Carbon Sequestration in Agricultural Soils

How to Unlock the Green Potential Of the Agricultural Sector

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- Agricultural soils have substantial potential to act as a global carbon sink. Carbon sequestration in agricultural soils can be an important contributor to global climate change mitigation and goes hand in hand with other important ecological, social, and economic benefits.
- Most agricultural soils that have been degraded by intensive modern agricultural systems can increase soil organic carbon (SOC) levels by changing practices. However, the farming sector is diverse, and the actual level of sequestration depends on many factors, among them the farming system (including management practices), the duration of the practices, the soil type, the climatic conditions and the farmer's level of knowledge.
- Despite scientific consensus on its potential and multiple benefits, agricultural practices that stimulate soil carbon storage and sequestration for climate mitigation remain limited in practice.
- Enhanced soil health has an immediate impact and value for farmers, landowners, financial institutions and society. It can be considered a collateral benefit of sequestering more carbon. Regenerative farming practices usually result in better soil health (and higher SOC sequestration and storage) and fewer emissions. But these practice changes require investment and it's currently uncertain who should pay (farmer, trader, consumer, banks or government). Voluntary carbon credit payments are one way to provide such finance. The practice of using voluntary carbon credits (VCCs) for offsetting is not without debate, however we believe that VCCs can create a win-win situation for agriculture and for those sectors (including agriculture itself) that cannot easily reduce emissions in the short-term but are committed to become net-zero.
- There is currently no centralized system for trading VCCs and the market still represents less than 1% of the global compliance market for credits traded under official emissions trading schemes. However, VCCs related to Agriculture, Forestry, and Other Land Use (AFOLU) have recently gained popularity.
- We expect a rapid rise in future demand for offset credits. This means supply will need to be ramped-up, providing scope for the inclusion of more nature-based credits (including those related to soil carbon sequestration) and a shift from the existing individual or 'bundled' projects to more jurisdictional/regional or commodity-wide solutions.
- Due to the large heterogeneity of carbon credits, and in particular AFOLU credits with co-benefits, volumes are too small to generate reliable, robust price signals. Greater credit price transparency and the development of contracts with more standardized terms or the creation of benchmark 'reference' contracts would consolidate trading activity around a few types of credits and promote market liquidity.
- We believe that rising VCC prices will provide incentives to address fundamental obstacles, while technological innovation to reduce Measurement, Reporting and Verification (MRV) cost will lower practical barriers to scaling soil carbon credits.
- Several important regulatory changes are anticipated to capture the full potential of VCCs in agriculture. As long as several sectors (including agriculture and forestry) are not included in

emissions compliance or carbon pricing regimes, these emissions will be addressed by voluntary carbon offset standards. For now, banks can provide supply-side and demand-side solutions. On the supply side, banks can support farmers and land operators through knowledge sharing, technical assistance, financial incentives for more sustainable farm practices (e.g. regenerative agriculture), quality guarantees for carbon offset credits, provision of a market platform and registry, and finance. On the demand side, banks can link companies that want to offset or compensate residual emissions[1].

The Potential of Soil Carbon Sequestration

How does agriculture fit into the wider challenge of climate change?

To limit global warming, we do not only need to reduce greenhouse gas (GHG) emissions, but we also need to sequester more carbon from the atmosphere. Agriculture is a potent carbon sink that is often overlooked. It is important to differentiate between mitigation practices that reduce or avoid GHG emissions and those that remove or offset atmospheric carbon by sequestering it in soil and plant biomass. This paper focuses on the sequestration of carbon in soil.

Carbon Terminology Explained

The three most abundant GHGs are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Total GHG emissions are expressed in carbon dioxide equivalents, or CO2eq, which is a unit based on the global warming potential (GWP) of carbon dioxide. This paper will use the generic term 'carbon' to refer to CO2eq in the context of emissions, and CO2 when referring to sequestration.

Soil carbon is usually expressed in terms of mass (1 GtC is equal to a gigaton of carbon) and represents the molecules of the element in the soil. When it is released into the atmosphere as a gas it becomes carbon dioxide. Carbon dioxide is approximately 3.67 (44/12) times the weight of carbon.

The entire food system including agricultural production, land use, storage, transport, packaging, processing, retail, and consumption accounts for 25%-30% or more of total annual human-induced emissions[2] . Without intervention, these emissions are likely to increase by about 30%-40% by 2050, due to rising demand from population and income growth, as well as changes in dietary patterns[3]. According to the scenario outlined by the Intergovernmental Panel on Climate Change (IPCC) in its 2018 Special Report on Global Warming of 1.5°C (to limit warming to 1.5°C with no or low overshoot) the AFOLU sector must act immediately and pursue ambitious GHG reductions[4] . The biggest source of GHG emissions from agriculture comes from land use change (e.g. deforestation, draining wetlands). Financiers and other value chain actors need to adopt standards that prohibit these practices.

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[1] Private sector GHG accounting and target-setting framework and principles (i.e. the Science Based Targets initiative, SBTi), currently do not allow for the use of carbon (offset) credits to meet a company's science-based emission reduction targets. Offsets are only considered an option for additional emissions reductions beyond their science-based and net-zero targets. Many national compliance systems also limit the use of offsets to achieve emission reduction targets. There is currently an ongoing discussion about whether and how carbon offsets should be allowed to be used towards net-zero emissions commitments.

[2] IPPC AR5: 11.1 ± 2.9 GtCO2eq y–1, 100-year GWP values

[3] IPCC. (2019). Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystem (SRCCL).

[4] Rogelj, J., et al., 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. Recommendation to eliminate CO2 emissions entirely by 2050, sequester 0.1 GtCO2/year by 2030 and 2.3 GtCO2/year by 2050; reduce methane emissions by 25%-35% by 2030 and by 50%-60% by 2050, and reduce nitrous oxide emissions by 10%-15% by 2030 and by 20%-30% by 2050 (versus 2010 baseline).

The untapped potential of soil to sequester carbon

Agricultural soils have substantial potential to act as a global carbon sink. Globally soils contain 2,000-2,500 gigatons of carbon. Worldwide soil contains about three times as much organic carbon as plants and twice as much as the atmosphere. However arable soils, especially in monocropping regions, have lost much of their soil carbon[5]. Literature reviews[6] estimate that agricultural soils have lost 30%-75% of their original soil organic carbon due to conventional farming practices. Almost all cultivated soil can be improved.

Emissions and Sequestration in Perspective

Historical cumulative carbon emissions since the industrial revolution have been 2,200 gigatons CO2 (600 gigatons carbon). Expected cumulative emissions up to the year 2100, if emissions follow a Business-as-Usual path, are 4,000-5,000 gigatons CO2. In order to stay within 1.5°C increase, this allows for 400-1000 gigatons (varies by 1.5 or 2°C limit) between today and the year 2100. Sequestration potential is estimated at 300-400 gigatons CO2 for comparison. (Source: van Vuuren, Detlef. Klimaatbeleid anno 2021: Geen tijd voor pessimisme. PBL. 2021.)

All soil carbon is in flux and the degree to which it is protected in undisturbed soil aggregates (protected from microbial decomposition and respiration) largely determines how long it is retained in soil.[7] Soil structure plays a big role in the stability of SOC. A considerable part of the depleted SOC pool can be restored through sustainable crop, soil, and water management. Carbon sequestration in agricultural soils is considered a powerful solution for global climate mitigation that is accompanied by other important ecological, social, and economic benefits.

Soil Explained

Soil decay rate: the rate at which soil organic matter (SOM) declines due to natural or human-induced factors releasing CO2 into the atmosphere. Warmer temperatures and the presence of oxygen increase the rate of SOM decay.

Soil respiration: carbon dioxide released from the soil via the combined activity of roots and micro- and macro-organisms decomposing plant litter and organic matter.

Soil aggregates: groups of soil particles bound together more strongly than to adjacent particles. Air and water exchange occurs between aggregates.

The 2019 IPCC Special Report on Climate Change and Land (SRCCL) estimates that the 30-year economic sequestration potential of grassland and cropland soils ranges between 0.38 to 2.5 gigatons CO2eq/year. Other studies (Lal, 2004) estimate even higher potential for world soils up to 4.4 gigatons CO2eq/year. Based on the midpoint of the more recent and conservative IPPC estimate (1.44 gigatons CO2eq/year), soil can potentially achieve more than 60% of the CO2 sequestration targets outlined in the 2018 IPPC scenario.

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[5] Notably, the Netherlands represents a special case (similar to regions of France, Belgium and northwest Germany). While intensive, three to four year crop rotations are common, soil carbon content hasn't decreased; this is probably due to the (over)application of manure (made possible due to Dutch arable farming's close proximity to relatively high-density livestock density areas).

