Regenerative Agriculture in Europe

An overview paper on the state of knowledge and innovation in Europe

Mark Manshanden, Allard Jellema, Wijnand Sukkel, Wil Hennen, Roel Jongeneel, Carlos Brazao Vieira Alho, Angel de Miguel Garcia, Lotte de Vos and Floor Geerling-Eiff

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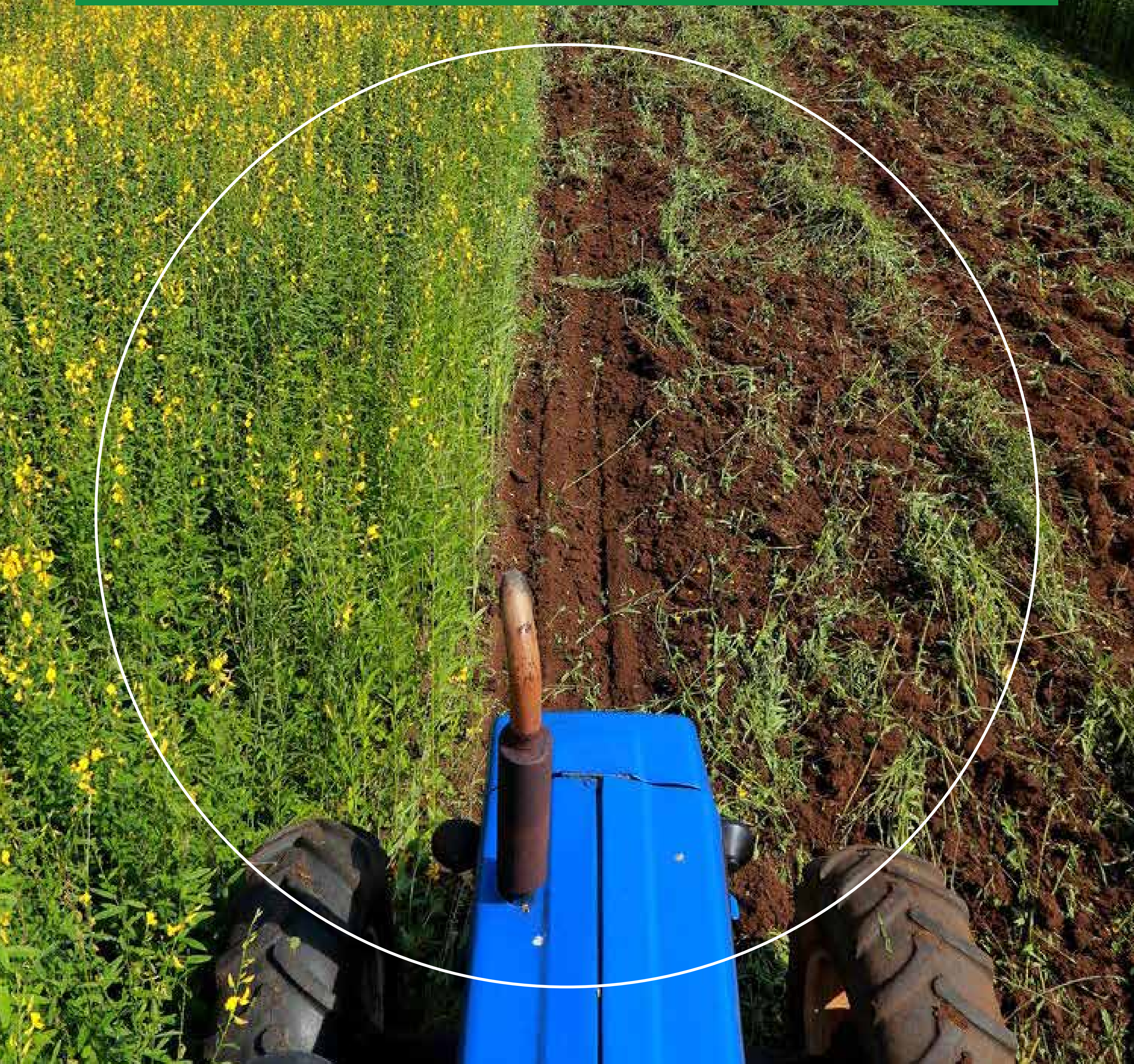

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Regenerative agriculture (RegenAg) is on the rise, aiming to make farming sustainable. But what is RegenAg? How does RegenAg compare to other agricultural concepts? How does RegenAg differ across Europe? Can RegenAg be economically viable? And can it be measured? This report identifies that it is difficult to assess the current state of a concept that does not have a clear definition. We compared RegenAg to agroecology, conservation agriculture and organic farming. The most striking differentiation seems to be that RegenAg is defined by its outcomes. This provides freedom to farmers, while considering the context specificity of RegenAg. Measuring actual outcomes is hard to accomplish and often has a weak relation with farm level measures. Hybrid measuring approaches based on farm measures in combination with farm data can be useful. This report concludes with recommendations to consider RegenAg as a set of objectives, rather than a set of measures and to start an EU-wide indicator system.

Key words: Regenerative agriculture, RegenAg, Definition, Markets, EU policy, Quantifying performance

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Preface

Our current food system is in a strong need to shift towards more sustainable food production and consumption. Many sustainability impacts relate to the farm level stage and surrounding landscapes. Herein, Regenerative Agriculture (RegenAg) is increasingly seen as an adequate approach to satisfy long-run sustainability.

Cargill requested an overview report on the current state of RegenAg in Europe with focus on key row crop production areas. The aim is to provide a good overview on the basics of RegenAg, the state of RegenAg in Europe and initial insights in the hotspots where most changes are required.

The research team wants to thank all parties who have contributed to the roundtable sessions for sharing their view on RegenAg. Furthermore, we thank our WUR colleagues for reviewing the results. Finally, we want to thank Albertine van Wolfswinkel, James Ede and Ashley McKeon from Cargill for the open and involved manner in which they supervised this project.

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Summary

S.1 Main research question

The aim of this report is to assess the current state of regenerative agriculture (RegenAg) in Europe. To investigate this broad topic, we defined several research questions. We started by defining RegenAg.

- *What is the definition of RegenAg?*
- How does RegenAg compare to other 'sustainable agricultural' concepts?
- How does RegenAg differ across Europe?
- How can RegenAg be economically viable?
- How are RegenAg impacts measured?

S.2 Outcome based sustainable agriculture

The research showed that it is difficult to assess the current state of a concept that does not have a clear definition. The definition chosen in this paper is that of Schreefel et al. (2020).

> 'RegenAg is an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production.'

Because there is no legal definition such as certified organic, everyone can claim their own version of RegenAg. And that has both advantages and drawbacks, the advantage being that it allows for easy adaptation. On the other side there is the drawback that the lack of a clear definition leaves the concept open for 'greenwashing'.

Although RegenAg does not have a clear definition, based on the available literature and expertise it is possible to compare RegenAg with other sustainable agricultural concepts. We compared RegenAg with agroecology, conservation agriculture and organic farming. The main difference between RegenAg and agroecology is the more political and activist approach agroecology takes on. Compared to conservation agriculture, RegenAg is sometimes considered an evolution. Organic farming is not defined by its beneficial ecological outcomes, in contrast to RegenAg.

Measuring actual impact and outcome is hard to accomplish and often has a weak relation with farm level measures. Quantifying the number (and possibly quality) of farm activities leading to a better sustainability performance on farm level has its limitations. The relation with the actual performance on farm level can be weak and context specific. Hybrid approaches based on farm measures in combination with input and/or output data are available and can be useful. A partly new and possible promising development is the use of Key Performance Indicators (KPIs) in the Netherlands.

RegenAg is context specific, making it difficult (if not impossible) to implement a one-size-fits-all approach. Large geographical datasets could help in better understanding the local context and identify local challenges and opportunities. Defining a general set of objectives which might have specific accents and ambitions according to the local farms context are preferred over prescribing a general set of farming measures.

RegenAg could sustain yield but with increased labour and more precise mechanisation, this leads to lower income. Therefore more margin would be required. RegenAg seems to align well with the new CAP (2023- 2027) and the Green Deal. And therefore, many practices used in RegenAg will most likely count towards the requirements set by the EU for receiving CAP payments. Funding can also be found in the private market; markets for ecosystem services are becoming increasingly popular, although most of them seem to be on project or trail basis, which raises the question of the permanence of these markets.

S.3 Methodology

Most of the paper is based on literature research using Google Scholar, mostly scientific but also some grey literature. RegenAg is a popular term and the definition seems for a large part to be forming in grey literature (and media). In addition to the literature, there have been two roundtable sessions with actors from the agricultural supply chain, NGOs, researchers and farmers.

The Global Detector has been applied, a data stacking model visualised on geographical maps.

The application of the Global Detector consists of three basic steps:

1. The basic data are retrieved. Subsequently, the data are transformed to a resolution that fits the Global Detector tool and are named 'Global-Detector indicators'. These indicators are related to the following themes:
    - climate;
    - land characteristics;
    - availability of water;
    - availability of labour;
    - investment climate;
    - land utilisation;
    - current agricultural production;
    - infrastructure;
    - market/demand;
    - economic activity and welfare.

   Country level data is retrieved from the World Bank, the Food and Agricultural Organization of the United Nations (FAO) and other organisations. If necessary, indicators that are not yet present in Global Detector can be added if available.
2. Based on both practical and theoretical knowledge, experts choose relevant Global Detector indicators and determine the importance of the indicators. Subsequently, from the set of indicators the experts together in an interactive workshop with the model builders to combine and weigh the indicators that are (most) relevant for assessing the potential of the product being assessed. For these indicators maps are created for a specified area.
3. In the final step, various Global Detector indicators are combined to a higher level, leading to maps showcasing information.

1 Introduction

1.1 Working towards a more sustainable food system

Our food system is one of the main drivers of climate change and biodiversity loss. Agriculture currently generates 19-29% of total global greenhouse gas (GHG) emissions (The World Bank, 2021). Furthermore, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) acknowledged agriculture as the leading driver of global land-use change and biodiversity loss (IPBES, 2019).

If no action is taken and our food systems continue with their current levels of application of pesticides, chemical fertilisers and use of fossil fuels, GHG emissions and biodiversity loss will continue to increase, undermining the ability of our planet to feed a growing world population and exceeding the planetary boundaries. Our key challenge is thus to produce enough safe, affordable and nutritious food for a growing and wealthier population without surpassing the planetary boundaries (Schreefel et al., 2020). This is also acknowledged in treaties and policies, such as the Paris Climate Agreement (United Nations, 2015), the EU Green Deal (EC, 2019), the EU Farm to Fork Strategy (EC, 2020) and the new EU Common Agricultural Policy (CAP) (EC, 2022a).

Moreover, it is increasingly recognised that the required change cannot be achieved in small steps. Transformative change, 'a fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values' (IPBES, 2019), is increasingly seen as a necessary societal response to climate change (IPCC, 2022) and biodiversity loss (IPBES, 2019).

Many of the ongoing challenges concerning climate and biodiversity have their origin in the large-scale application of conventional agriculture. Driven by technological developments, this form of agriculture underwent rapid changes in the 20th century. The size and capacity of mechanisation on farm level increased. To make these investments pay off, farms and fields increased and farms became more specialised (e.g. focusing on the production of certain products). In the same period synthetic (nitrogen) and mined (phosphorus and potassium) fertilisers, pesticides to control pests and diseases as well as herbicides to control weeds became available. After World War II, the so-called 'Green Revolution' took place, which can be seen as the industrial revolution in agriculture. With the aim to increase efficiency and product output, complex ecosystems were reduced into assembly lines for single crops (Durkin and McCue, 2021). As a result of the rise of mechanisation, synthetic fertilisers and pesticides, crop yields per hectare increased strongly while labour input drastically decreased.

During the 20th century conventional agriculture became a worldwide standard with the following characteristics:

- agriculture is able to produce an abundance of affordable food for the world population;
- only 12 plant species provide 75% of the human food supply and only three species (rice, maize, wheat) provide 50% of the human energy need;
- agriculture strongly depends on of fossil energy (nitrogen fertilisers & mechanisation), synthetic fertilisers and pesticides;
- large areas of monocultures are grown with very few natural elements such as trees, bushes, hedges, etc.;
- agriculture has relatively little crop diversity over time (narrow crop rotations);
- farm fields are brought back to a pioneer stage every year through intensive practices such as ploughing;
- agriculture is focused on mono function of the landscape for food production.

Although conventional agriculture has brought many advantages, it also has and continues to have a (in some cases) considerable (negative) impact on:

- soil quality (erosion, soil organic matter decline, compaction, salinisation, soil pathogens);
- climate;
- biodiversity;
- availability of resources (fossil energy, phosphorus);
- the environment due to emissions of pesticides and nutrients;
- water quality.

To make farming more sustainable, solutions are developed to change farming practices such as RegenAg. RegenAg is seen by some scholars and practitioners as a solution towards developing a more sustainable food system (Schreefel et al., 2020). RegenAg is an alternative means of producing food that potentially may have lower negative – or even net positive environmental impacts (Newton et al., 2020), such as improving water quality, biodiversity and even providing positive social impacts. RegenAg farm systems show potential for climate change adaption as well as mitigation, through reducing carbon losses from soils, as well as improving water, biodiversity and nutrient retention.

1.2 Assessment of the current state of RegenAg in Europe

Throughout Europe and the rest of the world, RegenAg is gaining ground. Despite this, RegenAg is still in its infancy. As such, this paper provides an overview of the basics of RegenAg in Europe. The following topics are addressed in this paper:

- *Definition of RegenAg*
  There is no singular definition of RegenAg. In this paper we shed light on the many definitions used to describe RegenAg. For this, we list definitions used in academia and research as well as definitions used by corporations, governments and non-governmental organisations (NGOs).
- *Comparison with different agricultural concepts*
  There are many different agricultural concepts applying different values, principles and practices. In this paper we compare RegenAg with three other agricultural concepts: agroforestry, conservation agriculture and (certified) organic agriculture.
- *Mapping RegenAg in Europe*
  We asses to what extent RegenAg practices are applied in Europe. Furthermore, as a successful implementation of RegenAg is context specific, we explore different environmental characteristics (soil type, weather, water availability conditions, etc.). For this we use geographical visualised data.
- *Valorisation of RegenAg both public and private*
  For the scaling of RegenAg to be successful not only the environmental context matters, but also governmental policies surrounding RegenAg and RegenAg profitability must be assured. As such, we explore different means to make RegenAg possible and dive into European Union (EU) policies and their relation towards RegenAg.
- *Measuring the impacts*
  To be able to evaluate the impact of RegenAg on farms, companies, regions and countries, RegenAg performance needs to be quantified. In this report we explore several quantification methods that can potentially be used to do this.

2 What is regenerative agriculture?

2.1 RegenAg is gaining ground

RegenAg has received considerable attention from farmers, corporations, consumers, research, as well as politicians, the media and non-profit sectors in recent years (Newton et al., 2020). The concept has gained such an amount of attention that some see RegenAg as a movement (O'Donoghue et al., 2022). As policymakers and food industries are looking for innovations that will secure sustainable food production, many countries and organisations are turning to RegenAg. In countries such as Brazil, India and the United States of America, corporations and other organisations are planning to have millions of acres turned over to regenerative methods (EIT food, 2020). Global corporations such as Danone (2019) and General Mills (2020) are investing heavily to develop and promote RegenAg models of agriculture. For example, General Mills committed itself in 2019 to advance RegenAg on 1 million acres (about 40,500 hectares) of farmland (General Mills, 2020). Furthermore, Cargill has the ambition to advance RegenAg practices across 10 million acres (about 405,000 hectares) of North American farmland by 2030 (Cargill, 2020).

Claims have been made by different parties on the potential of RegenAg to enhance a sustainable food system (Newton et al., 2020). For example, a report on climate change by the Intergovernmental Panel on Climate Change listed RegenAg as a farming practice that 'can be effective in building resilience of agro-ecosystems' (IPCC, 2019). Project Drawdown (2020) claims that RegenAg 'enhances and sustains the health of the soil by restoring its carbon content. This improves productivity and removes carbon dioxide from the atmosphere'. Kastner (2016) claims that RegenAg 'has the potential to reverse climate change by drawing billions of tons of carbon out of the atmosphere and locking it down to the soil'. Furthermore, the Rodale Institute (2014) advocates that through RegenAg 'we could sequester more than 100% of current annual CO_2 emissions'.

