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Farmland: An environmental solution

White Paper | April 2020

Agriculture always seems a subject for fierce debate. It just seems that farming has been in the news just a bit more lately. And the news not always exposes farming from its most appealing side. This paper aims to illuminate the other side, farmland and its role in nature. Nature can store carbon dioxide; nature can restore or regenerate degraded lands; nature can restore a badly functioning water cycle; and nature can restore rapidly degrading biodiversity. It can do all this while at the same time nourishing 10 billion people with more nutritious food. The Terraton Initiative[1], in our view one of the most positive initiatives for tackling climate change today, calls agriculture 'the most advanced technology for addressing climate change'. The Initiative's ambition is to use soil to store 1 trillion tons of carbon from the Earth's atmosphere and bring concentrations of greenhouse gases (GHG) back to pre-Industrial Revolution levels.

1 The Terraton Initiative is a global effort that seeks to remove one trillion of carbon dioxide from the atmosphere and use it to enrich our agricultural soils. In the face of a climate crisis, the world's 5 billion hectares of farmland and pastureland offer a scalable opportunity to remove this excess carbon dioxide. terraton.indigoag.com

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Using our soils to sequester carbon is a natural climate solution and can be achieved through regenerative farming techniques that allow for plants to store carbon in the soil, for soils to infiltrate water and for biodiversity to thrive above and below the ground. When looking for nature based solutions one only has to imagine what an ideal biome or prairie looked like before the industrial revolution. Think of the many different types of plant and tree species, quite a distant picture from today's monoculture landscape.
So where is the catch? Will farmers still be able to make money when looking through the lens of their long gone ancestors?

We don't think there is one. And yes, farmers will make a good living, and land will continue to offer a decent return. In this paper we will evaluate the actions available today, both on a macro policy level (which we will refer to as climate response options) and on a practical farming level (which we will refer to as nature-inclusive practices). We conclude that there should not be any dogmatic belief as to which policies or practices work where or when. There should only be the belief that if we do not start to make sensible steps in the direction of these policies and practices, it may be too late to achieve many of the climate and biodiversity goals that have been agreed to.
At Van Lanschot Kempen Investment Management (VLK Investment Management) we believe that farmland offers an appealing, stable, yet relatively unexplored asset class. But investing in farmland passively is not a sustainable solution. An active focus on ESG is essential, both to explore solutions such as its role as a carbon sink, and to manage risks such as use of pesticides, soil erosion and biodiversity.

1 Scope of this paper

To achieve the goals of economic growth and sustainability, the EU has invested in so-called nature-based solutions (NBS) under Horizon 2020 - an EU's research and innovation program established in 2015. Nature-based solutions are defined by the European Commission as 'living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits.' The International Union for Conservation of Nature (IUCN) defines NBS as 'actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'.

For the land-based sector, NBS mainly involve projects that restore soils and natural ecosystems to absorb CO_2-emissions from the atmosphere. This approach has long been recognized by academics as one of the most cost-effective strategies for climate change mitigation. More recently, nature-based solutions have become a prominent component of the long-term climate strategies of leading companies in oil, gas and other carbon-intensive sectors.

In this paper we will focus on NBS in the context of rural land, of rural landscape management and of soil and farmland in particular. The reason for this is that we believe that sustainable farming practices and soil management are probably the best shot at simultaneously mitigating climate change, feeding a growing population, mitigating water related issues, and reversing a degrading biodiversity. The paper explores the issues, response options and practical solutions related to a number of natural systems under threat, including climate, food, water and biodiversity. It focuses on productive farmland rather than forestland or non-productive biomes such as wetlands or peatland. It discusses climate positive practices such as conservation and regenerative farming. The paper explores the literature issued by some of the national and supranational authorities as well as some of the widely-published research initiatives conducted by the FAO, the IPCC and the European Commission.

In order for investors and corporate sponsors interested in nature-based solutions to assess and evaluate NBS options, the paper applies three steps. These are embedded in most nature-based initiatives[2].

Step 1

Understanding the system

Getting in-depth knowledge of the physical, biological and economic aspects of productive land. Understanding the agronomical system as far as life below the surface and life above the surface is concerned.

Step 2

Linking values to this system

Understanding which functions and services the farmland system provides and learning how these functions are challenged due to unsustainable behavior such as feeding the world challenged by desertification as an example. Distinguish realistic alternatives that lead to not only mitigation and compensation of these challenges, but also to safeguarding the system.

Step 3

Prepare the solution

Assess the practical solutions that can be implemented and monitored from the viewpoint of a landowner / land asset manager.

2 Three steps: These three steps are adopted by nature-based solutions, an organization of researchers and natural resource planners (nature-basedsolutions.com). The same logic is adopted by IPCC, the intergovernmental panel on climate change of the United Nations, in its most recent and broadly published climate change report called Climate Change and Land https://www.ipcc.ch

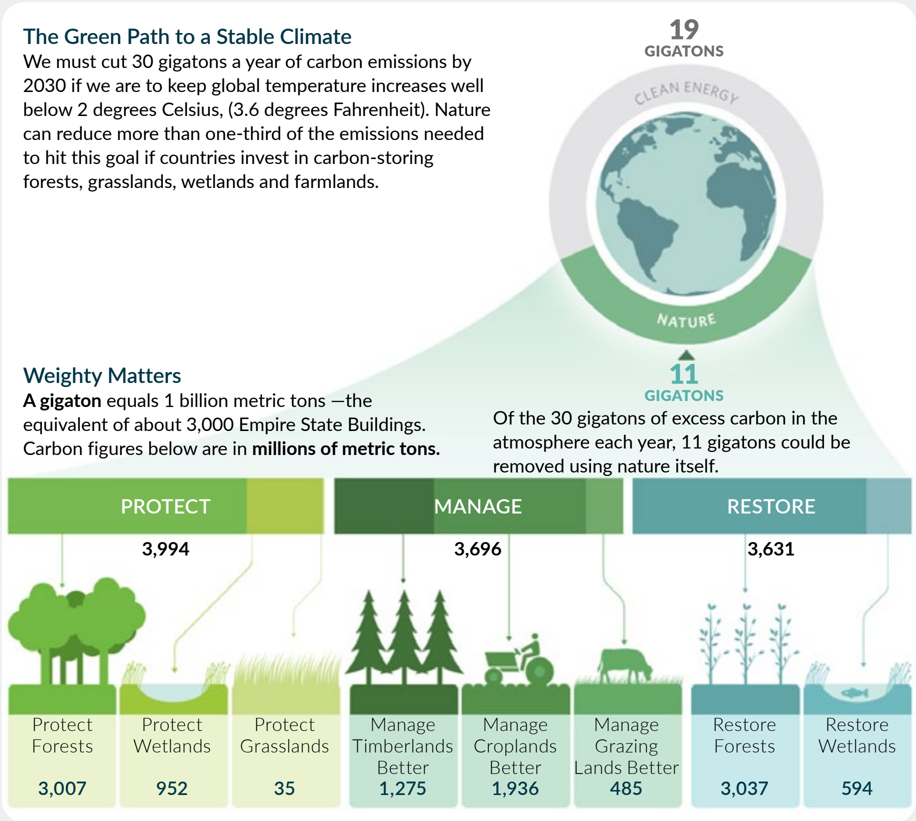
The next chapters will address each of these steps in turn. The main conclusion of the paper is that nature based, regenerative farmers are winning market share from 'conventional farmers'. They present compelling results, both from a sustainable and from a standard financial or agronomical point of view. They present a practical – on the field – solution to the ecological response options that are being presented globally by renowned climate institutes. For nature based or regenerative farming to become the norm however, various challenges still need to be overcome. The paper will conclude by explaining how to overcome some of these challenges and what the role of the various stakeholders can be and will explore both macro responses as well as micro farm-based solutions and will give local, crop specific examples.

Case Study: Nature-based solutions

In 2017, a study was published under the name of Griscom et al called "Natural Climate Solutions" (the Griscom study for further reference). The study was conducted under the supervision of various NGO's (including The Nature Conservancy) and a group of more than 20 research centers from renowned universities such as Ohio, Cornell and Wageningen just to name a few. The group examined how much nature can contribute to the goal of holding global average temperature rises below 2 °C. Twenty conservation, restoration and/or improved land management actions have been assessed that increase carbon storage and/or avoid greenhouse gas emissions across global forests, wetlands, grasslands and agricultural lands. It started with the premise that the most mature carbon dioxide removal method is improved land (or natural capital) stewardship. The report shows that these nature-based solutions can provide more than one-third of the cost-effective climate mitigation needed between now and 2030 to stabilize warming to below 2 °C.
It offers a powerful set of options for nations to deliver on the Paris Climate Agreement while improving soil productivity, cleaning air and water, and maintaining biodiversity.

Figure 1 offers a graphical summary (source: The Nature Conservancy) of the report. In the remainder of this paper – and as part of our daily profession – we will focus on the part in the middle, "manage croplands better", which mainly focuses on croplands (row crops and permanent crops), but will certainly also overlap with timberland and with grazing lands.

Figure 1 **The Nature Conservancy's green path to a stable climate**



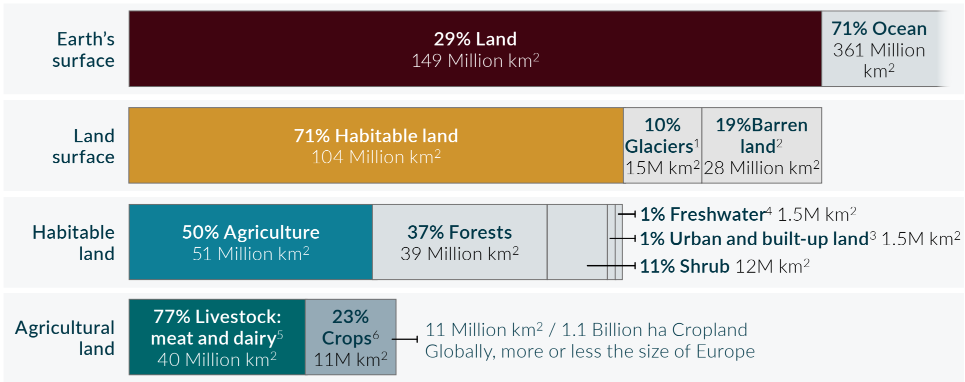
Source: www.nature.orgfree. Griscom et al: 'Natural Climate Solutions', 2017

Step 1: Understanding the system

In this chapter we will address the ecological footprint of farming based on land use in terms of GHG emissions, land degradation, water stress and loss of biodiversity. Although the paper has a focus on cropland management it is sometimes impossible to disentangle cropping from other types of farming such as livestock or marginal forestry.
Global population growth and changes in the consumption of food, feed, fibre, timber and energy have led to an ever-expanding area under agricultural use. By 2050, the global population is projected to increase to ten billion, resulting in an estimated 60% increase in demand for food[3].

Per capita supply of vegetable oils and meat has more than doubled since 1961 and the supply of food calories per capita has increased by about one-third[4]. Figure 2 illustrates the agriculture land use footprint today. When we break down the global land area, 10% of the globe is covered by glaciers and a further 19% is barren land. This leaves what is called 'habitable land'. Half of all habitable land is used for agriculture. And three-quarters of this agricultural land is used for grazing and the other quarter is cropland.

Figure 2 **Global land use**



1) 14M km2 of wich is the land area of Antartica.
2) This includes the world's deserts, salt flats, exposed rocks, beaches and dunes.
3) This includes settlements and infrastructure.
4) Lakes and rivers.
5) This includes grazing land for animals and arable land used for animal feed production.
6) Excluding feed.