[6] Global Carbon Project. Carbon Budget and Trends 2019; Zomer, R. J., Bossio, D. A., Sommer, R., & Verchot, L. V. (2017). Global sequestration potential of increased organic carbon in cropland soils. Scientific Reports, 7(1), 1-8.

[7] Lorenz, K., Lal, R. Cropland Soil Carbon Dynamics. In Recarbonization of the Biosphere; Lal, R., Lorenz, K., Hüttl, R.F., Schneider, B.U., Braun, J. von, Eds.; Springer Netherlands, 2012; pp. 303–346.

Conclusion: Agriculture is an important emitter of GHGs, but the sector can also play an important part in the fight against climate change due to the sizeable potential of soil carbon sequestration. But how can the sector improve soil carbon at a farm level?

Carbon Farming and Sustainable Agricultural Practices

How to increase soil organic carbon in agricultural soils and what is carbon farming?

Carbon farming is the use of agricultural practices for sequestering carbon in the soil or other biological matter (roots, wood, and leaves, generally referred to as 'biomass'). In general, there are two important pathways for increasing SOC and eventual SOC storage: (i) increase carbon-rich inputs (e.g. crop residues, compost, manure), and (ii) reduce the decomposition or decay rate of organic matter and soil carbon losses due to erosion (e.g. reduced tillage, erosion management, crop diversity). Increasing SOC is also closely intertwined with other co-benefits or goals of the farm and food systems, such as reduced land degradation, enhanced yields, and improved nutrition (contributing to food security). Carbon is a critical element for sustainability in general and climate in particular, but it is just one element/indicator out of many sustainability indicators (some of which might be more important in some regions or market segments than carbon). As such, the carbon credit market could serve as a model for establishing other potential tradeable (ecosystem) services or values such as soil health, water quality and availability, and animal welfare.

Although practices to increase carbon come in many shapes and levels of complexity, there are nine main ways in which farming can impact SOC levels[8]. The importance and relevance of these practices differ across land-based farming systems, which can generally be divided into: arable, permanent crops, livestock farming on grassland/pastures, and marginal agricultural lands with extensive grazing (regenerative grazing systems).

- **Erosion management:** topsoil erosion is a major cause of SOC loss.
- **Type of tillage:** tilling decreases SOC by exposing organic matter to the elements, accelerating decomposition and mineralization, disrupting processes that help stabilize SOC.
- **Irrigation:** more water reaching the soil increases organic matter inputs and favors biological processes; however irrigation can also cause salinity of soils and lowering of groundwater tables and therefore must be prudently implemented, ideally in a precision irrigation system.
- **Fertilization and management of organic matter:** the amount of stable SOC is proportional to nitrogen, sulphur, and phosphorous content in the soil. Soils with lower pH (more acidic) can hold less SOC under similar climatic conditions. Harvesting crops involves the removal of organic matter through extraction, burning, or tilling of residues. The use of organic amendments (e.g. manure, compost) will also affect SOC levels.
- **Selection of plant types and diversity:** above and belowground litter inputs and diversity vary significantly depending on the plants chosen. The plants selected for crop rotation, cover crops, or as permanent pasture can make a big difference in the resulting SOC.
- **Livestock integration and management:** the integration of livestock in agricultural systems can further increase SOC. Agrosilvopastoral systems with Adaptive Multi-Paddock (AMP) grazing achieve the largest increases in SOC storage.

[8] A detailed description of these practices is included in Annex 1.

- **Agroforestry**[9]**:** can be integrated into all of the above farming systems. The more diverse and deeper root species that are used will result in higher carbon sequestration potential and many other important benefits (e.g. less soil erosion, greater water retention, higher biodiversity).
- **Land use changes:** SOC capture can be achieved by changing from low to high SOC scenarios (e.g. change a portion of farmland from tilled annual monocrop with chemical fertilizer to permanent pasture with AMP grazing), or move marginal lands towards uses that increase SOC.
- **Innovative approaches:** several practices are under investigation, and may be financially viable due to secondary benefits (e.g. biochar[10] and melanized fungi inoculates).

Soil carbon sequestration potential is the maximum gain in SOC allowing a net removal of CO2 under a given climate condition and time period. Measured rates of soil carbon sequestration through adoption of better management practices on arable cropping systems range considerably (0.5 to 3.6 metric tons of CO2eq per hectare per year). It takes time to build up soil carbon. The IPCC approach assumes that the process of reaching a new soil carbon stock equilibrium occurs over 20 years. In reality it is a nonlinear process, usually occurring at diminishing rates, and over several decades (e.g. 10-50 years and longer). Soils eventually reach a new equilibrium (saturation). Therefore programs to incentive better soil practices should consider how gradual this process is, and subsequently how the practices can be maintained so that the carbon is not released back into the atmosphere (e.g. sink reversal, which happens either through a natural event —like a drought, or due to future management practices—for example, in many regions where no-till is practiced, deep plowing is still done every few years, which releases some soil carbon back into the atmosphere).

An important development supported by an increasing body of evidence shows that, far from reaching saturation after a few years, soils under well managed grazing can sustain these sequestration rates in the long run, building up soil with high carbon content. [11] However there is still important scientific debate on soil carbon sequestration and storage, and thus the extent to which certain practices actually sequester additional carbon. See Annex 1 for different practices categorized according to soil organic carbon potential and feasibility.

In recent years, specific soil carbon focused protocols in the voluntary carbon credit markets provide guidance on how to quantify, monitor, report, and verify agricultural practices that enhance carbon storage in soils (see Section 3). It is important to note that not all practices are applicable for all farming systems and crops (e.g. no-tillage). When assessing the applicability of the soil carbon enrichment practices, agronomists and farmers will need to consider other important aspects such as their impact on yields, weed and pest control. Furthermore, practices may have different overall cost-benefit impacts on different crops (e.g. if carbon sequestration practices result in 10% lower yields, the economic impact varies between Dutch potato and Australia wheat farming systems).

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[9] Agroforestry' is any group of trees (above a potential size or tree crown cover threshold) on agricultural land that is not legally classified as a forest but the definition varies by country. 'Various practices' includes silvopastoral, silvoarable and permanent crop agroforestry, as well as agro-silvopasture and tree landscape. In general agroforestry systems have many benefits including longer periods of permanence (even in fast-growth harvested systems), have more diverse and deeper root species and higher carbon sequestration potential than only pasture or row crop systems. The draft EU Common Agricultural Policy (CAP) Strategic Plans of each Member State (MS), the 2020 Farm to Fork Strategy (F2F), and the EU Carbon Farming Scheme all intend to include agroforestry. However, historically EU MSs have grossly under-delivered on their agroforestry targets.

[10] Biochar offers the largest maximum mitigation potential among agricultural pathways, but feasibility of large scale implementation of biochar is not well understood at this stage.

[11] Viglizzo et al., 2019, Reassessing the role of grazing lands in carbon-balance estimations: Meta-analysis and review.

What drives soil carbon sequestration capacity?

The type of soil and regional climate imposes a limit on soil capacity to store SOC. Conventional agricultural practices (tilling, fertilizer use, monocropping) reduce the original amount of SOC in the soil, with the worst-case scenario being intensive monocrop tilled soils combined with chemical fertilization with poor erosion control practices. In principle, most agricultural soils that have been degraded by intensive modern agriculture systems can increase SOC levels by changing practices.

Example: Label Bas Carbone (France)

In November 2018, the French Ministry of Ecological and Solidarity Transition created the Bas Carbone label initiative to remunerate actions beneficial for the climate. The label provides an MRV framework for GHG reductions (including a specific methodology for agriculture), supported by independent auditors and the CAP'2ER environmental footprint calculator to quantify carbon sequestered at the overall farm level. Carbon credits are based on sequestered or avoided CO2 emissions and then sold to voluntary funders with payments received at the end of the five-year project period. The label ensures traceability of carbon credits generated through a centralized registry.

Farmers individually assess project implementation costs and expected GHG reductions when setting minimum pricing for generated credits. The initial pricing for verified credits from the first agriculture and forestry projects is set at EUR 30-40 per metric ton of CO2eq. To account for non-permanence, a 20% discount is applied to projects which sequester in biomass or soil.

To date, 95 projects benefit from the label. The first nationwide ag project (managed by the France Carbon Agri Association) started in February 2020 and covers 300 farmers (primarily dairy and beef farms). Total positive GHG impact is estimated at 137,000 metric tons CO2eq at the end of the five-year period.