However, in the 40 years field trail done by the Rodale institute they conclude that reduced or no till does reduce soil disturbance, but does not affect soil organic matter. They state that to increase soil organic matter 'an adequate amount of high quality (lower carbon-to-nitrogen ratio) organic inputs that can stimulate microbial growth is necessary'. This requires diverse input that is usually more present in an organic system (Rodale Institute, 2021).

Although many bold claims have been put forward about RegenAg, a number of parties remain cautious about the potential impact of RegenAg (Newton et al., 2020). For example, the ability of certain RegenAg practices to remove carbon dioxide out of the air and store it as organic carbon in soil is questioned. For instance, in their report *Creating a Sustainable Food Future* (2019), the World Resource Institute emphasises that there is limited scientific understanding of what keeps carbon sequestered in soil, and, as a result, uncertainty about whether RegenAg practices actually sequester additional carbon. Some commentators point out that RegenAg may lead to a decline in productivity and consequently might harm global food security (Robertson et al., 2022). Furthermore, Newton et al. (2020) emphasise that 'no legal or regulatory definition of the term "regenerative agriculture" exists nor has a widely accepted definition emerged in common usage'. According to Giller et al. (2021), in writings on RegenAg, little attention is paid to alternative methods for pest and disease control, although this is one of the major challenges farmers are expected to face in order to reduce or phase out the use of chemical pesticides in agriculture.

2.2 RegenAg definition

The term regenerative agriculture is not new. It first gained prominence in the 1980s through research conducted by the US-based Rodale Institute. In the mid-2000s RegenAg had lost its momentum and faded into the background. It regained its prominence after 2015, when the occurrence of the term in books and news items grew rapidly (Giller et al., 2021).

While the concept of RegenAg is currently gaining prominence again, its definition remains contested (Merfield, 2019; Soloviev and Landua, 2016; Schreefel et al., 2020). As mentioned above, no legal or regulatory definition of RegenAg exists nor has a widely accepted definition emerged in common usage, in contrast to the now strictly regulated organic agriculture (EC, 2022b; IFOAM Organics International, 2019; FAO, 2022; Skal, 2022). As such, RegenAg is defined in many different ways (Newton et al., 2020). Since the term gained prominence in the 1980s, both broad and narrow definitions have been proposed. Most of these highlight or extend one or more of the elements identified by Rodale (1983).

Figure 2.1 shows a spectrum of definitions found in literature. The left side of the Figure features a strict definition with a focus on soil. When moving towards the right, climate, biodiversity and water are included. Moving further to the right, the optimisation of resource and nutrient recycling, air quality, habitats for species as well as animal welfare are included in RegenAg definitions. Moving even further, socio-economic aspects such as local sourcing and farmer income are also included in the definitions.

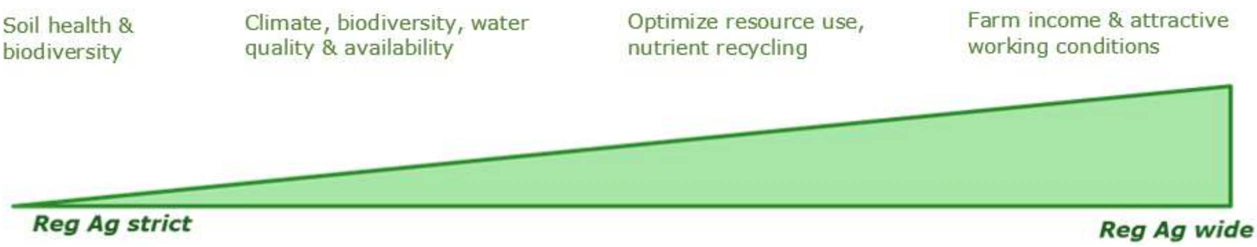


Figure 2.1 *Spectrum of RegenAg definitions*

In an attempt to define RegenAg, Schreefel et al. (2020) studied peer-reviewed articles to find definitions of RegenAg. Their initial search for articles resulted in 279 articles mentioning 'regenerative'. Based on a screening on their titles and abstracts, the articles were narrowed down to 43. After excluding 15 articles out of the 43 which did not contain a definition of RegenAg, 28 articles remained for further analysis. Based on those 28 articles they concluded that RegenAg definitions focus mainly on the environmental dimensions of sustainability, which cover themes such as the enhancement and improvement of soil health, optimisation of resource management, alleviation of climate change and improved water quality and availability, articulated through both activities (e.g. use of cover crops and no-tillage) and objectives (e.g. improves soil health and the recovery and preservation of biodiversity). These dimensions contribute to food security, regulating (e.g. climate regulation and soil erosion) and supporting (e.g. nutrient cycling and soil formation) ecosystem services. The authors also found a social-economic dimension of sustainability in the definitions used, such as improved human health and improved economic prosperity, which relate to aspects of cultural ecosystem services.

Based on the gathered insights, Schreefel et al. (2020) propose a provisional definition defining RegenAg as:

> 'an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production' (Schreefel et al., 2020).

Newton et al. (2020) reviewed 229 journal articles and 25 practitioner websites to characterise the term 'regenerative agriculture'. Their review demonstrated that there are many definitions and descriptions of RegenAg which can be categorised into roughly three categories. First, they encountered definitions and descriptions of RegenAg that were process-based. This means that they are focused on the inclusion or exclusion of one or more agricultural principles and/or practices (e.g. use of cover crops, the integration of livestock, and reducing or eliminating tillage). Second, the authors encountered definitions and descriptions that are outcome-based, meaning that they focus on agricultural outcomes (e.g. carbon sequestration, improved soil health, and the recovery and preservation of biodiversity). The third category combines process- and outcome-based definitions and descriptions.

Also Tittonell et al. (2022) show that RegenAg is approached in different manners. In their study they explore conceptual and practical similarities and differences between RegenAg and another agricultural concept: agroecology. Based on their examination they concluded that the RegenAg definitions can roughly be divided into three categories:

- *Philosophy RegenAg*
  RegenAg as adopted by individuals or networks, based on philosophical principles, close to permaculture or biodynamic approaches.
- *Development RegenAg*
  RegenAg as promoted by development organisations, with a strong focus on social and ecological principles, landscape approach, often top-down steered, and close to organic.
- *Corporate RegenAg*
  RegenAg as proclaimed by corporations, based on practical agronomic principles and corporate sustainability approaches, close to conservation agriculture.

By comparing these three categories of definitions with the 10 elements of agroecology, as identified by the FAO (2019), the similarities and difference between the three RegenAg categories identified by Tittonell et al. (2022) become apparent. This is illustrated in Table 2.1 (the table only shows a comparison between agroecology and different categories of RegenAg definitions, as such, when compared with other agricultural concepts, the content of the table might be different). One has to keep in mind that these categories all have different starting points. While philosophy RegenAg comes from idealistic networks, development RegenAg starts at a less optimised farming context and corporate RegenAg start in a highly optimised conventional farming system.

Table 2.1 *Comparison between agroecology and three categories of RegenAg definitions (based on Tittonell, 2022, own edit). Green = close match, orange = partial match, red = no match*

10 elements of agroecology as defined by the FAO (2019)	Philosophy RegenAg	Development RegenAg	Corporate RegenAg
Diversity	● (green)	● (orange)	● (red)
Efficiency	● (green)	● (green)	● (orange)
Recycling	● (green)	● (orange)	● (red)
Resilience	● (green)	● (green)	● (orange)
Synergy	● (green)	● (orange)	● (orange)
Human and social values	● (green)	● (green)	● (orange)
Co-creation knowledge sharing	● (orange)	● (orange)	● (orange)
Food and culture tradition	● (orange)	● (green)	● (red)
Circular and solidarity economy	● (orange)	● (orange)	● (red)
Responsible governance	● (orange)	● (orange)	● (red)

As mentioned above, in recent years many corporations, NGOs and other organisations have adopted RegenAg as a means to make agriculture more sustainable. Since no widely accepted definition of the term has emerged in common usage, most organisations use their own. In general, these definitions have a strong focus on soil but there are many differences as well. One thing is clear: most agricultural actors use their own constructed definition of RegenAg. The RegenAg definition and descriptions of a number of stakeholder are listed in Appendix 1.

2.3 Reflection on RegenAg definitions

As becomes clear from the previous section, a clear definition for the term 'regenerative agriculture' is absent. This creates multiple challenges. First, a clear and common definition is necessary to enable industries, governments, farmers and other actors to assess their performance. It also enables policy makers to establish supporting policies on RegenAg, researchers to have a scientific basis to gather knowledge on RegenAg and farmers to assess their performance on the basis of which they can adjust their activities (Schreefel et al., 2020). Without a clear definition it is potentially difficult to test claims about the benefits and outcomes of RegenAg (Goswami et al., 2017). Second, ambiguity and uncertainty about the meaning of a term such as RegenAg can lead to confusion, among, for example, consumers. Consequently, this might result in distrust and dissatisfaction towards RegenAg (Moon et al., 2017). Third, an elusive definition of RegenAg can potentially lead actors to exploit the term and falsely use it in their marketing, therefore weakening the term's value for actors more genuinely involved in efforts to become more sustainable. In other words, unclear definitions for RegenAg can make way for 'greenwashing' (Newton et al., 2020).

However, the lack of an unclear definition can also be perceived as an advantage. It can be argued that RegenAg more easily encourages conventional farmers to adopt sustainability measures as there are no pre-set restrictions and requirements. As a result, farmers can choose a definition that fits their needs and adopt RegenAg measures that fit their personal preferences and conditions. In contrast, for farmers to qualify as certified organic, farmers have to adhere to standardised regulations, restrictions and requirements. Furthermore, for conventional farmers to become organic, a transition period is required in which farmers convert from conventional agricultural practices to organic practices. This is very time and capital consuming, potentially preventing farmers from becoming certified organic. Due to a lack of an unclear definition, RegenAg, compared with certified organic farming, can be described as more accessible which in turn can facilitate a transition towards RegenAg, recognising that all farmers start from different places.

The use of synthetic fertilisers and pesticides is underexposed in most definitions. Only Rodale explicitly states that RegenAg should be organic. Whether a system could be called regenerative with the use of synthetic fertilisers and pesticides is still up for debate. However, in light of biodiversity and soil health (Baweja et al,. 2020), it is intuitive that their use should be at least minimised.

The definition used in the remainder of this paper is that of Schreefel et al. (2020):

> 'an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production'.

2.4 Five principles of soil health

Many actors in regenerative agriculture point to five principles of soil health that are the guiding principles for a regenerative system. The principles are based on natural systems and are put forward by Gabe Brown, a pioneering US RegenAg farmer. The principles have been described before as well in slightly different forms (Sherwood and Uphoff, 2000). But the principles come down to the same thing: working with the natural system.

The five core principles of soil health described by Gabe brown are:

1. ***Minimise soil disturbance***
   Disturbing the soil will negatively impact soil structure, soil fertility and soil health in general. Under disturbing the soil both chemical and physical disturbance are included. This means that tillage and chemical inputs should be minimised.
2. ***Maximise Crop diversity***
   Maximising diversity will increase the resilience of the system. It will support biodiversity and a rich and

healthy soil. This could be both in space and time, considering rotation and configuration (strip cropping, mixed cropping, etc).

3. ***Keep the soil covered***
   Bare soil is susceptible to erosion, evaporation and weed germination. Keeping the soil covered will protect the soil from weather and feed the soil life.
4. ***Maintain living root year-round***
   Maintaining living root will provide nutrients for soil life throughout the year.
5. ***Integrate livestock***
   Integrating livestock will improve the nutrient cycling of the soil. Natural systems all function in symbiosis with animals. For farming this should not be different.

From these five principles there are some that are already common practice in some regions in Europe. For instance, keeping the soil covered and minimising soil disturbance. However, minimising soil disturbance is mainly seen from a physical point of view. The chemical side is often neglected. Both have a big impact on farming practices. Where no or reduced tillage can be difficult in certain systems such as with finer seeds or ridges. Reducing chemical inputs will have a large impact on nutrient availability and crop protection. Maintaining living root seems to overlap in practice with keeping the ground covered.

Maximising crop diversity is a vague term as maximising is relative. However, increasing crop diversity is a difficult process as farms are specialised and/or need a certain level of income that is generally generated with a few cash crops.

Integrating livestock is a complex principle as currently many farms are specialised in either crops or livestock, although this differs across Europe. There are several regulations preventing animals from grazing in cropland, preventing implementation.

3 Comparison of agricultural concepts

3.1 Exploration of alternative agricultural concepts

Many farming approaches have been developed as a reaction to conventional agriculture as the dominant way of agriculture and its downsides (see Appendix 2 for more information about the development of conventional agriculture during the 20th century and its current state). All these approaches have different origins, inspiration sources, focuses and scopes. They can be described using different themes such as *values and intentions*, *objectives and indicators*, *system boundaries and scope*, *and tools and practices*. These themes are explored in more detail below.

3.1.1 Values and intentions

Farming concepts such as the ones mentioned in this section mostly have underlying values such as equality, honesty, food sovereignty, natural, respect, and social. In a few cases, the underlying values/principles are well described such as for organic agriculture (health, ecology, fairness, care). For RegenAg there are no unanimous and explicit underlying values defined, although Robert Rodale, the 'founding father' of RegenAg, described seven RegenAg principles: (1) pluralism, (2) protection, (3) purity, (4) permanence, (5) peace, (6) potential, and (7) progress. Included in these principles are ecological, environmental, social, economic, ethical and even emotional values. Unlike organic agriculture, where the underlying values are relatively well described, for most other agricultural concepts, including RegenAg, their underlying values have not (unanimously) been made explicit.

3.1.2 Objectives and indicators

Objectives of agricultural concepts are in many instances defined in a relatively abstract manner, at most they address specific impacts or states. Some examples of more abstract objectives are resilient, circular, multifunctional. More concrete objectives could be healthy soil, high value food production, clean environment (air, water and soil), rich biodiversity, non-depletion of ending resources, climate mitigation and adaptation, livestock health and wellbeing, fair income (farmer and employees) and short chains and proximity. The chosen objectives can vary in their ambition such as for example ranging from 'do no harm' or 'do not deplete' to 'restore' or 'regenerate'. RegenAg not only focuses on 'do not harm' but also clearly on improve, restore, and regenerate. Most explicit (narrow definition) objectives of RegenAg are 'restore soil health', 'carbon capture and storage of carbon' and 'recovery and preservation of biodiversity'.

The ambition level of a certain objective can be quantified by for example using indicators which translate general objectives (on for example biodiversity) to measurable variables on a specific level, such as regional or farm level (see also chapter *Quantifying performance of regenerative agriculture*). However, most agricultural concepts, including RegenAg, do not explicitly have a clear set of underlying indicators to make their objectives quantifiable. This is a clear drawback, as the ability to quantify the impact of a certain agricultural concept can ensure that set objectives are achieved and, where necessary, contribute to the gradual improvement of the concept. Without quantifying abilities, evaluation of an agricultural concept is hampered.

3.1.3 System boundaries and scope

Agricultural concepts can strongly differ in scope. For example, some concepts focus on a certain sector (plant production, animal husbandry, etc.). Other concepts only focus on the primary production (farm level) while others focus on an entire production chain. An example of a concept focusing on inputs, primary production and processing, is organic agriculture. Conservation agriculture focuses on plant production with an emphasis on arable production of row crops. Also the scope of the set objectives can differ considerably between agricultural concepts. For example, some concepts include socio-economic and ethical aspects;

other concepts focus merely on ecological issues related to agriculture. As shown above, there is no clear definition for RegenAg, resulting in many different interpretations. This also has implications for the set scope for RegenAg. For example, some wider definitions include social themes such as working conditions and farmer's income, while other definitions only focus on agricultural and ecological themes.

