compared and combined on the basis of their global warming potential (GWP) to give one aggregate metric. BS EN ISO 14064-1:2019 (p.3) describe GWP as "index, based on radiative properties of greenhouse gases (GHGs), measuring the radiative forcing following a pulse emission of a unit mass of a given GHG in the present-day atmosphere integrated over a chosen time horizon relative to that of CO_2." GWP is a measurement of the impact of each GHGE gas in terms of their capacity to absorb heat in the atmosphere. GWP is the amount of energy, the emissions of 1 tonne of gas will absorb over a given time period, usually a 100-year averaging time, compared with the emissions of 1 tonne of CO_2 (Vallero, 2019). However, some GHGEs whilst they absorb heat in the atmosphere, they do not have such a long residency period in the atmosphere when compared with CO_2. An example is CH_4, and residency period in the atmosphere of this gas is taken into account with the GWP100 or 100-year GWP calculation.

The GHGs most commonly considered in the GWP100 calculation are CO_2 (Lifetime 5 to 200 years depending on carbon cycling; GWP100 of 1), CH_4 (Lifetime 12 years; GWP100 of 25) and N_2O (Lifetime 114 years; GWP100 of 298) and hydrofluorocarbons and chlorofluorocarbons where the GWP100, varies, but can be thousands of times greater that of CO_2 (IPCC, 2007a; 2007b; Greenhouse Gas Protocol, 2015). Whilst GWP100 is a useful metric, it does not consider the difference between a stock gas and a flow gas. CO_2 is an atmospheric stock gas or stock pollutant i.e., due to its lifetime it contributes to the overall atmospheric stock of GHGs in the atmosphere (Ajani et al. 2013); and is the most important contributor (IPCC, 2007a).

Table 1. Carbon reservoirs within the carbon cycle (Adapted from Rackley, 2010; Ajani et al. 2013; NOS, nd).

Carbon reservoir	Description	Restoration time	Examples
Atmosphere	Atmospheric carbon is the carbon stored in the atmosphere.		The atmosphere carbon is almost completely CO_2 at about 0.04% by volume. CH_4 also present.
Biosphere	Biocarbon: the carbon stored in the biosphere.	Natural ecosystems (decades to millennia); semi-natural ecosystems (years to centuries); agricultural systems (annual to decades).	Living and dead biomass and organic and inorganic carbon in soils in terrestrial and marine ecosystems. Carbon stored in natural ecosystems (peatlands, savannah, forests) and managed natural ecosystems (food, fibre, biofuel).
Geosphere	Geocarbon: the carbon stored in the geosphere.	Geological time.	Fossil fuel reserves (oil, coal, gas), sedimentary rocks e.g., limestone, methane clathrates, marine sediments.
Ocean	Carbon stored or dissolved in the ocean e.g. via photosynthesis with algae and plankton.		Blue carbon is the carbon stock within the ocean and the coastal ecosystem e.g., sea grasses, mangroves, salt marshes, wetlands.

As a flow gas, methane is short-lived in the atmosphere and some argue that in the GWP100 the impact of CH4 is over-estimated and suggest the GWP* method should be used which better takes into account the production and breakdown of CH_4 (Rocha, 2022). Considering the carbon cycle there are multiple carbon stocks and carbon fluxes or flows between the stocks, especially as a result of the activities of humans (anthropogenic) contributing to the GWP100. Carbon reservoirs within the carbon cycle include the ocean; the atmosphere, the geosphere (geocarbon) and the biosphere and these are described more fully in Table 1. This carbon flux or dynamic interaction between GHG sources (processes that release a GHG into the atmosphere) and GHG sinks (processes that remove GHGs from the atmosphere) and GHG reservoirs such as the soil or forests that can store and release GHGs (BS EN ISO 14064:1 2019).