It is important to distinguish between regions where existing soil carbon must be maintained and regions where it must be increased. Tropical regions have faster decay rates due to higher temperatures than cooler, temperate regions. This means that for a given increase in carbon inputs, different soil types and climates may show different increases in SOC stock in relation with soil properties (i.e. the storage efficiency may vary with the rate of decay). In drier regions, decomposition at the surface of the soil is limited, and no-till has a greater impact on SOC than in wetter regions. Similarly, regions vary according to the differences in mineralization and initial soil carbon content (since sequestration potential is based on the relative increase in SOC). In some regions, the ability to increase SOC is limited by lower crop/plant productivity, which is often restrained by fertilizer or water (e.g. Australia's changes in SOC stock are highly correlated with precipitation patterns in that country). Some regions are known to have a higher SOC storage and sequestration potential in the short-term as they have been degraded by annual monoculture cropping systems over the last decades. For example, in regions with marginal grain crop production (in terms of productivity) more carbon could be sequestered if a switch to continuous perennial cover were made, such as permanent pasture (though regions must balance food/feed security objectives too). Perennial crops, if not tilled, increase belowground carbon inputs and reduce carbon losses (due to reduced soil disturbance), thus potentially approaching the SOC standing stocks of native grassland ecosystems.[12]

Conclusion: The practices that increase SOC are well known, yet we are still lacking practical knowledge about which practices fit each farm operation and how to implement them. There is no one-size-fits-all solution. The farming sector is diverse, and the actual level of sequestration depends

[12] Crews and Rusey et al., 2017.

on many factors, including the farming system, soil, climatic conditions and the farmer's level of knowledge (among others). Improving soil health and soil carbon sequestration in agricultural soils requires farm level measures and behavioral changes. As these practice changes cost money to implement and may come at the expense of short-term profitability, they cannot be implemented without the pressure of new regulations or other incentives (financial and/or operational) to comply. As has already been successfully demonstrated in other industries, verified carbon credits can be an effective mechanism to drive positive change, providing a potential source of additional income for operations that seek to actively improve soil health. Can carbon credits offer the financial incentive that is needed to encourage farmers to change their agricultural practices?

Carbon Credit Markets

What role does agriculture currently play in generating carbon credits?

Despite scientific consensus around its potential and multiple benefits, deployment of soil carbon storage and sequestration for climate mitigation remains limited in practice. This is partly due to the sector's near exclusion from the early carbon compliance market mechanisms, that is to say the Kyoto Protocol's Joint Implementation (JI) and Clean Development Mechanisms (CDM). The global compliance market was born in 2005 as Europe launched the EU ETS to trade CDM/JI offsets (initially created as a compliance standard under the Kyoto Protocol, but currently subject to uncertainty in upcoming negotiations). Historically, these compliance systems were designed to focus on larger industrial emission sources that are easy to quantify and limit through carbon allowances and/or offset credits equal to their actual reported GHG emissions. Most leading voluntary market standards have copied compliance market processes such as requiring a third-party validation process to ensure that projects are genuine, quantifiable, additional, verified, and permanent.

In 2021 many countries are expected to report updates on their Nationally Determined Contributions (NDC) since the Paris Climate Agreement (PCA) was adopted in 2015. Several countries have also set longer-term 2050 net-zero emissions or some form of carbon neutrality targets; at the same time many companies have made voluntary commitments to the net-zero [13] goals of the PCA by financing emission reductions through the purchase and retirement of carbon credits. Carbon markets are relevant to these net-zero targets and updated NDCs because parties can make more ambitious commitments if they are able to take advantage of differences in mitigation costs through trading. Ideally countries should make specific net-zero commitments that are formalized as part of their domestic regulations or part of their NDCs. The shift from the Kyoto Protocol to the PCA era prompted a parallel re-examination of the increasingly important role of voluntary carbon markets and the previously untapped potential of soil carbon sequestration as well. The PCA's focus on voluntary markets has led to a surge in independent crediting mechanisms which generate credits mainly used for voluntary offsetting purposes. Such credits reached 65% of total annual credits issued in 2019, compared to only 17 percent in 2015.

The development of soil-based credits has been slower than other sectors/project categories due to various factors: (i) data uncertainty and high variability in measuring and monitoring soil carbon stocks (in the land use sector) and stock changes, (ii) the fragmented and diverse nature of the land use sector, which is relatively more difficult and costly to reliably quantify GHG impacts compared to other sectors (e.g. power generation, transportation), (iii) the persistently low carbon

[13] Several important standards that will affect the private sector's use of offset credits and net-zero climate claims, are expected to be released later this year. Specifically, The Net-Zero Standard (expected in late 2021) is focused on setting criteria for corporate net-zero targets to be validated by the SBTi. The criteria will address permanence, quality, social and environmental requirements for carbon removal activities. The GHG Protocol Carbon Removals and Land Sector Initiative (expected in Q3 2021) is focused on developing internationally accepted guidance on carbon removal accounting and land-use emissions. More information: Net-Zero-Criteria-Draft-for-Public-Consultation-v1-0.pdf (sciencebasedtargets.org).

credit prices prior to 2020 (particularly in voluntary credit markets), and (iv) the fact that initial IPCC models may underestimate the sequestration potential of soil.

There is currently no centralized system for trading VCCs. Although the volume of purely voluntary offsets (excluding pre-compliance offsets) has reached its highest level since 2011, the voluntary market remains dwarfed by compliance markets. The Forest Trends' Ecosystem Marketplace reports that voluntary carbon offsets transactions for 2019 represented 104 metric tons CO2eq (approximate value USD 320m) in emission reductions, a tiny fraction (0.7%) of the USD 48bn compliance market, which accounted for over 3,000 metric tons CO2eq (taxes + ETS). Though a more apt comparison for voluntary carbon offsets transactions would be to the now defunct CDM, in which a mere 44 million Certified Emission Reductions (CERs) were newly issued in 2019. [14] That said, VCC volume has increased since 2018 and continued to grow through 2020 despite the Covid-19 pandemic. Within voluntary carbon markets, Natural Climate Solutions (NCS) – which include AFOLU sectors – have been integral to voluntary markets since the beginning, and have gained popularity in recent years. Offsets generated through forestry and land-use (of which soil-based credits represent only a minor portion) accounted for approximately 35% of all voluntary credits generated in 2019 (37 metric tons CO2eq valued at USD 159m) and have grown by 264% from 2016 to 2018. This recent increase in demand is partly due to the 2018 IPCC Special Report on Climate Change and Land, which identified carbon sinks (from NCS) as critical to meeting the PCA's 1.5 degrees target.

What is the demand and supply outlook for voluntary carbon credits?

The private sector has stepped up its commitments to contribute to addressing the global climate change crisis. To remain ahead of regulatory developments, but also to court increasingly climate-conscious consumers, large corporates have made bold commitments to reduce their emissions and ecological footprint over time. These often take the form of net-zero commitments using Science Based Targets [15] to reach the PCA goals by 2050. To reach these targets removal credits linked to sequestration projects are required, but at present these remain in short supply. The private sector initiative—the Taskforce on Scaling Voluntary Carbon Markets [16] indicates that future demand for offset credits could increase by a factor of 15 by 2030 (USD 50bn market size, 1.5-2 gigatons CO2 per year), and by a factor of 100 by 2050 (7-13 gigatons CO2 per year). The rapid rise in expected future demand for offset credits means supply will need to be ramped-up, providing scope for the inclusion of more nature-based credits (including those related to soil carbon sequestration) and a shift from the existing individual or 'bundled' projects to more jurisdictional/regional or commodity-wide solutions. [17] In turn, the increased demand for credits is likely to improve supply and demand dynamics of voluntary carbon markets and provide a more sustainable, stable, and attractive credit price for primary producers. While the increase in demand for carbon credits is significant, the same analysis indicates that demand could be adequately met by the potential annual supply of carbon credits (8 to 12 gigatons CO2 per year).

A further catalyst for the growth in the voluntary carbon market is the Biden administration's climate investment plan for the US (USD 2tn over the next ten years which may include a federal carbon price, support for natural climate solutions, leveraging agriculture for carbon capture and sequestration, and investment in regenerative agriculture practices). At the same time, the European Commission is working on an EU-wide carbon farming initiative that will include a

[14] CDM insights - intelligence about the CDM at the end of each month (unfccc.int), CERs issued and issuing.

[15] https://sciencebasedtargets.org/

[16] TSVCM (iif.com)

[17] Currently, the voluntary carbon offset market is based on carbon reduction or removal projects that follow different standards with different sets of requirements depending on focus and scope. There are no unified rules or regulations across jurisdiction or regions.

regulatory framework for certifying (results-based) carbon removal credits (see Annex 3) to serve as a guide for future projects in the EU.[18]

What are the protocols used to create agriculture-based credits?