3.1.4 Tools and practices

For the implementation of agricultural methods 'tools' and 'practices' are applied. These can roughly be divided in three categories:

- *Farming methods*
  Conservations tillage, application of green manure, landscape elements, etc.
- *Inputs and instruments*
  Fertilisers (both organic and synthetic), seeds, plants, pesticides, water, etc.
- *Technologies*
  Farming machinery (tractor, plough, weeders, harvesters, etc.), high-tech (digital) tools (sensors, artificial intelligence, drones, decision support systems, etc.), and breeding technologies.

How and to what extent these tools and practices are used, differs per agricultural concept. In some instances, certain tools and practices are prohibited. For example, certified organic agriculture chooses to restrict synthetic inputs. In contrast, there is no predetermined pathway outlined for RegenAg. As such, RegenAg can be perceived as more flexible as it focuses on outcomes (Noble Research Institute, 2022) whereas certified organic agriculture is more static (see Box 5.1 for further explanation).

3.2 Comparison RegenAg and other agricultural concepts

There are many different agricultural concepts. Examples are organic and biodynamic agriculture, circular agriculture, climate-smart agriculture, ecological intensification and permaculture. Only organic and biodynamic agriculture have clearly defined principles, environmental, economic and social objectives, and over time have evolved into clear and widely accepted concepts.

In this section, three agricultural concepts (agroecology, conservation agriculture and organic agriculture) are compared with RegenAg. These concepts have been chosen as compared to other agricultural concepts, they are applied on a relatively large scale. Although compared to conventional agricultural, the application of these concepts is still rather limited, for example, organic agriculture only covers 1.5% of agricultural land globally (IFOAM, 2020a) and 9.1% in the EU (Eurostat, 2022).

3.2.1 Agroecology

Description
Agroecology is a holistic and integrated agricultural concept that utilises ecological and social principles in the design and management of farm systems. This concept seeks to optimise the interactions between plants, animals, humans and the environment (FAO, 2022b). The definition of agroecology has developed from a rather narrow definition, mainly based on ecological principles, to a definition which incorporates social-cultural aspects (Oberč and Schnell, 2020). Agroecology can be described as scientific disciplines, agricultural practice and a movement. According to Silici (2014), agroecology as a scientific discipline involves the holistic study of agroecosystems, agroecology as a practice aims to enhance the resilience and the ecological as well as socio-economic and cultural sustainability of farming systems, and agroecology as a movement strives to establish a new way of considering agriculture and its relationship with society (Silici, 2014).

Principles
According to the Institute for Environment and Development (IIED) the core principles of agroecology are (Silici, 2014):

1. Planning: utilising a holistic view, agroecology regards agroecosystems as one. The health of this system is valued over the production of single crops. A farming system should be harmonised with the productive potential and limits of the surrounding environment.

2. Resource use: nutrients must be recycled and energy systems in a farm system must be optimised. This, for example, involves the recycling of biomass to optimise organic matter decomposition and nutrient cycling; minimising losses of energy, water, nutrients and genetic resources and the use of agrochemical or other applications.
3. Field and landscape management: boosting biological interactions and synergies among the different components of agrobiodiversity and promoting key ecological processes; diversifying species and genetic resources in agro-ecosystems; enhancing functional biodiversity, managing and preventing, rather than controlling, pests and diseases.

Practices

According to the IIED, examples of agricultural practices include (see Silici, 2014, for a comprehensive list of practices applied in agroecology):

- conservation tillage;
- mixing crops in a single plot;
- crop-livestock integration;
- cover crops and mulching;
- efficient water harvesting;
- crop rotation and fallowing.

Similarities with RegenAg

- Agroecology utilises an integral systems approach similar to RegenAg, with a main emphasis on the functioning of the ecology of the farm and reducing the impact of agriculture (Van Doorn et al., 2016).
- The FAO (2018) has, through a multistakeholder analysis, identified ten elements of agroecology (diversity, co-creation and sharing knowledge, synergies, efficiency, recycling, resilience, human and social values, cultural and food transitions, responsible governance, and circular and solidarity economy). Many of these elements correspond with RegenAg, although between RegenAg definitions the number of elements that correspond with this list differ (Tittonell, et al., 2022) (see Chapter 2 for further explanation).

Differences with RegenAg

- Agroecology is often seen as having a 'political' or 'activist' component (this can be considered as a reason why agroecology is more closely associated with peasant movements), while RegenAg is a concept that increasingly – but not exclusively – is also adopted by commercial, often large-scale farmers (Tittonell et al., 2022) as well as by corporations.
- Agroecology has a stronger focus on social aspects such as human and social values (Tittonell et al., 2022), although some definitions of RegenAg also incorporate a social dimension (see Chapter 2).

3.2.2 Conservation agriculture

Description

Conservation agriculture (CA) is an agricultural concept that promotes minimum soil disturbance, maintenance of a permanent soil cover, and diversification of plant species (FAO, 2022c). Through the conservation of soil, the concept contributes to enhancing biodiversity both within an above the soil, allowing it to capture more carbon, enabling higher efficiency of water and nutrient use, and ultimately resulting in improved and sustained food production (Overč and Schnell, 2020). CA systems are today widely adopted on soils that vary from 90% sand (e.g. North Africa, southern Mediterranean zone, coastal zones in tropical Africa, Australia) to 80% clay (e.g. Brazil's Oxisols and Alfisols). In addition, CA systems are widely adaptable as their presences extend to the equatorial tropics (e.g. Kenya, Tanzania and Uganda) and to the Arctic Circle (e.g. Finland) (Kassam et al., 2018). CA is now practised worldwide on around 200 million hectares (Landers et al., 2021). The reason CA works on such a large scale is because it eliminates destructive tillage and the daily attacks of sun, wind, and rain (Dent and Boincean, 2021).

Principles

The FAO (2022c) defines CA on the basis of three integrated principles:

1. continuous no or minimal mechanical soil disturbances;
2. permanent organic soil cover;
3. diversification of crop species.

Practices
For the above-mentioned principles the following practices are applied respectively (Overč and Schnell, 2022):

1. reduced or no tillage through direct seed and/or fertiliser placement;
2. maintaining soil cover by growing cover crops, leaving crop residues on land post-harvest, and mulching;
3. managing crop rotation, incorporating a wider range of plant species.

Similarities with RegenAg
- Both CA and RegenAg have a strong focus on soil health and restoration.
- Many definitions of RegenAg (for example industry backed definitions) apply CA practices (such as practices to restore and maintain soil health).

Differences with RegenAg
- RegenAg is sometimes considered an evolution of CA, which applies a more holistic approach to sustainability, for example incorporating aspects such as socio-economic sustainability (Landers et al., 2021).

3.2.3 Organic farming

Description
The International Federation of Organic Agriculture Movements (IFOAM) defines organic agriculture as:

> ‘a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity, and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promotes fair relationships and a good quality of life for all involved’ (IFOAM, 2005).

Certified organic farming is regulated by bodies such as IFOAM and the EU, which specify which practices, methods of pest control, soil amendments and so forth are permissible if products are to achieve organic certification (Silici, 2014). For example, in 1991 the EU provided a legal framework for the designation of organic agriculture. Today the EU regulations on organic farming are designed to provide clear guidance for the production of organic goods across the EU. In the EU, food producers, processors or traders who wish to market their food as organic have to register with a control agency or body responsible to verify compliance with organic rules (Oberč and Schnell, 2020). Organic agriculture covers 1.5% of agricultural land globally (IFOAM, 2020a) and 9.1% in the EU (Eurostat, 2022).

Principles
IFOAM defines organic farming on the basis of four principles:
- *The principle of health*
  Organic farming should work to improve the health of soil, animals, plant, humans and the planet.
- *Principle of Ecology*
  Organic farming should work to sustain, enhance and imitate natural systems as closely as possible.
- *Principle of fairness*
  Organic farming should offer opportunities that allow for fairness and dignity of labour.
- *Principle of care*
  Organic farming should practice caution in a manner that protects the health and well-being of future generations and the environment.

Practices
When it comes to certified organic agriculture the EU has a set of rules for organic production which are based on a set of key principles laid out in the regulation that governs organic farming. These include, focusing on arable farming:
- prohibition of the use of GMOs;
- forbidding the use of ionising radiation;
- prohibit the use of artificial fertilisers, herbicides and pesticides.

Because of these regulations, organic farmers need to adopt specific agricultural practices to maintain soil fertility and plant health. These include, among others:

- crop rotation;
- cultivation of nitrogen fixing plants and other green manure crops;
- no use of mineral nitrogen fertilisers;
- utilisation of resistant varieties and breeds (to reduce the impact of weeds and pests) and use of preventative techniques (IPM) encouraging pest control.

Similarities with RegenAg

- Many practices applied in organic agriculture are also applied in RegenAg (e.g. crop rotation).

Differences with RegenAg

- Care for nature is not as explicit an objective in organic farming (organic farming is not defined by its beneficial ecological outcomes in contrast to RegenAg). Instead, the focus mainly lies on reducing the impact of agriculture, for example through the prohibition of pesticides.
- Certified organic farming is highly institutionalised, in the sense that this agricultural concept is regulated through rules, restrictions and requirements (e.g. prohibition on the use of synthetic fertilisers and pesticides) and thus focuses more on practices (Durkin and McCue, 2021). As RegenAg focuses on outcomes (e.g. improved soil health) less focus is put on how to reach the set outcome.

4 Mapping RegenAg in Europe

RegenAg is about outcome, and getting there can be different for every farmer. RegenAg and its effects are dependent on the region-specific context. Successful implementation and impact depend on many different aspects. These aspects differ within countries, and even more between countries. Climate, soil, slope, labour availability, land costs, farm size and current agricultural intensity are determining factors among other items.

For example, on slopes that are sensitive for erosion, reduced tillage and continuous soil cover can be extra relevant. For river basins and deltas and on sandy soils nitrate and pesticide leaching and runoff might be extra relevant which makes for example buffer zones and catch crops more appropriate.

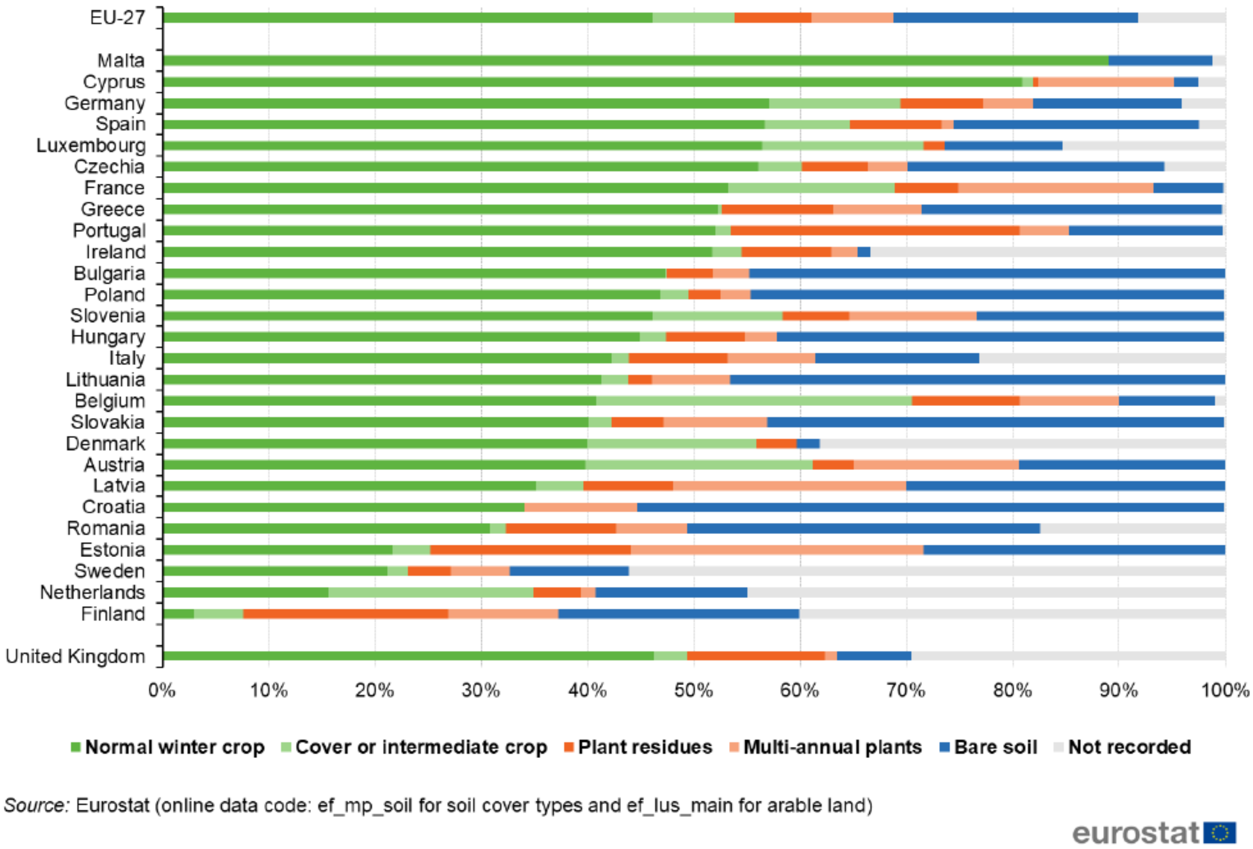
Because RegenAg is defined by its outcomes it is difficult to get a grip on the amount of regenerative farmers or farmland. In addition to this, the definitions of RegenAg, including the one used in this paper, are too wide to quantify. An alternative is to look at the implementation rate of RegenAg practices. There are several databases that gather data on a European level, although data on environmental and social indicators are scarce. The databases FADN, EUROSTAT and FAOSTAT are analysed and supplemented with literature.

FADN

The Farm Accounting Data Network (FADN) provides data on economic parameters, cropland and fertiliser. For cropland, cover crops are not included in the data and on fertiliser use only total fertiliser use is reported, at best on regional level. Currently, the FADN does not suit the needs to identify RegenAg practices. However, the FADN is going to be 'upgraded' to include sustainability parameters in the future. This new database, the Farm Sustainability Data Network (FSDN), will allow for the quantification of RegenAg practices, and potentially even on outcome basis.

EUROSTAT

EUROSTAT keeps statistics on a variety of European data, including agriculture. The general data do not include data covering RegenAg practices. However EUROSTAT does provide an overview of soil coverage (Figure 4.1) and tillage practices (Figure 4.2) acquired using the farm structure survey. This survey is done every three to four years as a sample and every 10 years as a census.



Source: Eurostat (online data code: ef_mp_soil for soil cover types and ef_lus_main for arable land)

Figure 4.1 *Share of soil cover in arable land during winter, EU-27 and UK, 2016*

Figure 4.1 shows almost 25% bare soil in winter in EU-27. As keeping the soil covered and keeping living root in the soil year round are RegenAg principles, reducing this by 25% is a RegenAg objective.

Source: Eurostat (online data code: ef_mp_prac)

Figure 4.2 *Share of tillage practices in tillable area, EU-27 and UK, 2016*

Minimising soil disturbance is another principle, this includes tillage. In Figure 4.3 it can be seen that there is still a small percentage of no-tillage. However, tillage is a very context-specific topic, meaning that conventional tillage is not excluded from RegenAg per se. Both figures shows differences across Europe. These differences can be the result of many different aspects, from climate and cropping system to availability of labour.

FAOSTAT
FAOSTAT provides a large worldwide dataset on a diverse set of indicators. Data on pesticide and fertiliser use can be found. However, for RegenAg the data need to be more specific, because general statements on average fertiliser use per hectare do not provide insight into management of regenerative farmland. Therefore, more context is needed.

Literature
In a recent study an attempt has been made to quantify the cover crops in Europe by combining satellite data and statistical survey data. The study resulted in good predictions and parcel level data (Fendrich et al,. 2023). But validation outside France has not been done. Figure 4.3 shows the results.