Carbon flux refers to the amount of carbon exchanged between carbon stocks, for example, the flux with farming activities between the geosphere and the atmosphere due to fossil fuel exploration and use especially artificial fertiliser production; and from atmosphere to biosphere through photosynthesis in natural, and semi-natural ecosystems and agricultural systems. Certain farming practices can influence the carbon inputs and outputs from the soil and if they are exploitative can cause the loss of soil organic content over time (SOC). Carbon farming practices are management practices that are known to sequester carbon and/or reduce GHGEs and if focused on soils increase SOC. Some of these practices are promoted by the United States (US) Natural Resource Conservation Service (NRCS) as conservation practices that improve soil health and sequester carbon while producing further important co-benefits. These co-benefits include increased soil water holding capacity, hydrological function, improved soil quality, enhanced biodiversity, and resilience (CCI, 2023). All farming systems can mitigate GWP through these farming practices, although the level of mitigation potential will differ across farm types, the appropriate options and different geographies (McDonald et al. 2021). Table 2 highlights a range of farming activities which form an element of carbon farming practices and these have been grouped into agroforestry, energy production, fibre production, resource appraisal and optimisation strategies including integrated crop and livestock systems, specific crop production practices, livestock production practices, and nature-based practices and their impact on the farming business and society. The public benefits of carbon farming include more resilient food production systems that underpin soil security and food and nutrition security (Pozza & Field, 2020), and positively influence hydrology, biodiversity and GHGE mitigation (Dumbrell et al. 2016).

Biofuel production on land and fibre production can arise from focused and/or integrated practices e.g., wool production provides fibre and can also support food security through meat as a byproduct; sugar cane production can provide both food and bioenergy through the production of ethanol (Higashi et al. 2023). Agroforestry combines food production and tree planting. Agroforestry is defined by Paudel et al. (2022, p.1) as “a land management system that integrates trees, agriculture crops, and animal farming in order to provide a diverse range of ecosystem services.” Silvopasture, a form of agroforestry, combines trees and livestock production from forage in a specific farming system (Jose et al. 2019).

Table 2. Carbon farming practices. (Adapted from Lal, 2015; Dumbrell et al. 2016; CCI, 2023)

Activities	Impact on farming business and society
Agroforestry (including silvopasture, woodland pasture, maintaining hedgerows, riparian restoration). **Energy production** (agrovoltaics, biofuel	Agroecosystem improvement Carbon sequestration Increased agricultural yields (food security) Increased soil moisture retention

production) **Fibre production** (hemp, flax, cotton, wool, leather) **Resource appraisal and optimisation strategies** (e.g. fertiliser, crop protection products). Integrated crop and livestock systems **Crop production practices** (application of biochar, green manure or mulch to land; biomass planting, compost application, crop residue retention, maintaining crop cover; direct drilling, inter-cropping with perennial pastures, multi-species cover cropping, no-till cropping practices, planting tree belts, retaining/incorporating crop residue/stubble after harvest) **Livestock production practices** (forage planting, maintaining appropriate grazing systems, feed additives to reduce methane production) **Nature-based practices** (using natural vegetation to reduce salinity and increase land sequestration capacity)	Improved efficiency of input use Improve nutrient storage capacity Improved profitability Improved soil biodiversity and earthworm activity Improved soil organic carbon (SOC) Improved soil structure Improved water quality Nutrient cycling Reduced point source and diffuse pollution Reduced soil erosion by water and wind. Resilience Restoration (biodiversity) Restoration (soil)

Agroforestry systems can have a range of elements in terms of:

- **structural components**: spatial (boundary, strip, hedges and mixed systems), or temporal (overlapping, sequential, simultaneous); and
- **functional components:** productive (food, fodder, fuel, other) or protective (windbreak, shade, shelterbelts with environmental (reducing diffuse pollution) and social (animal welfare) benefits and soil conservation and soil restoration) (Nair et al. 2021).

Agrovoltaics farming combines the integration of photovoltaics (PV panels) on land with crop or livestock production (John & Mahto, 2021), e.g., PV arrays in field and sheep production or PV arrays on buildings with crops and rainwater harvesting (Jain et al. 2021). In summary, land managers including farmers and foresters are managing large carbon stocks and associated carbon fluxes, and as a result they have a large role to play in climate change mitigation and delivery of net zero carbon emissions.