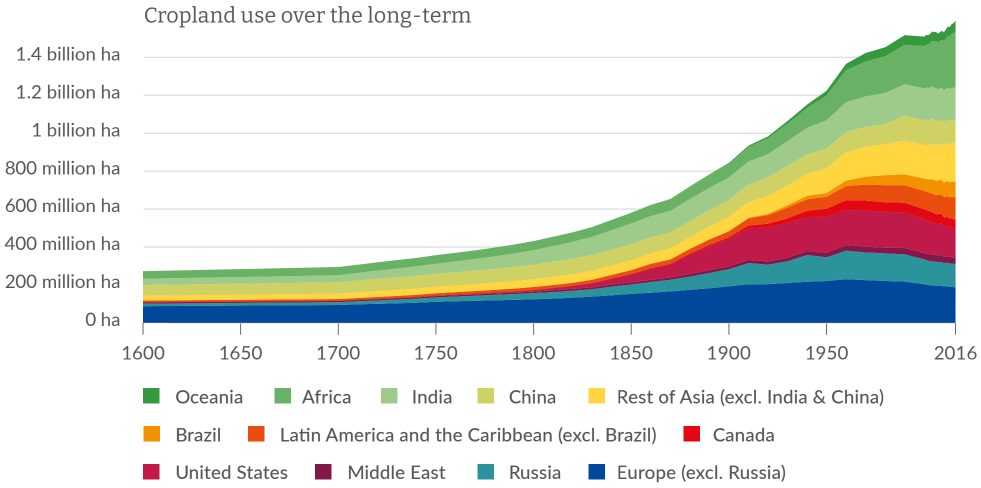
Source: UN Food and Agriculture Organization (FAO) 2019

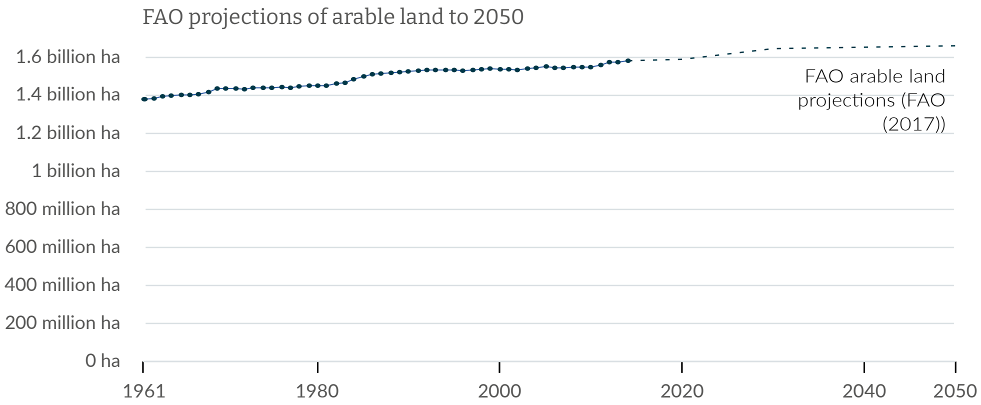
The impact of increased demand on global land use is offset by productivity gains in agriculture since more mechanized farming began. To put this in perspective it is worth mentioning that globally, to produce the same amount of crops as in 1961, we need only 30% of the farmland[5]. It is generally expected that the percentage of land used for cropping agriculture will rise despite continued increases in productivity. Figure 3 illustrates the long term trends in cropland use and UN FAO projections of arable land use through to 2050[6].

3 FAO: http://www.fao.org and https://ourworldindata.org/caloric supply
4 FAO: http://www.fao.org and https://ourworldindata.org/caloric supply

5 Ausubel, Wernick, and Waggoner (2013) https://ourworldindata.org/crop-yields. Various sources such as FAO and OWID based on the crop production index (PIN), which is the sum of crop commodities produced (after deductions of quantities used as seed and feed).
6 This projection is published in the FAO s World agriculture towards 2030/2050 Report Fao.org

Figure 3 **Top - Cropland use over the long-term (ha). Cropland is arable land and permanent crops. Bottom - FAO projection of arable land to 2050 (ha).**





Source: FAO

As the chart in Figure 3 reveals, the FAO predicts that cropland use will continue to grow to 2050, however, at a slower rate than over the past 50 years. Most of this growth is projected to result from developing countries, meanwhile arable land use in developed countries is likely to continue its decline.

New techniques such as vertical farming or new directions in genetic modification such as CRISPR[7] are often presented as strong arguments for cropland efficiency and ultimately a reduction of productive land use. We leave this debate outside the scope of this paper. Also the debate around new consumption patterns, particularly the migration from meat towards alternative, plant based protein and its impact on land use is deliberately left for another day.

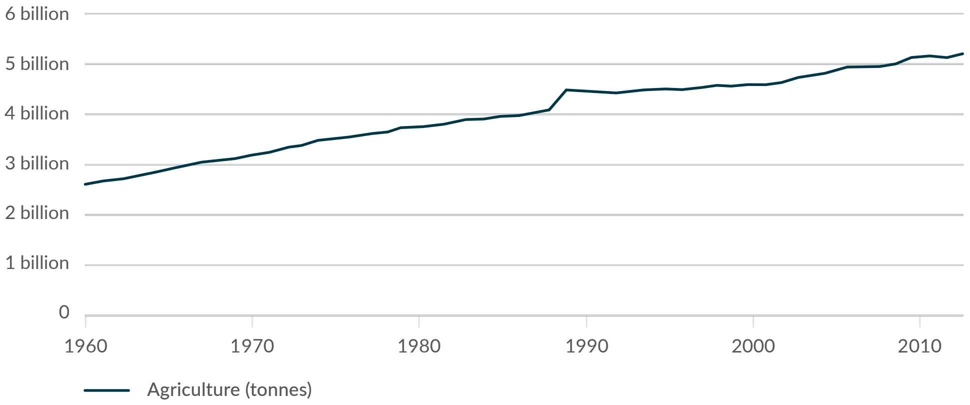
Net GHG emissions

With the increase in productive, arable land, also the ecological footprint of this land has increased. The food supply chain contributes around one-quarter of global greenhouse gas emissions, the majority of which occurs at the farm level[8]. Agriculture produces roughly five gigatons (Gt) of carbon-dioxide equivalent (CO_2e) emission in the atmosphere per year out of a total 55 CO_2e per year. The main components are methane (CH_4) and nitrous oxide (N_2O) emissions, mainly from manure management and manure applied to soil. It is beyond the scope of this paper to determine which part can be attributed to cropping and what part to dairy or livestock farming. The Griscom study argues that of these five gigatonnes two gigatonnes can be reduced through farming response options and better crop land management between now and 2030, which is a meaningful contribution to the goals set in the Paris accord.

7 CRISPR: Scientists have found a method to edit the genes in plants quickly and cheaply. It is a promising technology used for plant breeding. ISAAA.org/publications

8 FAO: http://www.fao.org and https://ourworldindata.org/global emissions

Figure 4 **Greenhouse gas emission measured in gigatons (Gt) of carbon-dioxide equivalents (CO_2e). The main source is Nitrous-Oxide (N_2O), roughly 70% of total emission, and Methane (CH_4), roughly 40% of total emission.**



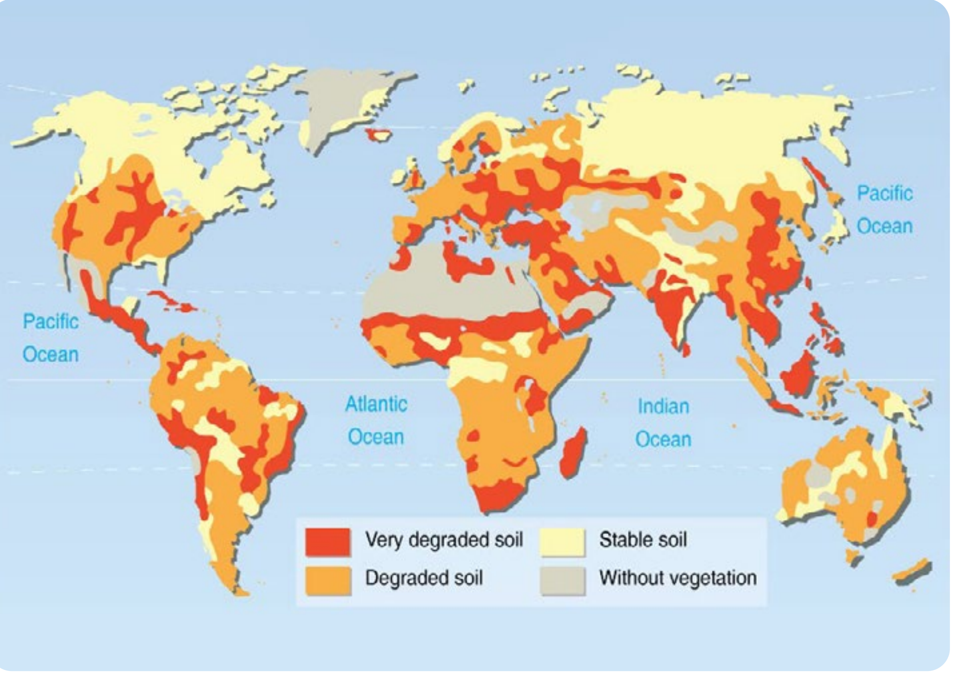
Source: FAO, IPCC, Griscom et al

The current debate in nature-based solutions concentrates mainly around protecting and restoring nature. This is for good reason, as reforestation and avoiding conversion of forests to cropland has the greatest climate mitigation potential. But the potential for managing agriculture is given insufficient attention. The Griscom study concluded that changing the way we farm could deliver 22% total CO_2e emission reduction. While farming is a net contributor, it has the potential to become a net carbon sink, i.e. a net detractor of GHG emission in the atmosphere. Also the Intergovernmental Panel on Climate Change (IPCC), promotes the claim that increasing soil organic content is a "large impact mitigation option" due to its capacity to reduce global emissions by at least two Gt CO_2e per year.

Land degradation

The IPCC Special Report on Climate Change states that a quarter of the Earth's ice-free area is subject to human-induced degradation (Figure 5).

Figure 5 **World Atlas of Desertification**



Source: Living Planet Report, UNEP, International Soil Reference in Information Centre

Land degradation is defined as a human-induced negative trend in land condition, expressed as a long-term reduction of biological productivity or value to humans. What it comes down to is a decline in soil health, water resources or wildlife, which deteriorates the economic productivity of the land.

It is important not to forget that soil is the second largest store of carbon after the ocean. Reduced soil health can be related to a loss of nutrients, such as nitrogen, or a decline in organic matter in the soil. Since the dawn of farming, most agricultural soils have lost between 30% and 75% of their original organic carbon. The widespread modernization of farming in the mid-20th century, involving monoculture farming, tillage and synthetic nitrogen fertilization, has accelerated the depletion of soil carbon stock. Climate change exacerbates this problem, either through gradual changes in temperature and rainfall patterns or through more extreme weather events. Reaching global land degradation neutrality by 2030 has now been formally incorporated into the UN Sustainable Development Goals. The United Nations Convention to Combat Desertification (UNCCD) states that at a minimum, the world needs to restore and rehabilitate the equivalent of 12 million hectares of degraded land – which equates to 1% of total crop land - to offset what is lost every year due to degradation and desertification. Moreover, the remainder of the world's land must be managed through a broad spectrum of sustainable land use programs[9].

Water

Agricultural production is highly dependent on water and increasingly subject to water risks. Agricultural irrigation accounts for 70% of water use worldwide and more than 40% in many OECD countries[10]. Intensive groundwater pumping for irrigation depletes aquifers and can lead to negative environmental externalities, causing significant economic impact on the sector and beyond. In addition, agriculture remains a major source of water pollution; agricultural fertilizer run-off and pesticide use contribute to the pollution of waterways and groundwater. Major droughts in countries like Chile, Australia and California (United States) have affected agricultural production while diminishing surface and groundwater reserves. These and other extreme weather events, like floods or tropical storms, are also expected to be more frequent due to climate change. Farmers in many regions face increasing competition from non-agricultural users due to rising urban population density and water demands from the energy and industry sectors. In addition, water quality is likely to deteriorate in many regions due to the growth of polluting activities, salination caused by rising sea levels and the abovementioned water supply changes.

These water challenges are expected to strongly impact the productivity of both rain-fed and irrigated crops. The pictures in Figure 6 illustrate the impact of drought effects in Australia. The farmer has just harvested a minimal winter crop, mostly hay and decided to forego on planting any summer crop in order to capture the moisture in the soil. It may be obvious that agriculture's water management is essential to a sustainable and productive agro-food sector.