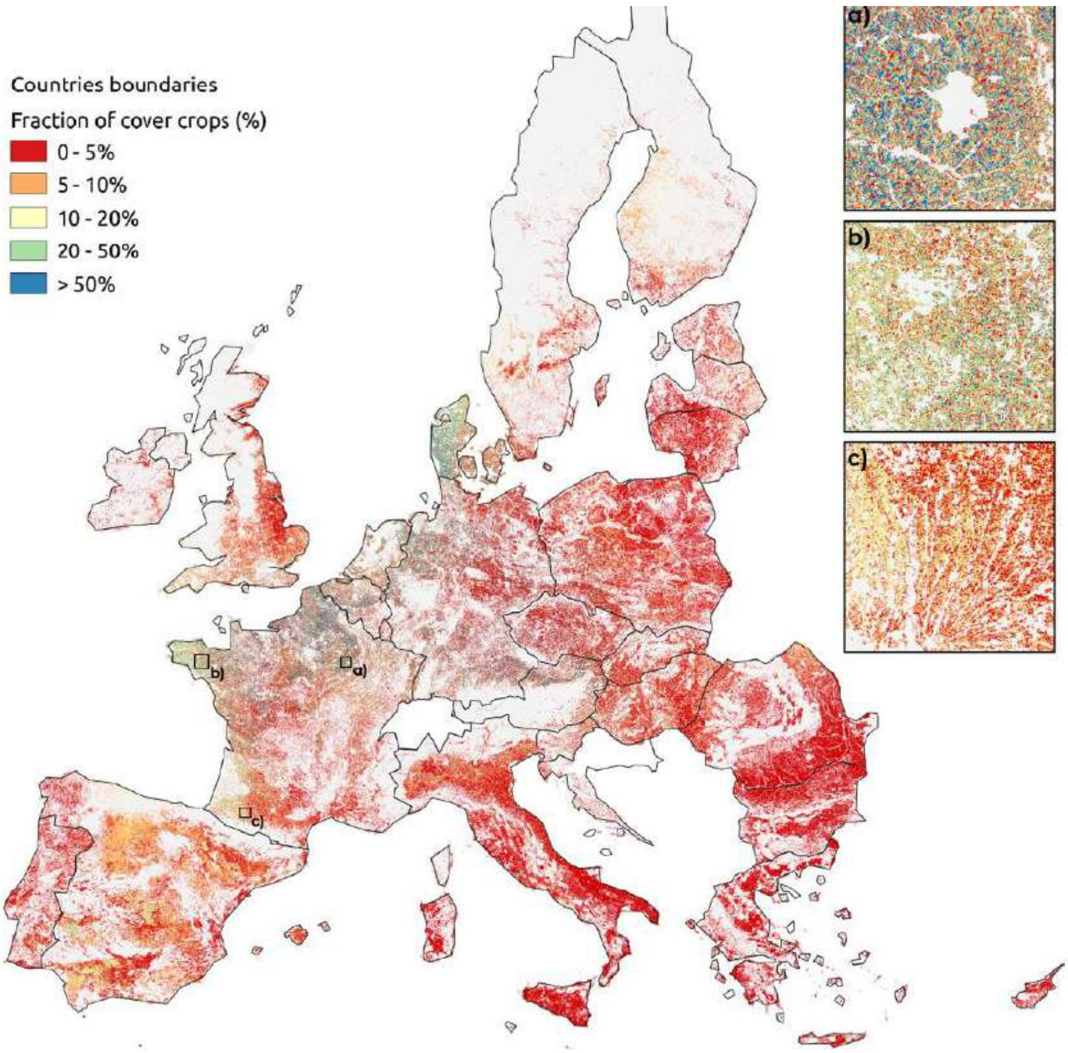


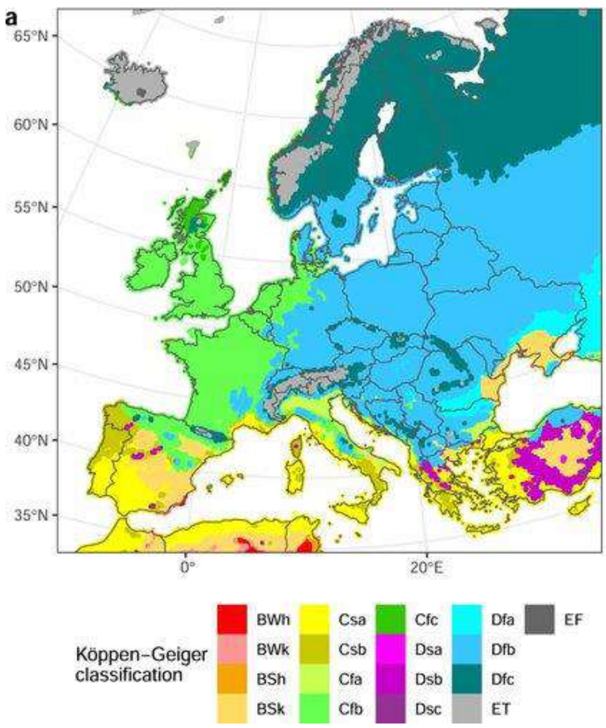
Figure 4.3 *Left: Model predictions of the occurrence of cover crops (CCs) in Europe. Right: Three zooms: predictions on the East, West and South of France (a, b and c, respectively)*

The datasets and literature study show some indication on the implementation of regenerative practices. However, information on the context is needed in order to find regions that have higher or lower implementation rates of regionally suitable regenerative practices. Data on the regional context are increasingly available and analysed in the next section.

4.1 Analysing of regional context

There are datasets available that can assist with the identification of the regional context in Europe. This can provide an overview of what the objective and targets for that region could be. These datasets can be visualised geographically.

The Koppen-Geiger climate zones in Europa (Figure 4.4) and the ESDAC European Soil atlas (Figure 4.5) give the relevant information on soil types and climates.



1st	*2nd*	*3rd*
A (Tropical)	f (Rainforest) m (Monsoon) w (Savanna, dry winter) s (Savanna, dry summer)	
B (Dry)	W (Arid Desert) S (Semi-Arid or steppe)	h (Hot) k (Cold)
C (Temperate)	w (Dry winter) f (No dry season) s (Dry summer)	a (Hot summer) b (Warm summer) c (Cold summer)
D (Continental)	w (Dry winter) f (No dry season) s (Dry summer)	a (Hot summer) b (Warm summer) c (Cold summer) d (Very cold winter)
E (Polar)		T (Tundra) F (Ice cap)

Figure 4.4 *Koppen-Geiger climate classification Europe with the classification elaboration on the right side*

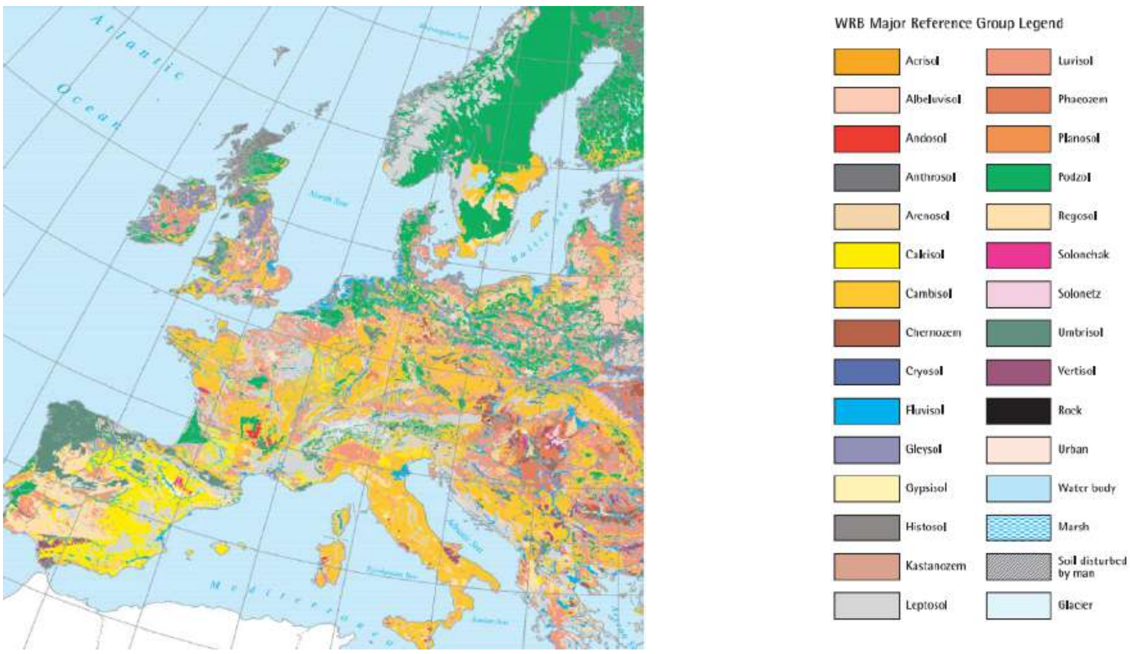


Figure 4.5 *ESDAC European Soil atlas*

The Global Detector (see next section) can combine a large range of data sources to identify specific sets of conditions for which certain risks play a role or for which, certain measures and techniques are more relevant.

4.2 RegenAg as potential solution for agricultural risk areas

To identify the regions where RegenAg could potentially be a solution to existing or future risks (e.g. water scarcity, erosion, biodiversity loss, soil compaction, global warming), Global Detector has been used. Global Detector, developed by Wageningen Economic Research, is a knowledge-based Geographic Information System that aims to detect potential for production, demand and market strategies worldwide (Hennen et al., 2017).

At any place in the world (i.e. a grid of 5′x5′, about 10x10 km), the Global Detector tool can show the value of a large number of indicators, such as climate, infrastructure, agricultural land use, and population density. By combining relevant indicators together with expert knowledge, a new indicator, for example showing 'climate-suitability for wheat production' can be established and converted into a combined map. This particular indicator can subsequently be used to identify favourable and less favourable locations for the production of wheat.[1]

The Global Detector can be applied for various needs or research questions, such as:

- detection of the potential for production (e.g. cut flowers, pig production);
- the expected demand for a product (e.g. consumption of cherry tomatoes, milk);
- options for local-for-local production (e.g. nursery (potted plants) for the local market).

The resulting maps are based on indicators that are available and selected by the experts. There might, however, be other factors that influence the production, demand or market strategies for which there are no indicators, such as cultural and demographic conditions (Hennen et al., 2017).

The application of Global Detector consists of three basic steps:

1. The basic data are retrieved. Subsequently, the data is transformed to a resolution that fits the Global Detector tool and are named 'Global-Detector indicators'. These indicators are related to the following themes:
   - climate (e.g. monthly temperature, precipitation);
   - land characteristics (e.g. type of soil, slope);
   - availability of water;
   - availability of labour;
   - investment climate;
   - land utilisation (e.g. % cropland, protected areas);
   - current agricultural production;
   - infrastructure (e.g. distance to markets, vicinity to harbours);
   - market/demand;
   - economic activity and welfare.

   Country-level data are retrieved from the World Bank, the Food and Agricultural Organization of the United Nations (FAO) and other organisations. If necessary, indicators that are not yet present in Global Detector can be added if available.
2. Based on both practical and theoretical knowledge, experts choose relevant Global Detector indicators and determine the importance of the indicators. Subsequently, the experts organise an interactive workshop together with the model builders to combine and weigh the indicators that are (most) relevant for assessing the potential of the product being assessed. For these indicators maps are created for a specified area.
3. In the final step, various Global Detector indicators are combined to a higher level, leading to maps showcasing information (e.g. best locations to produce cherry tomatoes).

[1] More information about Global Detector can be found in the following paper: *Global-Detector: GIS and Knowledge-based Tool for a Global Detection of the Potential for Production, Supply and Demand* (2017) by Hennen et al.

In this study, the Global Detector tool has been used to identify potential favourable areas for RegenAg. Figure 4.6 shows the outcomes of this assessment (France is used as an example, maps of other countries can be found in Appendix 2). The map in the centre of Figure 4.6 shows areas (shaded green) for RegenAg[2] when combining all indicators covered in maps A to F. Maps A to F include the following indicators:

- *Map A: Cropland density*
  Indicators: cropland density (dark green shows areas where cropland as a percentage of the total land is higher than 80%).
- *Map B: No exclusion (areas where agricultural activities are not excluded)*
  Indicators: populations density, forests, and protected areas.
- *Map C: Water availability*
  Indicators: irrigation options, access to rivers, lakes and groundwater, amount of rainfall, aridity, and climate change.
- *Map D: Soil characteristics*
  Indicators: erosion, bulk density, soil biodiversity, organic matter, and organic carbon.
- *Map E: Crops (current production areas)*
  Indicators: sunflower, wheat, rape and turnip, and maize.
- *Map F: Animal density*
  Indicators: aggregated livestock units.

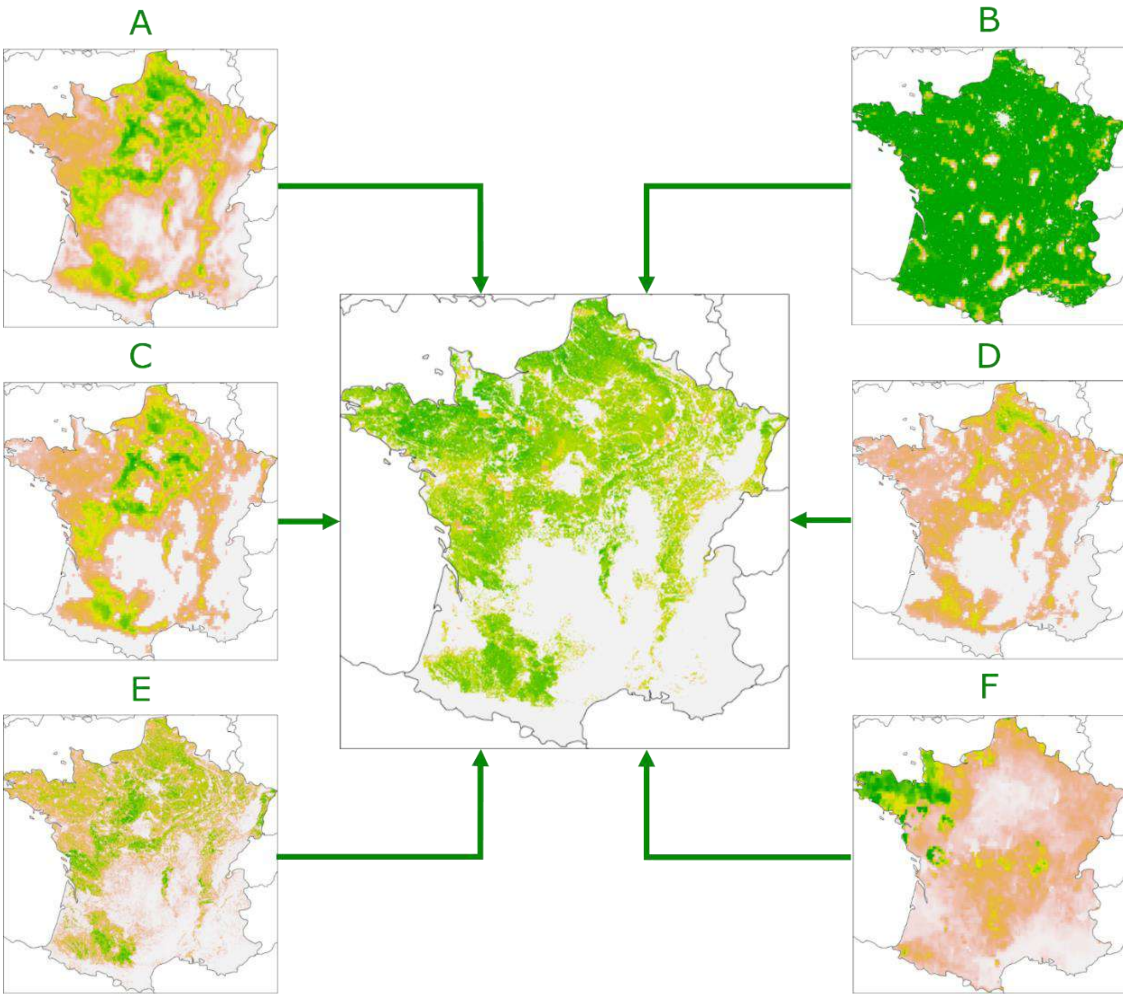


Figure 4.6 *Potential for regenerative farming in France (generated using the Global Detector Tool). The combined map in the middle shows favourable areas (shaded green) for regenerative agriculture when combining all indictors covered in maps A to F. See above for a description of maps A to F. The individual values for the indicators used to create map E (crops) are shown in Appendix 2. The combined maps of Bulgaria, Germany, Hungary, Poland, Romania and the United Kingdom are shown in Appendix 3.*

2 These maps are not meant to exclude other areas where RegenAg could also have high potential. RegenAg is context specific and could very well be suited for regions that are not indicated as high potential on the maps presented here.