This introduction is not intended to provide an exhaustive analysis of carbon farming per se, but to use examples to introduce key terms and to demonstrate the range of options that can be combined into an effective carbon farming strategy that may include a portfolio of activities from food production to energy production, biodiversity enhancement and water management. The activities can be focused on economic, environmental or social aspects of carbon farming but they all are centred on improving capital assets and enhancing business performance however it is measured. Natural capital is the "stock of renewable and non-renewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people." (BS 8001:2017, p. 15). Whilst financial, physical, human and social capital are understood and embedded into business strategy, what natural capital is and how it is an inherent aspect of the 'business balance sheet' has gained more recent attention. Effective management of these 'five capitals' underpins the resilience of farming systems, their interrelationship with natural systems and the ability to effectively recirculate resources through complex and interconnected systems.

Natural ecosystems and agri-food systems are dynamic, ever changing and this means that to be resilient they need to be able to buffer and adapt to shocks (Manning, 2023). Organisational resilience can therefore be considered as the "ability of an organisation to anticipate, prepare for, and respond and adapt to incremental change and sudden disruptions to both survive and prosper." (BS 8001:2017, p. 16). To deliver long term carbon sequestration farming systems must be carbon resilient. Carbon resilience is defined as the capacity to absorb carbon risks and thrive in a range of circumstances and situations, whilst also delivering a decarbonisation transition (Talebian et al. 2023). Carbon farming needs to embed this resilience if it is going to demonstrate prolonged impact and as a result attack financial payments for the decarbonisation impact derived. Carbon farming offers the opportunities for assuring resilience in agri-food systems and supporting them to adapt to the negative effects of climate change and mitigate the agri-food sectors contribution to climate change (Basso, 2022).

The aim of this chapter is to consider carbon farming in terms of standards, practices, reporting and verification. The chapter explores aspects of carbon farming and also the processes that can be adopted to ensure there is effective governance of approaches, claims and reporting. There are significant barriers to the adoption of carbon farming in terms of a lack of validated practices on farm, the costs and difficulties associated with carbon certification and a lack of metrics for effective verification, limited access to green finance, instability of carbon markets and a lack of articulation of the benefits for farmers of engaging (Sharma et al. 2021). The European Commission (2023) concur that effective, robust and transparent regulatory frameworks need to be in place for certifying carbon removal from atmospheric stocks and carbon sequestration. These barriers and potential options to address them are considered in this chapter. The next section considers the development of carbon footprinting of products and life cycle analysis.

2. **Carbon footprinting and life cycle analysis**

Organisational and product carbon standards are often based on product carbon footprinting and life cycle assessment (LCA). The carbon footprint of a product is the “sum of GHG emissions and GHG removal in a product system expressed as CO_2e and based on a LCA using the single impact category of climate change (ISO 14067:2018). A product carbon footprint is only valid for the specific production system that has been assessed and the footprint which will be influenced by multiple factors and will be different if assessed within another business or another supply chain. For example, comparing two farms producing carrots, one farm may have all its fields within a five-mile radius whilst another may be travelling up to twenty miles to harvest carrot, or importing carrots from Israel to pack. One farm may sell carrots loose in trays, the other may sell carrots in 1kg plastic bags and then they are put into trays. This simple example shows that the product carbon footprint and the details of the analysis of each life cycle differ, so the footprint will vary as well as the opportunities for carbon mitigation.