Figure 6 **VLK Investment Management field visit with farmers in Moree, New South Wales, Australia, right after a record dry winter season and during the worst bush fires 400 km Eastwards around the Eastern coastline of Australia**

9 UNCCD, 2015

10 Based on OECD data https://www.oecd.org/agriculture/topics/water-and-agriculture/

Biodiversity

The expansion of agriculture has been one of humanity's largest impacts on the environment. It has transformed habitats and is one of the greatest pressures on biodiversity. Of the 28,000 species thought to be threatened with extinction on the IUCN Red List, agriculture is listed as a threat for 24,000 of them[11]. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) last year issued its Global Assessment Report on Biodiversity and Ecosystem Services report, also picturing a grim state of affairs[12].

No matter what resource or part of the ecosystem is affected, it is important to understand that all these issues do not evolve in isolation. Net GHG emissions exacerbate climate change. Climate change exacerbates soil degradation (particularly in low-lying coastal areas, river deltas and drylands), soil degradation exacerbates water runoffs, water runoffs leads to topsoil and nutrient runoffs, which leads to fewer plants, which heats up the land in the summer and so forth. The system is in a downward spiral that can be reversed if one is willing to look at the farming ecosystem in another way. To be able to look at it in another way we need to understand the connections. One important connector already mentioned is the functioning of soil. Why? Because it is the element over which the farmer has control, much more at least than over elements such as water or the weather.

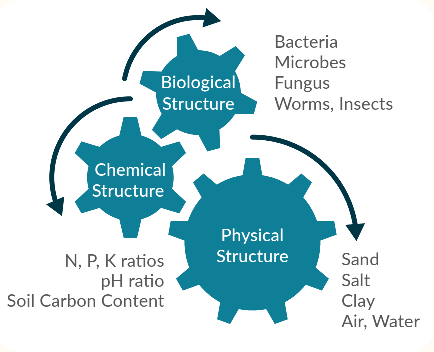
11 Established in 1964, the International Union for Conservation of Nature's Red List of Threatened Species has evolved to become the world's most comprehensive information source on the global conservation status of animal, fungus and plant species. https://www.iucnredlist.org/

12 https://ipbes.net/global-assessment

Tutorial: How do our soils work?

In order to describe soil one can describe it by its physical, its chemical or its biological characteristics. Physically soil is the matter that keeps the plants standing upright. Soils anywhere in the world are typically composed of 50% minerals (sand, silt and clay), 25% water, 15% air and less than 10% organic matter. Biologically, soil is a system run by billions of microscopic organisms. Green plants take energy from the sun and feed the organisms, who in turn build the soil and feed the plants. Chemically, soil is a complex mix of nutrients and various binding substances (e.g. N, P, K) with critical chemical conditions. All these characteristics are in a complex natural symbiosis, only really understood by scientists. The interaction between these elements and characteristics and the effect on the quality and fertility of the soil is still to be understood by scientists. There is a much better sense of what constitutes soil health, including the proper use of water and nutrients, the diversity of biological life in the soil, how much carbon is being stored and how resistant the soil is to erosion.

Figure 7 **Soil symbiosis**



For an investor or a financial expert this can all be quite daunting. Therefore the functioning of the soil can perhaps be best explained by an analogy. The analogy of a trading boot, or a currency exchange. Symbiosis in the soil is nothing more than a constant trade. So when we talk about soil organic matter, fungi, bacteria, nutrients and above all carbon, we are basically talking about the main actors and facilities on an underground currency exchange.

Organic matter – the traders

Soil organic matter are the traders, they form the heart of the soil. Damage or remove the heart and the patient will be in serious trouble and there will be no trade. Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. Soil organic matter or soil organic content (SOC) typically makes up less than 5% of the soil by weight, but controls 90% of soil functions essential for plant growth.

Carbon – the currency

Carbon is the currency of the soil. Carbon is a major and essential part of soil organic matter. Soils contain one of the largest organic carbon stocks on the planet with close to 1 billion metric tons of carbon to a depth of 1 meter. It feeds the organisms that comprise the soil food web so they can fix, decompose, acquire and cycle essential plant nutrients. Through the process often called photosynthesis, plants are able to absorb carbon dioxide from our atmosphere and convert it into energy-rich sugars or carbon exudes. Plants transform these sugars into a wide array of other compounds. Many of these compounds are used by plants for growth, however, a significant amount of them are transferred to the root tips where they are 'leaked' into the soil as root exudates to feed microbes. The plants, in return, benefit from the nutrients released from the soil and transferred to their roots. This soil-root interface is called the rhizosphere, which in our analogy is the trading pit, it is where the 'open outcry' action happens. This microbial activity also drives the process of soil aggregation, aeration, infiltration and water-holding capacity. When plant material decomposes, these organic molecules contribute to building healthy soils by improving structure and nourishing microbial life along with a world of other benefits. Before Earth's 3.6 billion acres of farmland had been cultivated, the soil contained 3% carbon. Today, it contains 1% carbon, signaling not only the loss of soil organic carbon content, but also the opportunity to again build carbon concentrations in our agricultural soils.

Nutrients – the dollars

Nutrients such as nitrogen or ammonium is the food of the soil, it is the base currency, the dollars on the exchange. The majority of available plant nutrients are contained in, or made available by, the living fraction of soil organic matter. Up to 10% of what we refer to as soil organic matter is living organisms. It is this living fraction that fixes nitrogen from the air and decomposes everything from crop resides to dead animals to rocks, making nutrients available to plants.

Mycorrhizal fungi – the house

Mycorrhizal fungi in the soil is key. Mycorrhizal fungi is the glue in the soil. It allows for respiration of the soil. It protects plants from diseases. It helps bind soil particles together, and the more soil particles, the more pore spaces. This is where soil microbes live. The more pore spaces, the more water infiltration. While the understanding of soil carbon stabilization mechanisms is evolving, it is clear that mycorrhizal fungi play an important role in the longevity of carbon in the soil. Not only are these good fungi responsible for fixing carbon, but also for fixing it over long time periods (we will talk about permanence of carbon sequestration later in this paper). Research suggests that the fungal component of the soil is the most important factor to most plants early in life. It is much more important than nutrients such as nitrogen, phosphorous, potassium, or even organic matter.

Figure 8 **Mycorrhizal fungi is a root-symbiotic fungi that secrete a protein called glomalin; this fungi-root partnership and its glomalin are responsible for creating persistent, stable soil aggregates that protect carbon from being lost as CO_2.**

Diversity of plants – the market

A diverse plant population provides a much more diverse diet of root exudates for soil microbes. This increases the amount of carbon cycled through the soil i.e. using a market analogy, more actors buying and selling, more volume.

Applying fertilizer – disturbing the level playing field

The problem for plants isn't nitrogen. Crops need nitrogen to feed the microorganisms in the soil as mentioned. The problem is excess nitrogen. If too much nitrogen is added to the soil at planting time the relationship between microorganisms and the plant is disturbed. In a natural state, plants trade carbon to soil microbes in exchange for nutrients. Applying too much nitrogen can suppress the association that microbes have with the plant. Fertilizer gives plants "free" nutrients, so they don't need to trade carbon for nutrients from microbes. When that happens, the plants keep a lot of that carbon for themselves, which means the microbes don't get enough food to grow and reproduce, and their populations suffer. So when excess nitrogen is available, plants will use the rapidly available nitrogen from fertilizer instead of relying on soil organisms to supply it to them from natural sources. As if they were saying, I have found a much easier supply, I don't need you anymore. On the trading boot, there is a new trader offering much better pricing. The by-effect is that the plant becomes a **nitrogen addict**, dependent on an artificial supply of nitrogen. Rather than feeding the plant it is better to feed the soil, so it can feed the plants.

Water and plants – the real economy

Soils are a key element in how water moves, collects and distributes across the land. It is the exchange necessary for the water economy and the plant economy to function rationally. Bypassing this exchange creates chaos and undesired side-effects. Water will take its own course (runoff), collecting nutrients on its path and dumping those nutrients in river beds and estuaries. Only about 40% of the synthetic nutrients applied in a given year on croplands are actually taken up by the plants that year. The remainder stays in the soil, leaks into the groundwater or ends up in rivers. The economy is wasting those dollars in a part of the economy where it is not productive or counterproductive. Soil carbon is the key element for water holding capacity. As soil organic carbon increases from 1% to 3% by weight, the water holding capacity of the soil doubles. Improving soil structure results in more water infiltration and less runoff, giving the ground an improved ability to absorb water during intense rainfall events. And also plants, the other economy providing our daily food, will take their own course and start to transact opportunistically as we explained with the fertilizer example. Despite all new technologies, without functioning soil there will be more empty plates.

Figure 9 **The increasing problem of nutrient runoff on the American coastline**

Literature: Jon Stika – A Soil Owner's Manual | Gabe Brown – Dirt to Soil | Judith Schwartz – Restoring Soil to heal the Earth

For more information on the functioning of soil check out the following video content:

Life in the soil - https://www.youtube.com/watch?v=XapUm5n1zuM

Wat leeft er in de bodem, WUR - https://www.youtube.com/watch?v=W-4V7kQLrkQ

Step 2: Linking values to this system

Agriculture differs from other high-emitting sectors in that it can act as both a source (contributor) and a sink (detractor) for GHG emissions. For this reason, agriculture has the potential to be a net positive sector from an emissions perspective. At the same time, agricultural productivity is vulnerable to climate change and central to supporting adaptation and resilience through its provision of ecosystem services.

In recent years, there have been some encouraging signs that the agriculture sector of OECD countries is capable of meeting its environmental challenges. Notwithstanding these improvements, there is still more to do, with an important role for policymakers on a national or supranational level. Various policymakers have developed recommendations on how to develop cost-effective agri-environmental policies, how to manage water issues for agriculture, how to deal with climate change challenges, and how to preserve biodiversity and manage ecosystem services related to agriculture. This chapter addresses some of the recommendations and climate initiatives, referred to as response options. Of particular interest is how mitigation practices in farmland and agriculture are scoped and presented by these policy makers.

While there is unlikely to be a "one-size-fits-all" solution for dealing with environmental concerns in agriculture, as agro-ecological conditions and public preferences differ across countries, we will list some of the policymakers, their policies and strategic focus.

OECD

To help governments assess whether the policies they have in place minimise environmental damage, the OECD has developed a set of agri-environmental indicators (AEIs)[13]. This publicly available database offers insights in environmental conditions and trends in most countries and highlights where new environmental challenges are emerging. With the help of accurate data the OECD can assist policymakers in meeting environmental targets.

13 https://stats.oecd.org/

UN

When thinking of ecological values the climate industry often refers to the Sustainable Development Goals set by the United Nations. The key SDGs in the context of NBS / rural-land-based solutions are:

- SDG 2 – Zero Hunger;
- SDG 6 – Clean Water;
- SDG 13 – Climate Action;
- SDG 15 – Life on Land.

US EPA

The United States Environmental Protection Agency (EPA) is the federal agency conducting research and offering sustainable policies on a federal or state level. Examples of farming related policies being monitored by the EPA are the Clean Air Act or the Toxic Substances and Control Act and Water Infrastructure Finance and Innovation Act. In 2018 the EPA presented its strategic plan, emphasizing the EPA's "back-to-basics" agenda addressing three main goals: environment; communities and land.

Australia

The Australian National Landcare Program, launched in 2014 and now running its second phase, is considered to be the most concrete ecological stimulus in this country right now[14]. It is a funding platform that helps support local environmental and sustainable agriculture projects. It focuses on communities (including indigenous communities), improving the natural resource base (i.e. soils and water), landcare and the rehabilitation and restoration of the natural environment.

EU

The 2013 reform of the European Union's Common Agricultural Policy (CAP) introduced a green direct payment scheme. The aim was to improve the sustainable management of natural resources linked to farming through payments for practices beneficial to the environment and the climate. Besides

14 http://www.nrm.gov.au/national-landcare-programme

crop diversification and the maintenance of permanent grassland, greening requires farmers to reserve 5% of their arable land for ecological focus areas (EFAs). Since 2019 there is a revised policy in the making, which will carefully review and evaluate the effectiveness of the payment scheme.

