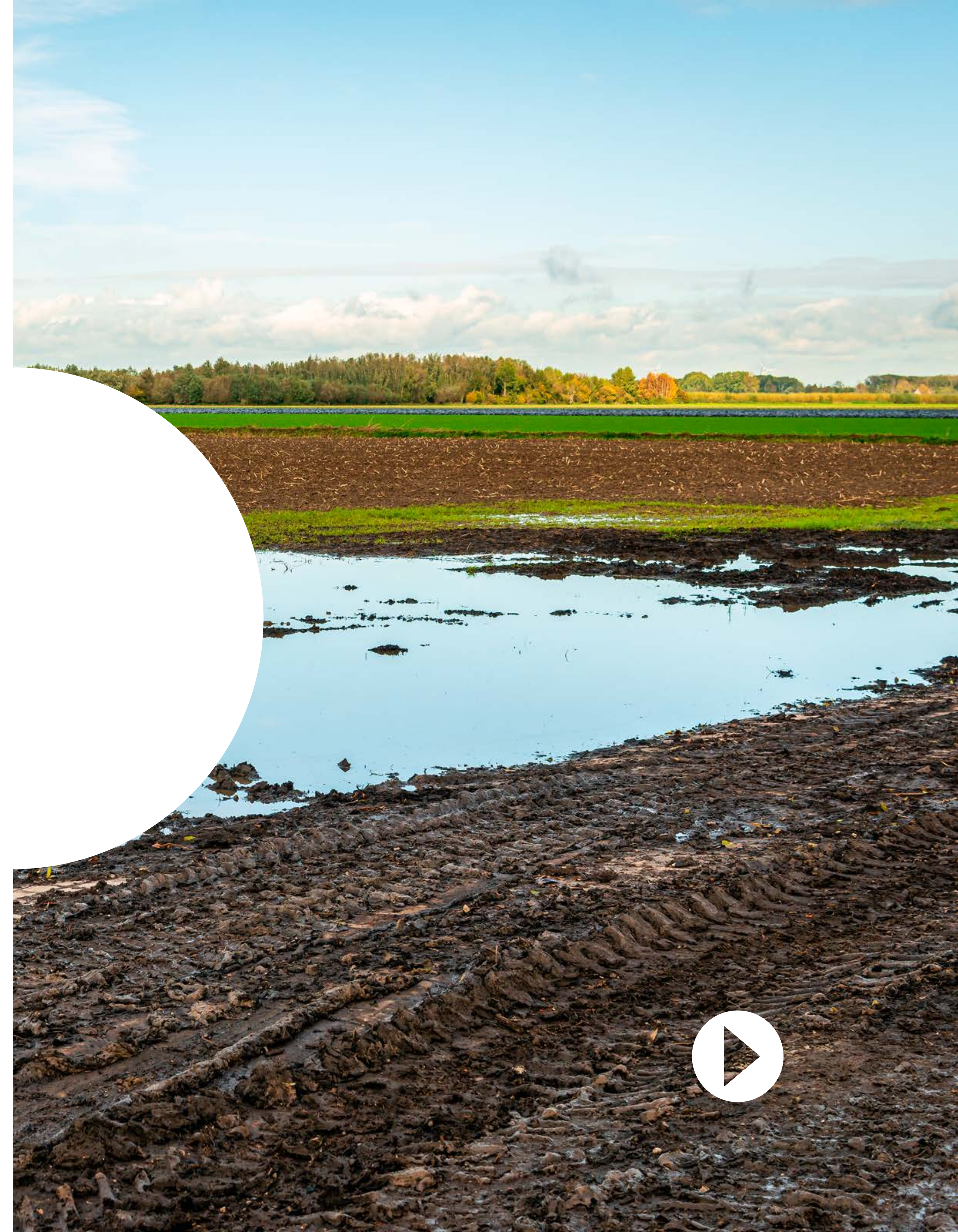
SOILS FOR SUSTAINABILITY

JUNE 2020



Council
for the Environment
and Infrastructure

About the Council for the Environment and Infrastructure

The Council for the Environment and Infrastructure (*Raad voor de leefomgeving en infrastructuur*, Rli) advises the Dutch government and Parliament on strategic issues concerning the sustainable development of the living and working environment. The Council is independent, and offers solicited and unsolicited advice on long-term issues of strategic importance to the Netherlands. Through its integrated approach and strategic advice, the Council strives to provide greater depth and breadth to the political and social debate, and to improve the quality of decision-making processes.

Composition of the Council

Jan Jaap de Graeff, Chair
Marjolein Demmers MBA
Prof. Pieter Hooimeijer
Prof. Niels Koeman
Jeroen Kok
Annemieke Nijhof MBA
Ellen Peper
Krijn Poppe
Prof. Co Verdaas
Em. Prof. André van der Zande

Junior members of the Council

Sybren Bosch MSc
Mart Lubben MSc
Ingrid Odegard MSc

General secretary

Ron Hillebrand PhD

The Council for the Environment and Infrastructure (Rli)

Bezuidenhoutseweg 30
P.O. Box 20906
2500 EX The Hague
The Netherlands
info@rli.nl
www.rli.nl

CONTENTS

SUMMARY

The sustainability of agricultural, forest and natural soils in rural areas of the Netherlands is in jeopardy. Despite the unambiguous regulatory and policy framework on sustainable soils provided by national and international policies and guidelines, soils suffer from acidification, eutrophication, desiccation, compaction and heightened vulnerability. This prevents objectives for nature, water and climate from being achieved. In this advisory report the Council for the Environment and Infrastructure makes the case for a more vigorous soil policy.

Rural soils are crucial for several land uses and functions: not only agriculture, but also forestry, nature, water quality, and water and carbon storage. All these uses and functions depend on sustainable soils, but their sustainability is being put at risk by intensive use and the presence of hazardous substances. Climate change exacerbates this situation by increasing the rate at which organic matter is broken down, which adversely affects water retention capacity, soil fertility and greenhouse gas emissions. Faced with the extreme weather conditions associated with climate change, what we really need, though, are more sustainable soils that can store more water and more carbon.

This decline in soil sustainability has a negative impact on the land uses and functions which directly depend on the soil. Agricultural yields are increasingly hard to maintain, forests are less productive and ecological quality is being lost. The conservation status of most protected ecosystems is moderate to poor. Water quality also fails to meet the required standards and soils retain too little water. Poorer soil sustainability restricts soil carbon storage, which leads to higher volumes of greenhouse gases being emitted, rather than being broken down and stored in the soil.

Maintaining sustainable soils is the responsibility of society as a whole, but the government has a key part to play. First, it must ensure that all relevant players are much more aware of the urgent need to restore the sustainability of rural soils and of the various functions they perform. Although there are numerous good initiatives, sustainable soils deserve much more attention from value chain partners and policymakers.

As land is scarce in the Netherlands, soils must be suitable for multiple uses, such as agriculture and carbon storage to combat climate change, forestry and water storage, and agriculture combined with nature conservation. However, this is only possible if the soils are sustainable and if the use of the soil does not damage its sustainability, but improves it. This also means that the aim should not be to make soils suitable for all possible activities and functions, but rather to follow the principle of ‘function follows soil’. National government should adopt it in the National Environment and Planning Strategy and encourage multifunctional use of soil wherever possible. The responsibility for translating this principle into practice should lie primarily with the provincial governments, which should exercise it in the planning decisions they make and through the use of area-based processes.

Given the agenda-setting nature of this advice, the Council does not make any detailed recommendations for adapting policy or legislation. However, the Council does see the need to make several changes to the relevant policy instruments in order to put a ‘sustainable soils first’ policy into effect. In the opinion of the Council, this should at least include establishing a monitoring and knowledge system to collect and share more information on soil sustainability, amending the regulatory framework (including agricultural tenancy, fertiliser and fiscal policies), introducing targeted remuneration packages (e.g. via the common agricultural policy or regional branding) and introducing ecological restoration measures. The Council gives some examples of ways to do this. The details will have to be worked out in practice.

PART 1 | ADVICE

1 AN INTEGRATED APPROACH TO SUSTAINABLE RURAL SOILS

A sustainable soil is essential for agriculture, forestry and nature,[1] to maintain and improve water quality, and for the storage of water and carbon. Agriculture provides us with food, forestry provides us with wood, nature and forests provide biodiversity, habitats and ecosystems. The filtration and storage function of sustainable soils also provides us with enough safe water for drinking and other uses. Soil carbon in the form of organic matter is a key component of the global carbon cycle. And the build-up and breakdown of organic matter has a substantial influence on the amount of greenhouse gases in the atmosphere and therefore plays a major part in the climate problem.