The voluntary carbon credit market consists of a multitude of carbon credit registries, reporting protocols, standard bodies, third-party verifiers, certification bodies (for project design and impact assessment) and service providers. Most of the voluntary registries started with protocols that focused on other sectors. However, some have begun to develop agriculture- and livestock-specific sub-protocols, and more recently (since 2020) specifically for agricultural and soil carbon sequestration. Soil-based carbon credits are currently underrepresented in the global VCC market, compared to other project types such as forestry and renewable energy. There are four main registries for the voluntary carbon market that provide soil carbon sequestration standards in their accepted projects; these include: Gold Standard, Verra/VCS, American Carbon Registry, and Climate Action Reserve (see Annex 2). They are responsible for setting the standards that are used to verify, monitor and certify carbon credits (which is carried out by accredited third-party validation, verification and certification bodies).

Are (voluntary) carbon credits a tool for greenwashing or a win-win for farmer and industries that cannot yet reduce emissions?

Voluntary carbon markets have been plagued by scandals in recent years where credits were awarded to projects which did not in fact reduce GHGs, credits lacked traceability, or were in some cases miscounted (or double-counted). As such, scepticism grew regarding the use of carbon credits for offsetting emissions and the practice is often criticized as greenwashing. This negative perception is formally rejected by industry experts leading the fight against climate change, most notably the recently launched Taskforce on Scaling Voluntary Carbon Markets (led by UN Special Envoy on Climate Envoy and former Bank of England governor, Mark Carney). [19]

The growing consensus is that carbon markets remain a vital funding source for delivering climate-positive solutions, particularly given not all industries have the financial or technical means to reduce emissions in the short-term. Therefore, voluntary carbon markets are increasingly accepted as complementary to and indeed a key part of global climate action. For agriculture in particular, the sale of VCCs can provide an additional financial incentive for farmers to change their practices. However, this must be supported by a large, transparent, and liquid market for credits.

[18] However at a higher level, the treatment of AFOLU-related emissions and removals in national climate agreements, GHG accounting inventories and mitigation targets varies across countries and is still under deep discussion. This is due to the high uncertainties around future net AFOLU removals and emissions. For example, under the current EU Land Use, Land-Use Change, and Forestry (LULUCF) Regulation, EU Member States are limited to the number of net removals (to balance LULUCF GHG emissions) from the LULUCF sector that can count towards compliance targets; this is called the 'no debit rule'. A new EU regulation is expected by 2022.

[19] Taskforce on Scaling Voluntary Carbon Markets (TSVCM) is a private sector initiative working to scale an effective and efficient voluntary carbon market to help meet the goals of the Paris Agreement. TSVCM (iif.com).

Example: Indigo Carbon

Boston-headquartered IndigoAg is a global agribusiness company that has developed the Indigo Carbon platform to pay farmers for drawing down carbon into their soil. Indigo's methodology is based on the protocols developed by Climate Action Reserve and Verra and the platform is the first to adopt and operationalize these new standards. Indigo notes that compared to forestry and oceans, agriculture is the most scalable, affordable (USD 15-20/metric ton CO2eq), and immediate solution to sequester atmospheric CO2.

Growers are required to submit their field boundaries to the platform and to identify fields for practice changes. Historical practice data and soil samples are collected and then compared to end-of-season data to establish a GHG baseline and overall GHG abatement/SOC sequestration. The offsets are then validated and verified before being issued to Indigo for resale. The credits are sold to large corporates through Indigo Marketplace after which proceeds are transferred to the grower.

Indigo Carbon is currently active in the US with over 1,000 farmers across 21 states and approximately 2 million acres. The first verified credits are due to be issued in late 2021 with farmers receiving an inaugural credit price of USD 20/metric ton CO2eq. A pilot project is also underway in Germany and Sweden with 20 cereal growers, which is scheduled for rollout across the EU in 2022.

The private sector can play a role in the transmission of clear demand signals via publicly available registries of GHG commitments or consortia/industry-wide consolidation of such commitments. These will provide credit suppliers (including farmers) with the necessary demand and price certainty they need to implement changes today. In this context, companies need to be mindful of the proper use of carbon credits for offsets (in accordance with ICROA [20] best practices) to avoid actual or perceived greenwashing. Offsets should be considered a transitory solution and only allowed for offsetting unavoidable GHG emissions. [21] The goal should be to make carbon neutral agriculture and sustainable diets (using true pricing for food products) a mainstream agenda that will also drive change in agricultural practices. Carbon farming is not only about removing GHGs from the atmosphere, but also about reducing emissions in the agricultural systems. Using regenerative farming practices will allow soil to absorb more carbon and emit less total GHGs.

Conclusion: Compliance and voluntary carbon markets have historically largely ignored agriculture as a source of credits. With the PCA coming into effect and the emergence of various soil carbon protocols, this is changing. Based on strong future demand forecasted for VCCs, we expect interest in soil carbon credits to gather momentum. To avoid abuse of carbon credits for greenwashing, it is important to follow internationally acknowledged best practices for offsets. Moreover, offsets should only be allowed for unavoidable GHG emissions. On such conditions, VCCs can create a win-win situation for agriculture and for those sectors that cannot easily reduce emissions in the short-term. But are there (structural) obstacles that need to be addressed?

[20] International Carbon Reduction and Offset Alliance.

[21] Unavoidable GHG emissions (CO2 and non-CO2) are from sectors which decarbonize at a slower pace (e.g. industrial process CO2 emissions) or have some remaining, unavoidable emissions (e.g. some non-CO2 emissions, like nitrous oxide and biogenic methane, from agriculture).

Obstacles Hindering the Inclusion of Soil Carbon Sequestration in Voluntary Schemes and Protocols

Permanent/Fundamental obstacles

Permanence testing in traditional carbon markets ensures that projects avoid or sequester the GHG emissions captured from the atmosphere for a reasonable length of time. Permanence in storing carbon through soil enhancing measures remains a challenge as there is a risk of reversal events, such as future tillage, flooding or drought, that would release previously stored carbon back to the atmosphere. Although permanence is also an issue for forestry projects (which have been widely accepted in existing protocols), the sustainability of soil carbon relies to a large extent on farmers continuing to demonstrate carbon-positive behaviors over the long-term, and thus the permanence requirement could be problematic for farmers seeking to incorporate new technology and/or new crops in response to changing market or climate trends. Since we are dealing with long-term, dynamic biological processes (soil carbon and other field emissions), there is a material timing difference between (i) project costs and investments in practice changes, (ii) the timing of carbon stock changes (a slow gradual process to reach a new soil carbon stock equilibrium), and (iii) the timing of selling/paying out carbon credits to farmers. Existing carbon programs provide mitigation measures (mostly by using a buffer pool/ reserve account) to monitor, mitigate and compensate for non-permanence (the buffer credit pool usually represents about 20%-30% of the total number of credits estimated at project start). The usual offset project credit period (5-30 years) reflects the difficulty of guaranteeing land and farm management practices for longer periods of time. [22]

Additionality requirements mean that in order to qualify for credits in most existing markets, projects must demonstrate that their actions go beyond what they are required to do anyway to comply with local regulations and involve adoption of technologies or processes that are not currently common practice. This draws concerns for farmers who have been practicing more sustainable agriculture for some time as there is limited scope for them to qualify for future credits. The additionality criteria of most carbon credit protocols require proof that in the absence of offset credit sales revenue, the activities to reduce emissions or remove CO2 would not be profitable.

Heterogeneous soils and the **fragmented nature of primary agriculture** also present challenges to scaling soil-based credits as there is no one-size-fits-all solution which can be rolled out over a large geographic area given each area has different sequestration potential. Other challenges specific to agriculture include: **the trade-off between carbon removal and nitrous oxide emissions** and the **risk of displacement or leakages** of carbon across agricultural lands (resulting in no net carbon removal).

Temporary/Short-term obstacles

High monitoring, reporting and verification costs represent the most important short-term obstacle. Carbon credits are most often associated with strict MRV procedures, based on methodology development and third-party certification. The relatively high MRV costs (both as an upfront cost and compared to the low voluntary carbon market price) play a significant role for the financial viability of carbon projects, especially for small-scale agricultural projects. In the case of aboveground biomass estimates (carbon storage) such as in forestry, new remote sensing and drone technologies have reduced these costs and have become more widely accepted by carbon

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[22] However the general move to conservation agriculture practices (e.g. periodic tillage, every 10-15 years, of permanent grassland) is preferred over more intensive (e.g. annual grassland tillage) as it allows for a much higher build-up of soil carbon content before plowing.

credit protocols. For belowground carbon stock and flux measurements, remote sensing/satellite technology does not yet provide accurate enough estimates and thus must use direct soil sampling, in addition to soil carbon modelling. [23] However, we expect emerging technologies (particularly for belowground) to improve in the next few years and be widely accepted in existing protocols, ultimately lowering MRV costs and increasing accuracy over time.