In 2019 the European Union agreed to adopt the Sustainable Finance Action Plan, referred to as "taxonomy" for classifying green investments. It is part of an ambitious action plan with a goal of "reorienting" capital flows towards sustainable investments, with the underlying goal of a net zero carbon economy by 2050.

Institutions like the UN (more specifically the IPCC) or the various national or supranational policymakers will prioritize their own national interests and natural boundaries, but often with the same goal in mind. Nearly all countries have subscribed to the Paris goals of net-zero emissions in every sector by 2050. In the context of agriculture, net-zero is a means to ensure that even where GHG emissions cannot be reduced to zero, they can be compensated through increased removals (through carbon sequestration) on farmed land. It may be that some countries - with concentrated production systems, with small land areas, lots of rainfall, and with almost saturated carbon soils (all of which may be the case in the Netherlands) – would struggle to reach net-zero emissions within the agriculture sector alone. In the table below we list some of the main proposed response options offered by some institutions.

Figure 10 compares the various response options highlighted by some of the leading international institutions.

Figure 10 **Comparison of climate response options (strategic objectives) IPCC(UN), EU and ALP and US EPA**

IPCC(UN) 2019	EU Sustainable Finance Action Plan 2019	Australia Landcare Program I, II 2014, 2018	US EPA 2018
– **Conservation** Ecosystem conservation or re-creation	– **Conservation** Ecosystem conservation or re-creation	– **Conservation** Ecosystem conservation or re-creation	– **Conservation** Ecosystem conservation or re-creation
– **Improved Soil Management** Including reduced desertification, soil salinization and soil compaction	– **Improved Soil Management** Including reduced desertification, soil salinization and soil compaction	– **Improved Soil Management** Including reduced desertification, soil salinization and soil compaction	– **Crop & Input management** Safety of chemical use
– **Water Management** Improved Water Management	– **Crop & Input** management	– **Water Management** Improved Water Management	– **Water Management** Improved Water Management
– **Crop Rotation** Crop Diversification and Crop Rotation	– **Water Management** Improved Water Management	– **Communities** Indigenous communities	– **Communities** Indigenous communities
	– **Recycling** Circular economy and waste prevention		

Four key values

The level of risk posed by climate change depends on how population, consumption, production, technological development and land management practices evolve. In the previous chapter we have linked agriculture to the various ecological issues and we have explained how agriculture has the potential to mitigate some of these challenges. For the purpose of this paper we have summarized the goals in four key values:

1 Climate change mitigation (Climate)
2 Zero Hunger (Food)
3 Life on Land (Biodiversity)
4 Clean Water (Water)

This paper does not consider soil quality as a value on its own, but rather as a means to an end. We will however sufficiently address the role that soil quality plays in the various response options in this chapter.

For the remainder of this paper we will address the following five response options: 1) Conservation; 2) Crop & Input Management; 3) Water Management; 4) Crop Rotation and 5) Improved Soil Management. The top table in figure 11 details each of the response options and maps them to our defined set of issues. For example conservation presents a direct response option to both climate issues and water issues as well as to biodiversity issues. The bottom table in figure 11 offers the main implementation challenges linked to the five response options. For further explanation on how the response option links to the issues or value(s) explained in step 1 and what those challenges entail, we refer to the appendix in the back of this paper.

Figure 11 **Summary table of potential values (ecological issues) versus response options**

Response Options	Addressing which issues / values					
	Climate	**Water**	**Food**	**Biodiver-sity**		
Conservation	x	x		x		
Crop Management		x	x	x		
Water Management		x				
Crop Rotation			x	x		
Improved Soil Management	x	x	x			
	Main Challenges / Benefits					
	Time	**Competi-tion for land**	**Local**	**Satura-tion**	**Co-benefits**	**Costs**
Conservation	Immediate	Yes	Yes	No	Yes	Low
Crop Management	Long term	No	Yes	Yes	Yes	Low
Water Management	Immediate	No	Yes	Yes	Yes	Varies
Crop Rotation	Long term	No	No	Yes	No	Neg
Improved Soil Management	Long term	No	Yes	Yes	No	Neg

Scientific literature providing insights on the mitigation potential on categories of individual response options indicates that it is the combination of practices and techniques which are applied over large areas and over a longer period that leads to substantial mitigation, i.e. an approach is required where all feasible mitigation practices are being pursued at the same time.

Step 3: Prepare the solution: nature-based farming

In the previous two chapters we have addressed the twin policy challenge of ensuring global food security for a growing population while improving environmental performance. We have talked about increased GHG emissions, expensive inputs, degraded soils, water runoffs and pollution issues. We have summarized the ecological consequences in four key values. Subsequently we have linked the various response options offered by some leading institutes to these values. In this third and final chapter we will look into how some of the response options can be applied in practice. We will now look through the eyes of a farmer and discuss various practices currently being deployed either on a local or global scale. Some have been practiced for generations (perhaps unknowingly), some are in full swing, others are new or in a pioneering phase.

We will focus on:

A. conservation farming,
B. regenerative farming and
C. precision farming.

At the end we will briefly address carbon credits and carbon sequestration. We are cognizant of the fact that various terms and definitions are being used and that sometimes the definitions overlap. The paper will conclude in expressing that any combination of practices will ultimately yield the best result.

A. Conservation Farming

Conservation farming focuses on acquiring productive farm and pasture lands with significant conservation and natural resource values in mind. It is an area of investing that to date has received most interest in forestry or timber investments through so-called conservation easements. The typical conservation transaction would combine investor capital and conservation capital (capital offered by an NGO in return for conservation commitments) to acquire property with the aim to generate financial income as well as conservation values. It allows the owner to buy the land at a reduced price and therefore it reduces the risk for land depreciation. In return the new owner commits to certain conservation measures such as water (ponds, lakes, streams), buffer zone conservations, or wildlife protection areas. Conservation management groups work with conservation capital or conservation easements, habitat conservation plans or other commitments. Today, this is an area of investment that is only practically available in the US due to its fairly active conservation community and often well capitalized not-for-profit conservation organizations but also due to the fact that US property law allows for separation between legal title and legal use.

In the most rudimentary form conservation farmers commit to give operational land back to nature. From a landowner's perspective this may not be that financially rewarding. At the other extreme a conservation can mean that farmland remains farmland, as opposed to a residential area or any other productive use. Landowners may look for solutions where the conservation principles can be integrated into a productive farm. Farmers can establish conservation areas, for example biodiversity reserves, afforestation areas, corridors for native wildlife to pass through or windbreaks, just to name a few. These are all examples of designated areas that shouldn't interfere too much with the capacity of the land to produce so-called cash crops. So in this regard managing a productive and profitable farm can go perfectly hand to hand with conservation goals. As discussed in chapter two (appendix to figure 11), the long-term increase in biodiversity attracts native species supporting pollination or fighting invasive predators and as such, adds to the resilience of the operation. The main challenge for conservation farming is that it is hard to build significant scale. There is simply not enough financial and natural capital available today to create a big impact. As demand for nature- based solutions, for example in the corporate offset market (later in this paper), takes off this may change.

Case study: Texas Row Crop investment – Conservation Resource

This project in Texas (US) involves 7,000 hectares of row crop investment in partnership with a conservation group to protect estuary and waterfowl habitat via water surface rights. The land can be purchased with water rights and can work with the conservation agency to set up certain targets. Improvements on the land will include irrigation, land leveling (preventing run-off) and water control structures. In this transaction the conservation payment is a lump sum at the start of the project.

Figure 12 **Texas Row Crop – Source: Conservation Resources**



Case study: California Permanent Crop investment – Conservation Resource

This project involves 3800 hectares of permanent crops in San Joaquin Valley. Conversion from cotton and tomatoes to almonds and wine grapes in land that is close to wildlife refuges. Ability to work with conservation groups to protect flyways for bird species by providing buffer zones and connectivity between wildlife refuges. Also potential for wetland mitigation and other conservation purposes. A canal system owned by the property can bring water from one end of the property to another, or can connect into the local canal system.

Figure 13 **San Joaquin Valley Property - Source: Conservation Resources**



B. Regenerative Farming

Titles such as holistic farming (a term initiated by the Savory institute[15]), organic farming, nature-inclusive farming as well as regenerative farming are all more or less working from the basic premise which is nature and natural ecosystems[16]. In this chapter we will stick to the definition regenerative farming.

15 Savory.org
16 In the Netherlands a network of sustainable farmers refer to 'natuur-inclusieve landbouw, kringloop landbouw' and more specifically to 'Niet Kerende Grondbewerking (NKG)'. The reference table at the end of this paper will specifically point towards websites and video content of the most relevant institutes, initiatives and practitioners.

The name regenerative farming stems from Robert Rodale: “Regenerative agriculture takes advantage of the natural tendencies of ecosystems to regenerate when disturbed”.

In that primary sense it distinguishes from conventional farming which ignores the value of these natural tendencies. To repeat what one of the regenerative farming advocates, Gabe Brown, is saying: “what is conventional about today’s farming practice when the current production process is only about killing – killing weeds, killing roots, killing fungi – when nature’s tendency is very clearly to self-heal?” Regenerative farming practices work to maximize carbon sequestration, while minimizing the loss of that carbon once returned to the soil, thereby reversing the climatic effect.

Regenerative practices aim to go back to a natural system, and nature’s natural tendencies. Try to picture a piece of land with dark brown colored soil covered with cover crops at least a meter high with animals roaming freely around it. Figure 14 presents some pictures from a demonstration on a regenerative annual crop farm in the US corn belt, with a cocktail of shoulder-high winter crops.

> “Regenerative agriculture takes advantage of the natural tendencies of ecosystems to regenerate when disturbed

This nutrient-rich, un-tilled soil provides answers for challenges that have traditionally been solved with inputs like synthetic fertilizers. When applied at scale regenerative practices offer a powerful way to address climate change and a powerful tool to stop land degradation.

Figure 14 **VLK Investment Management field visit with Daniel DeSutter, a regenerative, organic corn and soy farmer in Indiana.**

The Terraton Initiative

The Terraton Initiative seeks to remove CO2 from the atmosphere and capture it in agricultural soils through implementation of regenerative agriculture practices. The initiative intends to provide incentives to farmers to switch to regenerative practices without a long-term, binding commitment or sign up cost. Indigo Ag, a Boston based AgriTechnology company founded in 2016, intends to require the measurement of a participant's baseline carbon content at the beginning and end of a growing season, provide technical assistance, and cover other transaction costs such as verification and monitoring. For inspiration watch the TED presentation.

https://terraton.indigoag.com

The Savory Initiative

Non-for-profit organization founded by Alan Savory in 1984 with the aim to fight the degradation and desertification of the world's grassland ecosystems and form the idea of holistic farming (holistic and regenerative are almost overlapping terms whereby holistic applies mostly to grasland and regenerative to cropland). The institute has the aim to develop 100 farm hubs, holistically managed farms in Africa, by 2025. For further explanation watch the TED presentation.

https://savory.global/holistic-management/

How does regenerative farming work?

VLK Investment Management has interviewed many farmers, ranging from potato farmers in the Netherlands, organic soy and corn growers in the US to organic horticulturists in Hawkes Bay, New Zealand. Regardless of country, region or crop, farmers demonstrate that regenerative practices can offer significant benefits. The definitions and practices may depend on soil or crop type or local circumstances, but a number of basic premises and principles are always present: disturb the soil less; provide a greater diversity of plants; maintain living roots in the soil as much of the time as possible and keep the soil covered with plants and their residues at all times. Some farmers practicing regenerative techniques also integrate living animals or livestock in the process.

The practices developed based on these principles are:
1) **cover cropping**; 2) **no-tilling or low-tilling**; 3) **crop rotation**;
4) **input reduction** and 5) **integrating animals**, which we will explain in the overview on the next page.