Nevertheless, it is difficult to give soil the place it deserves in management, in policy and with parties in the food chain. Many different parties have an interest in the soil and much of the land is in private ownership. Moreover, several ministries have responsibilities for the soil and laws and regulations often apply to just one sector or field of activity. An example is the Soil Strategy, which applies only to agricultural soils; no such specific soil strategy exists for forest soils and natural soils. There is legislation

1 Where we refer to nature this includes forests as well. Forestry is referred to separately where timber production is the prime objective.

that applies to certain aspects of soils, such as regulations on specific substances in soils, but much of this was drawn up in response to disasters. This is exemplified yet again by the current efforts to find measures that can help to resolve the nitrogen and PFAS problems. It seems as if we lurch from one incident to the next – with no overall vision. In the opinion of the Council it is high time to adopt an integrated approach to the sustainability of rural soils in the Netherlands.

1.1 Major land uses are dependent on sustainable soils

Soils in rural areas are managed by farmers, foresters and nature conservation bodies and are essential for the proper functioning of agriculture, forestry and nature and for water quality and the storage of water and carbon. To perform these functions effectively, soils must be sustainable. In the opinion of the Council, a soil is sustainable if its quality is sufficient to sustain the activities and functions stated above. Sustainable agricultural soils produce sufficient quantities of healthy food, sustain the production of safe drinking water and play an essential part in the breakdown of greenhouse gases and the sequestration of carbon. Sustainable natural soils are the foundations on which resilient ecosystems that support biodiversity are built. They also retain a sufficient supply of water. The sustainability of the soil is determined by several properties: organic matter content, soil chemistry (including the nutrient balance), soil biodiversity and soil structure (Figure 1). Changing one property influences the others and together they make the soil resilient and adaptable to change. If they are disrupted, the sustainability of the soil declines. As the soil is a slow system – the effects of activities only become visible much later on (often generations later) – building or restoring soil sustainability is a lengthy process. Chapter 1 of Part 2 gives more information on the status of the various soil properties. Chapter 2 of Part 2 provides details on each of the uses and functions of soils.

Figure 1: Properties and functions of soils

1.2 The sustainability of Dutch soils is at risk

Intensive human activities have for some time been exerting a detrimental effect on the sustainability of soils, both in the Netherlands and elsewhere in the world. In response, several national and international policy measures, legislation and guidelines have been adopted to improve the quality of soils and make them suitable for performing the functions that depend on them (Box 1 and Figure 2).

Box 1. Soil sustainability enshrined in policy, legislation and guidelines

- Soils are on the road to full recovery and by 2030 agricultural soils will be managed sustainably (SDG 15.3, United Nations, 2015a; Tweede Kamer, 2018a and 2019b).
- Soils sustain the production of safe and healthy food and by 2030 natural resources will be managed sustainably and used efficiently (SDGs 2 and 12, United Nations, 2015a; Codex Alimentarius[2] FAO & WHO 2020).
- Soils provide safe and healthy water. This means that the objectives stated in the Water Framework Directive (WFD), the Nitrates Directive, the Groundwater Directive and SDGs 6 and 14 have been achieved (United Nations, 2015a; European Parliament and the Council, 1991, 2000 and 2006).
- From 2030 each year soils capture and store an additional 0.5 Mt of atmospheric carbon dioxide. Until 2030 the aim is to increase the soil carbon percentage by 4 ‰ per year. Emissions from grassland, arable land and managed forest during the period 2021–2030 must be no higher than in the reference period. Emissions from 'forested land' and 'deforested forest' should be zero. Countries where emissions are higher will be able to compensate for this (LULUCF) (Tweede Kamer, 2019b; SDG 13, United Nations, 2015b; European Parliament and the Council, 2018; Arets et al., 2019).
- Soils form the basis for the conservation and restoration of biodiversity and protected ecosystems. The Natura 2000 sites should be sustainably conserved (United Nations, 1992; SDG 15, United Nations, 2015a; European Parliament and the Council, 1979 and 1992; Tweede Kamer, 2019c).
- In 2030 the area of forest will have been increased by 37,000 hectares. Forests have been restored to health and are managed sustainably. In the period 2011–2027 the area of natural ecosystems will have been increased by at least 80,000 hectares (Tweede Kamer, 2013 and 2020a; United Nations, 2015a).

Despite national and international policy, legislation and guidelines, Dutch soils are not in a good state. This can be seen in Table 1, which shows the current status of soils in the Netherlands. Policy objectives and targets are not being achieved and the sustainability of soils is under intense pressure, which is adversely affecting the various functions performed by the soil.

2 The Codex Alimentarius contains international food standards for the protection of public health worldwide and to promote fair trade In food products.

Figure 2: Sustainability of soils is enshrined in policy, legislation and guidelines

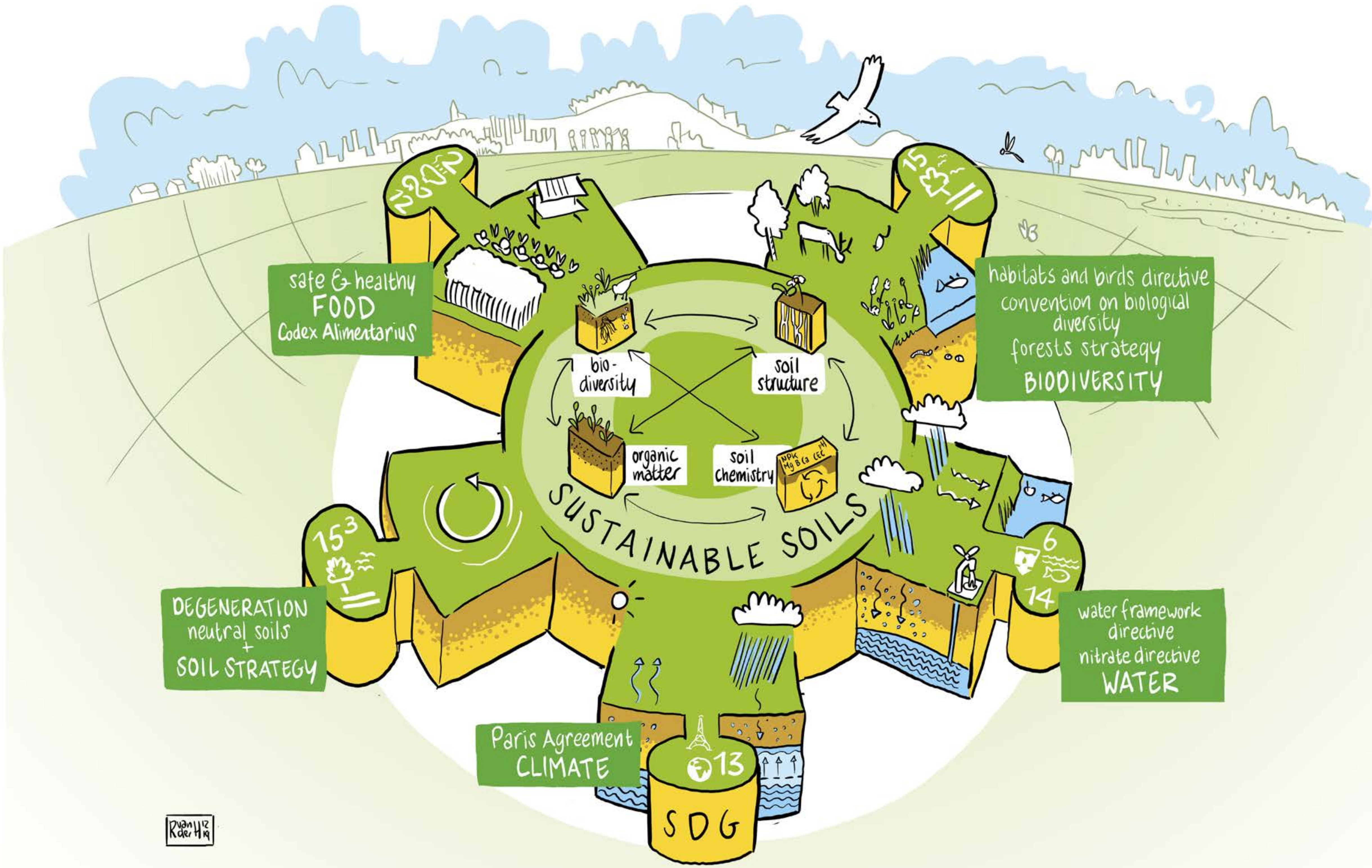


Table 1: Current status of Dutch soils: national/international goals, legislation and guidelines are not being met