Other relevant short-term challenges include **knowledge gaps** (particularly for farmers) regarding sustainable practice changes and the related costs and benefits, carbon markets, and expected co-benefits (e.g. drought/flood tolerance, nutrition, enhanced yields, reduced inputs). There are also difficulties in determining **project scope** (field versus farm, carbon versus all GHGs).

Conclusion: While there are both fundamental and practical obstacles to the creation of soil carbon credits, we believe that rising VCC prices will provide incentives to address fundamental obstacles, while technological innovation to reduce MRV costs will lower practical barriers to scaling soil carbon credits. What other changes are needed and how could banks like Rabobank and FMO support their clients to make the necessary changes?

How to Accelerate Soil Carbon Sequestration

Regulatory/market changes

Industry analysis [24] has already detailed some general market principles (e.g. standardization of terms (taxonomy, quality, and contracts), trade and post-trade infrastructure, principles for proper use, and mechanisms to track, report, record and retire VCCs) that the voluntary carbon market needs in order to expand and professionalize. [25] In the current voluntary carbon market, the inconsistency among credits means that matching an individual buyer with a corresponding supplier is often a time-consuming, inefficient process transacted over the counter. The large heterogeneity of carbon credits, and in particular AFOLU credits with co-benefits, make the volumes too small to generate reliable robust price signals. Greater credit price transparency and the development of contracts with more standardized terms or the creation of benchmark 'reference contracts' would consolidate trading activity around a few types of credits and promote market liquidity in the over-the-counter environment.

Other required reforms include the following:

- **Consistently higher VCC prices:** average voluntary carbon prices are currently much lower than compliance carbon markets (2018 weighted-average offset price: USD 2.85/metric ton, 2019: USD 4.26/metric ton), though average offset prices vary by type and project attributes (e.g. co-benefits are generally valued higher). [26] For carbon markets to be effective, the carbon price should be closer to the cost of the practice and the real estimated cost of carbon mitigation. The low price is partly due to a supply-demand imbalance, which is expected to level out in the next few years. In the meantime, public and private initiatives can increase the reward/financial incentive to stimulate more sustainable agricultural practices (and encourage farmers who are waiting for higher prices in the short-run).

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[23] The current challenges to MRV, especially in regards to soil carbon measurement and monitoring, should not be downplayed. In addition to high spatial variability and heterogeneity of soils across a single field, and more so, a farm, there are temporal and climate dynamics to consider: soil organic carbon content changes occur very slowly and dynamically from year to year. These spatial, temporal, and climate uncertainties ('noises') in measuring the baseline stock can make it hard to detect relatively small changes taking place.

[24] https://www.mckinsey.com/business-functions/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenges

[25] Borghesi, S. and Montini, M., 2016.

[26] State of the Voluntary Carbon Markets 2020: The Only Constant is Change - Forest Trends (forest-trends.org)

- **Alignment of MRV protocols:** this is currently a major obstacle for some farmers and supply chains. In the near future, we hope that cost-effective approaches that use public data can be made available to a wider range of projects and regions.
- **More overlap of existing and developing VCC protocols:** the private sector has a head start on developing AFOLU-related protocols, including soil carbon sequestration. However, more private and public sector (compliance-related) protocols, methodologies and project designs are being shared and iterated on. Transparency of protocols, methodologies and measurements and collaboration across registries, compliance/voluntary boundaries, and sectors is essential.
- **International alignment and clarity:** Agreement on key international policies (Paris Agreement and Article 6) has significant implications for shaping regional, national, and subnational carbon markets. Carbon and environmental policies are based on national goals and subject to change which can a?ect investment and exit strategies (at the upcoming COP26 event in Glasgow, many countries will present their revised NDCs to achieve global targets and may agree on rules for international trading of emissions reductions). Governments, NGOs, businesses, and established programs should align policies and create shared principles and methodologies for carbon trading and carbon farming. There is a need for smart accounting, sophisticated registries, improved monitoring and measuring, and a more equitable distribution of the costs and profits associated with soil carbon sequestration.
- **Continued government support for voluntary carbon markets:** Voluntary carbon markets are generally considered as a transitional mechanism until national or regional compliance systems also include AFOLU sectors. The lines between compliance and voluntary markets are blurring, as standards established for voluntary transactions are increasingly being considered for inclusion in compliance markets. A credit used to satisfy a regulatory requirement is not considered voluntary though. Until AFOLU sectors are included in compliance markets, voluntary approaches should harmonize with international and domestic emissions/removals targets and methodologies. On the other hand, direct government intervention in the market as sole offtaker of soil-based credits (like the Australian Emissions Reduction Fund) could potentially hinder the development of larger and more transparent voluntary carbon markets.

Role of the financial sector in generating soil-based VCCs

Commercial banks (particularly those focused on climate and/or agribusiness, such as Rabobank), development finance institutions (DFIs, such as FMO), and investment funds play a crucial role in allocating capital and funding agribusiness projects and corporates. Banks that directly finance primary production can incentivize farmers/landowners via sustainability-linked finance, and encourage buyers to prioritize and support better agricultural practices (e.g. by taking equity stakes in regenerative agriculture projects, offering farmers longer-term purchase contracts at a favorable, agreed price) or to offset in an ethical way (i.e. when an offset is transparent, real, additional, verifiable, and permanent).

However, important to note is that financiers typically do not directly finance smallholders, but rather mid-size and large corporates (traders, primary producers, or agri-processors). Thus the proposed solutions may need to be rolled out by the client (i.e. the private sector) in their upstream supply chain, rather than through a direct interface between financiers and farmers. Furthermore, there is no one-size-fits-all solution as each farm, region, or client will have different potential for soil carbon sequestration and credit generation. Financial institutions will need to investigate their own client base to determine those areas with the highest potential and determine the best solution on a case-by-case basis. Pilot programs can then commence with trusted partners committed to exploring carbon farming and soil carbon sequestration. Crucially, financial institutions often have a global perspective and deep reach in their respective markets and are thus well placed to develop solutions that can generate positive impact on a large scale across the globe.

Example: Rabo Carbon Bank

The ultimate goal of Rabo Carbon Bank is to enable more sustainable agriculture with voluntary high-quality, nature-based carbon solutions. They work closely together with farmers to protect, sustainably manage and restore natural and modified ecosystems. In 2020, the Rabo Carbon Bank began developing climate-smart propositions focused on carbon farming and supply chain decarbonization. Their ambition is to reduce CO2 emissions and remove CO2 from the atmosphere, totalling up to 1 gigaton by 2030.

Carbon farming: They develop voluntary carbon credit-generating projects that restore soils, create additional revenues for farmers, and drive reduction and compensation schemes for businesses. The climate solutions are focused on storing more carbon in trees, crops and soils. Carbon farming aims to improve farmers' soil, yields and biodiversity, as well as create a new revenue stream through nature-based voluntary carbon credits. Rabo Carbon Bank connects carbon farmers with corporates seeking to meet net-zero commitments and offset unavoidable emissions. In addition to the recently launched agroforestry based pilot, Acorn, they are running pilots related to soil health and sequestration in the US and in the Netherlands.

Supply chain decarbonization: A growing number of corporates and large organizations want to reduce their 'Scope 3 emissions'. Rabo Carbon Bank offers decarbonization consultancy services and financial products with flexible rates and conditions that reward sustainable practices and sustainability-linked targets. They are currently working on pilots with large food and agribusinesses on how to achieve, monitor and verify emission reductions from farmers in their supply chains.

Other suggested actions include:

- **Support robust, transparent carbon sequestration** and soil health projects and protocols.
- **Leverage alternative funding sources** to reduce MRV and project costs. Concessional funding or grants can be used to fund upfront payments to farmers for practice changes and for financing initial MRV costs to determine the baseline (while they remain high in the short-term).
- **Provide a temporary price floor or fixed and transparent VCC** price insofar there is no market available (internationally or domestically) for the client to sell credits.
- **Partner with local specialists and consultants who can educate clients** and their upstream supply chain about the benefits of regenerative practices and proper soil management for carbon sequestration, facilitating peer-to-peer learning and knowledge transfer.
- **Partner with the private sector to launch a specific independent soil carbon platform** for a particular region or commodity.
- **Specialist funds can be established to de-risk commercial investment** in soil-based carbon projects [27].
- **Encourage existing clients to link-up directly with long-term commercial buyers of carbon credits,** finding innovative ways to link soil health and sustainability to offtaker contracts and financing terms.