Cover Cropping

- Keep the soil covered at all times
- Experiment with type of crops depending on what you want to achieve
- Enter a local network of practitioners and advisors

We have explained the mechanics of a healthy soil in the previous two chapters. When improving soil health, one should not see the soil very often. Regardless of land use, soil should always be covered by growing plants and/or residues. Why so? Fallow land fails to accumulate biomass carbon. Bare soil is more susceptible to wind erosion, water evaporates more easily and bare and relatively dry soil heats up quickly. When water evaporates, salt is left behind at the soil surface. Cover crops can help keep soil intact, as well as increase soil nitrogen and can cycle other important nutrients. Planting cover crops keeps the soil covered with living roots year-round, prevents moisture evaporation, and protects it from invasive weeds. Cover crops can be temporary crops planted between main cash crops (winter crops in mild climates as in Northern Europe), nutrient catch-crops (such as various clover cover crops) or perennial crops. In some regions cover crop fields can be two meters high holding at least 15 different crops. Elsewhere it is just some winter wheat barely growing 20 centimeters high. Which cover crops to choose is very much dependent on the type of soil, climate, season and upon what the main remedy for the soil should be. According to farmers and consultants the most important factor is the carbon:nitrogen ratio in the soil. Some crops and residues have a very high ratio of carbon, others a very low one. Most important is the variety in root types and root depth and the type of leaves. Red clover (pictured right) is a cover crop with very deep roots. Similar cover crops such as sorghum / sudangrass, cereal rye, annual ryegrass, phacelia and other clovers all produce large amounts of root mass, which supports the root system. Growing cover crops is as much an art as a science. Most countries host an entire network of farmers and consultants sharing research and experiences as part of their no-till initiatives.

No- or low-tilling

- Disturb the soil as little as possible
- Leave residue on the field
- Adjust the equipment to allow for no-till farming and reduce compaction

The practice of tilling dates back many centuries. It is used to kill residues, weeds and de-compact soil. Although perhaps practical in the short term, it is not healthy in the long term. Why is this? Tilling exposes the soil to more oxygen, which promotes further degradation of beneficial organic matter and allowing formerly stable soil carbon to be released as greenhouse gas. When the soil is opened up by tillage, carbon dioxide leaves the soil much the same way carbon dioxide leaves a can of carbonated beverage; from higher concentration in the soil to lower concentration in the atmosphere above the soil. Over the course of days bacteria use the additional oxygen added to the soil to consume the biologically produced glues that hold soil aggregates together (mycorrhizal fungi as discussed in chapter one). Tillage breaks down the growth of mycorrhizal fungi breaking down its role in aggregate formation. For simple evidence the effect is best illustrated in a 'Haney soil test'. The picture on the right demonstrate such a test and shows the function of the glues in the soil. One can imagine what reduced compaction means for moisture holding capacity. The no-till soil is like a sponge. The tilled soil is more like sand. A tilled soil will seal faster, resulting in ponding of water in flat areas or runoff of water in sloping areas, creating all kinds of issues (high concentration of undesirable inputs in water systems for example). By not tilling, the soil is left undisturbed, where it will be allowed to thrive and regenerate. It should also not be left unnoticed that tillage requires heavy machinery and heavy fuel consumption. Heavy machinery also leads to more compaction. No till machinery is much lighter, more flexible and much more fuel sensitive. The use of precision farming as discussed in the next chapter will also play an important role.

The good news is that there are plenty of new no-till machines and technologies available. The pictures demonstrate rolling machines designed to crimp the cover crops as opposed to till the soil. Planters are designed to plant directly into the undisturbed soil and plant residues.

Crop Rotation and diversity

- Rotate crops after every production year
- Plant different species simultaneously

By switching the crops in different fields in a coordinated sequence, farmers are able to reduce the loss of nutrients that occurs when the same crop is planted over and over again. By cycling through different plant species, nutrients are added back to the soil naturally. Some plants take certain nutrients from the soil, while the next crop can deposit those nutrients back. Also weeds are better controlled with crop rotation.

Rotation is not the only practice to move away from the typical monoculture with fallow rotation. Integrating seeded grass species or other perennials with deep root systems increases soil life. Also the retention of crop residue is a significant driver of soil carbon accumulation.

Strip farming or cultivation (picture on the right) is another practical option aiming to create a robust and more disease-resilient, plant-based food production system. The strips, often three to twelve meters wide, grow alternating crops, sometimes two or three different types at the same time. Many institutions such as Wageningen University and the Louis Bolk institute in the Netherlands are experimenting with this type of farming as well as with 'pixel' cropping[17], showing some interesting results.

Reducing Synthetic Inputs:

- Use natural fertilizers and plant residues and reduce synthetic inputs
- Use precision agriculture for efficient nutrients use

Regenerative farming is foremost an organic system, refraining from the use of synthetic pesticides, which disrupt soil life. Opting for natural fertilizers, such as compost, and reducing the use of synthetic inputs helps to enrich the soil. As explained in chapter one, natural fertilizers contribute to the soil ecosystem, keeping it healthy and allowing it to both lock-in carbon and support plant and microbial life that will accelerate the carbon sequestration process. Many synthetic products only supply a narrowly focused set of specific compounds and hence do not help to make the system more resilient.

Nutrient management plans are important to optimize fertilization and improve nitrogen use efficiency. Modern technology such as precision agriculture (more about this furtheron in this chapter) can play an important role here. The plan should be based on soil testing, estimating of crop nutrient requirements, recording of nutrient applications, considering field characteristics and soil type, estimating soil nitrogen supply and, where applicable, analysis of manure nutrient content prior to application. It is not just the volume of inputs, but also the methodology and the timing that is important. In most regulations it is required that a low-

emission, nitrogen-application technology is used (e.g. slurry injection, incorporating manure in the soil within two hours of spreading). Again there is no one-fits-all solution and when starting with a no-till, regenerative regime it is paramount to adjust the nutrients program slowly and intelligently and to seek advice from consultants, cooperatives and/or neighbor farmers.

17 Wageningen University and the Dutch Ministry of Agriculture have started a strip cultivation project in 2017. https://www.wur.nl/en/project/Strip-cropping.htm

Animal Integration

— Let cows and animals do the work for you

Better even than injecting slurry in the soil with machines is to let cows and animals graze the crop-land. Incorporating livestock into cropland with carefully managed grazing can improve total system productivity and health. The fertilizing benefits of animal manure deposited in a field supports crop plant nutrition. The subsequent photosynthesis from the foliage helps to lock more carbon into the soil. Also the hooves of livestock do the work of a rolling crimping machine (shown on the picture above). We have left this practical option out of scope for this paper.

C. Precision farming

Another practice that has gained interest from the technologically savvy farming community is precision farming. The implementation of precision agriculture was born in the early 1980s in the United States, whereby crops are managed by observing, measuring and responding to variability in crops through satellite navigation systems, geographical data systems and sensors located on machines or on the land. The data gathered is used to improve decision-making, resource-use and contribute to a more efficient and sustainable farming system. The main objective is to reduce inputs, i.e. greater production achieved with fewer resources. One of the most widely used applications is soil mapping. State-of-the-art technologies are implemented to obtain more precise data about the condition of the soil, the climate and crops. Mapping enables users to know the composition, characteristics and features of the farmland in more detail. The physical, biological and chemical characteristics of the soil determine if and what nutrients and what type of manure are required, or how much water should be applied and where. The aim is to have enough information to be able to read the soil condition and improve yields and reduce the resource use.

Benefits and challenges to overcome

All these nature-inclusive practices - conservation, regenerative farming, precision farming and perhaps many more - have a high potential for GHG emission reductions, especially when all deployed simultaneously. They promote carbon sequestration, improve food security, and build healthier ecosystems, all of which provide us with a better chance of addressing climate change at scale. Billions of hectares of farmland could be activated to remove carbon dioxide from the atmosphere.

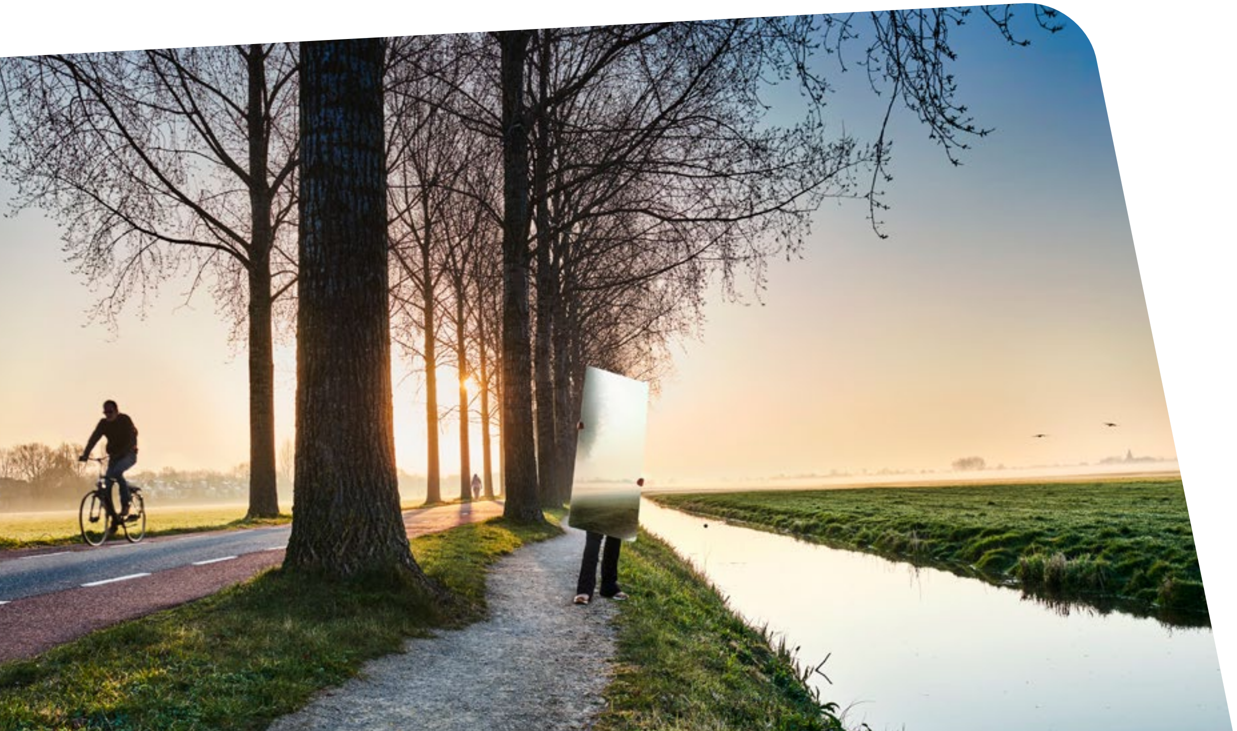
All these methods have been subject to broad debate amongst the farming community for a number of years now. In many parts of the world farmers have been using regenerative practices for generations without calling it that. The benefits of reduced tillage and keeping the field covered all-year long has been well understood amongst many farming communities. It helps to:

1. Sequester carbon and mitigate climate impact;
2. Produce healthy soils and healthy food;
3. Produce clean water and far less run-off;
4. Produce clean air using input from the farm;
5. Increase the productivity, economic return and acceptability of the farm and the land;
6. Make farming a knowledge intensive enterprise rather than a chemical and capital intensive one.

The last two arguments, economic return and farming as an enterprise, have little direct effect on the four key issues we addressed in chapter two ('Linking values to this system'). However, we think they are very important nevertheless. The farming sector suffers from succession issues, from ageing and an increased spotlight on its social and environmental footprint. It can seem a pretty hostile environment for a young farmer entering the sector. To stimulate a younger generation out of university or higher education into farming as a profession, something may have to change. Believing that one can make a farm more profitable whilst at the same time being a solution to climate change rather than a problem could make a meaningful difference.

2 What are the main challenges towards implementation?

Unfortunately, even as this all seems like a no-brainer to a minority group of farming communities who have been deploying these practices for generations, on a large scale these practices remain underutilized. So what can be done to enhance further deployment of these practices?
The observation that the farming community suffers from demographic and succession challenges as well as financial viability can mean that regenerative farming is not a top priority for a large part of the existing generation of farmers. Buying a new tractor and new machinery with the latest GPS system and all kinds of new sensing devices may be out of the question. So for further adoption, all stakeholders (landowner, farmer, distributor and consumer) in the food chain will have to be inspired and need to get involved.



We can identify three hurdles:

- Hurdle #1 – Perception: How to address the concern that regenerative farming may be costly or may cause a deep j-curve effect (a big investment that may only be cash flow positive somewhere in the future)?
- Hurdle #2 – Evidence: Seeing is believing, how to measure the various impacts, financial and non-financial?
- Hurdle #3 – Alignment: How to commit landowners, land operators and other stakeholders?