Policy	Objectives	Current situation
SDG 15.3 Soil Strategy National Agricultural Soils Programme	· Soils are on the road to full recovery (United Nations, 2015a) · By 2030 all agricultural soils in the Netherlands will be managed sustainably (Tweede Kamer, 2018a and 2019a)	· 50% of agricultural soils are compacted (Van den Akker, 2019) · The critical load for nitrogen deposition is exceeded in 92% of forests and 72% of natural ecosystems (CLO, 2019) · 1.6% of forest soils and 3.6% of natural soils have a poor pH (PBL, 2018) · 19.8% of forest soils and 14.9% of natural soils have a moderate pH (PBL, 2018) · 15% of forest soils and 14% of natural soils are severely desiccated (CLO, 2018) · 18% of forest soils and 23% of natural soils are moderately desiccated (CLO, 2018)
SDG 2 and SDG 12 Codex Alimentarius	· Soils sustain the production of safe and healthy food (United Nations, 2015a) · By 2030 natural resources will be managed sustainably and used efficiently (United Nations, 2015a) · Food safety standards (FAO & WHO, 2020)	Subsoil compaction in agricultural soils reduces yields by 10% (Akker, 2019) · The organic matter fractions (organic particles and mineral-bound organic matter) in European agricultural and forest soils are demonstrably reduced; recovery is needed for food production and CO_2 storage (Lavallee et al., 2019). · The concentrations of micronutrients (zinc, boron, phosphorus, potassium, sulphur and calcium) in Dutch soils are declining. The use of fertilisers has so far prevented this from reducing plant growth (Hospers-Brands et al., 2016). · The available stocks of some minerals (zinc, boron, manganese, molybdenum and selenium) will be depleted within a few decades (Bastein & Van Bree, 2012). · For some years the amounts of various minerals (copper, magnesium, calcium, sodium, iron and potassium) and other nutrients in potatoes, vegetables and fruit have been declining. As a result, consumers have been ingesting fewer vitamins (A, B, E, D) and minerals (Ca, Fe, P, Mg, Se, Zn). In the Netherlands this has not yet led to deficiency diseases (Hospers-Brands et al., 2016).
SDG 6 and SDG 14 Nitrates Directive, WFD and Groundwater Directive	Groundwater (European Parliament and the Council, 2006): · 50 mg nitrate per litre · 2.0 mg nitrogen per litre in regions with sandy soils · 6.9 mg nitrogen per litre in other regions	· Under current policy, in 2027 the targets for nitrogen and phosphorus will not be met in about half of all surface water bodies. Ecological objectives will therefore not be achieved. · In 2027, the nitrate concentrations in groundwater in the southern region of sandy soils will exceed the nitrate target by 20%. This will affect drinking water quality (PBL, 2017).
	Surface water, targets for 2027 (European Parliament and the Council, 2000): · 0.11 mg phosphorus per litre of water in regions with sandy soils · 0.22 mg phosphorus per litre of water in regions with clay and peat soils · 2.3 mg nitrogen per litre of water in regions with sandy soils · 2.4 mg nitrogen per litre of water in regions with clay and peat soils	· In the period 2000–2015 the quality standards for drinking water were exceeded in 89 drinking water sources in sand deposits, which is probably related to the higher application rates of nitrogen fertilisers and manure in the past (PBL, 2017). · It is expected that sea level rise will lead to exceedance of the drinking water standard (annual average) of 150 mg chloride per litre in surface water or in drinking water for one or more days (Helpdeskwater.nl, n.d.).

Policy	Objectives	Current situation
SDG 13 LULUCF National Climate Agreement	· From 2030, each year soils will capture and store an additional 0.5 Mt of atmospheric CO_2 (Tweede Kamer, 2019b). · Until 2030 the percentage of carbon in soils will rise by 4‰ per year (United Nations, 2015b). · In the period 2021–2030 soils and forests will capture and store 2.7 Mt CO_2 equivalents (PBL, 2019). · Land use goal for 2050 (LULUCF): 2 Mt CO_2 equivalents (Lesschen et al., 2020) · In 2021–2025 and 2026–2030 net CO_2 emissions and uptake in grasslands and agricultural soils should be zero. The reference amount (the average in 2005–2009) may be subtracted. · The reference amount may not be subtracted for ‘forested land’ and ‘deforested land’ (where there has been a change of use). This is permitted for managed forest (European Parliament and the Council, 2018; Arets et al., 2019).	· Risk calculations indicate that the critical limit of 1.5% carbon in arable farmland will not be reached for at least 50 years (Conijn & Lesschen, 2015). · The organic matter fractions (organic particles and mineral-bound organic matter) in European agricultural and forest soils are demonstrably reduced; recovery is needed for food production and CO_2 storage (Lavallee et al., 2019). · Climate change is increasing the rate of decomposition of organic matter. The reduction in organic matter content is greater in arable soils; the rate of sequestration is lower in grasslands. According to model calculations, a 2°C increase in temperature will lead to an average reduction in the annual carbon balance of 290 kg per ha per year. An additional 0.6 t of effective organic matter will be needed to compensate for this loss (Conijn & Lesschen, 2015). · Nature: trend unknown · Forest: decrease in carbon due to forest ageing; in 2021–2030 0.1 Mt CO_2 equivalents will be released (PBL, 2019). · Emissions from land use in 2017 (LULUCF): 6 Mt CO_2 equivalents (Lesschen et al., 2020). · Reporting to the UNFCC indicates that in 2017 grasslands and wetlands emitted 2.5% and 9.1% more greenhouse gases than in 2016. Arable and forest soils emitted 0.4% and 0.2% less greenhouse gases than in 2016 (EEA, 2019).
SDG 15, Habitats Directive, Birds Directive, Convention on Biological Diversity Letter on the ambitions and targets of the Forests Strategy	· Soils offer a basis for the restoration of biodiversity and protected ecosystems (United Nations, 2015a; European Parliament and the Council, 1979 and 1992). · Deforestation is halted in 2020, forests are managed sustainably and forests have been restored (United Nations, 2015a). · Conversion to nature of at least an extra 80,000 ha in the period 2011–2027 (Tweede Kamer, 2013) · Expansion of the area of forest by 37,000 ha (10%) by 2030 (Tweede Kamer, 2020a)	· In 2006–2015 the areas of forest and agriculture declined by 1% and 2% and the area of natural ecosystems increased by 12%. In the same period the total rural area declined by 2% (CBS, 2018a). · The conservation status of 46 of the 52 protected ecosystems is moderate to poor (Tweede Kamer, 2019d, 2019e and 2019f). · Decline in soil biodiversity: the complexity of the soil community and the biomass of most soil organisms are decreasing (Van der Putten, 2019). The decline in soil biodiversity has consequences for ecological cycles and biodiversity above ground: on average, the number of characteristic animal species declined by 50% in agricultural areas and in open ecosystems, such as heath; in forests the number of characteristic animals species remained on average about the same (WNF, 2020). · A minimum of 41,257 ha still has to be converted to nature by 2027 (IPO et al., 2019).

Chapter 2 takes a closer look at the problems facing Dutch soils and the causes of these problems.

1.3 Research question and contextualisation

This advisory report concerns rural areas only. In its advice the Council attempts to answer the following question: What can the government do to restore the sustainability of rural soils in the Netherlands such that they are able to sustain the activities and functions that directly depend on them (agriculture, forestry, nature, water quality, and water and carbon storage)?

This advice is restricted to soils in the Netherlands and does not consider soils abroad where crops are grown to provide food or animal feed for the Netherlands. It includes the standards for the application of manure and other fertilisers to the soil, but does not address the issue of animal numbers. Changing the food system to reduce emissions, as described in the Council's advisory report 'Sustainable and Healthy' (Rli, 2018), will certainly make a positive contribution to the sustainability of soils, but that is not the subject of this advice. Neither does this advisory report look at pollution from point sources, major soil remediation operations, geothermal heat, fracking or soil subsidence. The subject of soil subsidence (and the associated problem of salinisation) is dealt with in the Council's advisory report on soil subsidence (Rli, 2020a). Archaeological values are not discussed because they do not directly concern the sustainability of the soil.

The advisory report is agenda-setting and suggests potential solution pathways.

2 DISRUPTION TO SOIL PROPERTIES UNDERMINES SUSTAINABILITY OF SOILS

The sustainability of Dutch soils is in jeopardy. There are two reasons for this. First, agricultural soils in the Netherlands are intensively farmed to obtain high yields. For many decades market forces have been driving this intensification of food production, which has been brought about through the use of pesticides, fertilisers and manure, high-yielding crops, monocultures, intensive cropping plans and large, heavy machinery, and by lowering the water table. Not only does this have consequences for agricultural soils, but also for forest soils and natural soils, whose health is declining as a result. The complex interplay of soil properties is being disrupted.

In addition, all rural soils contain at least some hazardous substances, such as per- and polyfluoroalkyl substances (PFAS), microplastics, residues of medicines, pesticides, antibiotics and nanoparticles. It is not clear where exactly these substances are present and in what quantities, or the trends in their concentrations and whether or not they present any danger (Rli, 2020b; Beltman et al., 2019).