BS EN ISO 14044:2006 (p.1) defines a life cycle as the “consecutive and interlinked stages, from raw material acquisition or generation [of the product] from natural resources to final disposition.” The iterative LCA approach encompasses, within the system boundaries set, the aspects of natural environment, human health and resources for the life cycle of a product from raw material extraction and purchase, the energy used, material production, manufacturing, sale, use, end of life treatment and final disposal (ISO 14044:2006; BS 8001:2017). The system boundary specifies the unit processes that are part of the system being considered (ISO 14044:2006). A LCA is described as the “compilation and evaluation of the inputs, outputs and the potential environmental and/or social impacts of a product or service system through its life cycle” (BS 8001:2017). Potential trade-offs when determining a carbon footprint can also be identified and assessed. Normalisation and weighting are optional elements of a life cycle impact assessment (LCIA), and they improve the credibility of a LCA (PD ISO/TS 14074:2022). Normalisation is the calculation of the magnitude of the live cycle inventory results or indicator results relative to the reference information (PD ISO/TS 14074:2022). Weighting allows the aggregation of results into a single score or several scores by applying a context specific weighting factor to individual situations and determine as a result which environmental impacts are the most important. In order to align LCAs with risk and cost-benefit analysis of environmental aspects and impacts, monetary valuation methods need to be applied (BS EN ISO 14008:2020). The standard (BS EN ISO 14008:2020) states that monetary valuations enable comparisons and determination of trade-offs between environmental issues to inform organisational strategy and investment programmes, product and service design and implementation, financial analysis and performance evaluation, environmental assessment especially the impact on natural capital, management, reporting and compliance with legislative compliance. However, are all the benefits of carbon farming associated with derived financial value only? Are some elements of defined value not monetary, and if so how are these complex trade-offs determined?

The United Kingdom (UK) British Standards Institute (BSI) has two standards associated with LCAs: PAS 2050:2011 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. PAS 2050 was developed to assure the consistent application of a methodology to quantify product carbon footprints. Product carbon footprints can be a *cradle-to-gate inventory* i.e., a partial LCA from material acquisition to the boundary of the organisation's 'gate,' reflecting business to business (B2B) product flows. Alternatively, *a cradle-to-grave inventory* is a LCA with the boundaries from material acquisition to end of product life (Greenhouse Gas Protocol, 2011; Carbon Trust, 2023). Whilst the cradle to grave inventory is a business to consumer assessment, recycling and disposal of the product is also often included (Carbon Trust, 2023). Using PAS 2050 as a tool, organisations can determine the carbon footprint of their goods and services and opportunities for emissions reduction within the LCA approach. Other internationally recognised carbon footprint standards are the Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard (2011) and ISO 14067:2018 Greenhouse gases – carbon footprint of products – Requirements and guidelines for quantification. There are a number of BS EN ISO standards that are related to these two standards and cover aspects such as verification and validation of GHGEs related statements, quantification and reporting of GHGEs among others.

PAS 2060:2014 Specification for the demonstration of carbon neutrality states that achieving carbon neutrality i.e., the state of being carbon neutral is difficult to achieve in practice. The standard (p.2) describes the state of being carbon neutral as the "condition in which a during a specified period there is no net increase in the global emission of GHGEs to the atmosphere as a result of the GHGEs associated with the subject during the same time period." If a process in itself cannot achieve carbon neutrality one option is to associate the activity with options for carbon offsetting to achieve overall neutrality. PAS 2060: 2014 (p.3) describes a carbon offset as a "discrete reduction in GHGEs not arising from the defined subject [the entity being analysed], made available in the form of a carbon credit .... and used to counteract emissions from the defined subject." Thus, a carbon credit or carbon offset is an asset that is tradeable between organisations where one organisation e.g. a farmer, guarantees that they are undertaking a practice to reduce GHGEs to offset the GHGEs of another organisation who's activities lead to carbon emissions. As a result of trading this carbon asset the second organisation can state that overall they are carbon neutral. For example, an organisation can purchase a carbon credit that represents 1 tonne of CO_2e to offset the 1 tonne of CO_2e that they are emitting through their activities. Increasingly organisations are coming under pressure from governments who have implemented policies for countries to be 'net zero' in terms of GHGEs by 2050. The Carbon Trust (2023) are certifying a series of stages of delivery in terms of carbon footprinting and achieving carbon neutrality, based on the adoption of PAS 2050 and PAS 2060 including:

- **Reducing CO_2** (product) compared to a baseline (excluding offsetting as an option);
- **Reducing CO_2 in packaging**;
- **Carbon neutral** including offsetting through verifiable carbon credits.
- **Carbon neutral packaging**; and
- **Lower CO_2** compared to other equivalent products.