We will elaborate on these three hurdles.

Hurdle #1 - Perception

During our farmland visits we have heard many stories from regenerative farmers about the successes they have already achieved during the first few years. Not only has the quality of their soil improved, but also the yield on their operation and input costs making their farm more profitable. Many argue they should have stopped writing checks for micro nutrients, herbicides and other inputs much earlier.

The Rulon Enterprises case study presented below shows a simple calculation: Even after a few years growing regeneratively the operation should add a US$ 142 per hectare net benefit to the farm. This would be the equivalent of a quarter of the income in a normal year.

Case study: Rulon Enterprises, Corn Belt US

Rulon enterprises in Arcadia, is a fourth-generation family farming operation. The farming business includes 3'500 acres (1,400 hectares) of no-till corn and soybeans in central Indiana (US corn belt). The family has been running their farm deploying regenerative practices since 1989. The family offers a simple calculation on how cover crops free up fertility, increase yields and improve soil health, providing a $142 ($237 - $95) per ha net benefit (a 24% improvement in operating yield).

Rulon Enterprise (3'500 acres, 1'400 ha) - Cost benefit of no-til farming

Cost	$ per ha	$ per ha	Benefit	$ per ha
Seed Cost	40		Fertilizer saved	40
Planting Cost per ha	55		Yield increase	85
Seeding costs		12,5	Drought tolerance increase	85
Tractor hours		7,5	CSP program payment	27
Labour		5		
Fuel		5		
Planter repair & wear		25		
Cost per ha	95		Benefit per ha	237
# hectares	1400		# hectares	1400
Total Cost	**$133.000,00**		**Total Benefit**	**$331.800,00**
% landvalue ($20k/ha landprice)	0,5%			1,2%
% yield (3% net yield)	16%			40%
Net Benefit				$198.800,00
% landvalue ($20k/ha landprice)				0,7%
% yield (3% net yield)				24%

Net benefit is estimated to be US$ 142 per hectare due to fertilizer savings, yield increase, drought stress tolerance, erosion reduction as well as a conservation programme.

1) Fertilizer: spending $40 per ha less in phosphorus (P) and potassium (K) fertilizer every year compared to corn belt fertilizer recommendations
2) Yield: the Rulon operation sees on average a 17-bushel corn yield increase per hectare when it follows cover crops vs. no cover crops, resulting in 17 times 5 $/bushel = $85 per ha gain
3) Drought tolerance: the Rulon operation sees a doubling of the yield increase in drought years, when commodity prices go up adding another estimated $85 per ha gain
4) Conservation Stewardship Program (CSP) can add another $27 per ha

Of course the seeding costs, planting costs as well as the conservation benefits are more or less predictable. The other savings as well as the yield increases are less predictable. Data from the US Natural Resources Conservation Service (NRCS), a USDA department, indicates that improved soil quality can lead to a more conservative $ 35 per ha net benefit (ex program payments) due to increased soil biology, reduced erosion and improved drought tolerance.

It is also important to note that these benefits don't typically happen in the first year of cover crops or no-till operation. They're the combination of many practices, including investment in drainage, variable-rate seeding, Nitrogen application based upon yield goals, and of course long term no tillage.

Source: https://www.covercropstrategies.com - https://www.nrcs.usda.gov/wps/portal/nrcs/

Still a group of conventional farmers out there are arguing it wouldn't work for them because there is too much clay, too much sand, too wet, too dry, too hot, too cold. Some argue that the banks are uncomfortable financing farms that are experimenting with new practices. It doesn't help that traditionally the only agronomical advice comes from the seed company selling inputs. Needless to say, they won't like the idea of not selling as much glyphosate or any other herbicides or pesticides anymore. The vast majority of soy or wheat planted every year is so called 'round-up ready', which allows the farmer to kill everything except the cash crop. Fortunately there is another voice as well which is getting louder. It is the voice from farmers that have converted to regenerative farming but also the voice of food-producers and consumers calling for regenerative or organic crops, fruits and vegetables. There is growing evidence, but in this paper we will only mention a few cases addressing costs versus benefits:

- A group of 10 Dutch environmental stakeholders have conducted a survey amongst 1100 farmers as to why they have or haven't converted to regenerative farming yet, what financial reward would further entice them to do more, what practices are preferred today and what role the European EFA related subsidies play. We summarize the main outcomes.
- Around fifty farmers in France and Belgium enrolled their farm for an analysis of their performance in the 2018-2019 season using a diagnostic tool to measure regenerative performance offered by a startup called Soilcapital[18]. The experiment showed that the top ranked farmers in terms of emission reduction were the most profitable by a healthy margin.
- Other interesting case studies of farms interviewed by VLK Investment Management are the Dan de Sutter farm (800 acres in Indiana) or the Gabe Brown farm (over 1,000 acres in Northern Dakota), both demonstrating the profit that a healthy farming operation brings. Both present the outcomes of their soil test, their water infiltration tests, and the yield the farm produces with a sense of pride. It is perhaps still worth mentioning that not all farms in these studies are 100% organic farms or 100% regenerative farms. They have sometimes converted a part of their farm to be organic, but being 100% organic is not their aim[19].

18 Organic farming and regenerative or holistic farming are not the same. Organic farming typically focusses on the reduction of inputs, which is only one element in range of regenerative practices. Even though the organic food discussion is much debated, this paper only makes a small reference to organic farming.

19 https://www.soilcapital.com/farm-diagnostic

Case study: A survey amongst Dutch farmers on the topic of Holistic farming

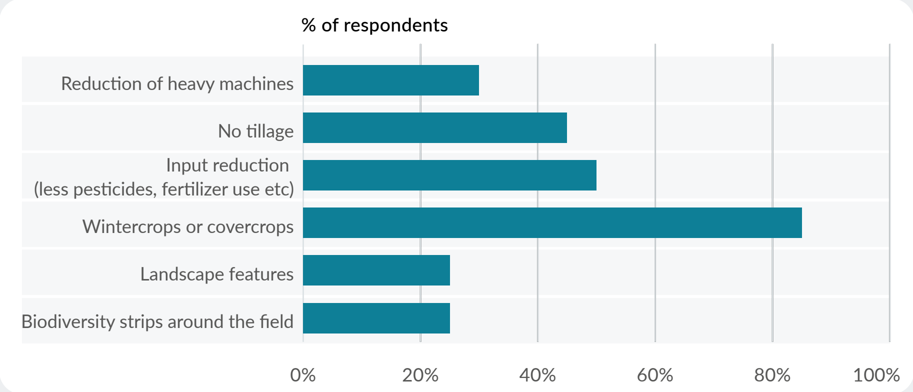
2019: The Dutch environmental organization 'Planbureau voor de Leefomgeving' and ten other institutions (among which Universities, Cooperatives, Corporates and Banks) have conducted a survey amongst 1'100 farmers out of roughly 9'000 farmers active in the Netherlands. What does nature inclusive or holistic farming mean to them and how could they be enticed to do more?
The report offers some interesting results:

- 55% of all respondents and row crop respondents claim they have integrated some nature-based practices in their operation, typically around the edges of the farm
  - This group has typically adopted four different measures
- 10% of all respondents and 8% of the row crop respondents respectively claim they operate their farm regeneratively
  - This group has on average adopted seven measures
- 40% of the respondents say they would do more if there would be an immediate financial incentive or reward such as extra land based subsidies, bank loan discounts or product premia
  - Of those respondents that could be incentivized financially, the majority are dairy or mixed farmers
- 4% of the 78'000 hectares of row crop land farmed in the Netherlands is farmed organically, producing products under the Skal certificate
  - There appears to be a strong link between having a Skal certificate or being member of a nature-based cooperative and operating holistically

In the row cropping community there seems to be more of an attitude that farming extensively is already financially rewarding without further financial incentives than amongst dairy of mixed farmers. An explaining factor may be that cropping farms are typically less financially levered than dairy farms. An argument often heard is that banks are still somewhat reluctant to finance a green transition. Various studies show that financial incentives are not the only driver for farmers. Other factors such as ownership structure of the farm, the workforce, age and education, proximity and location, the operational intensity, trust in the eco-system, personal experiences with regenerative farming and experiences of neighboring farms may play an equally important role. Those studies also show that financially incentivized farmers typically choose for the easy 'around the edges' solution, 'the low hanging fruit', whilst the more intrinsically motivated farmers choose more comprehensive, integrated solutions.

When looking at the type of measures being used it turns out that farmers in the first group typically choose those measures falling under the EFA obligation - hence are subsidized - and those measures that interfere very little with their productive operation, such as planting winter crops (as illustrated in the EU CAP case study on the next page in the EU CAP case study). Measures that are more integrated, often irreversible (planting of hedges or transition to no-till farming) and more interfering with standard operations require a stronger appetite. The chart below shows the measures taken by the 1'100 respondents.

Figure 15 **Breakdown of measures used by respondents**



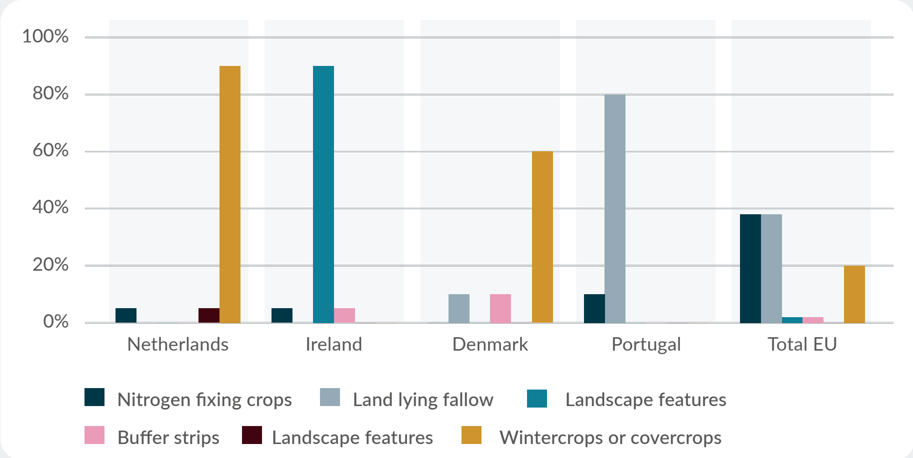
Source: Department for environmental planning (Planbureau voor de leefomgeving, PLB): "Natuurinclusieve Landbouw, wat beweegt Boeren?"

The conclusion of the study is that money isn't the only driver for farmers looking to grow more extensively. Knowledge and an intrinsic motivation appear to be important drivers as well. Which is of course not to say that paying a fair price for nature's capital isn't of the essence.

Case study: EU CAP and the EFA obligation

In 2015, 70% of the EU total arable land fell under the EFA obligation. The most frequently declared EFA types were those linked to productive agricultural areas such as nitrogen fixing crops (38%), cover crops (33%) and land lying fallow (25%). EFA types linked to less productive agricultural use such as landscape features and buffer strips are found only in certain countries that have suitable landscapes to do so.

Figure 16 **Breakdown of the main types of EFA area, after applying the weighting factors**



Source: Member States' uptake data 2015 EU-27)

Hurdle #2 - Evidence

Farmers can be very accurate in explaining what their inputs are: fuel usage, amount of fertilizer and pesticides etc. Same with output, harvested yield and financials. But when it comes to impact questions it is a different matter. Most farmers simply do not have the tools to measure the environmental impacts of their actions. An important condition for being able to measure the environmental impacts is accessible (i.e. low cost), reliable and continuous data. The good news is that we see an increasing number of institutions active in data and data technology. They either act alone or in a collaborative (open source) fashion. Examples include the European Centre for Medium Range Weather Forecasts (ECMWF) or the US National Oceanic and Atmospheric Administration (NOAA) spending large amounts of resources on climate impact in farming and collecting data on temperature, number of frost days and rain days etc. The FAO, ARABES, CSIRO (both Australia) or universities such as WUR (Wageningen, Netherlands) spend huge resources on soil, agronomic and regional land use data all influencing farm actions and farm productivity. New promising alliances between universities and large companies are launched, such as Cool Farm Alliance20 that develop tools and standards around measuring GHG, biodiversity and water. New cooperatives are created amongst a network of profound advisors such as SoilCapital offering a free diagnostical tool to monitor the effects of regenerative farming quantitatively21. And many more diagnostic companies often start-ups, are founded by young data scientists, collecting data and developing algorithms to map weather patterns, soil parameters, slopes, water systems and so forth. The innovative power of these groups in areas such as digital soil and weather mapping, stratification, big data and artificial intelligence is creating an entirely new industry. As data becomes more available (open source), better quality and more relevant to the local farmer we believe that adoption will accelerate. When combined with the tools (equipment and sensors) used in precision farming it becomes clear how evidence can be collected and key performance indicators can be established.