[27] For example, the AGRI3 Fund established by Rabobank, FMO, and IDH provides risk-mitigation products (e.g. first loss, subordinated guarantees, tenor extension) to partner banks on proof-of-concept agribusiness projects, with the goal of catalyzing commercial funding.

General role of the banks driving carbon-positive agricultural practices

A too narrow focus on VCCs alone could crowd out the wider financial sector from investing. There is now successful, albeit limited track record of financing carbon-credit based projects. [28] However, investor confidence in the sector will continue to grow as compliance and VCC markets mature. In the meantime, banks still have an important role to play in driving the necessary sustainable practice changes at a client level which enhance soil health and carbon sequestration. For example:

- Farmer actions linked to management practices and ultimately GHG reductions can be agreed upfront with deadlines and documented in contractual agreements, for example in the Environmental and Social Action Plan (ESAP).
- Farmers can be incentivized to undertake practice changes through a reduction in the interest margin on existing loans for meeting certain targets for GHG emissions (avoided or sequestered in soil). Such incentives can also extend to holistic results on broader sustainability indicators such as water retention, water table height, yield improvements, biodiversity of plants/wildlife, reduced use of crop protection.

Conclusion: Regulatory changes are awaited to capture the full potential of VCCs in agriculture. For now, banks can provide both supply-side and demand-side solutions. On the supply-side, banks can support farmers and land operators through knowledge sharing, technical assistance, financial incentives for more sustainable farm practices (e.g. regenerative agriculture), quality guarantees for carbon offset credits, provision of a market platform and registry, and finance. On the demand side, banks can link companies that want to offset or compensate residual emissions.

[28] Most notably the BioCarbon Fund (a World Bank initiative) and Althelia Climate Fund (managed by Mirova Natural Capital).

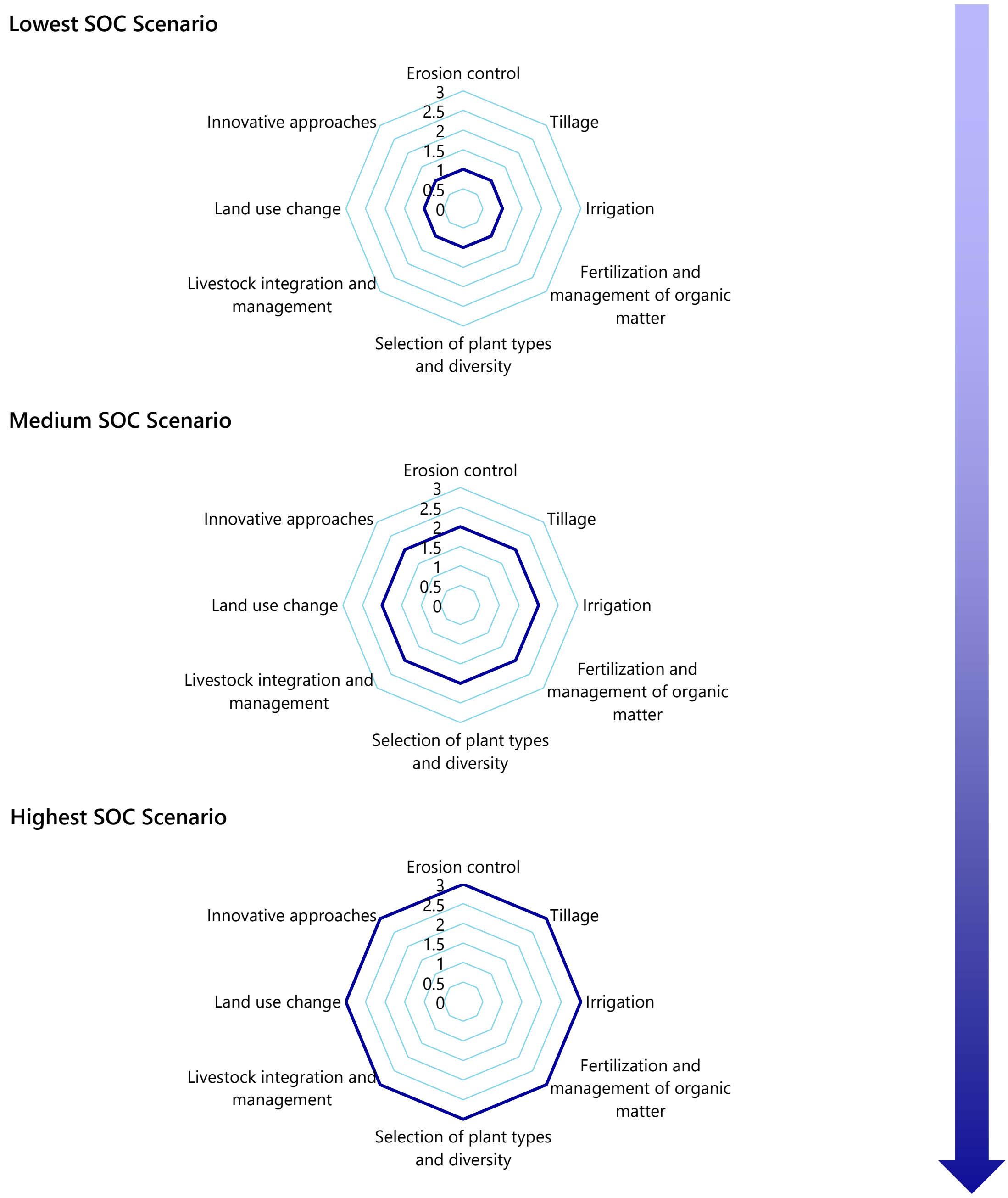
Annex 1: Different Agricultural Practices and Their Carbon Storage Potential[29]

Type of action	*Lower* *carbon storage potential*	*Medium* *carbon storage potential*	*Higher* *carbon storage potential*
Erosion control	High erosion. No erosion management.	Medium erosion. Some erosion management.	Low to negligible erosion rates. Erosion management top priority.
Tillage	Conventional (with inversion). Deep tillage, secondary and occasional.	Conservation tillage with reduced tillage. Tillage only for special purposes.	No-tillage (direct drilling).
Irrigation	Water deficit significant part of the year, no irrigation possible.	Some water deficit. Drip irrigation possible.	No water deficit year round. Drip* or sprinkler irrigation possible (*better water use efficiency).
Fertilization, organic matter management	N, S or P deficiency. Only chemical fertilizer used. Plant residue removed (burned/tilled).	Chemical fertilizer (no nutrient deficiency). Low residue removal rate, addition of untreated manure.	Combination of chemical fertilizer, plant organic matter (mulching, composting) and treated animal manure.
Selection of plant types and diversity	Monocrop plantation (annual or perennial), no rotation. No buffer areas.	Crop rotation for annuals. For permanent crops, allowance of some cover crops.	For annuals: Crop rotation with selected cover crops. For permanent and annual crops: proactive management of C:N ratio of crops and cover crops for maximization of soil carbon capture.
Livestock integration and management	No livestock.	Some livestock is integrated in the system (one type, sub-optimal grazing system).	Full integration of livestock (multi-species, optimal grazing technique and treated manure management).
Land use change	Farmed area not linked to carbon storage potential. Marginal areas under production.	Some areas are prioritized for carbon potential. Marginal areas left fallow.	Farming approach to reach maximum SOC potential ('carbon farmer'). Marginal areas managed to maximize above and belowground SOC.
Adoption of innovative approaches	Late majority (does not like to try innovative approaches).	Early majority (adopts only once most have adopted).	Early adopter (will try innovation even if others are doubting).

Source: authors' own elaboration, EIP-AGRI Focus Groups

[29] European Commission. EIP-AGRI Focus Groups. Focus Groups | EIP-AGRI (europa.eu).

Figure 1: 3 SOC scenarios based on practice changes[30]



Source: authors' own elaboration

[30] When considering whether an investment can move into a higher SOC scenario, it will be useful to look at the current practice in each of the key activities, and whether the investment can move towards the right, that is, towards activities that increase carbon storage.