The damage being done to the sustainability of soils is reflected in the various soil properties and this is discussed briefly below. In the years to come, the sustainability of Dutch soils will be put under additional strain by climate change and the energy transition. All these developments put the functions performed by soils at risk.

2.1 Properties of agricultural soils

Some forms of agriculture have a greater impact on the soil than others. Flower bulb cultivation, for example, has a particularly damaging impact on the soil (see Box 2).

Box 2: Bulb cultivation has a major impact on the soil

Bulbs are cultivated on dune sand soils near the coast in the west of the country. They are also cultivated in the east of the country on cover sand soils and on livestock and arable farms (Bokhorst et al., 2008). The province of Noord-Holland in the west accounts for half of all the bulbs cultivated in the Netherlands, followed by the provinces of Flevoland and Zuid-Holland, and Drenthe in the east (CBS, 2018b). Bulb cultivation is highly profitable. In 2019 bulb growers earned about €140,000 per unsalaried annual work unit (Van der Meulen, 2019a); the equivalent in arable farming is €37,000 (Van der Meulen, 2019b). But growing flower bulbs requires special, often artificial conditions. The soil is treated to create ideal conditions for the growth of the bulbs. This means maintaining a low groundwater level and ensuring the soil is well aerated. On the other hand, in dry periods the fields are frequently irrigated, which in the west can lead to underseepage pressure and a high salt load (DHV, 2009). Bulbs need nutrients before the organic matter in the soil has started to mineralise in the spring (Bockhorst et al., 2018). They are also susceptible to fungal and viral diseases. In the period 2015–2017 the environment impact of pesticide use amounted to 14,000 mbp (environmental impact points)[3] per ha (Smit, 2019a); for comparison, pesticide use on arable farms in recent years amounted to less than 2,000 mbp per ha (Smit, 2019b). About two thirds of the pesticides applied to bulb fields leaches to surface waters (particularly insecticides and soil sterilants) and about a third remains in the soil. A small amount enters the groundwater (Smit, 2019a). There are indications that all this leads to a lower organic matter content in the soil and a reduction in soil biodiversity, which in turn prompts growers to look for new methods or new land (Van Roekel, 2015).

Soil structure is disrupted

The physical structure of half of all agricultural soils has been degraded by the use of heavy machinery and is compacted. Water is not retained as well as it should be, which can lead to desiccation or to waterlogging where water remains on the surface. In wet conditions nutrients leach from the soil more quickly and soils that are too dry are more likely to erode. These

3 Environmental impact points (milieubelastingspunten) are calculated using the CLM Environmental Yardstick tool which indicates how harmful a pesticide is for the environment. The tool was developed in the Netherlands for Dutch soil types.

effects are already leading to demonstrably suboptimal yields (Van den Akker, 2019).

Soil biodiversity, organic matter content and soil chemistry are disrupted
Widespread use of monocultures, such as maize and ryegrass, is causing biodiversity to be lost. Moreover, intensive cropping plans (such as potatoes, onions and beet) include a limited number of break crops, limiting the capacity of the soil to restore organic matter content (Van den Akker, 2019; Beltman et al., 2019; Koopmans & Van Opheusden, 2019; Van der Putten, 2019). The declining nutrient content of the soil is compensated to a certain extent by the application of chemical and organic fertilisers, but the problem with this is that the nutrient composition of the fertilisers disturbs the nutrient balance in the soil. All this makes the soil more vulnerable. Moreover, the available fossil reserves of some nutrients in chemical fertilisers will be depleted within a few decades (Bastein & Van Bree, 2012). The amounts of various minerals and other nutrients in food (potatoes, vegetables and fruit) are declining worldwide. In the Netherlands this has not yet led to deficiency diseases (Hospers-Brands et al., 2016).

2.2 Properties of forest and natural soils

The Council notes that the health of forest and natural soils is declining (see Box 3 on natural soils in the province of Noord-Brabant).

Soil chemistry and biodiversity are disrupted
The chemical composition of forest and natural soils has been disrupted by years of atmospheric deposition, mainly of nitrogen and sulphur, which causes acidification and eutrophication. As a result, these soils have become susceptible to drought, pests and diseases (Beltman et al., 2019; Van der Putten, 2019). The acidification of natural habitats and ecosystems is eroding landscape diversity as nitrophilous species become more dominant. Species richness is decreasing. Just 6 of the 52 protected ecosystems in the Netherlands are in a favourable conservation status (Tweede Kamer, 2019e and 2019f) and poor habitat quality (caused among other factors by eutrophication and water abstraction) is responsible for 84% of the unfavourable conservation status (Pouwel & Henkens, 2020). The health and quality of forests, especially those on the poorer sandy soils, are also under pressure (Tweede Kamer, 2020a). Even if nitrogen deposition were to decrease sharply overnight, acidification of soils will continue for many years because the soil composition responds very slowly to changing conditions.
Water tables are lowered to increase agricultural production. The abstraction of drinking water can also draw down the water table. Both forests and nature are affected by this and can suffer from severe desiccation (PBL, 2018).

Box 3: The sustainability of natural soils in the province of Noord-Brabant
The sustainability of natural soils in the province of Noord-Brabant has been mapped by analysing soils for desiccation, eutrophication and acidification. The results show that all is not well with the sustainability of natural soils in the province: 7% of these soils (including soils in forests

with a timber production function) fall in the sustainability class 'good', 32% in the class 'moderate' and 61% in the class 'bad'. Moreover, there are indications that the sustainability of soils is not only being damaged by atmospheric pollution and desiccation, but also by the input of nutrients via groundwater (Witte et al., 2018).

2.3 Climate change and the energy transition can exacerbate soil problems

Climate change is driving up soil temperatures, which accelerates the decomposition of organic matter. Besides increasing emissions of greenhouse gases, this has consequences for the water retention capacity and fertility of soils. At the same time, the heavier showers and longer periods of drought brought on by climate change make greater demands on the sustainability of soils (Van den Akker, 2019; Beltman et al., 2019; Koopmans & Van Opheusden, 2019; Van der Putten, 2019).

Climate change is also causing sea levels to rise while at the same time the land is subsiding. In the lower lying areas of the Netherlands brackish deep groundwater is being pushed up towards the surface (seepage) via the soil and will enter the shallower groundwater and surface water bodies, salinising the soil and the groundwater and surface water systems. This will affect agriculture, drinking water quality and nature (Helpdeskwater.nl, n.d.).

Forestry and agricultural residues are an important source of organic matter for the soil. As part of the energy transition, branches and top wood from forests and leaf litter from agricultural soils (biomass) are increasingly used as raw materials for energy generation (Vereniging van Bos- en Natuurterreineigenaren, 2017) or for processing into new products in the circular economy (such as packaging materials). This has led to competition for these residues.

2.4 Functions of the soil at risk

Disruption of soil properties undermines the sustainability of soils and puts the functions that soils perform at risk. The biggest problems for agriculture are soil compaction, greater vulnerability and susceptibility to extreme weather, pests and diseases, and the presence of the hazardous substances mentioned above. This has consequences for the amount and quality of the food that can be produced in the Netherlands, and thus for farmers' profits. Forestry and nature conservation are adversely affected by the acidification, eutrophication and increased vulnerability of soils, and most protected ecosystems have a moderate to poor conservation status. Water quality standards are not being met as a result of nutrient leaching and runoff due to soil compaction and the application of both chemical and organic fertilisers. Moreover, soil compaction and the lowering of water tables for agricultural purposes are reducing the capacity of soils to retain water. Disruption of the processes involved in capturing and storing organic matter results in greenhouse gases being emitted in greater quantities rather than being broken down and fixed in the soil. Climate change only makes matters worse.

3 TOWARDS SUSTAINABLE SOILS

As described above, the sustainability of Dutch soils is in jeopardy. In the long term there is a danger that large areas of the Netherlands may become less able to sustain vital land uses and functions. This problem is compounded by the fact that land is scarce. Nevertheless, national and international policies, legislation and guidelines clearly state the criteria that soils must meet to ensure their sustainability. In the opinion of the Council, the problem lies in putting these into practice. What is needed, therefore, are changes to the policy instruments. The Council proposes that this is guided by three basic principles:

- Aim for sustainable soils which can support multiple functions: multifunctional soil use.
- Function follows soil: to make optimal use of the soil, the permissible combination of land uses and functions should be determined by the type and properties of the soil itself.
- Numerous government instruments have an influence on the sustainability of soils and they should all be amended.

These principles have been worked up into concrete measures in the recommendations to the authorities discussed below. Step 1 concerns the importance of multiple functions. Step 2 elaborates the principle of function follows soil. Step 3 examines possible instruments for fostering sustainable soils.

3.1 Step 1: Aim for multiple functions

Recommendation 1 to the authorities: Impress on everyone how extremely urgent the need for action is and aim for sustainable soils that can sustain multiple functions. Provinces: Take the lead in implementing policy for sustainable soils.