20 https://coolfarmtool.org/
21 https://www.soilcapital.com/farm-diagnostic

Case study: Data analysis in australia

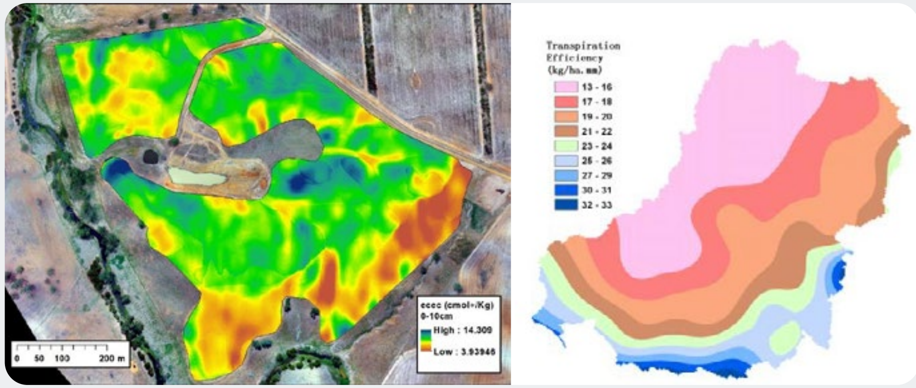
One of the challenges to implementing regenerative programs is measurement: how do we measure the SOC in the ground? There are various technologies in use. A simple periodic soil test can reveal nitrogen, phosphorus, potassium and biological parameters such as the water-extractable organic carbon (WEOC), water-extractable organic nitrogen, organic C:N ratio, organic matter and the water infiltration rate. A typical test for all these parameters is a Haney test. The Haney test uses all these parameters to arrive at a final soil-health score. Soil sampling and laboratory analysis are the preferred standards, but are costly and time intensive. The gold standard for carbon testing is dry combustion sampling. It measures the change in the soil's organic matter through heating a fraction of soil to 900 ˚C. What makes this technique costly is that multiple samples at multiple depths along the field have to be taken. Other techniques as illustrated in figuur 17 on the next page: spectroscopy (basically detecting the color with an infrared beamer as soil with high carbon content is darker), remote sensing (satellite images or drone images using algorithms of vegetation mapping) and predictive SOC mapping through machine learning are being deployed as well and are cheaper.

Figure 17 **Spectroscopy based on Terrain information**

Source: CSIRO Australia

CSIRO, Australia's Commonwealth Scientific and Industrial Research Organization has developed a simple tool for estimating potential carbon abatement arising from soil and vegetation management called LOOC-C (Landscape options and opportunities for Carbon Abatement).
Figure 18 below shows some maps illustrating eCEC, which is a test for the soil's capacity to hold important nutrients (left) or transpiration efficiency, which is a test for the soil's capacity to grow plants per unit of water. Both tests are important in dry conditions like Australia.

Figure 18 **Left: Soil map eCEC on 0-10cm / Right: Wheat water use efficiency Murray Darling Basin, Australia**



Source: CSIRO Presentation February 2020

Hurdle #3 - Alignment

Farmers in many parts of the world have been farming regeneratively for generations because it has always been in their interest. The benefits of reduced tillage and keeping the field covered all year long has been well understood. It may be sufficient that regenerative farming practices are established as the norm in a landowner – farmer relationship, as in some sort of mission statement. However, it may be the case that a more formal and concrete commitment is needed, for example in a lease arrangement, in an off-take agreement between a farmer and a retailer or in the form of credits as we will discuss in the next chapter.

Lease

Landowners often engage in short term (one-year) or longer term (5-years or more) lease arrangements with tenant farmers, quite similar to rent arrangement between real estate owners and corporate tenants. There are many different forms and shapes of lease arrangement, the most typical being a five-year rolling term, which can be automatically renewed, subject to a farmer not being in default and continued adherence to standards of care. Carefully drafted environmental or regenerative farming practices can be outlined in the lease agreement. There is often a debate amongst landowners whether operating the land under own supervision is a less risky proposition from a sustainable point of view. Leasing the land to a tenant who may be more concerned about short term yields and financial objectives than long term productivity of the land is the typical concern. The long term nature of the leasehold helps to mitigate the risks of not being a good steward of the land. A longer term rolling lease to a certain degree aligns the interest of the landowner with those of the farmer to ensure that the farmland is operated on an "as-if-owned" basis. The lease may also draft best practices and long term goals targeting some/all the values as addressed in this paper. Which values are prioritized depends on the country, the climate, the soil, basically the set of issues at hand. It also leaves room for interpretation and the creativity of the farmer/operator to implement sensible practices. Another important component in the lease may be a sustainability capex plan, where a budget is assigned to required infrastructure improvements that lead to yield and ecological benefits longer term. Examples are tile drainage, irrigation systems, water catchments or other surface water or water course management systems, solar or wind energy systems, wind breakers etc. One way to align interest between the land owner and tenant farmer is to agree on risk sharing. The land owner may finance the capex plan partially or in whole in return for financial benefits in the future.

Carbon credits and carbon sequestration

An extra incentive for farmers and a real catalyst for conservation practices or regenerative practices to be adopted can be found in the various carbon offset programs or other environmental market-based mechanisms that governments, companies and industries are adopting. Some countries such as the US, Canada, Australia, NZ, South Korea and many others have developed carbon accrual protocols that include some of the practices discussed in this paper.

Agricultural soil carbon sequestration and emissions reductions can be immediate and present affordable levers in addressing climate change. But here the second hurdle (evidence) is even much greater as this requires a high degree of confidence in how carbon quantities in the soil are measured and how greenhouse gasses emitted by the farm are measured. Rigorous standards for quantification, monitoring, and verification are to be established for the creation of agricultural carbon markets in countries such as the US and Australia. There is an increasing market for GHG or carbon credit in the US, Europe and Asia. Unfortunately farmland only plays a minor role today. There is no easy, practical way yet for a farmer to earn carbon credits. While some protocols do exist, they are either too costly to be adopted, or not rigorous enough to be valuable. As a result, almost none of the tens of billions of dollars of carbon credits that are purchased each year go to farmers, and the vast potential carbon sink that lies in agricultural soils remains untapped. The tutorial discusses some of the prevailing challenges on soil carbon offset programs and how these can be overcome in the not too distant future.

Tutorial: Offsets

There are currently only a hand full of countries offering offset programs involving agriculture. California (US) has the California Air Resources Board (CARB) for which soil health and improved agricultural management practices form part of their mission and hence set protocols under their trade program. The Climate Action Reserve is the premier carbon offset registry for the North American carbon market. Given their limited resources they focus on protocol development for North American cropping assets. They focus on conservation tillage, more efficient irrigation and cover cropping, among others. Australia has adopted an offset program called ERF (Emission Reduction Fund). The program allows projects to use a 25 or 100 year carbon reduction period. This fund does not recognize or reward any other benefits apart from GHG mitigation.

There are a number of challenges that go with carbon offsets:

- **Measuring:** There are new less costly techniques available to measure carbon sequestration. Eventually this hurdle will be overcome.

- **Costs:** All offset or mitigation projects face transaction costs such as implementation costs (planting trees or cover crops) as well as monitoring, reporting and verification costs. Such costs need to be weighed against the potential benefits of including these practices. It is the opinion of many market practitioners that the price for credits will go up as the end-date (2050) gets nearer.

- **Permanence:** For a carbon offset created from the removal and storage of a tonne of carbon from the atmosphere to be considered permanent, it must be protected for at least 100 years. Carbon in soil is highly dynamic, and it is difficult to ensure it will remain stable for such a long time. Also farmers' choices for land management are generally variable from year to year, making it difficult to commit to long-term management approaches. A solution to the permanence problem is to give projects shorter time commitments, for example 10 or 20 years, balancing the payment required to finance the project on one hand and ensuring real GHG benefits on the other hand.

- **Additionality:** A SOC accrual protocol needs to ensure that all sequestration is additional, in other words that the atmospheric carbon removal enhancement would not have occurred in the absence of the project. To determine additionality of offset projects, the adopted practices must be different to what would have happened in a baseline scenario. A solution to this problem is simply comparing the SOC to a SOC reference baseline, i.e. just measure the delta.

- **Scope:**As the name suggests, most of the carbon offset initiatives only focus on emissions reduction and do not recognize or reward any other benefits apart from GHG mitigation. This is a missed opportunity as many of the initiatives benefit multiple values as we have explained in chapter two of this paper. We see more pilot projects being initiated which account for biodiversity, activities that address threatened species and habitat, improved landscape connectivity, rotational grazing and rewilding.

Australia for example has set up the QLD Government's Land Restoration Fund on top of their Emissions Reduction Fund (ERF) which provides 'top-ups' to eligible ERF abatement projects that deliver significant other benefits. The program will use a 'Accounting for Nature' framework on which to determine the payment price. Concepts of natural capital and natural capital accounting, will be forefront in these schemes. One specific opportunity in creating areas of less productive land is in biodiversity conservation. Australia is experimenting with Farm Biodiversity Certification Schemes, showcasing best practice biodiversity management of natural resources. The CCBA (climate, community and biodiversity alliance) - a partnership of leading international NGOs that was founded in 2003 with a mission to stimulate and promote land management activities - is on a path to offer biodiversity checks and rates on NBS projects.

Where does this bring us today?

So even though there still may be sceptics, there is growing evidence that these hurdles can be overcome both from a regulator or policymaker point-of-view, from the farmers point-of-view, from the point-of-view of producers and retailers and from a consumers point-of-view.

From a regulator or policymaker point-of-view:

- Throughout this paper we have accumulated some evidence that policymakers all over the world are making sincere steps involving farming to address climatic and biodiversity issues
- Significant change in regulation can be witnessed in the use of chemicals, water use, designated areas etcetera, something which cannot be ignored by farmers or the food-industry

From the farmers point-of-view:

- More and more farmers worldwide are presenting very healthy yields and healthy farmland returns with sustainable farming practices, be that conservation or regenerative practices
- There is a general realization amongst farmers that there is a systematic risk attached to continuing to grow food conventionally – every month there is another country or province contemplating to ban certain chemicals such as glyphosate to just name one
- The equipment and technology required to farm regeneratively is becoming more accessible and more diverse
- More relatively independent farmers are switching agronomist from those that are linked to the chemical companies to those that are relatively independent

From the producer and retailer point-of-view:

- The US has been importing a record amount of organic corn and soy last year according to the U.S. Department of Commerce, suggesting that demand is growing faster than domestic supply
- The major food companies are looking for long term contracts directly with farmers to secure supply of regenerative and/or organic food
- The banks are creating new departments to offer loans to farmers growing regenerative or organic food

From the consumer point-of-view:

- There is a growing consumer appetite for safe, traceable, regeneratively farmed or organically farmed food and consumers are willing to pay a premium price
- The consumer is becoming increasingly critical, learning to understand the healthy soil – healthy food – healthy living relationship and the link between soils and food nutrient density

The other important element is that there is growing alignment within the food chain between all the stakeholders, not just between the landowner and the farmer. A comparison with other sectors such as transportation or energy can be made. The renewable energy industry (wind and solar) also started with some pioneers or evangelists, spilling over to a specialist industry of developers and private equity sponsors to end up being fully adopted by the main stream energy and utility companies. The transition from conventional to regenerative farming may follow a similar pattern from niche to main stream. Even in the absence of effective incentives (subsidies) or inductive political will in some part of the world, one can observe that consumers, retailers, packers, farmers and investors are determined to follow the regenerative, nature based path. The undercurrent is simply too strong. This is not to say that policies and regulation are not important. They are. And as in the example of renewable energy, incentives and subsidies have truly accelerated the process. Policies such as the EFA related subsidy in Europe or the Landcare Program in Australia can play a very positive role.