This use of carbon footprint methodologies is gaining pace as more organisations are seeking to decarbonise their activities and to deliver reduced emissions and ultimately carbon neutrality.

3. Organisational journey to net zero

The GHG Protocol Corporate Accounting and Reporting Standard (2015) is aimed at organisational accounting and reporting on seven GHGEs addressed by the Kyoto Protocol namely CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PCFs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). The emissions are divided into three groups or scopes:

- **Direct emissions** from GHG sources (processes that release GHG into the atmosphere) owned or financially or operationally controlled by the organisation i.e., within the organisational boundary (BS EN ISO 14064-1:2019). These are often called *scope 1 emissions.*
- **Indirect emissions** result from a consequence(s) of an organisation's operations and activities where the GHG sources are not directly owned or controlled by the organisation but are within the organisational boundary (BS EN ISO 14064-1:2019). These are described as *scope 2 emissions.* The final group are *scope 3 emissions* which are also indirect emissions but are outside the organisational boundary and associated with the organisation's upstream (supply chain) and downstream (outsourced activities, waste disposal or end of life disposal) activities. In the food supply chain, farms as suppliers are associated with a either a food manufacturer's or food retailer's scope 3 emissions.

In the farming context, direct land use change (dLUC) is the change in the human use of land within a given boundary (BS EN ISO 14064-1:2019) e.g. an area of rainforest. dLUC can in some instances lead to an increase in emissions e.g,, conversion of wild habitats or forests to farmland, draining of peatland or conversely the greater sequestering of carbon e.g. afforestation or changes in farming practice. There are multiple established codes for land use and the carbon implications of their management including the UK Woodland Carbon Code (https://woodlandcarboncode.org.uk) and the UK Peatland Code (https://www.iucn-uk-peatlandprogramme.org/peatland-code/introduction-peatland-code). These are now explored.

4. Carbon codes and Principles for Responsible Investment in Natural Capital

Carbon codes, such as the UK Woodland Carbon Code (WCC) and Peatland Carbon Code (PCC), are also known as carbon offset codes or carbon credits (Woodland Carbon Code, 2022; The National Trust for Scotland, 2023). Carbon codes play a crucial role in certifying and quantifying the carbon sequestered through changes in farming practices. By complying with specific carbon codes, carbon farmers can generate tradable carbon credits, which can then be bought by companies or organisations seeking to offset their own carbon emissions (Sechi et al. 2021). This fosters the implementation of sustainable farming methods while incentivising carbon sequestration to address climate change challenges, albeit that the businesses purchasing the credits may still be following a business as usual, rather than a business insetting decarbonisation strategy. Insetting is associated with the organisational activities that aim to reduce a company's own supply chain emissions rather than offsetting (Green Finance Institute, 2023). A carbon credit is a unit of measurement used to represent a discrete reduction in GHGEs, where one carbon unit represents one ton of CO_2e that has been removed from the atmosphere. A carbon credit is more formerly described as "any tradeable certificate or permit presenting the right to emit one tonne of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO_2e equivalent) to one tonne of carbon dioxide' (ISO/TR 14069:2013 p.3). Under the WCC, this reduction in GHGEs is achieved by planting and growing trees while under the PCC the reduction is achieved by restoring depleted peatland. These schemes can be part of a carbon trading system, which aims to incentivise organisations and individuals to reduce their carbon footprint and mitigate climate challenge through a range of interventions (Wallace, 2021).