Making soils sustainable is not just a task for farmers, foresters and conservation managers. Society as a whole[4] has a job to do and a responsibility to meet. But the Council argues for a greater role for government as a whole, with a more coherent package of instruments at its disposal than at present. This is all the more urgent because the slow responsiveness of the soil system means that the effects will only become fully visible on a timescale of generations. Only government is capable of assuming responsibility for challenges with a time horizon of more than a generation. In the Council's opinion, national government should use policy instruments to set out the course to be followed.

4 The value chain consists of farmers and growers, the retail trade, landowners/lessors, contractors, industry, consumers, forest and conservation management organisations, financial organisations, consultants, public authorities (municipalities, provinces, national government and water authorities), educational establishments and scientists.

The National Environment and Planning Strategy makes it possible to pursue land use and development policies that support the return to sustainable soils (Box 4). The Council observes that municipalities will have an increasingly large part to play because national and provincial structures, such as the Technical Committee on Soil Protection, are being abolished (Eerste Kamer, 2019), and responsibilities are being transferred from the provinces to the municipalities, including the tasks under the Nature Conservation Act. However, it is questionable whether the municipalities are adequately equipped to take on these responsibilities, given the complexity of the problem and the expertise and manpower required. Moreover, areas with natural soils often span municipal boundaries and landowners and land users sometimes have land in more than one municipality. The Council therefore advises including provisions in the National Environment and Planning Strategy that give the provinces responsibility for pursuing sustainable soil management through area-based processes, because provincial governments have experience with rural planning. In addition, the provinces and the municipalities must jointly take on the task of coordinating efforts to establish sustainable soils that can sustain a combination of land uses and functions.

Box 4: National Environment and Planning Strategy

In the National Environment and Planning Strategy the Minister of the Interior and Kingdom Relations, recognising that land in the Netherlands is scarce, has set out a number of policy lines for the planning of the physical environment:

- we cannot do everything everywhere;
- the growing pressure on the physical environment forces us to make critical fundamental choices and requires a leading role by national government in giving direction on the future spatial development of the Netherlands, to shape the major development agendas and ensure well-coordinated decision-making;
- specific strategies for each region;
- for every decision, ensure a good match between what happens above ground level and the conditions below ground level, a better alignment of land uses with the properties and functions of the soil and water system;
- the existing toolbox of policy instruments, such as planning instruments, emission credits, area visions and land development instruments, must be renewed.

(Tweede Kamer, 2020b)

Changing the direction of policy requires political leadership to set the ball in motion and initiate experiments by encouraging and giving recognition to pioneers and innovators. Some players are already working for fundamental change to restore the sustainability and vitality of soils, such as local groups of land users, and initiatives are indeed being taken to make soils sustainable (Box 5). Experiments are being carried out. For the parties involved, sustainability of soils is a live issue, but they are often unable to get beyond the pilot project stage to scale up their initiatives and get them adopted as standard practices. Among these initiatives is a method for cultivating bulbs that does not affect the soil. Unfortunately, such initiatives tend to fail because the market for organically grown bulbs is weak. The value chain could make greater efforts in this direction, because they too have an interest in sustainable soils to ensure a supply of products. Structural help from the authorities is needed to move these initiatives beyond the pilot stage.

Box 5: Examples of initiatives for sustainable soils

The examples mentioned here focus primarily on the sustainability of the soil and less on the idea that soils should have multiple functions and uses.

Examples of organisations and groups that are working for the sustainable management of agricultural soils are organic and biodynamic farmers, Carbon Valley, the Duinboeren and Herenboeren movements, the Land van Ons cooperative, forest gardening initiatives, Beter Bodembeheer PPP, Caring Farmers, nature-inclusive farmers on land owned by Staatsbosbeheer (the government's conservation management agency) and on private estates, organic farmers on land managed by Natuurmonumenten, etc.

Some provinces and water authorities have adopted policies for sustainable soils. For example, the provincial government of Noord-Brabant has a Sustainable Soil Implementation Plan that contains several measures to improve the sustainability of soils (Provincie

Noord-Brabant, 2017). The Ministry of Agriculture, Nature and Food Quality acknowledges that changes are needed in practices that affect agricultural soils (Tweede Kamer, 2019a). The government is working with farmers in the vicinity of Natura 2000 sites to find out if agri-environment schemes can help reduce the intensity of agricultural use. The common agricultural policy should ensure that even in a market-oriented agricultural system the weaker social values (such as soil quality, climate and biodiversity) are actively protected and that the conditions needed to do this are created (Tweede Kamer, 2018b).

An important part of many ecological restoration projects is the restoration of soil sustainability. Nitrogen and phosphate rich sediments have been dredged from the Nieuwkoopse Plassen lakes and turf has been stripped from acidified reed and hay meadows. Rock dust is spread on acidified forest soils and ecologically impoverished grasslands to restore the nutrient balance in the soil where buffering minerals such as calcium and magnesium have largely disappeared. And trees and shrubs are being planted in forests in Noord-Brabant to restore the nutrient balance in acidified soils. The national and provincial governments are working on a joint Forests Strategy (Tweede Kamer, 2020a and 2020c), which also aims to improve the quality of forest soils as part of the wider aim of healthy forests for future generations. Another method for putting sustainable soils first is close-to-nature forestry, in which a continuous cover of forest is always maintained, the development of the forest is determined by natural processes, and all management activities are aligned with this principle (Kuper, 2019).

During the negotiations on drafting the National Climate Agreement the consultation panel on agriculture and land use explored ways in which soils can contribute to climate change mitigation.

Less attention is given to the multifunctionality of soils (for agriculture, forestry, nature, water quality and the storage of water and carbon). For example, agriculture and carbon storage can go well together, as can water storage and nature conservation. Not all parties are convinced of the need for a transformation as they do not recognise the urgency of moving towards sustainable soils that are able to sustain multiple functions. Sometimes the need for change is recognised, but legislative, economic or practical objections stand in the way. There is a need for a social movement to drive the shift to sustainable soils that can sustain multiple functions. For the Ministry of Infrastructure and the Environment and the Ministry of Foreign Affairs, Rijkswaterstaat has launched an awareness-raising campaign on the role of land and soil to generate the momentum required for the adoption of soil- and land-inclusive practices (Ploeg, 2019), focusing on the multiple functions of soil. The Council advises the government to set up a broad public campaign along similar lines, but aimed at all relevant groups and backed by an area-specific approach. Because public information campaigns are often not particularly effective (see the Council's earlier advisory report on encouraging people to adopt sustainable practices (Rli, 2014)), additional actions will be needed. A forward-looking approach should be considered as this tends to be lacking among many of the relevant parties. Once land users and landowners have a better understanding of how future developments will affect their soils, they will become more aware of the importance of managing the land to improve soil sustainability. For this reason, the government should make the information it possesses available to land users and landowners in the form of open source data. This could include information on expected trends in soil subsidence and salinisation per parcel of land and on the KNMI scenarios describing the likelihood of extreme weather events as a result of climate change.

3.2 Step 2: Function follows soil

Recommendation 2 to the authorities: Let the sustainability of the soil guide land use and soil functions and enshrine this principle in the National Environment and Planning Strategy. Use planning legislation and instruments to put this principle into practice. Protect soils essential for certain functions by designating them soil protection areas and prohibiting unsuitable activities.

Under current policies, the availability of fertilisers and pesticides and the ability to adjust groundwater levels make it possible to grow almost any crop anywhere. But what is good for one function (e.g. agriculture) is not necessarily good for another (water quality) (Box 6).

Box 6: Field vegetable cultivation on sandy soils

On horticulture farms growing asparagus, leek, strawberries and leaf crops such as lettuce on sandy soils in the southern provinces of Limburg and Noord-Brabant, nitrate concentrations in the groundwater are high (on average 1.5 times higher than the permitted level, with peaks as much as eight times as high as the 50 mg per litre limit). The calculated soil nitrogen surplus[5] on these farms is also higher than average, because nitrate does not break down easily in sandy soils. Moreover, field vegetables take up nutrients less efficiently than other crops in the same type of soil (Hooijboer et al., 2014). These crops are grown in these areas for historical reasons, but the scale of their cultivation is not optimal for soil and water quality.

If we want soils to be sustainable enough to function sustainably in perpetuity, they must be used optimally and without adverse effects. The nature of the soil should be a determining factor in land use planning. As the Minister of the Interior has said, the adage ‘soil follows function’ must be turned on its head: ‘function follows soil’ (Box 4). This principle for soil quality should be clearly stated in the National Environment and Planning Strategy. It means that agriculture, forestry, nature, water quality and the storage of water and carbon will take place there where the soil is suitable for the function in question, without the need for all sorts of external inputs, such as fertilisers and pesticides, or interventions, such as adjusting the

5 Based on total nitrogen: nitrate, ammonia and organic nitrogen.

water table. This does not mean that soils cannot be used for multiple functions, but some functions will not be possible on some soils because they would damage the sustainability of the soil.