Annex 2: Overview of Major Voluntary Offset Market Project Protocols and Registries (With Soil Carbon Methodologies)

Registrys	*Buyer geography*	*Related soil carbon sequestration protocols*	*Offset project crediting period*	*Greenhouse gas emissions included in protocols*
Verra/ Verified Carbon Standard	Global	Soil Carbon Quantification Methodology (Nov 2012)[31]; SD Vista; Methodology for Improved Agricultural Land Management (Oct 2020).[32]	10-30 years	SOC, N2O, and CH4
Gold Standard	Global	Soil Organic Carbon Framework Methodology (Jan 2020)[33], SOC activity module: Improved Tillage Practices (Jan 2020).[34]	10 years	Primarily CO2, other gases depend on total emissions change and module.
Climate Action Reserve[35]	North America	Soil Enrichment Protocol (Sept 2020).[36]	10-30 years	SOC, N2O, and CH4
American Carbon Registry	North America	Compost Additions to Grazed Grasslands (Oct 2014).[37]	10-30 years	SOC, N2O, and CH4

[31] Soil Carbon Quantification Methodology. VM0021. V1.0. Published November 2012. VM0021-Soil-Carbon-Quantification-Methodology-v1.0.pdf (verra.org)

[32] Methodology for Improved Agricultural Land Management. V0042. V1.0. Published October 2020. 0 (verra.org). Note: this protocol was made together with IndigoAg, which focuses on the US market and has proprietary satellite data (Atlas), which trained with actual ground observations, provided a national inventory (estimate) of current adoption rates of such practices: cover crops, no-till, and crop rotations).

[33] Soil Organic Carbon Framework Methodology. Published January 2020. 402_V1.0_LUF_AGR_FM_Soil-Organic-Carbon-Framework-Methodolgy.pdf (goldstandard.org)

[34] Soil Organic Carbon Activity Module: Increasing Soil Carbon Through Improved Tillage Practices. Published January 2020. 402.1_V1.0_LUF_AGR_AM_SOC-Module-Improved-Tillage.pdf (goldstandard.org). Note: Gold Standard is developing other activity modules under the SOC framework methodology including sustainable grassland management, cover cropping and organic soil amendments.

[35] There is one project listed (December 2020) so far under this protocol. IndigoAg is the project owner.

[36] Soil Enrichment Protocol - Climate Action Reserve : Climate Action Reserve

[37] Compost Additions to Grazed Grasslands — American Carbon Registry

Annex 3: Designing a Soil Organic Carbon Sequestration Mechanism

The European Commission has completed a two-year study[38] in which they reviewed a number of existing results-based carbon farming schemes focused on SOC and developed a recommended SOC sequestration framework aligned with global best practices and closely mirroring the most successful soil-based credit schemes in the US (e.g. Indigo Carbon, now being rolled out in the EU[39]). The roundtable also identified a few result-based initiatives already operating in the EU including LIFE Carbon Farming (Finland) and CarbonAgri/Label Bas Carbone (France). The methodologies used by these projects and schemes form the basis for new designing mechanisms. The summary below serves as a useful blueprint for designing new results-based schemes and highlights the most important challenges and key issues of such schemes for industry stakeholders.

Objective: to incentivize the increase of SOC stocks while ensuring that the overall GHG balance is improved as well.

Scale/coverage: arable land, grassland, horticultural use or permanent crops on any type of farm, with the provision that all applicable land on the farm will be included in the mechanism.

Climate Actions: any actions that maintain and increase SOC levels and benefit soil health.

MRV: as a minimum farm-level monitoring quantifies improvements in SOC levels (metric tons of CO2eq); mechanisms should demonstrate steps taken to quantify the full GHG balance associated with soil management (i.e. GHG emissions associated with tillage or fertilization are accounted for) since SOC sequestration also includes an emissions component.

1. Sufficiently robust baseline level of SOC on the farm is established through sampling and/or calculation.
2. Farm advisors/consultants assist farmers to identify management actions to maintain/enhance SOC levels and develop a SOC management strategy for the project period.
3. Farmers implement the actions and keep records.
4. Advisors visit farms at selected intervals to evaluate and discuss potential adjustments. Intermediate measurement can be taken.
5. At the end of the project, a final measurement takes place.
6. The farmer commits to maintain the levels for at least five years after receiving the last payment.

Rewards: Farmers are rewarded at a set rate of € per metric ton of sequestered carbon, as long as they meet eligibility criteria. To reduce the risk for farmers and increase the rates of uptake, a hybrid model may be necessary, whereby farmers are paid for management changes topped up with a bonus for amount of metric ton CO2eq sequestered.

Design principles: (i) reduce MRV costs while maintaining robustness; (ii) shift costs away from farmers (to maximize farmer uptake and decrease overall scheme costs); (iii) learning-by-doing through refinement of MRV as improved or more cost-efficient methods become available.

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[38] The two-year study published several reports of the roundtables and findings (October 2019 and September 2020). See the roundtable findings here: CF_Roundtable_Background_04102019 (europa.eu); CARBON FARMING SCHEMES IN EUROPE - ROUNDTABLE - Streaming Service of the European Commission (europa.eu); https://ec.europa.eu/clima/events/2nd-carbon-farming-roundtable_en.

[39] https://www.indigoag.eu/for-growers/carbon-farming

Annex 4: The Current Status of the Dutch Climate Agreement and National approach to Soil Carbon Sequestration

The 2019 Dutch Climate Agreement (DCA) set the goal to reduce total GHG emissions in the Netherlands by 49% in 2030 compared to 1990 levels and by 95% in 2050 (compared to 1990 levels). The Climate Law (Klimaatwet) with the above targets was also approved in 2019[40]. In September 2020, the EU Commission (as part of the EU Green Deal) proposed to raise the EU target GHG reductions in 2030, including emissions and removals, from 40% to at least 55%[41]. This likely means that the Dutch government will have to tighten their 2030 goals as well (from 49% to 55%)[42]. The pressure is increasing for the current government to accelerate actions to reach the Climate Law targets (and not delay until the new incoming government is formed). The DCA specifies how each sector is to achieve the 2030 goal.[43] While there are differences between sectors, the government and several agricultural and land-based sectors have agreed on specific targets. The agriculture and land use sector agreed to reduce total emissions by an additional 3.5 metric megaton[44] (plus the ambition to reduce another 2.5 metric megaton), including the reduction of 1 metric megaton from the land use sector (mainly peatland meadows used for dairy), the reduction of 1 metric megaton from the greenhouse horticulture sector (the sector ambition is 2.2 metric megaton, which highly depends on government support and regulation[45]), the reduction of emissions from trees, forestry and nature sector by 0.4-0.8 metric megaton,[46] and the sequestration of 0.4-0.6 metric megaton CO_2/year on mineral agricultural soils. The livestock sector has agreed (so far) to reduce methane emissions from pork by at least 0.3 metric megaton (with 1 metric megaton being a sector ambition)[47] and to reduce methane emissions from the dairy sector by 0.8 metric megaton (plus an additional 0.8 metric megaton being an ambition) by 2030. The DCA also mentions an ambition for the agriculture and land use sector to be net-zero by 2050[48], however the feasibility has yet to be determined.

The Dutch agricultural sector is working to reduce emissions and sequester more carbon on arable croplands and pasture through the Smart Land Use Program (Slim Landgebruik). The Smart Land Use Program is coordinated by the Louis Bolk Institute, experts from WUR, and the Centre for Agriculture and Environment (Centrum voor Landbouw en Milieu) and intends to collect data on baseline C stocks and develop a monitoring strategy across the Dutch agricultural sector.[49] The technical sequestration potential (per hectare) of different arable and livestock farming practices

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40 Wetten.nl - Regeling - Klimaatwet - BWBR0042394 (overheid.nl)

41 2030 climate & energy framework. 2030 climate & energy framework | Climate Action (europa.eu)

42 Newsletter Climate Agreement. Published: 03-02-2021. Nieuwsbrief Klimaatakkoord | Actueel | Klimaatakkoord.

43 Klimaatakkoord hoofdstuk Landbouw en Landgebruik. Published: 28-06-2019. https://www.klimaatakkoord.nl/binaries/klimaatakkoord/documenten/publicaties/2019/06/28/klimaatakkoord-hoofdstuk-landbouw-en-landgebruik/klimaatakkoord-c4+Landbouw+en+gebruik.pdf.

44 1 metric megaton (abbreviated as Mt) is a unit of mass equal to 1 million metric tons.