4.3 Combining context and regenerative practices

When the regional context and the implementation rates are combined, the data become useful. For specific regenerative practices it becomes possible to identify regions where these practices are useful and to what extent they are already implemented. It should be noted that the data above are still at a very aggregated level, even though Global detector is relatively detailed. When assessing the regional applicability and implementation of regenerative practices (or if data are available, outcomes) there should be more focus on regions. The national (France) and even European (Climate and soil type) focus, chosen for this exercise because of data availability, is still too aggregated.

5 Regenerative agriculture and markets

5.1 Valorising Regenerative Agriculture

Depending on the farm context, but especially the first few years after implementing RegenAg measures, there is a likely reduction in income. Reducing inputs require more careful anticipation and precise application. Yields could be kept at the current level, although more labour or more precise mechanisation would be required. The learning curve for new farming systems is also a challenge.

Besides expected lower short-term income, there are, in general, lower costs for inputs, such as synthetic fertilisers and pesticides. However, it must also be said that (currently) biofertilisers and mechanical weeding are often more costly than conventional methods for crop protection and fertilisation. But as transition continues, returns to scale and innovation will likely reduce cost.

In general, without additional funding or higher product prices, the farm profit will decline in the short run. Therefore, it is important to generate additional revenue to successfully convert conventional farms into RegenAg farms.

5.1.1 Valorising ecosystem services

The current trend of thinking is to assign (economic) value to ecosystem services provided by the farmer. Ecosystem services are ‘services’ that natural systems provides, such as pollination, water retention and clean air. A farmer could for instance improve water retention with good soil management.

Ecosystem services that are often mentioned are: carbon sequestration, supporting biodiversity, water retention, landscape management and soil health. By far the most prominent ecosystem service that is used to generate revenue is carbon sequestration. There are both private and public markets being set up to pay farmers for carbon sequestration. Currently, methods are being validated. Biodiversity, soil health and landscape management appear to be more difficult to assign a value to.

Water is another relevant ecosystem service to consider, although assigning values remains challenging. This is in part because of the complexity of the water cycle. Impacts on the water cycle are highly dependent on local conditions such as soil type, rainfall intensity and slope. Some practices can also affect the water cycle in multiple ways. For example, cover crops can reduce runoff and erosion. They can however increase water demand, which can reduce water availability in arid regions. It depends highly on the local conditions which outcomes are desired. Therefore, it is important to consider at what scale the benefits are valued. It is not always straightforward that a reduction of water use at the farm scale will provide benefits at the watershed scale. An overuse of water may be reused downstream, or infiltrate and return to the natural system. Therefore, quantity and quality of local water resources should be considered as inherent properties in water valuation.

Other ways of increasing the total revenue without increasing production are to increase the margin on the product. This is a common practice for RegenAg farms. Observed strategies are the short supply chain (direct sales to consumers or to local shops), supply chain integration (processing on farm), price premium through (organic) labelling and expanding into other sectors (tourism, energy production, education) at the farm (which does not increase the crop margin but the farmer’s income).

5.1.2 Valorising based on product differentiation

A frequently heard statement in RegenAg is that there should be a focus on quality instead of quantity. The argument is that, while RegenAg farms often have a lower yield in weight, but some claim nutrient-wise the produce would be of higher quality. If this could be proven, this would allow for product differentiation based on the higher quality compared to conventional products.

There have been studies that show the decline in nutrients in crops (Marles, 2017) mostly due to a breeding focus on maximum yield, but little is known about the effect of farming systems such as RegenAg on nutrient content of products.

Recently, a study looked at the nutrient density on ten RegenAg farms compared to ten proximal conventional farms. The study concludes that RegenAg farms had 'higher levels of phytochemicals, vitamins, and minerals, although which ones and by how much varied among farm pairings' (Montgomery et al., 2022). This study is an indication that there might be a basis for the claim that RegenAg farming systems have the potential to produce more nutrient-rich crops. However, this is a study with a fairly small sample size. There is a need for more research to prove such a claim.

5.2 Regenerative agriculture and EU policy

As has been described in Chapter 2, there are different definitions of RegenAg, where the narrow or strict definitions focus on the soil, soil health, with close linkages with climate (carbon sequestration in the soil by means of improving its organic matter content) and biodiversity. Broader definitions cover other aspects such as provision and cycling of nutrients, local air quality, habitats for species, maintenance of genetic diversity, pollination, biological control, farmer income, animal welfare, attractive and meaningful work, attractive landscapes, and the rural-urban connection (Groot Koerkamp et al., 2020). The evaluation to what extent the Common Agricultural Policy (CAP) addresses or promotes RegenAg is dependent of the definition used for RegenAg, as well as on the set of measures included in the CAP.

For this section, the following approach has been chosen. The focus is on the core elements of RegenAg, being soil preservation and restoration, carbon capture and storage, and the preservation of biodiversity and reduction of biodiversity loss (EASAC, 2022). Note that this definition includes organic agriculture but also qualifies nature-inclusive, ecological agricultural (conventional) approaches as regenerative.

From a policy perspective, there are several relevant aspects to address. First, there is the reformed CAP, which will impact EU agriculture for the period 2023-2027. Another important policy document is the EU Green Deal Roadmap (EGDR) and the elaborations from this into specific strategies, notably the EU Farm to Fork Strategy (F2FS) and the Biodiversity Strategy (BDS). Whereas the CAP 23-27 is EU legislation, which directly affects farm policies in the Member States and their impacts on agricultural production, the EGDR and F2F and BD Strategies are more 'umbrella-documents' that provide direction of the future policy course of the EU, with a clear increased emphasis put on sustainability.

CAP 2023-2027
As regards the reformed CAP, this has been influenced by the 'umbrella-documents' as the EU Commission has recommended Member States (MS) to do so. The process of the CAP reform was already ongoing when the 'umbrella documents' came out. Moreover, these documents do not have a legislative status and there is not yet an established consensus among MSs about ambitions. As a result, it is currently not clear to what extent the GD, F2F and BD have affected (will affect?) the design of the new CAP. The new CAP is characterised by a new delivery model, and by National Strategic Plans (NSPs) at MS level, in which each MS motivates and indicates their policy choices for the coming period within the CAP-framework of the EC. At the moment of this writing, not all NSPs are yet agreed upon and more generally an assessment is still needed to see how the choices made in the NSPs of the MSs generate a joined effort at EU level, and how this compares to the EU's nine strategic policy objectives (SOs). As regards the chosen (narrow/core) definition of RegenAg, especially the SOs 4 to 6 are important: climate change action (SO4); environmental care (SO5); and preservation of landscapes and biodiversity (SO6).

The new CAP contains a number of policy measures, which in turn comprise specific instruments. See Table 5.1 for further details. As these strategic objectives indicate, the EU has important objectives which align with important aspects of RegenAg. It is also important to note that the EU has put high priority on the environmental, climate and sustainability objectives. Moreover, as is illustrated by the policy instruments, the EU and MSs have a broad toolkit at hand to implement concrete policies promoting a more sustainable and more regenerative agriculture. Note that included are various measures affecting soil preservation and restoration.

__Table 5.1__ Overview of EU policy measures that contribute to the promotion of various aspects of RegenAg and illustrative instruments

Policy measures in new CAP *)	**Examples of relevant policy instruments**	**Aspect of regenerative agriculture**		
		soil preservation and restoration	**carbon capture and storage**	**preservation of biodiversity and reduction of biodiversity loss**
Conditionality (Article 17, 18)	Good agricultural, environmental, and climate conditions (GAECS) see further detail below.	green	green	green
Eco-scheme (Article 28)	Voluntary measures aimed at eco-schemes, designed to pay farmers that are likely to deliver on their stated environmental objectives, including support for organic agriculture, carbon fixation, and nutrient surplus reduction.	green	green	green
Differentiation of basic income support (Article 18,2)	Includes targeted support enhancing carbon fixation.		green	
Coupled support for sustainability (Article 29-32)	Per hectare payment for specific sectors, including protein crops.	green		
Sectoral support (Article 39-63)	Including incentive policies for promoting sustainability.	green		
AECM (Article 65)	Agri-environmental and climate measures, including support for (switching to) organic agriculture and management measures for climate action.	green	green	green
Areas with natural handicaps (Article 66)	Includes compensatory measures for farmers to cope with natural handicaps, linking to maintain landscape diversity and rural landscape use by agriculture, while taking into account sustainability criteria.		green	
Areas with specific restrictions WFD, BHD (Article 67)	Incentive policies supporting measures to help farmers to satisfy with the Water framework and Bird and habitat Directives.	green		green
Investment support (Article 68)	Incentive measures to support farmer investments, including non-productive investments related to investments aimed at improving sustainability at farm level.		green	green

Source: Author Source: author, based on input from Baaijen et al. (2021).
Legend: green = estimated positive impact; white = estimated neutral impact.
*) The articles refer to the EU Directive.

Except from the (enhanced) conditionality and the coupled income payment, all other measures mentioned in Table 5.1 are voluntary as regards the farmers-side, who can freely decide to adopt such measures.
Table 5.1 comprises the most relevant measures and does not provide a complete overview of all CAP measures. For example, when using a broad definition of RegenAg also various other measures would qualify as relevant, such as the various direct (per hectare) payments. Table 5.2 provides an overview of the measures that have been identified to contribute to specific aspects of RegenAg. The eco-schemes include potentially several farm management practices, or combinations of these (Jongeneel and Gonzalez-Martinez, forthcoming).

As regards the enhanced conditionality, there are several GAEC criteria that have a potential positive impact on the facilitation of RegenAg (see Table 5.3). This specifically holds for GAECs 4, 6 and 7. In the new CAP the GAECs, which are obligatory side conditions (EU cross compliance), contain several measures. In the past these were linked to the green payment. Now they have no link to any direct compensation anymore but are basic requirements for receiving direct payments anyway. As such the greening criteria have become stricter in the new CAP relative to the past one, which is in general in favour of RegenAg practices.

Table 5.2 *Enhanced conditionality and their correlation with specific aspects of regenerative agriculture*

GAEC	**Description**	**Regenerative agriculture**		
		soil preservation and restoration	**carbon capture and storage**	**preservation of biodiversity and reduction of biodiversity loss**
GAEC 1	Bufferstrips along watercourses			
GAEC 2	Abstraction of water for irrigation			
GAEC 3	Protection of groundwater against pollution			
GAEC 4	Minimum soil cover			
GAEC 5	Minimum land management reflecting site specific conditions to limit erosion			
GAEC 6	Maintenance of soil organic matter			
GAEC 7	Retention of landscape features			

Source: Author.

Legend: green = estimated positive impact; white = estimated neutral impact.

EU Green Deal, Farm to Fork and Biodiversity Strategies

As regards the Green Deal, its most important objective is to target for a climate neutral EU, including a climate neutral agriculture by 2050. This ambitious topic goes together with a wider integrated policy approach, which alongside climate also affects nutrient surplus-reduction, fertiliser, pesticides and antimicrobial input reductions (see F2F) and the preservation of biodiversity (see the BD, with its targets for high diversity landscape features and organic agriculture). As the F2F and BD strategies are elaborations of the GD and define specific targets, they are relevant to mention. Since no specific measures have yet been defined for the F2F and BD strategies, a mapping of the quantified objectives and the three basic components of RegenAg are provided (see Table 5.3). Here, it has been assumed that reducing nutrient losses and fertiliser application will go together with less intensive ways of production, which will have a positive impact on the soil and/or on biodiversity.

Table 5.3 *Estimated relation between F2F and BD targeted objectives and regenerative agriculture aspects*

Policy strategy / theme	Objective and target value	Aspect of regenerative agriculture		
		soil preservation and restoration	**carbon capture and storage**	**preservation of biodiversity and reduction of biodiversity loss**
Farm2Fork Strategy				
Climate:	35% reduction of GHG emissions between 2015-2030			
Pesticides	50% reduction in use and risk of (hazardous) pesticides by 2030			
Fertilisers	50% reduction in nutrient losses, no deterioration of soil fertility;			
	20% reduction in the use of fertilisers by 2030			
Antimicrobials	50% reduction in sales by 2030			
Biodiversity Strategy				
Organic	25% of land under organic farm management in 2030			
Biodiversity	10% of agricultural area to be set aside for high diversity landscape features			
	additional habitat and species protection			

Source: Author.

Legend: green = estimated positive impact; white = estimated neutral impact.

Concluding remarks

Both the current CAP reform (CAP 2023-2027) as well as the EU Farm to Fork and Biodiversity strategies have several likely positive impacts on key aspects of RegenAg. In particular, measures aimed at improving soil conditions (e.g. promoting the implementation of practices beneficial to soil such as catch crops, cover crops and nitrogen-fixing crops), including several GAECS, act as a leverage to facilitate RegenAg. The synergies between climate action and biodiversity preservation measures further facilitate RegenAg and create positive interaction effects. A number of budgetary safeguarding provisions also contribute to this because they ensure a minimum budget expenditure on biodiversity and climate action measures (including a minimum spending on eco-schemes). Meaning that both the CAP, the Farm to Fork and Biodiversity strategies provide a stepping stone for farmers as the basic conditions are a step towards RegenAg and RegenAg practices fall within the eco-scheme payments.

A detailed review of the accepted NSPs at MS level would be needed to more in detail determine the impact of the new CAP on EU regenerative agricultural practices and heterogeneity with respect to Member State policies with regard to RegenAg.

5.3 Private market programmes

There is an increasing trend towards private markets for incentivising and valuing ecosystem services. RegenAg is considered an approach that contributes to ecosystem services and is often mentioned in these programmes. The advantage of private programmes is that it does not count on governmental funding, which by law (WTO) are maximised to prevent international market disturbances.

Increasingly, companies and other associations are voluntarily paying for these ecosystem services. The motivations can vary from marketing-based reasons, to corporate social responsibility, to intrinsic motivations. Whatever the motivations might be, there is a growing market for ecosystem services that could potentially pay for the transition towards RegenAg.

Private sector schemes aim to value ecosystem services, in a monetary or non-monetary fashion. In the list below there are several programmes aimed at incentivising RegenAg. The list is not exhaustive: many initiatives are regional projects and therefore not communicated on a European level. The programmes that are shown come from a short recent analysis available to the authors that is still forthcoming.

List of some private market programmes in the EU:
- Soil Regenerative Agriculture Group;
- Sustainable Farming Incentive;
- Soil Capital;
- RegenConnect;
- OleoZE;
- Naturellement Pop Corn;
- Sols de Bretagne;
- CarbonThink;
- France Carbon Agri Association;
- Stiftung Lebensraum;
- Haslachhof;
- BobenOp e.V.;
- FarmFacts GmbH;
- Go-klimaneutral.de;
- Myclimate;
- EM Chiemgau;
- Wisber EU;
- CO_2-land;
- Agricoin;
- Climate Recharge;
- Fokus-Zukunft;
- Climate farmers;
- CarboCert;
- Positerra;
- Klim.eco;
- Indigo;
- CarboAgrar;
- Działanie rolno-środowiskowo-klimatyczne.

Box 5.1 Naturellement Pop Corn

Naturellement Pop Corn is a project of a French popcorn chain that aims to have positive impact on the environment and climate by carbon sequestration. It pays farmers for implementing cover crops and thereby sequestering carbon. The project intends to create a measuring tool to calculate the amount of carbon stored.

Practice eligible for credits:
- Planting of cover crops.