Carbon farming through engagement with carbon codes and adopting carbon farming practices directly impacts on the generation and trade of carbon credits within a trading scheme. Such as reforestation, agroforestry, and soil carbon sequestration, contribute to increased carbon stocks on agricultural lands. Dales (1968) introduced and highlighted the benefits of a "cap and trade" system, the first carbon trading system, which allows governments to issue a certain number of permits (carbon credits) i.e. set a ceiling for all emissions giving a sector the right to emit pollution to a certain level. Under this type of system, the number of permits issued are lower than the amount of emissions the industry is currently producing, thereby creating a market for trading of carbon emission permits. Thus, firms that are unable to comply with the number of permits allocated to them are either incentivised to reduce emissions or trade with other firms that have carbon emissions below the permitted allowance. While the 1997 Kyoto protocol established three flexible mechanisms for carbon trading, with the first commitment for trading being made for the period between 2008 and 2012, the first voluntary trade was carried out in the late 1980s (Hepburn, 2007). As of 2023, China is the world's largest emissions trading market and covers around 4800 million metric tons of CO_2e, with the potential for covering approximately 7800 million metric tons by the end of the calendar year (Tiseo, 2023). Since 2012, multiple carbon codes and carbon trading schemes have evolved and been implemented around the world as regional and national levels to address climate change and promote carbon emission reduction efforts. Recent developments such as the Paris Agreement (United Nations Climate Change, 2016) have further aided in the development of such calls to build on and expand the mechanisms introduced by the Kyoto Protocol. One example of such schemes is now described.

4.1. The Seven Scottish Principles for Responsible Investment in Natural Capital

In the UK, the Scottish government developed the Interim Principles for Responsible Investment in Natural Capital (Scottish Government, 2022) for "responsible private investment in natural capital to communities, investors, landowners, public bodies and other market stakeholders". The aim of the principles is to provide a framework that enables design of policies that contribute to long-term economic and societal transformation, and climate change and biodiversity improvement through a Just Transition approach. Just Transition refers to the equitable and fair transformation of economies and societies to low carbon and sustainable practices, in a way that is fair and inclusive to individuals and communities through the creation of decent work opportunities and ensuring that no one is left behind (International Labour Organisation, 2015; Wang & Lo, 2021).

A. Investment that delivers public, private and community benefit

This principle emphasises on the importance of creating shared benefits among public, private, and community interests, via a just transition (Scottish Government, 2022). This means that investment and utilisation of natural resources should consider the needs and interests of all stakeholders to ensure a fair and equitable distribution of benefits. Moreover, the focus is on ensuring that the value derived from land and ecosystem services benefits local communities, promoting their well-being and prosperity. In line with the concept of Community Wealth Building, investment and management decisions should prioritise reinvesting the generated value back into local economies, fostering sustainable growth and long-term benefits for the communities involved. By adhering to these principles, Scotland can ensure that its natural capital contributes to a more inclusive and sustainable future for all its citizens.

B. Investment that demonstrates engagement and collaboration

This principle emphasises the importance of engaging with local communities in decisions about LUC as per the Scottish Government's Guidance on Engaging Communities in Decisions Relating to Land (Environment and Forestry Directorate, 2018).

C. Investment that is ethical and values-led

Investments into natural capital programmes, including carbon farming, should consider aspects such as rights and responsibilities, just transition, and fair work supporting positive social and environmental outcomes while considering the rights and responsibilities of all stakeholders involved (Scottish Government, 2022).

D. Investment that is of high environmental integrity

Investments in natural capital for carbon farming and land use for carbon management and the associated practices needs to be quantifiable, verifiable, transparent, visible and accountable in line with recognised standards such as the WCC and PCC (Scottish Government, 2022).

E. Investment that supports diverse and productive land ownership

Diverse and productive land ownership should be promoted in the activities and range of green products developed.

F. Investment that delivers integrated land use

Investment that delivers integrated land use approaches, of which an element is carbon farming, should take into account the impacts of all five capitals: natural, social, human, economic, and societal. This means that carbon management needs to be integrated with activities to address other environmental, social, and economic outcomes For example, carbon management approaches can be integrated with practices to improve soils, to reduce emissions to air, land and water and enhance biodiversity recovery. Effective approaches also need to be tailored to specific locations, land types and community objectives such as flood alleviation.

So how can the WCC and the PCC support this transition?