Figure 3 shows that in 2007 some grass and arable crops were not located in the right place given the properties of the soil (physical, chemical and biological) and in terms of maximising crop yield with minimum environmental impact and a minimum use of inputs (Hack-ten Broeke et al., 2008). This map is out of date and shows the results of a limited study that was only meant to be an example of such research,[6] but it gives an indication of how we can assess which areas are suitable for which combination of functions. It shows that the sandy soils were highly vulnerable to agricultural practices in 2007, and that it is better both for the soil and for farmers to use the clay soils for arable farming instead of livestock farming.

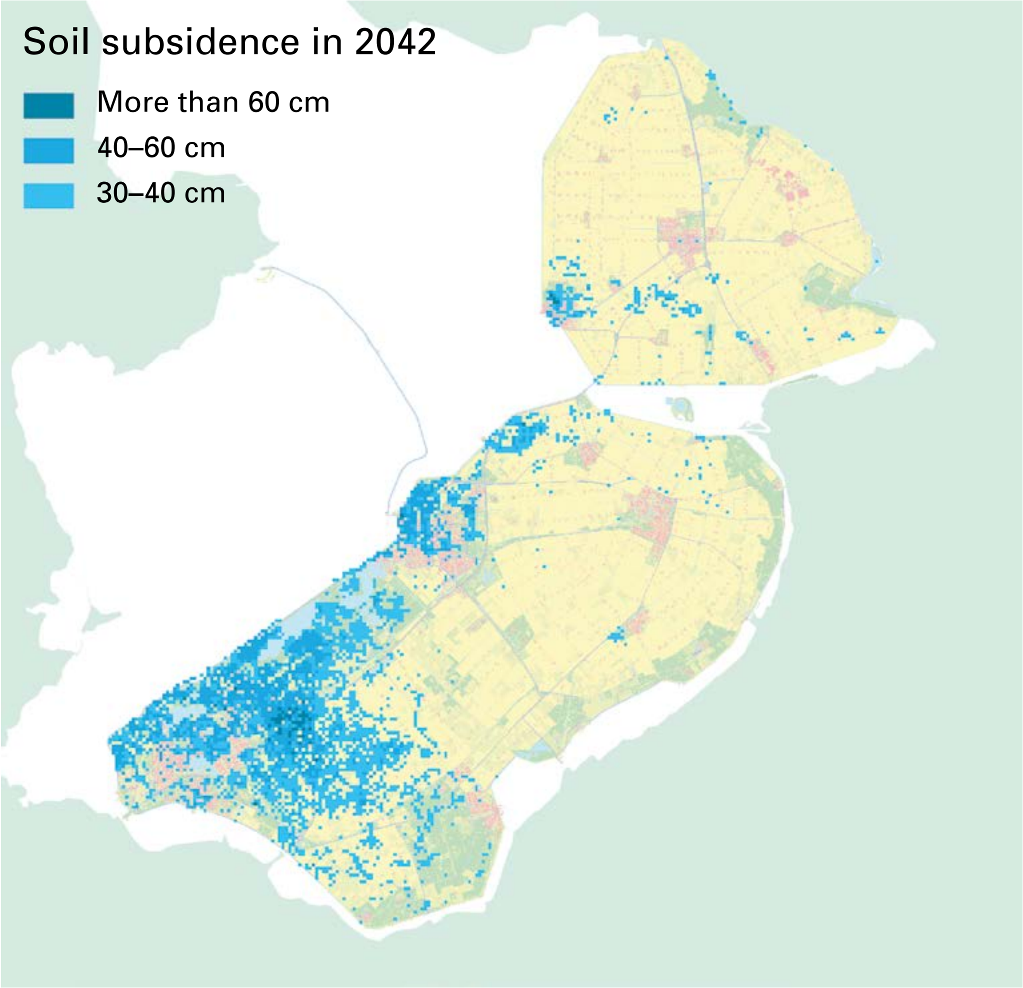
Figure 3: Agricultural land use in suitable locations with low environmental impact in 2007

Source: Hack-ten Broeke et al., 2008

Such maps should be brought up to date and a forward-looking component added by taking into account aspects such as climate change (including soil subsidence and salinisation). For the province of Flevoland this would give somewhat different picture (Figure 4, Vogelzang et al., 2019).

6 It also shows that the quality of soil monitoring has worsened over the years.

Figure 4: Soil subsidence prognosis for 2042

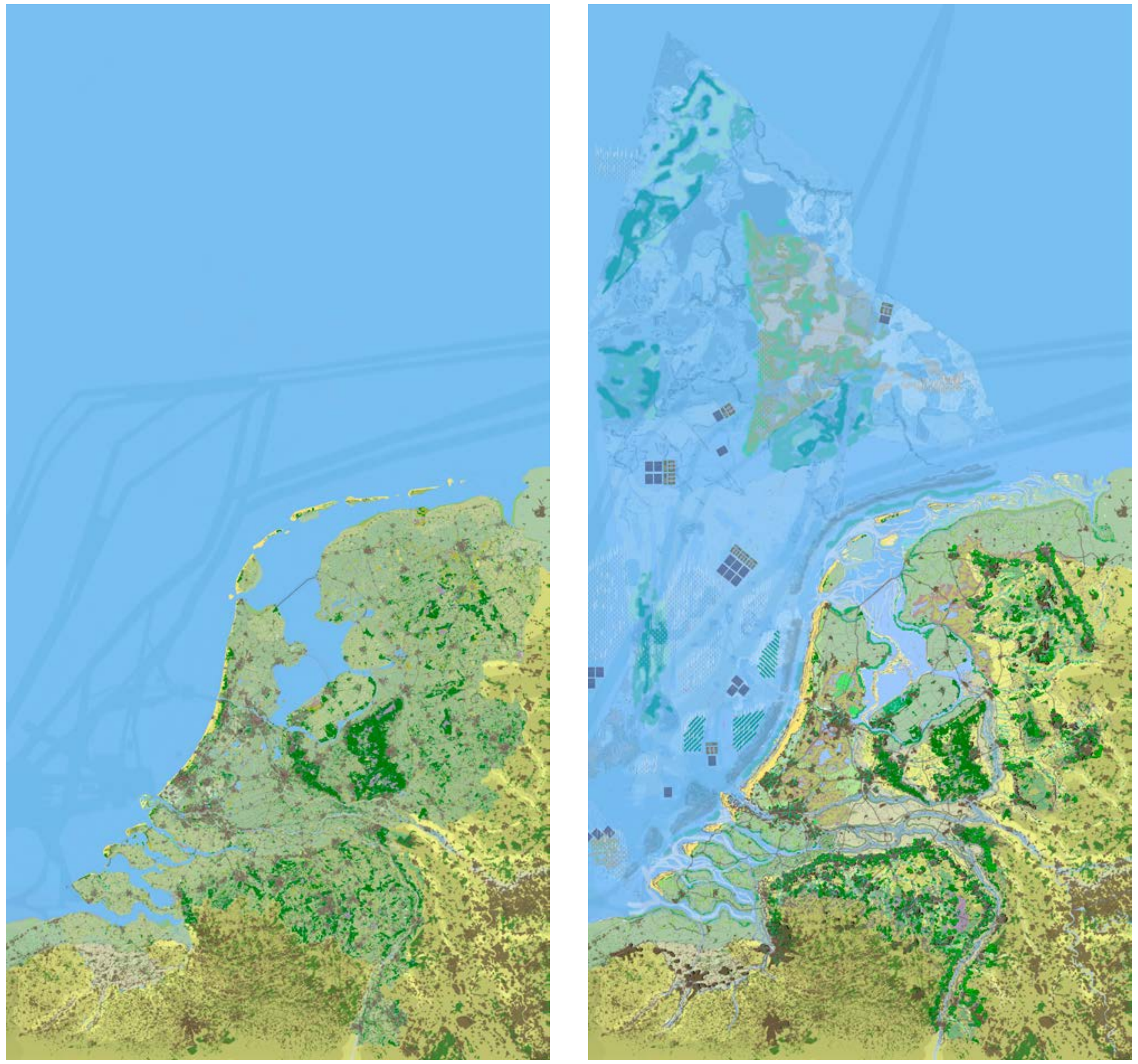


Source: Vogelzang et al., 2019

There are also major policy objectives for forests and nature conservation. The target for the national ecological network is an additional 40,000 ha by 2027; there is a similar target of 37,000 ha for the planting of new forests. The challenge is to find which sites are suitable and whether or not the soils are able to sustain multiple functions at the same time (agriculture, forestry, nature, water quality and the storage of water and carbon). However, this does not mean that all soils should be able to support all functions. Maps have been made for 2120 (Baptist et al., 2019) that are not based solely on the natural system as the guiding principle, but also on the optimal use of water, a nature-inclusive society, a circular economy and an adaptive spatial structure. Such maps should be worked up in more detail for specific regions according to the principle of 'function follows soil'.