45 Klimaatakkoord - 28 juni 2019 (kasalsenergiebron.nl)

46 Note: The Forestry Strategy (Bossenstrategie), currently under discussion, proposes to expand the area of forested land (+37.000 hectares by 2030, representing approximately 1% of the Dutch territory), which may involve converting some agricultural land into forested areas. This goal and its financing should be coordinated between the federal and provincial governments as well as the private sector (e.g. Rabobank has proposed to start a EUR 1bn fund for Reallocation (Herallocatiefonds) to support such land use changes. More info: Klimaatakkoord.nl, presentaties-ruimte-maken-voor-nieuw-bos. 16-01-2021).

47 The pork sector has estimated that it can contribute to a methane reduction of 1 metric ton by 2030 (through herd reduction and manure management). Vitalisering Varkenshouderij en het Klimaatakkoord. Published: 08-01-2019. https://www.klimaatakkoord.nl/binaries/klimaatakkoord/documenten/publicaties/2019/01/08/achtergrondnotitie-landbouw-vitalisering-varkenshouderij/Landbouw+en+landgebruik+-+Vitalisering+varkenshouderij.pdf.

48 This is expressly a joint ambition of farmers and greenhouse horticulturists, site managers, NGOs, food processors, suppliers and supermarkets. The coming years, will be used to ascertain how the agriculture and land use sector can achieve that equilibrium.

49 See link for more information about such programs: Slim Landgebruik - WUR.

was identified in the 2012 report by Alterra/Lesschen et al. (*see Table 1*). It is important to note that the estimated adoption rate (the number of hectares) is difficult to estimate. According to Lesschen et al. estimates, the realistic sequestration potential is approximately 0.5 metric megaton CO_2/year by 2030. That would imply that on all 1.5 million hectares of mineral soils, the organic matter would need to increase by an additional 1 metric ton/ha (over 2021-2030) to realize an 0.7% increase in SOC content on average soils, resulting in an average SOC content of 4.3 %.

Table 1: Estimated (maximum) technical and realistic sequestration potential of individual farm management practices (per hectare per year), estimated implementation rates, and overall (technical and realistic) sequestration potential per year

Measure	*Maximum potential (kiloton CO2/year)*	*Implementation (%)*	*Realistic (kiloton CO2/year)*	*Maximum per ha (kg CO2/ha/year)*
Non-inversion tillage	475	50	238	608
No-till	912	20	182	1167
Catch crop/green manure	311	50	156	398
Improved crop rotations	942	20	188	1205
Crop residues retention	628	20	126	803
Field borders management	145	40	58	186
No grassland renewal	710	30	213	3586
Total realistic combinations	2270		790	2316

Source: Lesschen et al. 2012

Currently though, there are only a few regional projects to incentivize, implement and measure these practices over a longer period of time (usually 10 years) to better understand the carbon sequestration potential of different practices on different cropping systems and soil types. The national agricultural soils program (Nationaal Programma Landbouwbodems, NPL), a public-private effort to improve agricultural soil management has indicated the importance to preserve and improve soil quality, along with other goals such as biodiversity, good water quality, climate change risks, and ecosystem services.[50] NPL intends that all soils in the Netherlands are sustainably managed by 2030, however there is not yet a clear agreement on what constitutes a sustainably managed soil.

However the reality of the Dutch arable farming sectors is that the agronomic/operational, economic and social incentives to achieve robust and significant soil carbon sequestration at farm level are limited and fragmented. Many of the arable farming practices that have the highest sequestration potential (according to Lesschen et al, 2012) are subject to significant conditions. Table 3 describes the sector, practice, potential limitations/conditions of each practice, scientific certainty/agreement.

[50] Rijksoverheid. Nationaal Programma Landbouwbodems. Published: 04-09-2020. https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2020/09/04/nationaal-programma-landbouwbodems/bijlage-nationaal-programma-landbouwbodems.pdf.

Table 2: Overview of suggested practices, their sector, operational and scientific considerations

Practice	*Sector*	*Operational considerations*	*Scientific considerations*
Reduced or no-till	Arable	Depends on cropping systems (not possible with root crops); requires good soil compaction and weed management strategy.	Reduced/no-till can increase carbon in top soil profiles, but not at deeper depths without additional C inputs.
Cover/catch crops	Arable	Easy to integrate.	Additional emissions (from seeding, fertilizer, equipment use, soil respiration) must be offset by C-delivery to the soil.
Longer/more diverse crop rotation	Arable	Lower farmer margins if substituting high-value crops (potatoes) for legumes or grain crops.	Functional diverse crop rotations (higher C input) more likely to increase SOC concentrations.
Increase C inputs (i.e. manure, compost)	Arable/dairy	Limited by nutrient regulations, local availability/supply.	Manure still implies similar N2O emissions.
Higher crop residue retention	Arable/dairy	May compete with forage or biofuel demand (silage).	Overall GHG emissions differ according to crop, climate; straw returns general increase SOC content to a certain point (after 10-15 years).
No grassland renewal (more permanent grassland)	Dairy	Grassland productivity will decrease without re-seeding and sward management.	Grassland renewal (reseeding) with reduced soil disturbance and diverse sward composition can increase SOC more than total renewal.

Source: Lesschen table; Pers. Comm. Kuikman; Paulsen (Ed.) 2020.

Notably there are several important data and research gaps to be addressed before scalable progress can be made including: the current adoption rate of these practices, supply/demand of local flows of manure/residue/biomass, and impacts on productivity and farmer profitability.

The Green Deal/Farm-to-Fork Strategy and the new common agricultural policy (CAP) reform will influence the financial incentives to motivate practice change (where possible). The new CAP reform 2021-2027 will ring-fence (dedicate) approximately 25%-30% of direct payments for eco-schemes. Therefore, the Dutch Smart Land Use Program can also incentivize sustainable soil management practices by using the new payment schemes under the CAP reform: the dedicated funds of the Green Deal/F2F program, and the EU results-based carbon farming initiative that is currently being developed.

Currently the national registry for the voluntary carbon market, the National Carbon Market Foundation (Stichting Nationale Koolstofmarkt, SNK) is still in the early days. There are a handful of agriculture-related projects (i.e. peatland[51] and forestry) with a validated emissions reduction of <1k metric tons CO2/year (as of mid-May 2021).They are currently developing methodologies for carbon credits for permanent grassland sequestration; the outcome is expected in May 2021. Many projects for sequestration on agricultural soils that would register on the SNK are still in pilot phase, including Rabo Carbon Bank's soil sequestration proposition, for which pilots are taking place in the US and in the Netherlands[52]

[51] Peatlands represent mostly avoided emissions, not necessarily additional sequestration or removal. Regional peatland strategies (following the Veenplan 1e fase, 2018) are expected to be presented in 2021 and in 2020/21 several pilot programs registered/verified to the national voluntary carbon market for peatland water management were initiated (Klimaatakkord.nl, 21-7-2020). Regionally-coordinated, farm-specific plans are needed especially in peat meadow areas (e.g. Friesland, Groningen, Overijssel, North Holland, South Holland) where there's the opportunity to link with the nitrogen declaration (close to Natura2000 areas) and other financial supports (e.g. Natuurmonumenten, Urgenda) that can help alleviate the lower revenues/higher costs.

[52] Rabo Carbon Bank (rabobank.com)

In conclusion, the opportunities in the Dutch agriculture sector's GHG emissions strategy revolve around maintaining soil C stocks on peatland (largest land use source) and reducing emissions from existing production, rather than significant additional sequestration/removal on arable croplands or perennial grasslands.

Annex 5: List of Acronyms and Abbreviations

AMP	Adaptive Multi-Paddock
A/R	Afforestation/reforestation
AFOLU	Agriculture, Forestry, and Other Land Use
CAP'2ER	Environmental footprint calculator
CH4	Methane
CO2	Carbon dioxide
CERs	Certified Emission Reductions
CDM	Clean Development Mechanisms
CAP	Common Agricultural Policy
DCA	Dutch Climate Agreement
DFIs	Development finance institutions
ESAP	Environmental and Social Action Plan
EU ETS	EU Emissions Trading System
F2F	Farm to Fork Strategy
GWP	Global warming potential
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
ICROA	International Carbon Reduction and Offset Alliance
JI	Joint Implementation
LULUCF	Land Use, Land-Use Change, and Forestry
MRV	Measurement, Reporting and Verification
MS	Member State
N2O	Nitrous oxide
NDC	Nationally Determined Contributions
NCS	Natural Climate Solutions
NPL	Nationaal Programma Landbouwbodems
PCA	Paris Climate Agreement
SBTi	Science Based Targets initiative
SNK	Stichting Nationale Koolstofmarkt
SOC	Soil organic carbon
SOM	Soil organic matter
SRCCL	Special Report on Climate Change and Land
TSVCM	Taskforce on Scaling Voluntary Carbon Markets
VCCs	Voluntary carbon credits

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