3 Conclusion

Farming should reclaim its position as a landscape manager of the world, working in a living ecosystem, generating healthy food for a growing population. An increasing part of the industry has chosen a path of nature-inclusive agriculture that will yield high-quality and safe food, whilst reducing the burden on the environment, improving biodiversity on farmland and increasing the positive perception of the agricultural sector. Investing in farmland passively is not going to do much in terms of claiming this ecological fame. It requires active stewardship from a landowner's and investor's perspective, reaching out to all the stakeholders to do the utmost.

We have started this paper by addressing the ecological issues and by highlighting four key values. We have then introduced some response options offered by the various policymakers. To validate these response options we have tried to explain the link between these values and the response options.

Why does better soil management have a positive impact on a whole host of ecological issues? We have then looked through the lens of the farmer and identified current farming practices responding to those response options. And finally we have laid down the benefits and the main practical challenges to those practices and have concluded that there is plenty of evidence that these challenges or perceptions are being overcome, as they have been overcome in other industries such as renewable energy or electric vehicles.

Making this transition is not something that can be achieved in one step. It requires a long process in which each step yields something better than the previous one. Broad involvement is necessary: support is needed from the agricultural sector, from policy makers, from retailers, food producers and importantly from consumers. Nature-inclusive farming practices have great potential. Technology will ultimately play an important role, but it is incorrect to think that technology is the cure for everything. Technology has led to monoculture farming systems, big 'round-up ready' wheat or soy fields, and masses of proteins for industrial-scale livestock farms. Nature based farming is a different type of technology, the type that reinforces nature and helps nature to regenerate. It is ok to give something back to nature. Eventually nature will pay in return, as it always has.

Appendix

Explanation of the five response options (Step 2)

The table below aims to: 1) describe the response option; 2) explain how the response option links to the value(s) and 3) offer the main challenges and benefits of the response option. In the next and final section we will offer more practical solutions to these response options.

Conservation: Ecosystem conservation or re-creation	Conservation practices are perhaps most common in forestry, where conservation groups issue easements to protect native tree species, water routes or wild life. Farmland conservation options are getting more widespread as well however. Conservation groups like the Nature Conservancy in North America have become more active in promoting farmland conservations. As suggested in chapter one by the conservancy report, protection and re-creation may have the biggest potential in climate mitigation. There are also many forms of integrated conservation practices, sometimes only involving small areal percentages. Farmers can integrate corners, plant pollinator strips, plant buffer strips, create water elements or special wild areas in their productive (cash crop) land.	**Climate:** Protecting and conserving forest, peatlands, wetlands or biome's with high carbon intensity may have the biggest impact on GHG. Leaving land, habitat and soil undisturbed means carbon remains locked in the ground. **Biodiversity:** Leaving land, habitat and soil undisturbed means biodiversity is not disturbed. Bringing back some of the native elements restores the balance on the land and offers great benefits for biodiversity. Biodiversity simply means a diversity of life. Diversity actually means stability. Stability means resilience to respond to changes and a healthier crop production and ultimately a higher farm yield and more food. **Water:** Preserving or creating water elements (pools, streams) as well as investing in water routes, terraces and tiles can add to the resilience of the local water system and mitigate erosion.	**Time:** A key benefit is that the effects can be shown very quickly. **Competition:** The main challenge is the competition for land. In the most rudimentary form farmers return operational land back to nature. However there are many different practices where conservation and re-creation can be integrated fully into a productive farm. **Local:** Some response options are land or region dependent. Conservation practices that relate to organic soils, peatlands and wetlands only apply in applicable terrains or biome's. To mention the obvious, building terraces for water management and erosion mitigation is not really practical in the Dutch lowlands. Other more integrated options qualify in nearly all land types. **Co-benefits:** Restoring rural landscapes can also offer great communal and social benefits, which can't be underestimated.
Conservation: Ecosystem conservation or re-creation	Some institutions emphasize compliance related response option ('do no harm') that restricts conversion of high carbon stock land to alternative land use. Wetlands should remain wetlands, forestry should remain forestry.		A key benefit is that a 'no harm' policy can be easily standardized. On a 'no conversion policy of high carbon stock land' most treaties and policies are conducted on a specific cut-off date. All investments should comply with the standard that the land has not been converted after 2008 to a lower carbon stock purpose.

Crop Management: Input reduction	Current agronomic practices are often focused on supplying various inputs hoping for an output without a true understanding of what lies in between. Between the 1960's and today the use of nitrogen fertilizers increased by 800%. Most of the academic research focuses on the role that nutrients (fertilizers such as nitrogen or phosphate) and plant protection products (e.g. pesticides and herbicides) play. The general trend is the fewer input goes into the ground, the healthier the soil becomes.	**Biodiversity:** Less input allows for a better biological balance in the soil. As explained in chapter one ("how do our soils work"), rather than feeding the plant it is better to feed the soil, so it can feed the plants. **Food:** Applying too much nitrogen can suppress the association that microbes have with the plant (chapter one "how do our soils work"). Fertilizer gives plants "free" nutrients, so they don't need to trade carbon for nutrients from microbes. When that happens, the plants keep a lot of that carbon for themselves, which means the microbes don't get enough food to grow and reproduce, and their populations suffer. This leads to lower yields. Also applying too much nitrogen leads to less healthy plants that are more susceptible to disease. **Water:** Less input also reduces the risk of severe runoffs into water and river systems.	**Time:** The main challenge is that this response option will not have an immediate effect and needs careful management. Cancelling a nutrient program overnight is like cutting off an addict from drugs. Also this is not a one-size-fits-all solution. Improved crop management has to do with making sure these inputs are targeted in their application and are delivered at appropriate levels and with appropriate techniques. **Co-benefit / Cost:** The key co-benefit is that the artificial fertilizers and pesticides are expensive so that over time great sums of money can be saved.
	Reducing the use of diesels and other carbon fuel through modernizing mechanization and irrigation systems can contribute to mitigation. And also the effect of downstream use (recycling) of waste materials can be of great benefit.	**Climate:** The reduction in fossil fuels has a mitigating effect on GHG emission.	**Time:** Clearly there is limited capacity to improve things and the effects may only be felt longer term. There may also be a cost effect and a longer earn-back period in some practices.
Improved water management	Combating desertification through water harvesting and irrigation, restoring degraded lands using drought resilient plants and other agro-ecological practices. Taking efforts to lead waterways and avoid erosion or desertification has profound impacts on climate indirectly. Making sure that farming activities do not lead to a decrease in water availability in catchments where this is a concern. Land drainage (regularly check and maintain drainage where it has been installed to avoid water-logging and compaction which in turn reduces emissions).	**Water:** The functional capacity of the water cycle on most agricultural soils is rather poor. Runoff, erosion, floods and droughts are all symptoms of soil not properly performing the function of capturing, storing, supplying and filtering water. Very often soils experiencing runoff had poor aggregate stability and as a result were dysfunctional in their capacity to infiltrate water. A combined effect of bad water cycling and the abundant use of inputs is that a big portion of the input is leaking into the water system.	**Cost:** One of the key challenges is costs. Farmers have been reluctant to invest in irrigation systems, as canals and water catchments all cost money. The subsidy system in countries like the US may exacerbate the issue. Farmers in the US are being compensated when due to heavy rainfall they cannot get the seeds in the ground. **Co-benefit:** The benefits are various. We talked about runoff, erosion, floods and droughts all being symptoms of non-performing water cycles in the soil.

Crop Rotation: Crop Diversification, mixed croppingand Crop Rotation	This response option covers various practices such as crop rotation, crop variety or mixed cropping as well as always keeping a root in the soil. Increasingly common mixed cropping practices such as strip-farming or pixel-farming as well as mixed cover crop - cash crop farming are also part of this option and will be discussed in the next chapter.	**Biodiversity:** A diverse plant population both increases biodiversity above the ground as well as under the ground. Above the ground it attracts native species supporting pollination or fighting invasive predators and as such, adds to the resilience of the operation. Under the ground it provides a much more diverse diet of root exudates (sugars) that feed the biological life in the soil. By cycling through different plant species, nutrients are added back to the soil naturally. Some plants take certain nutrients from the soil, while the next crop can deposit those nutrients back. **Food:** A diverse plant population allows for more carbon cycling and enhances plant resilience leading to a higher yield during periods of drought or outbreaks of diseases(chapter one "how do our soils work").	**Cost:** A challenge is education (what plants, what root system, what leaves) and the perception that one plant at the time should be enough. **Time:** Biodiversity above the ground or in the soil does not change overnight. It requires a systematic approach and may take years before yielding any reward.
Improved Soil Management	This response option involves reversing soil degradation and improving soil health. Sustainable land management can prevent and reduce land degradation and maintain and increase land productivity. Decades, or even centuries, of intensive agricultural activity has depleted the historical soil organic matter pools in soils around the world. However, these agricultural soils have the capacity for soil organic matter to be rebuilt to their pre-agricultural conditions, if managed appropriately.	**Climate:** When we talk about restoring degraded land to health, it primarily means the creation of new topsoil from subsoil. The degradation that has occurred to soils worldwide is to a large degree due to the decline in the amount of carbon in soil organic matter in the soils which results in more carbon sequestration. **Food:** Adding soil organic matter in the soils also improves the biological balance in the soil leading to healthier crops, producing more food, lower synthetic nutrient consumption. **Water:** Adding soil organic matter and improving the biological balance leads to more efficient water infiltration and less water runoff and pollution.	**Saturation:** An obvious challenge is that you cannot sequester carbon indefinitely. There is a natural saturation point for every type of soil. Another challenge is the variability of carbon sequestration and stocking potential. Those areas with low carbon stock potential will not be able to deliver substantial sequestration. This makes it difficult for benchmarking impact measurement. Competition: A key benefit of restoring carbon in the soil is that it doesn't require a change of land use. It can therefore be deployed on a much greater scale than those options that involve competition for space. **Time:** Also it doesn't need to take ages to rebuild a couple of cm of topsoil.
	Reduced soil compaction as a response option is very much linked to soil management. Frequency and timing of field operations should be planned to avoid traffic on wet soil. Drainage assessment and improvements need to be carried out regularly.	**Water:** Compacted soils become less able to infiltrate and absorb rainfall, thus increasing runoff and erosion. **Food:** Affected land produces less yield, as plants have difficulties to grow in compacted soils.	**Local:** Soil compaction and other related issues such as erosion, desertification and soil salinization are location (climate) dependent. **Cost:** The key benefit is that it often requires little investment or effort to improve practices.

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http://destaatvandeboer.trouw.nl

Video content recommended

Life in the soil
https://www.youtube.com/watch?v=XapUm5n1zuM

Wat leeft er in de bodem, WUR
https://www.youtube.com/watch?v=W-4V7kQLrkQ

Indigo Terraton Project
https://www.youtube.com/watch?v=383DF803e5U

Alan Savory Holistic Management
https://www.youtube.com/watch?v=vpTHi7O66pI
https://www.youtube.com/channel/UC1QAfgh0XDTTZYYnyhwSnrA

Water and agriculture OECD
https://youtu.be/TbCwZyJEb8Y

Wageningen University Strip Farming
https://youtu.be/Y52oOb-k9t0

Gabe Brown - Keys to building a Health Soil
https://www.youtube.com/watch?v=9yPjoh9YJMk

Dan deSutter - Conservation Cropping Systems Initiative
https://www.youtube.com/watch?v=AIeo16QNli8

Podcast recommended

https://soundcloud.com/investinginregenerativeagriculture/interview-david-r-montgomery

Books recommended

- A Soil Owner s Manual, How to Restore and Maintain Soil Health. Jon Stika
- Dirt to Soil. Gabe Brown
- Climate Pragmatism, The rightful place of science. Ted Nordhaus a.o.
- Full Planet, empty plates. Lester Brown

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