The Council is not making a case for separate spatial development structures for different land uses (see Box 7). Based on firm conditions regarding the soil, it should be possible in an area-based process (Rli, 2016) to determine which functions can be permitted in an area and where certain functions are not possible. For farmers this would mean that in the short term they could adopt different agricultural systems that will make it possible to continue the same activities in their current locations. In the long run, a vision for the future such as Figure 5 could indicate a direction of travel, which implies some rearrangement of functions and land uses. These changes will have a major impact on the spatial development of the Netherlands. Priorities will have to be set regarding what should be done first and what can be done later.

Figure 5: Map of the Netherlands in 2020 and a vision for the future of the Netherlands in 2120



Source: Baptist et al., 2019

Box 7: Agricultural spatial structure

Arguments are sometimes put forward for defining a separate agricultural spatial structure, but in the opinion of the Council there are reasons for not doing so and for taking an integrated, area-based approach instead. In a number of areas in the Netherlands there is little discussion about the role of farming in the countryside, such as in the far north-east of the country (Noord-Groningen), the island of Noord-Beverland in the south-west delta (Zeeland) and the Flevopolder (province of Flevoland). For some areas it is also clear that nature should have priority, such as the Biesbosch National Park (at the head of the Hollands Diep estuary to the south-east of Rotterdam) and the Hoge Veluwe National Park north of Arnhem. However, in most of the country there will be a mix of functions and land uses. Competition for land is intensifying as the population grows and demands are made on land for things like carbon storage, solar farms and recreation. It will therefore be increasingly necessary to use land for more than one function. Moreover, past experience shows that the designation of agricultural development areas has not led to the desired results. In 2002 the regions with sandy soils were divided into three types of agricultural zones: extensification zones, mixed use zones and intensive livestock farming zones. In the areas where intensive agricultural activities were meant to be concentrated resistance was so great that the more intensive farms relocated to the mixed use zones where farming was supposed to be less intensive (Dienst Landelijk Gebied & LOLA Landscape Architects, 2010).

Sometimes it may make sense to reserve certain areas as soil protection areas, along the lines of water protection areas and quiet areas. These would be areas with soils that are so important for a specific function, such as food security or nature conservation, that they need to be protected. This would only be the case in a limited number of situations (Box 8).

Box 8: Example of a soil protection area for nature

Certain soils have such specific properties or relevance, not only for food security but also for nature conservation, that they deserve protection. An example would be zones around nature reserves and protected areas that can act as a buffer between nature and agriculture. These buffers can protect natural ecosystems and habitats from further degradation or loss of quality (as proposed in the letter from the Minister of the Interior, Box 4).

The national ecological network designates areas of existing natural ecosystems and habitats and areas that are to be converted to nature. But outside this network there may also be areas of soils with special properties that have such a special significance for nature that they should also be protected. Examples are small ecotopes[7] fed by mineral-poor and mineral-rich water, base-rich and base-deficient sloping fens, areas of groundwater seepage in the wet sandy soils landscape, willow and bog myrtle scrub (relevant for fauna) and birch-dominated swampy woodland. These ecotopes are generally found on soil and hydrological gradients in small-scale, naturally nutrient-poor, damp to wet and predominantly moderately acid and acid landscapes. These soil conditions are the reason why these ecotopes, despite their relatively small area, can contain valuable biodiversity. They are often isolated, which hampers the dispersal of the characteristic plant and animals species they support. Changes in the hydrological conditions, both quantitative and qualitative, present the greatest threats to the functioning of these special ecotopes (Bobbink et al., 2013).

Relocating and mixing land uses can be achieved by pursuing an active land policy. Such an approach is already being taken to resolve the nitrogen problem around Natura 2000 sites by buying out livestock farms (Tweede Kamer, 2020d). A few provinces are also taking steps towards an active land policy (Box 9). One option for steering the land market in the direction of the desired mix of land uses is to use the Municipalities (Preferential Rights) Act to oblige landowners when selling land to offer it first to the municipal or provincial authority. The Council realises that this area-based approach requires public sector investment in the short term, but is also aware that continuing on the current path will only lead to much higher costs in the end. For one thing, maintaining the same level of production is probably going to require increasing inputs of fertilisers and pesticides, and that means the costs of water treatment to maintain water quality standards will rise.

7 Ecotopes are the smallest ecologically distinct landscape features in a landscape mapping and classification system (Wikipedia.org, 2020)

Box 9: Examples of public land acquisition

'Province of Brabant uses purchase-leaseback arrangement to stimulate nature-inclusive farming

The province has reserved €30 million to buy agricultural land under a leaseback arrangement with the farmer. This will give farmers the financial leeway to buy the extra land they need to convert to nature-inclusive farming. … It is expected that the scheme will be taken up mainly by livestock farmers located close to protected areas. With additional land they will be able to convert to nature-inclusive farming, which makes use of ecological processes requires lower inputs of chemical fertiliser, pesticides and medication, and accommodates a greater diversity of plants and animals on the farm. A sustainable soil, a diverse soil biodiversity, and closed-loop mineral cycles form the basis of nature-inclusive farming.'
(Provincie Noord-Brabant, 2020 – translated from the Dutch)

Province of Friesland

The provincial government's coalition agreement (Provincie Fryslân, 2019) states that the province supports the idea of a land bank and will join with other public authorities to investigate the best form for this to take.

3.3 Step 3: Tune policy instruments to sustainable soils

Current national and international policies, legislation and guidelines (section 1.2) set down clear parameters for sustainable soils. However, they are not enforced and the current policy instruments are not adequate to meet these objectives. At the moment, both the food supply chain and the regulatory framework are geared towards the intensification of agriculture. As the Council has already reported, certain players in the food supply chain (particularly the major retail chains and food manufacturers) have considerable power over both producers and consumers (Rli, 2018). Until now the Dutch revenue model has been based on low-cost standard products, a strategy which has been behind the current huge volumes of Dutch agricultural exports and imports of animal feed. This intensification has a negative impact on soil properties. For example, the legislation encourages the use of manure as a fertiliser as much as possible, irrespective of the needs of the crops or the soil itself. There are also incentives to plough up grasslands more often, which is disadvantageous for the climate because it releases greenhouse gases. More information on agricultural governance can be found in Part 2, Chapter 3.

To steer policy towards sustainable soils it is necessary to remove the pressure for intensification, as that is what has led to the current problems. However, the remit of this advice is not to change the current agricultural system, but to steer policy towards sustainable soils. In the Council's opinion, the policy instruments needed for this should include at least the following: improve the monitoring and knowledge system, amend the legislation and regulatory instruments, deploy targeted remuneration packages and introduce restoration measures. The Council gives examples that illustrate how the regulatory framework steers developments in the wrong direction (Part 2, Chapter 4). As this report is agenda-setting in nature, our advice is limited to examples of the type of approach that could be taken. The Council hopes that these examples will show the direction the amendments to the legislation should take. Some amendments could be made in the short term, for example because the laws or regulations in question are currently under revision; other amendments must be set in motion now in order to be completed in the longer term.

It may be helpful to translate the above steps into the following more specific principles:

- Less tillage and less use of heavy machinery promote sustainability of soils.
- More crop diversity and more break crops promote sustainability of soils.
- Deeper rooting crops promote sustainability of soils.
- Maintaining the levels of water tables instead of lowering them promotes sustainability of soils.
- Lower inputs of chemical fertiliser and pesticides promotes sustainability of soils.
- More solid manure and less slurry promotes sustainability of soils.
- Opportunities for farm expansion and lower land prices reduce the need for intensification and promote sustainability of soils.
- Forest harvesting within the limits set by the nutrient balance maintains sustainability of soils.

These principles can be used to check whether steps are being taken in the right direction.

3.3.1 Monitoring and knowledge system

---

*Recommendation 3 to the authorities: Improve the monitoring and knowledge system so that it covers **all** rural soils and gives insight into soil sustainability and the ability of the soil to support **all** functions.*

The current monitoring and knowledge system has not been designed with the objective of sustainable soils that can sustain multiple land uses and functions. There are a number of reasons for this:

1. Measurements are not made on a systematic basis. There is no accepted and/or nationally adopted method for measuring all the functions a sustainable soil should perform. The measurement methods apply only to agricultural soils and not to forest or natural soils.
2. Measurements are not independent and it is not clear who is permitted to use the data and for what purposes.
3. Much is known about soils, but much remains unknown.
4. There is a lack of knowledge among stakeholders.