4.2 Carbon codes, validation and verification

The WCC links elements of sustainable forestry management with carbon accounting methods with associated validation and verification processes. All WCC projects or schemes must be initially validated by an independent validation/verification body accredited by the UK Accreditation Service (UKAS) where the body assesses against the requirements of the WCC (Woodland Carbon Code, 2022). UKAS accredits a range of schemes including emissions trading schemes (ETS) whereby under the UK ETS all submitted emissions reports must be verified by an organisation accredited to ISO/IEC 14065: 2020 (UKAS, 2023). Organisations who are accredited to ISO14065 need to demonstrate to UKAS that they can undertake validation of the specific scheme competently, accurately, consistently and with impartiality of schemes such as PAS 2050 for carbon footprinting, the WCC carbon sequestration scheme and UKAS is also trialling accreditation of PAS 2060 (UKAS, 2023). For the PCC the validation/verification body must also have UKAS accreditation to ISO 14060-3 or ISO/IEC 14065: 2020 (Peatland Carbon Code, 2023).

The UK Land Carbon Registry (2023) lists and provide public access to the status of transactions associated with all the WCC and PCC projects and their ownership, the carbon sequestration that has led to pending issuance units and how these have been converted, for example, to woodland carbon units equivalent to 1 tCO_2e. These credits can then be used in offsetting or carbon neutrality claims such as with PAS 2060 (Woodland Carbon Code, 2022). Projects under the WCC scheme are reviewed five years after establishment where pending issuance units can be converted to WCU or woodland carbon units, then at least every ten years after the start date (Woodland Carbon Code, 2022). The woodland carbon credits are issued on the basis of the degree of carbon sequestration related to the baseline audit in the biomass within the woodland area and the soil (carbon pools) the potential for carbon leakage where GHGEs increase outside the project boundary as a results of the project (deforestation elsewhere, intensification of agricultural activities elsewhere), and the additional sequestration within the project boundary within the carbon pools. As of June 2023 there are 1931 projects in the UK registered with the Land Carbon Registry and area of 72.6 thousand hectares (82.3% of which is in Scotland) with 23.8 million tCO_2e of which 9.4 million has currently been validated and 2.0 million tonnes verified at five years (Woodland Carbon Code, 2023).

There are five peatland condition categories which are associated with the peatland and the degree of GHGEs and sequestration potential which ar Pristine, Near Natural, Modified, Drained and Actively Eroding (Peatland Carbon Code, 2023) and following changes in management practices over the same time as previously reported pending issuance units can be converted to Peatland Code Units or PCU. The UK Peatland Code Registry (2023) has also been developed which has open access to see the current projects that are established.

5. Concluding thoughts

The aim of this chapter has been to consider carbon farming in terms of standards, practices, reporting and verification. The chapter has explored aspects of carbon farming and also the processes that can be adopted to ensure there is effective governance of approaches, claims and reporting. Carbon codes, such as the UK WCC and PCC are integral components of carbon trading and play a critical role in quantifying and certifying the carbon sequestered through land use change. These codes allow carbon farmers to generate tradable carbon credit, contributing to efforts in mitigating climate change. In addressing environmental challenges and promoting positive social and economic outcomes. Furthermore, frameworks such as the Scottish Principles for Responsible Investment in Natural Capital foster inclusivity and sustainability. By adhering to such principles and integrating carbon codes into carbon farming practices, investors can contribute to a more sustainable and equitable future, while also ensuring high environmental integrity and engaging with local communities in a transparent and collaborative manner. As we continue to explore the potential of carbon farming and carbon trading, further research is needed to map existing carbon codes against frameworks like the Scottish Principles, ensuring that investments in natural capital align with responsible and ethical practices.

Governance frameworks around carbon trading associated with changes to farming practices are not as robust. There are some examples of carbon footprinting calculators for farming practices that are certified to ISO 14067 and can integrate with PAS 2050 and the GHG protocol e.g., Sandy (https://www.trinityagtech.com/carbon-audit) and Agrecalc which is certified to PAS 2050 (https://www.agrecalc.com). However, other carbon footprinting models do not claim that level of assurance. Over time these governance frameworks need to develop further to provide the trust needed in the tools themselves and also how representative they are of the benefits of carbon farming.

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