Source: (www.cesbio.cnrs.fr/agricarboneo/naturellement-popcorn/)

Box 5.2 Soil Heroes

Soil Heroes is a company in the Netherlands that acts as a link between farmers and industry. They provide the method and infrastructure for measuring and trading 'ecosystem credits'. They currently valorise carbon sequestration, biodiversity efforts and water storage. Farmers pay a fee for the services; this is an initial fee to connect to the platform and a fee to pay for the measuring. Farmers get paid for the amount (tonnes) of CO_2 sequestered, the area (m_2) of biodiversity corridors and the additional amount (litres) of water stored.

Soil Heroes markets the credits to parties that want to buy these credits on a voluntary basis. That means that the credits have no legal basis in for instance the Emission Trade System (ETS). The credits are not third party certified; some organisations only work with third party certified credits to ensure accountability.

Practices eligible for credits
- Minimum/zero tillage (prerequisite);
- Planting of cover crops;
- Application of organic amendments;
- Biodiversity lanes/margins.

Source: (https://soilheroes.com)

Most of these initiatives are based on carbon farming. The initiatives differ but the basis are the agronomic practices that increase carbon sequestration and therefore are eligible for the 'creation' of carbon credits. When a farmer takes these practices or extends the application of these practises, it is commonly accepted that carbon credits are created and then sold to parties that want to compensate their carbon footprint. Common practices that are found to be eligible in these initiatives are cover crops, reduced tillage, diversifying the rotation, raising ground water tables and reducing synthetic inputs. Most of the initiatives are project-wise, initiated as a first trial with a small group of farmers and other partners. Some are standalone initiatives or organisations that work with farmers in valorising ecosystem services in the market. In the text boxes 1 and 2 below, examples of both are mentioned.

Green bonds, funds and interest rates

Green bonds are introduced in 2007 with the aim to increase investments in 'green' projects (Dupont et al., 2015). These bonds provide a lower interest rate for investors but allow for mission-based investment. Green bonds can be and are already a potential source of capital for the transition towards RegenAg. With green bonds there are several ways to finance regenerative agriculture as sustainable land use and conservation, which is seen as a 'green' project. Available options would be: land purchase for sustainable management, payment for ecosystem services and loans for sustainable machinery (e.g. interrow weeders). There are initiatives that use crowdfunding as a form of green bonds, with the funds, land is purchased and leased to farmers that are willing to manage the land in a regenerative fashion. Besides bonds there is the option of funds that pay for sustainable projects, such as the Unilever Climate and Nature fund. Banks also make use if this system with mortgages. Farmers who can show that they are farming in a sustainable fashion are eligible for an interest rate reduction.

Stacking premiums

Market premiums can be small. A recurring idea is that the premium for the same product is paid by several actors, stacking up to a premium that allows sustainable farming practices. Together these premiums add up to a more substantial sum. This works if several chain partners pay a premium for regenerative products or promote regenerative products in another way, e.g. reduced quality demands or reduced interest rates. This stacking also invites hybrid premiums, from both market and government parties. Examples would be: reduce waterboard taxes, regenerative premium by the chain and reduced interest rates from the bank.

6 Quantifying performance of regenerative agriculture

If it is the objective to improve the sustainability performance of agriculture by implementing production schemes such as regenerative agriculture, it is crucial to measure this performance. To be able to evaluate the RegenAg performance of agricultural management of farms, companies, regions and countries, this performance needs to be quantified. Quantification can be used for example as a form of accountability towards customers or society, to measure the effect of certain measures or to test and improve the farm performance. For quantification of performance, we need to know the objectives of a certain production method such as regenerative agriculture. From these objectives, indicators can be derived to be able to measure the performance on the different objectives. To express a quantified ambition level target, values and/or threshold values for these indicators need to be defined.

6.1 From objectives to indicators and target values

Farm sustainability objectives can be described in different ways. They can be very general or abstract such as in the terms regenerative, resilient, circular or social. These general objectives are often translated into more concrete topics or themes, such as the following:
- healthy soil (physical, biological, chemical);
- sufficient food production (quantity, quality, stability);
- clean environment (air, water, soil);
- rich biodiversity (Basic nature quality);
- no depletion of ending resources (e.g. fossil energy, phosphorus);
- climate change mitigation and adaptation;
- health and wellbeing of farm animals;
- fair income (farmer and employees).

Each objective can be divided into sub-objectives that are quantifiable. For example, clean environment can be subdivided in clean surface water, clean groundwater and clean soil. For clean ground and surface water the indicators phosphorus, nitrate and pesticide concentrations in the ground- or surface water could be used. The target values for these indicators could be related to the legal drinking water norms and the Nitrate Regulation. For clean soil indicators for soil concentrations of (persistent) pesticides, microplastics, copper, cadmium or antibiotics (from manure) could be used.

An example of quantifying all round farm sustainability performance, is given by the RISE model. In this model scores for different sustainability categories are dominantly based on farm management measures. The performance in a certain category is indicated in a red (problematic), yellow (critical) or green (positive) score (see Figure 6.1).

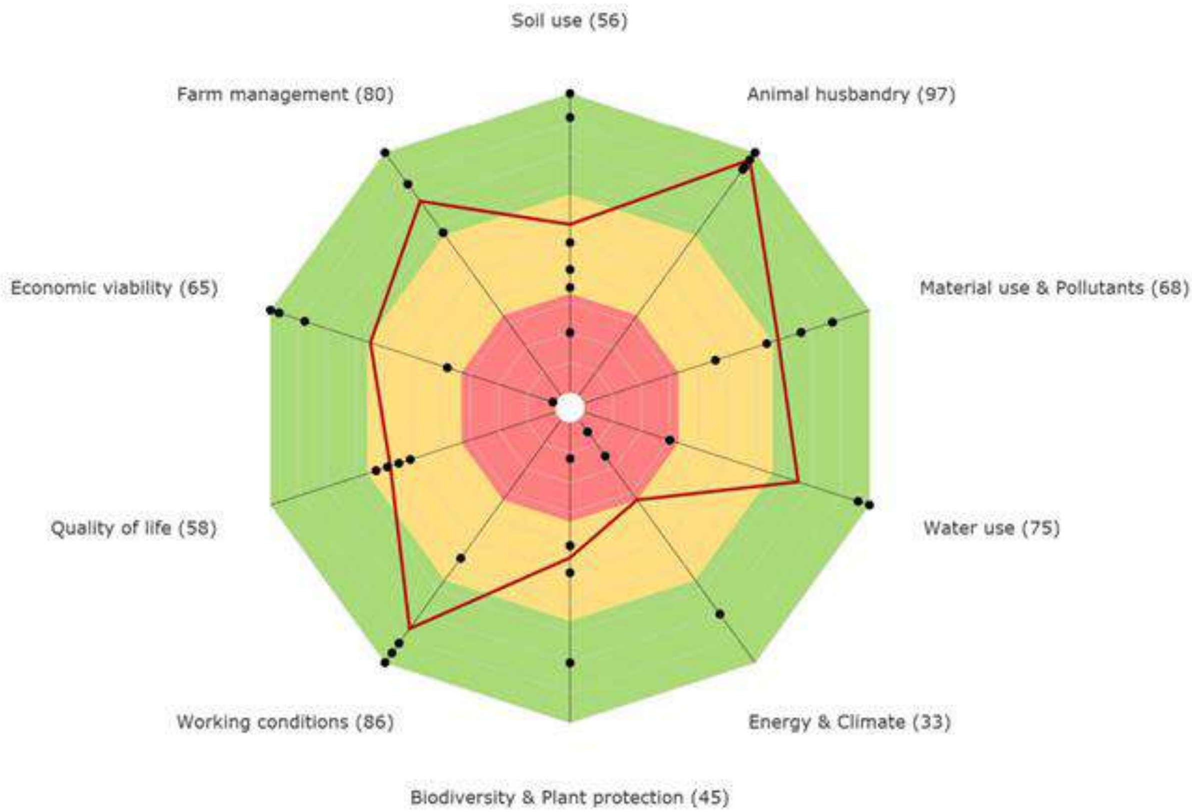


Figure 6.1 *Visualisation of Rise*
Source: https://www.bfh.ch/dam/jcr:0540a777-ab97-4555-b7ca-bb71904ae97c/what-is-rise.pdf.

6.2 Different indicator systems

There are several different approaches to construct sustainability indicators. The choice of an indicator system is dependent on the goal it is meant to be used for. It can be used for accountability, for rewarding ecosystem services, to measure the effect of certain policies or for the farmer's insight in his farms performance in order to improve that performance.

Indicators might be categorised with the DPSIR Framework (FAO, 2004). The Driver-Pressure-State-Impact-Response (DPSIR) Framework provides a structure to present the indicators needed to enable feedback to decision makers on environmental quality and the resulting impact of the policy/management choices made, or to be made in the future. The DPSIR framework assumes a chain of causal links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical and biological) and 'impacts' on ecosystems, human health and functions, eventually leading to 'responses' (prioritisation, target setting, indicators). Here the DPSIR model is used to gain insight in the differences, pros and cons of different approaches to quantify farm sustainability performance.

The DPSIR framework can be translated to the farm level. For example, one of the Drivers for climate change caused by agriculture could be ploughing. The pressure resulting from ploughing could be an increased breakdown of soil organic matter resulting in increased CO_2 emissions. The State would be a lower soil organic matter and a lower soil biodiversity. The Impacts caused by this Driver could be erosion, a decreased water retention of the soil and/or increased climate change (through increase of CO_2 emissions).

One Driver often leads to several impacts and a specific Impact mostly has several drivers.

In the example: ploughing influences biodiversity, erosion, water retention and climate change. However, climate change has many drivers from agriculture and from outside agriculture such as fossil fuel use, methane emissions of ruminants, deforestation, nitrogen fertiliser use, etc.

The objectives of a farming system mostly reflect State and or Impact categories, like the objectives in the narrow definition of regenerative agriculture: restore soil health, carbon capture and storage and reversal of biodiversity loss. Soil health and carbon capture and storage are State objectives which can be measured on field, farm scale or larger scales, reversal of biodiversity loss is an Impact category. In general, impacts such as biodiversity decline and climate change, often exceed the scale of the farm level and are influenced by several Drivers.

There are different demands/qualities an indicator system needs to consider, amongst others:
- Relation to the defined objectives/impacts;
- Fraud sensitivity;
- Repeatability;
- Variability;
- Reliability and robustness;
- Universally applicable or context specifically applicable;
- International standardised/harmonised;
- Stable available and maintained (longevity);
- Costs;
- The influence of farmers on the indicator;
- Ease of use.

The relevance of the above-described characteristics is dependent on the purpose for which the indicator system will be used. For example, for financial rewarding based on performance on certain indicators, fraud sensitivity would be very relevant.

Ideally, the impacts/objectives should be measured. However, the impacts are often not influenced only by agriculture (the farm). Moreover, measuring is mostly costly and sometimes very hard to measure directly. For example: biodiversity on a farm is influenced by the farm operations and the farm lay-out but also by the surrounding environment. For these reasons many indicator systems focus on farm measures and inputs (Drivers), for instance indicator systems such as AgBalance.[3]

The information needed to calculate the indicators in these systems is relatively easy to obtain and relatively easy to control or even to certify in certification systems such as GLOBAL-GAP or On the way to PlanetProof. The disadvantage of these approaches is that the relation with the actual impacts or objectives is often quite weak. Another disadvantage is that the resulting impact from farm measures can be very context (climate, location soil type, ...) specific. For example, non-inversion tillage (not ploughing) can be very advantageous on slopes to prevent erosion or under (semi) arid condition to sequester more carbon. However, in moderate climate zones these effects are less relevant and disadvantages such as herbicide use and weed pressure might outweigh the advantages. So, objectives such as carbon sequestration, erosion prevention and water storage are mostly universal, although the measures to reach these objectives might differ per farming context such as climate zone and soil type. An approach that has both a good relationship with desired impacts but also can be influenced by farming measures, might be preferred.

An approach that holds the middle between Driver-oriented indicators and impacts oriented indicators is the use of Key Performance Indicators (KPIs). KPIs are specific, measurable, and quantifiable performance metrics used to track progress over time towards a particular objective or goal. KPIs provide organisations, companies or teams with targets to aim for, milestones to gauge progress, and insights to help guide decision-making throughout an organisation. By monitoring KPIs, organisations can identify areas of strength and weakness, make data-driven decisions, and take actions to optimise performance. KPIs can also be applied on farm level to measure progress over time towards specific sustainability goals as for example defined in regenerative agriculture.

The Dutch branch organisation for arable farming (BO Akkerbouw), the Dutch province of Groningen, Rabobank and the World Wildlife Fund for Nature (WWF) have developed a Biodiversity Monitor for Arable farming (BMA). This monitor helps to measure the performance of arable farmers in terms of biodiversity on

[3] https://www.agricentre.basf.co.uk/en/Sustainability/AgBalance/ or RISE (https://www.bfh.ch/en/research/all-our-consulting-services/rise/)

the farm (Van Doorn et al., 2021). Performance is scored on the basis of an integral set of KPIs (see Table 6.1 for an overview of the KPIs used in the BMA). As a follow up, the Dutch ministry of Agriculture assigned Wageningen Research to develop a set of KPIs for circular agriculture. These indicators are momentarily being developed. The general objectives of circular agriculture resemble the general objectives often included in definitions of regenerative agriculture. Therefore, this indicator set might be interesting to be used to quantify performance and progress of regenerative agriculture.

KPIs translate general objectives (on for example biodiversity) to measurable variables on a specific level (e.g., regional or farm level). A KPI system thus explicitly focuses on objectives, which an individual farmers can influence by applying certain measures and farming practices. Van Doorn et al. (2021) argue that this is preferable to prescribing measures as it allows for farmers to be actively involved in achieving the set objectives and have the liberty to choose measures that fit the best in their farming context. Working with KPIs allows farmers to decide themselves, based on their interests, circumstances and capabilities, how they want to achieve set objectives.

In this way, KPIs form the link between the objectives and tasks on the one hand and the action perspective of arable farmers on the other hand.

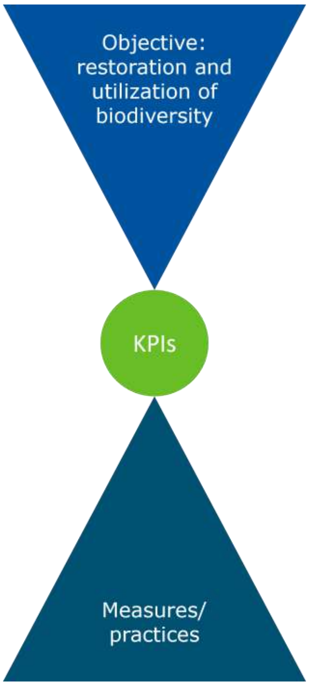


Figure 6.2 *KPIs: the relationship between objectives and tasks on the on hand and action perspective of arable farmers on the other hand (based on Van Doorn et al., 2021)*

Development of the Biodiversity Monitor for Arable Farming

As the Biodiversity Monitor for Arable Farming (BMA) is already developed and now being implemented in practice, it serves as an example how a KPI system can be developed. The indicators developed for the BMA forms the basis of the KPI set being developed for circular agriculture, the latter probably being suitable to quantify performance of regenerative agriculture.

Erisman et al. (2016) have developed a conceptual framework describing the interaction between biodiversity and dairy farming. This framework also forms the theoretical basis for the BMA. The framework shows the four pillars of biodiversity, how they are interrelated and what role they play in farming (Figure 6.3 shows the relations between the pillars):

1. *Functional agrobiodiversity*: Arable farming makes use of the functions offered by biodiversity. These are, for example, fertile soil, sufficient water and resistance to diseases and pests.
2. *Landscape diversity*: Landscape elements such as hedges, trees, verges and ditches bring variety to the landscape. This, in turn, can benefit biodiversity, including functional agrobiodiversity.
3. *Diversity of species*: The agricultural surroundings provide habitat for specific species of flora and fauna. Through targeted management, these species can be preserved and strengthened.
4. *Source areas and wildlife corridors*: Specific species and biological processes are not only present on farm level but cover a wider area. As such, by linking areas and applying regional management, biodiversity can be increased at a regional level.

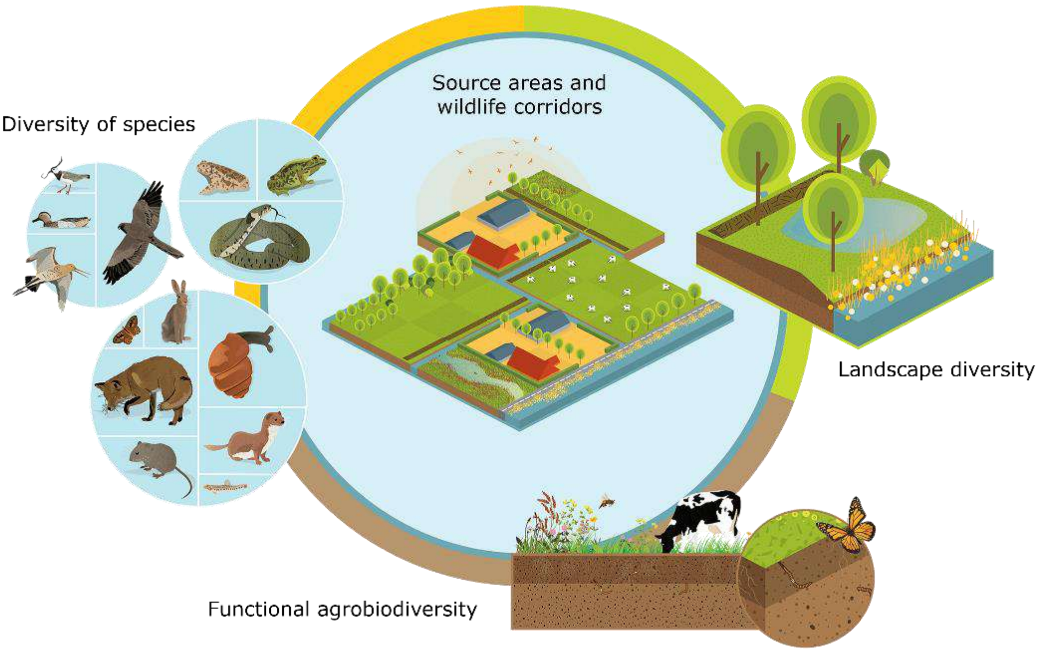


Figure 6.3 *The four elements of biodiversity (Erisman et al., 2016)*

During the development of the BMA and the KPIs, a number of principles were applied that assure the effectiveness of the BMA (Koopmans et al., 2017):

- The KPIs have a scientific foundation when it comes to the measurement of biodiversity.
- Data form the basis of the KPIs used in the BMA. As such, the following principles apply:
  - All arable farmers can supply the data required in the BMA.
  - It takes a minimal amount of effort to obtain the required data.
  - The data is in line with existing national and/or international measurement and control instruments.
  - The farmers' privacy is respected.
- The KPIs can be applied in an integral and cohesive manner, minimising the risks that the KPI's impact one and other negatively.
- A zero measurement of reference value is available for the KPIs.
- The BMA should be user-friendly. As such, the amount of KPIs used should be limited to absolute minimum, while still providing a good and integral representation of performance on biodiversity.

Table 6.1 *KPIs used in the BMA (BO Akkerbouw, 2021)*

KPI	
1.	KPI 1 Amount (%) of rest crops
2.	KPI 2 Organic matter balance
3.	KPI 3 Nitrogen surplus
4.	KPI 4 Environmental impact of plant protection products
5.	KPI 5 Amount (%) Land cover
6.	KPI 6 Carbon footprint
7.	KPI 7 Amount (%) nature and landscape management
8.	KPI 8 Crop diversity

For each individual KPI a *threshold value* and a *target value* has been established (Van Doorn et al., 2022):

- *Threshold value* indicates the value at which biodiversity the current level of biodiversity not declines any further. Values higher than the threshold value indicate a positive effect on biodiversity. This is the starting point for biodiversity recovery.
- *Target value* refers to the ecological optimum for biodiversity for arable farming. A target value is a dot on the horizon: the ideal, most optimal situation for biodiversity.

Threshold values and target values make it possible to benchmark KPI scores against biodiversity targets. Both the ecological optimum (target value) and the point at which biodiversity ceases to decline (threshold value) are difficult to determine, due to many variables and complex interactions between the KPIs. For this reason it has been decided to base the threshold values and target values on:

1. international and national set objectives in terms of biodiversity, environment and climate;
2. scientifically proven relationships between the KPIs and biodiversity (when international and national set objectives are absent);
3. improvement of biodiversity of the current situation (when scientifically proven relationships between the KPIs and biodiversity are absent).

6.3 Pros and Cons of different indicator systems

Indicator system based on measuring State or actual Impacts
Examples of these indicators could be: actual on farm biodiversity, nitrate level in surface and groundwater, actual erosion or actual climate change.

The advantage of this type of indicators is that it has a very close relation with the objectives of a certain farming approach. However for all indicator examples as mentioned above, it is obvious that the relation with actual farm measures is rather weak. This is very clear for climate change, which is a result of a whole range of causes and agriculture has a relevant but relatively small contribution in climate change. On-farm biodiversity is not only influenced by farm measures but also by the landscape surrounding the farm. Moreover, monitoring actual impacts is often quite costly and or difficult to quantify.

Measuring State or actual impacts is often not very suitable to quantify sustainability progress, as a result of farming approaches such as regenerative agriculture.

Indicator systems based on registration of applied farm and crop management measures
Examples of these indicators could be: application level of cover crops, application of minimum tillage, application of specific precision techniques, using certain decision support tools, etc.

The advantage of these type of indicators is that they are relatively easy to measure or register and are often relatively easy to control. Therefore, these type of indicator systems are quite often used for certification, legislation or rewarding sustainable management. A food chain company sourcing their products from a range of farms can, for example, measure the sustainability performance of their supply chain by indicating the percentage of their suppliers, which have implemented certain management measures.

The disadvantage of this approach is that it restricts the freedom of choice of the farmer, to reach certain sustainability goals with a mix of measures that fits the best for his or her situation. Moreover, the relation with certain farm measures with the intended sustainability goals can be weak or very site specific. Again, the example of non-inversion tillage (not ploughing). This can be very advantageous on slopes to prevent erosion or under (semi) arid condition to sequester more carbon. However, in moderate climate zones these effects are less relevant and disadvantages such as herbicide use and weed pressure might outweigh the advantages.

There are various tools available which make use of quantifying performance by registration of farm management measures. Some of them are a combination of registration of farm measures and with registration of farm inputs or outputs. Examples of these approaches are AgBalance.

Key Performance Indicators
Examples of these indicators could be the nitrogen balance or surplus, the organic matter balance, crop diversity, surface or ecological infrastructure.

The advantage of this approach is that there is a relatively good relation with the intended impact but still leaves the farmer enough choice to choose his toolbox of measures to influence the value of these KPIs in the direction of the desired levels. The costs for assessing the data needed to calculate these KPIs are in general, relatively low.

Disadvantages might be that it can give a relatively big extra administration load for the farmer. Although, part of the registration is already quite often obliged to fulfil certain certification demands such as GLOBAL-GAP. Also, the reliability or controllability of part of the registration data, might be an issue.

In the Netherlands, systems which are completely based on KPIs are momentarily under development or in a practice testing phase,. The above mentioned models such as RISE, Cool Farm Tool and AgBalance are a mixture of registered farm management measures, input-output data and indicators, which could fall under the definition of a KPI.

7 Conclusions and recommendations

This report looked into the current state of RegenAg in Europe, specifically for row crops. In this chapter the main conclusions are highlighted. Subsequently, based on these insights recommendations and actions to enhance RegenAg practices in European Agriculture are provided.

7.1 Conclusions

7.1.1 The lack of a unified RegenAg definition bring advantages and drawbacks

RegenAg is more present than ever. NGOs, multinationals, farmers, knowledge institutes and others are all defining RegenAg. Each definition is a bit different than the other. The common denominator seems to be soil, while the most disagreement is on the restrictiveness. Do pesticides and chemical fertiliser have a place in RegenAg? Because there is no legal definition such as certified organic agriculture, everyone can claim their own version of RegenAg. That has both advantages and drawbacks.

The advantage being that it allows for easy adaptation. For instance, there are no restricting rules such as a two year transition period in certified organic farming. Farmers can find measures that work for their context.

On the other side, there is the drawback that the lack of a clear definition leaves the concept open for 'greenwashing'.

7.1.2 RegenAg shares many similarities with other sustainable agricultural concepts

Although this paper shows that the concept of RegenAg does not have a clear definition based on the available literature and expertise, it is possible to compare RegenAg with other sustainable agricultural concepts. In this paper we compared RegenAg with agroecology, conservation agriculture and organic farming. These concepts were chosen as compared to other agricultural concepts, they are applied on a relatively large scale.

RegenAg shows many similarities with agroecology and conservation agriculture. For example, agroecology utilises, similar to RegenAg, an integral system approach with a main emphasis on the functioning of the ecology of the farm and reducing the impact of agriculture. Furthermore, all three concepts have a strong focus on soil health and restoration.

The main difference between RegenAg and agroecology is the more political and activist approach agroecology takes on. Furthermore, agroecology has a stronger focus on social aspects such as human and social values. Although some definitions of RegenAg do also incorporate a social dimension. However, compared to conservation agriculture, RegenAg is sometimes considered an evolution of this concept, applying a more holistic approach by for example incorporation aspects such as socio-economic sustainability.

Many practices used in RegenAg are also applied in organic farming (e.g. crop rotation). However, there are considerable differences between RegenAg and organic farming as well. Organic farming is not defined by its beneficial ecological outcomes in contrast to RegenAg. Instead, the focus in organic farming mainly lies on reducing the impact of agriculture, for example through the prohibition of pesticides. Furthermore, certified organic agriculture is highly institutionalised, in the sense that this agricultural concept is regulated through rules, restrictions and requirements (e.g. prohibition of the use of synthetic fertilisers and pesticides). As RegenAg focusses on outcomes (e.g. improved soil health), less focus is put on how to reach the set outcome.

7.1.3 Successful implementation of RegenAg requires a context specific approach

RegenAg will be different according to the local context, depending on various factors such as amongst others: climate, soil, farm type and even farmers. This makes it difficult to implement as a one-size-fits-all approach will not work. Large geographical datasets could help in better understanding the local context and identify local challenges and opportunities. But farmers would need the freedom for their own custom-made RegenAg approach. Defining a general set of objectives, which might have specific accents and ambitions according to the local context, would probably be more effective in developing all-round sustainability rather than prescribing a general set of farming measures. A toolbox of technical, agronomic and ecological measures, which could improve the sustainability performance will be very helpful. However, the choice of specific measures from this toolbox should be context specific.

7.1.4 RegenAg practices are gaining ground in agricultural policies

On the economic side, RegenAg seems to align well with the new CAP (2023-2027) and the Green Deal. This indicates that RegenAg is in line with the direction the EU wants its agriculture to develop. Therefore, many practices used in RegenAg will most likely count towards the requirements set by the EU for receiving CAP payments. There are also economic opportunities on the private market. Markets for ecosystem services are becoming increasingly popular. However, most of them seem to be on project or trial basis. This raises the question of the permanence of these markets.

A key point for valorisation but also evaluation of the concept, is measuring impact. This is mostly done using indicators with a clear link to the objectives. The indicators should have a target value in order to have a dot on the horizon, a direction where to focus the effort on. A good and recent example is the Biodiversity Monitor Arable farming (BMA). This provides a set of eight indicators that show the progress on biodiversity objectives.

7.1.5 Quantifying RegenAg performance is essential for RegenAg success

If you can’t measure it, you can’t improve it. If one wants to improve the sustainability performance of farming with regenerative agriculture, it is essential to measure the farms sustainability performance. Different approaches for quantifying performance are possible. Measuring actual impact is mostly very hard to accomplish and often has a weak relation with farm level measures. Quantifying the number (and possibly the quality) of farm activities leading to a better sustainability performance on farm level, is often used but has its limitations. The relation with the actual performance on farm level can be weak and can be context specific. Hybrid approaches based on farm measures in combination with input and/or output data are available and can be useful. A partly new and possible promising development is the use of KPIs in the Netherlands. However, these indicator sets are just being implemented and have not proven their usefulness in practice (yet).

7.2 Recommendations

Agriculture can play a pivotal role in making the world more sustainable. To do so, we need to reshape our current agricultural system into a system that puts a halt to unsustainable agricultural practices and instead aims to put more into the environment and society than it takes out. In short: *we need to regenerate*.

7.2.1 Use a broad definition of RegenAg for a sustainable approach with high potential

The core focus of RegenAg lies on healthy soil, climate and biodiversity. However, RegenAg has the potential to contribute to a range of other themes such as a clean environment, non-depletion of ending resources, food security as well as soco-economical themes. As such, these can make a significant contribution to the United Nations Sustainable Development Goals (SDGs). Defining the objectives broader than only on the basic RegenAg themes, provides a good overall sustainability approach.

7.2.2 Define the current status of sustainable agriculture and set goals accordingly

The overarching notion in the agricultural systems analysed in this paper, whether it is conservation agriculture, organic agriculture or regenerative agriculture, is the goal to increase sustainability. When one sets aside the challenge of the definition and focuses on the goal to increase agricultural sustainability, the question changes into: how to get to a more sustainable agriculture. The first step is then to define the current level of sustainability and set goals for the future. These can be different depending on the context. One has to keep in mind that there are different starting points. While philosophy RegenAg comes from idealistic networks, development RegenAg starts at a less optimised farming context and corporate RegenAg starts in a highly optimised conventional farming system.

7.2.3 Consider RegenAg as a set of objectives rather than a fixed toolbox

Regenerative agriculture is based on setting goals and measuring outcomes, leaving a lot of freedom to farmers to reach goals using their own skills and preferences. This means considering RegenAg as a set of objectives rather than a fixed toolbox of farming methods and techniques. This will enable farmers to find their own farm specific best practices. It will not exclude other sustainable concepts and it will enable farmers to fit their best practices in line with financial incentives. An intermediate option would be a more hybrid approach where the causality between regenerative practices and the outcomes are proven and therefore the practices can be measured as well.

Some practices applied today are still under scrutiny. The results of these practices are not yet measured and identified. This creates unfounded expectations of practices that might not work after all. The link between the practice and the outcome should be evident and well-founded before promoting it at a large scale. Be aware that some RegenAg practices require major system changes and others might be small steps, depending on the farm context. Where in some regions increasing diversity by expanding the rotation will come at great cost, including cover crops might be another option to increase diversity and is economically more feasible.

7.2.4 Put emphasis on the position of chemical fertilisers and crop protection in the RegenAg transition

Chemicals are mentioned, but typically more in the side-line of the five key RegenAg principles, while these have a major effect on soil and water resources in agri landscapes. And, the substitution of these chemicals is also seen as a major challenge.

7.2.5 Start defining indicators and targets

To make a start with a system that enables regenerative agriculture, measuring outcomes and quantifying the performance resulting from RegenAg practices, is key. Therefore, a set of indicators and desired levels (targets) of these indicators needs to be defined. After targets are defined it is possible to identify the baseline, keeping in mind that this baseline is different for each farmer. Ideally, the indicators strike the balance between what is feasible to measure, sufficient insight on (positive) impact contribution and the freedom for farmers to choose their (context-specific) optimal farm practices. Furthermore, the indicators will be harmonised throughout European agri value chains, and integrated in measurement and certification schemes to enable transparency on RegenAg performance.

7.2.6 Organise the data infrastructure to facilitate monitoring

Develop and organise a data infrastructure which facilitates the monitoring, reporting and evaluation of RegenAg uptake and its impact. This should be connected with leading data sources (FADN/FSDN, FAOstat, EUROSTAT) to provide a common base of harmonised information for the different RegenAg indicators.

For setting the targets, the regional context needs to be considered. A first attempt can be achieved through large datasets and the global detector. This will show indicators, which combined, can provide a first step in the context. There are systems in place that organise data and facilitate monitoring on outcomes in other supply chains, which could provide inspiration.

7.2.7 Work towards revenue models

Develop and summarise revenue models for farmers and key stakeholders. Currently, there are few data on the financial costs and benefits of RegenAg. Providing answers on finances will support farmers in their decision making concerning RegenAg. This includes both market and (local) government revenue streams (i.e. stacking of income sources) but also changes in yields. Especially concerning public funding, farmers require support for fully utilising the (complex) available government instruments for RegenAg. For funding the transition, it is important to promote objectives in line with the CAP. This will synergise the payments from the CAP with bonusses the market could pay. This payment by the market could be ecosystem services such as for carbon sequestration or could be indirect rewards, such as lower interest rates. Another option could be to reward the potential higher food quality. However, this is still to be proven. Ideally, in the long run, each farmer and agri value chain converges to a competitive revenue model independent of subsidies and other government support.

7.2.8 Facilitate knowledge sharing

Regenerative agriculture is working with nature instead of working against it. This requires new knowledge and training. Providing training to farmers will help the implementation of RegenAg. Besides the technical knowledge it is important to share knowledge of RegenAg at different levels, such as improvement options, revenue models and supporting policies. For instance, through leveraging existing European networks of agri innovation hubs and demo-farms.

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Appendix 1 Overview of RegenAg definitions

To get a good overview of different definitions used, the list below includes different types of corporations that are active in agriculture in different ways. For example, companies supplying farm input (e.g. Agrifirm, Syngenta Group) have been included, as well as the food and beverage companies (e.g. Nestlé, Unilever). In addition, international organisations, non-governmental and non-profit organisations are included in the list below to provide an overview of non-corporate definitions. As this study focuses on the current state of RegenAg in Europe, and as such goes beyond the country level, only international operating corporations and organisations are included in the list. The information below is distilled from websites, articles and other available sources.

International organisations, non-governmental and non-profit organisations

- *Ellen Macarthur Foundation*
  The Ellen Macarthur Foundation, a charity committed to creating a circular economy, describes RegenAg as a broad set of food productions methods with two complementary outcomes: 'the production of high quality food and the improvement of the surrounding natural ecosystem'. According to the foundation, the concept of RegenAg acknowledges that farms are part of a larger ecosystem, and that agriculture must not just extract from this system, but also contribute to it (Ellen Macarthur Foundation, 2022).
- *European Institute of Innovation and Technology (EIT)*
  EIT, an independent EU body working to strengthen the EU's ability to innovate, describes RegenAg as a system of farming principles and practices that increase biodiversity, enriches soils, improves watersheds, and enhances ecosystem services. EIT Food emphasises that RegenAg 'works according to a whole ecosystem approach, meaning aiming to work with nature instead of against it'. EIP sees soil health as one of the most important aspects of RegenAg (EIT Food, 2022).
- *Rodale Institute*
  The US-based Rodale institute is an organic farming focused research, training, and education centre. Rodale coined the term 'regenerative organic farming', stating that soil health is the number one priority. Besides soil, regenerative organic farming also encompasses animal welfare and socio economic aspects. The most remarkable in the definition from the Rodale institute, is that they consider RegenAg beyond organic, meaning that 1) RegenAg has an overall higher level of sustainability than organic agriculture, and 2) a non-organic farmer cannot be considered regenerative. The Rodale institute refers to the Regenerative organic certified scheme for the more elaborate description of regenerative agriculture (Rodale Institute, 2022).
- *World Wildlife Fund (WWF)*
  WWF, an international NGO working in the field of wilderness preservation, has no specific definition of RegenAg. Their focus is more general, on sustainable production, where nature positive production is considered keeping soils healthy, water flowing, storing carbon and providing homes for a range of biodiversity. They do state that compared to other strategies that intent to reduce GHG emissions, regenerative agriculture's additional strength is the focus on soil.

Corporations

- *Agrifirm*
  Agrifirm, a Dutch agricultural cooperative enterprise supplying farm inputs (seeds, artificial fertilisers, plant protection products, animal feed, etc.), initiated RegenAg in 2022 together with a small group of farmers. Soil (quality) and farmer income are at the centre of this programme. Practices such as reduced tillage, cover crops and permanent soil coverage are applied in the programme. Other practices that are considered for the near future are increased collaboration between arable farmers and livestock farmers. The income part is focused on carbon credits (Agrifirm, 2022).
- *Danone*
  RegenAg is central in Danone's strategy, a French food company specialised in dairy and beverages, with the ambition to achieve net zero emissions by 2050 (Danone, 2021). Danone sees RegenAg as resting on three pillars: protecting soil, empowering a new generation of farmers, and promoting animal welfare (Danone, 2020).

- *General Mills*
  For General Mills, a US multinational manufacturer of branded processed consumer food, RegenAg is part of their sustainability approach. They clearly define RegenAg as a holistic approach that delivers positive environmental, social and economic outcomes. They have set goals and monitor progress. They adhere to six core principles of RegenAg; minimising disturbance, maximising diversity, keeping the soil covered, maintaining living roots, integrating livestock and considering the farm context (General Mills, 2022).
- *Nestlé*
  For Nestlé, a Swiss food and beverage company, RegenAg is part of their sustainability programme. Nestlé defines RegenAg as 'an approach to farming that aims to conserve and restore farmland and its ecosystem. It delivers benefits to farmers, environment and society'. The focus is on soil, water, biodiversity and integrating livestock. Nestlé promotes the introduction of RegenAg practices as a way of continuous improvement of current farming conditions (Nestlé, 2021). Among other topics, Nestlé has a large interest in assessing the impact of RegenAg in the water cycle, both from the farm and the watershed perspective.
- *PepsiCo*
  For PepsiCo, a US food and beverage company, regenerative farming is part of their positive agriculture programme. The goal is to have 7 million acres (2,83 million ha) farmed with regenerative farming practices. Regenerative farming means the practice of at least two locally appropriate regenerative practices, and a practice is regenerative if it at least improves two of the five dimensions. The five dimensions are: carbon emission reduction and sequestration, soil health, enhanced biodiversity, watershed health and improved livelihoods. PepsiCo indicates that it needs suppliers to report on their carbon footprint and one other dimension of choice (PepsiCo, 2022a). PepsiCo publishes a Regenerative farming practice bank. This is a list of practices with the definition and the likely impact in the five dimensions (PepsiCo, 2022b).
- *Syngenta Group*
  The Syngenta Group, a Swiss-Chinese producer of seeds and plant protection products, defines RegenAg as 'an outcome-based food production system that nurtures and restores soil health, protects the climate and water resources and biodiversity, and enhances farms' productivity and profitability' (Syngenta Group, 2022).
- *Unilever*
  Principles for RegenAg for Unilever, a British multinational consumer goods company, are to have a positive impact on soil health, water and air quality, carbon capture and biodiversity. RegenAg should enable local communities to protect and improve their environment and wellbeing, produce crops with sufficient yield and nutritional content, while keeping resource inputs as low as possible, and optimise the use of renewable resources while minimising the use of non-renewable resources. They recognise that it requires changes at a system level (Unilever, 2021).

Appendix 2 Individual values crops indicators

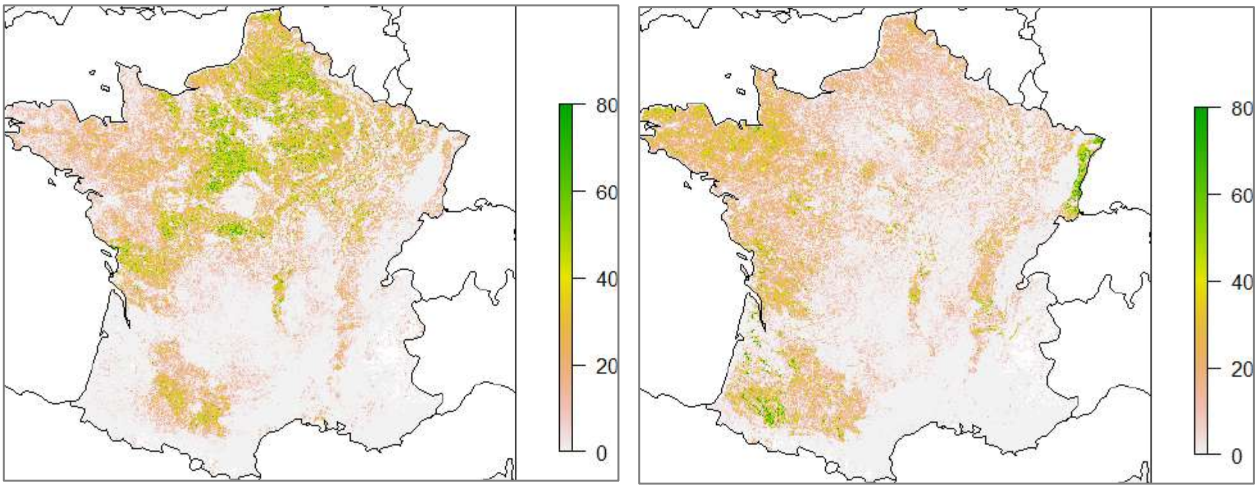

Figure A2.1 *Production areas in France for wheat % (left) and maize % (right). Source: JRC EU crop map*

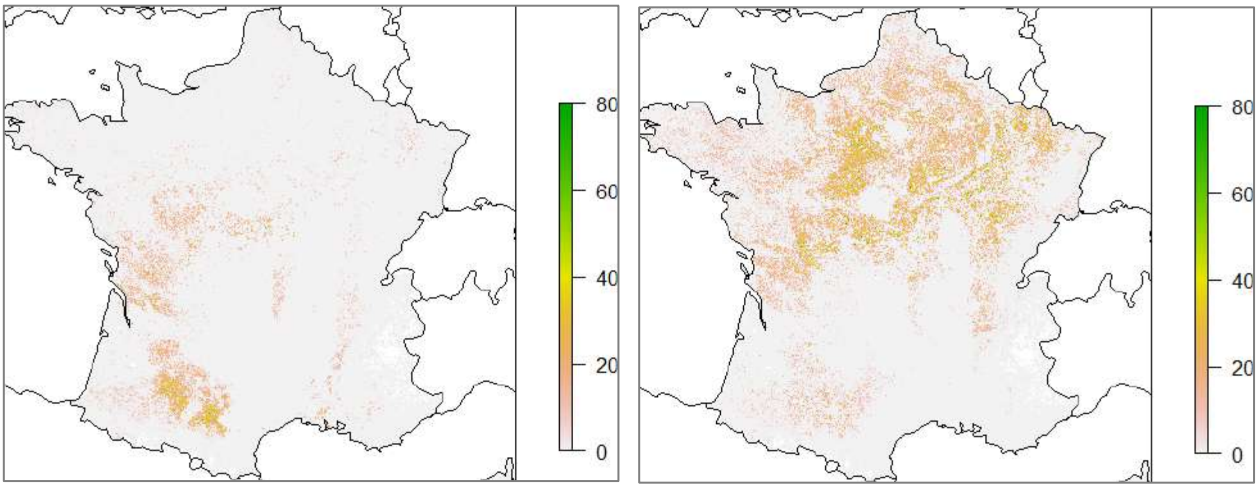

Figure A2.2 *Production areas in France for sunflower % (left) and rape % (right). Source JRC EU crop map*

Appendix 3 Potential areas for Regenerative Agriculture

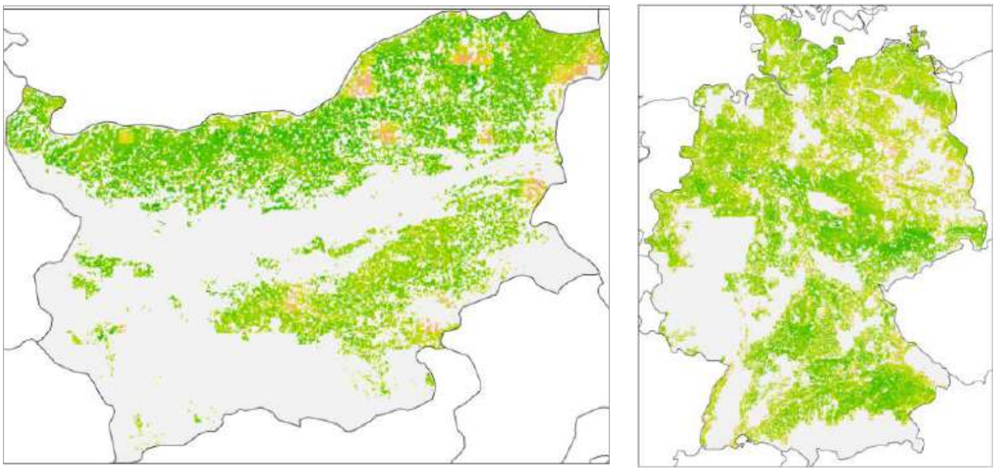

Figure A3.1 *Potential for RegenAg in Bulgaria (left) and Germany (right). Based on the following categories of indicators: cropland density, no exclusion, water availability, soil characteristics, crops, and animal density*

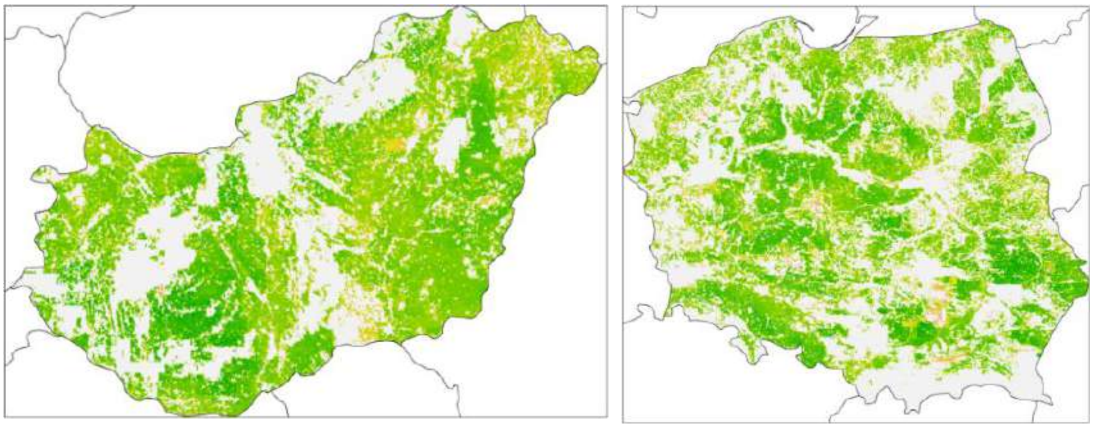

Figure A3.2 *Potential for RegenAg in Hungary (left) and Poland (right). Based on the following categories of indicators: cropland density, no exclusion, water availability, soil characteristics, crops, and animal density*

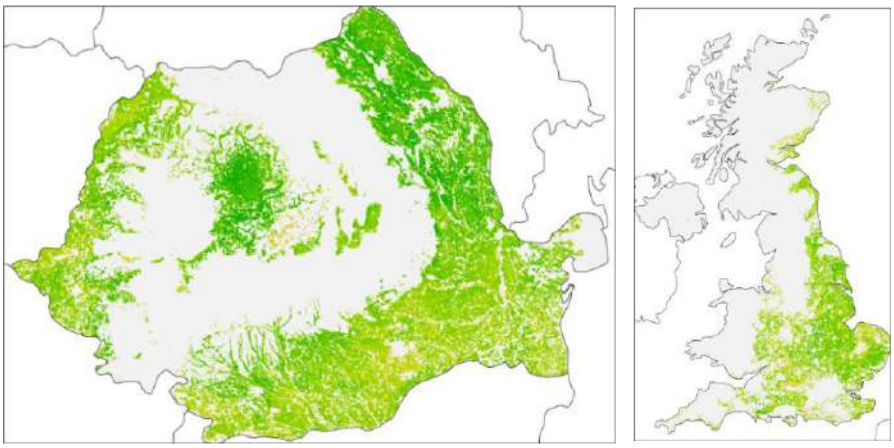

Figure A3.3 *Potential for RegenAg in Romania (left) and the united Kingdom (right). Based on the following categories of indicators: cropland density, no exclusion, water availability, soil characteristics, crops, and animal density*

To explore the potential of nature to improve the quality of life

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