Enshrine a national measurement system in the National Environment and Planning Strategy

The Council is aware that at the time of preparing this advice work is progressing in the national programme on agricultural soils (*Nationaal Programma Landbouwbodems*) to develop an accepted measurement instrument. A number of agreements are being made with players in the food supply chain. The Council notes that there are several measurement systems (see Box 10). When developing a national measurement system it is important that the indicators are based on soil sustainability and not just on the old indicators for soil fertility for agriculture. The Council argues for a single national index that is consistent with the idea that soils can be used for more than one function. In other words, one that provides information on how a soil supports the range of uses and functions (agriculture, forestry, nature, water quality and the storage of water and carbon). The monitoring system must cover all rural soils (forest, nature and agriculture) and its independence must be guaranteed. It must also be future-proof, for example by investigating how citizen science and high-tech solutions could play a part in sharing and interpreting data. Enshrine the chosen national system in the National Environment and Planning Strategy.

Box 10: Different measurement systems for agricultural and natural soils

The indicator set for agricultural soils in the Netherlands (*Bodemindicatoren voor Landbouwgronden in Nederland* – BLN) consists of 17 indicators for assessing the quality of agricultural soils. Besides the name and unit of measurement, the BLN states how each indicator can be measured, using a standard and/or a quick and cheap method. Selected indicators can be used for specific forms of land use, soil types and assessment objectives. The indicator set is based on soil fertility and carbon storage properties (Hanegraaf et al., 2019).

Rabobank, a.s.r. (real estate insurers) and Vitens (drinking water company) are developing the Open Soil Index (*Open Bodem Index* – OBI). This index is expressed as a single score for soil quality. The index takes account of the soil type and the use to which it is put, and is compiled from measurements of biological, physical and chemical properties and processed management data (such as cropping plan and tillage). The index is limited to agricultural soils and in its current stage of development focuses primarily on soil functions for sustainable agricultural production. Other functions may be incorporated at a later date (Openbodemindex.nl, n.d.).

A set of critical performance indicators (CPIs) is being developed under the circular agriculture implementation programme (*Uitvoeringsprogramma Kringlooplandbouw*). These CPIs should provide information for use in determining remuneration or financing packages in support of revenue models for food supply chains (Erisman J.W. & F. Verhoeven, 2019). The preliminary study has investigated the following soil properties: organic matter management, soil compaction, crop diversity, crop protection, nutrient management and water management. The total set of CPIs covers additional parameters, such as biodiversity, farming intensity (the degree to which farm management is land based) and inputs (e.g. nitrogen and protein), climate impact and CO_2 storage, and water buffering and water quality. The CPIs are designed to promote quality improvement without prescribing any specific measures to allow room for local solutions and for the development of methods and practices for an integrated approach in which insight into the linkages between various management methods is more important than a total score. The Council has previously advised on an integrated points system for the CAP to allow for a more flexible and adaptive steer towards circular agriculture (Rli, 2019).

For natural soils use is made of the ITERATIO computer program. This program uses vegetation mapping to derive terrain conditions (abiotic value maps) based on the strong correlations between soil conditions and vegetation. This means that fewer direct measurements are needed and these are based on the natural functioning of the soil (Synbiosis. alterra.nl, n.d.).

Perform measurements at different scales

To obtain a good understanding of the effects and value of soil management techniques it is necessary to obtain a long-term series of reliable measurements on an appropriate spatial scale. National and provincial monitoring networks that were set up in the past to measures the effects of policies on the soil have in recent years either been abandoned or were set up on a spatial scale inappropriate for informing land management practices. Data collection has been fragmented, with varying sampling intensities and locations, and using different methods of sampling and analysis. The Council therefore advises taking measurements on different scales and at set times in line with nationally determined measurement methods. These data should be transferable to farm suppliers and advisers and to landowners (where land is leased or rented) in the interests of a transparent land market and improved soil sustainability (comparable with house energy labels and clean soil certificates).

Make data transferable and public

Farmers are given advice on soil management and cropping plans from suppliers of fertilisers and pesticides. Interpretation of data by third parties such as these is therefore seldom independent.[8] Alternatively, farmers can pay consultants for advice, but that will often involve a return-on-investment time that is too short for sustainable soil management. Also, the data needed for all this advice are often not made available to farmers or are not available for further use. The ownership of data is not clearly regulated and data are often 'lost' to private parties. There is no collective management and no exchange mechanism for obtaining new insights from larger datasets or for giving feedback, whereas much is expected from the application of data science (artificial intelligence).

The Council therefore feels it is important that agreements made on data ownership should follow the principle of open data as this would make it possible to implement soil management practices for sustainable soils and to remunerate users of the soil for doing so. It would also be advisable

8 Appropriate land use, an active land policy and independent knowledge dissemination have been put forward as solutions. This raises the question of whether the Council should argue for the reuse or resurrection of the rural land development policy instruments, the land bank or the Government Service for Land and Water Management (DLG). The answer is no. Far more important is that there is a sense of urgency among the public authorities and value chain parties. Organisations must want to work together, because they could then bundle their knowledge. A new organisation is not necessarily needed, but a new working relation – a new form of governance – is.

to make agreements on the conditions under which data should be made available, the way they are to be exchanged and who should be permitted to use them, with the aim of preventing certain market participants becoming too dominant should open data not be a possibility. This aspect of the government's ICT policy needs to be tightened up (Tweede Kamer, 2019g).

Commitment to the dissemination of knowledge through mutual learning
The Council places particular importance on learning from each other as this can help to make the shift in governance more socially and culturally acceptable. Farms are not isolated entities, but are embedded in a social and cultural context (what type of farmer are we talking about, how do they see their role, what group do they belong to, and what values, norms and opinions do they hold?). Farms are part of a value chain (which chain does the farm belong to and how is it influenced?) and use resources (where do they come from?). Ultimately, it is the personal views and preferences of the farmer that determine the way the farm is run (Methorst, 2016; Westerink et al., 2019). Also, it is important that this knowledge is not only disseminated among farmers and their suppliers and advisers, but also among foresters and conservation managers.

Knowledge development remains necessary
We know much about soils, but much remains unknown. In general, far too little research is being done into the functioning of natural and forest soils. The research effort has recently picked up, for example in the OBN Knowledge Network for Nature Restoration and Management (Ontwikkeling + Beheer Natuurkwaliteit, n.d.), but much of what is known remains indicative and conceptual. An obstacle is that forestry and nature conservation cannot draw upon substantial co-financing, which prevents long-term research in these sectors from getting off the ground. The ministry finances knowledge development via public-private partnerships (Tweede Kamer, 2019a), while fundamental research into soils and soil ecology is financed nationally by NWO (the Dutch Research Council) and internationally. Data and expertise from farmers, foresters and conservation managers can help the research effort. Indicator sets must be dynamic so that they can incorporate new insights. The systematic collection of data can increase knowledge about soils and lead to better understanding of how the soil system works.

An important knowledge gap concerns the restoration of damaged soils. Some areas of natural and forest soils on the 'higher sandy soils' have been irreversibly altered by deposition of sulphur compounds and ammonia in particular. Knowledge needs to be acquired on possibilities for restoration.

3.3.2 The regulatory framework

Recommendation 4 to national government: Identify where the regulatory framework facilitates sustainable soils and where it frustrates the development and maintenance of sustainable soils. Change those provisions that work against sustainable soils.

The national government is pursuing policies for soils on a number of fronts: in the National Environment and Planning Strategy (*Nationale Omgevingsvisie*), through its Soil Strategy (*Bodemstrategie*) and in its vision on the environment (*Milieuvisie*). Soil sustainability is also heavily influenced by many other policies (fertiliser, agricultural tenancy and fiscal policies), but these do not ensure that national and international objectives are achieved and guidelines complied with (Part 1, section 1.2). The regulatory framework is still geared mainly towards increasing agricultural production and the associated intensification of the use of agricultural soils. It enshrines the interests and investments of the established parties. An example is the investments in animal housing with slurry collection systems and manure injection equipment, which will obstruct the move towards solid manure management (one of the principles for sustainable soils mentioned earlier). Similarly, the legislation on agricultural tenancy has always protected the position of the tenant and in recent decades has been liberalised to support specialisation in high-yielding crops (flower bulbs, vegetables, trees). The land user therefore has no long-term interest in the proper management of the soil. Landowners can, however, include requirements for sustainable management as conditions in short-term contracts. These could be made compulsory in the interests of sustainable soil management and based on results obtained using the national measurement method. The position of landowners who want to set sustainable soil management conditions when renewing the lease can also be strengthened. In Chapter 4 of Part 2 a number of examples are given of how the regulatory framework obstructs the move to sustainable soil management and how it should be amended.

3.3.3 Remuneration packages

Recommendation 5 to all parties: Use remuneration packages to stimulate good practice, backed by a set of critical performance indicators.

Agricultural products command a price, but nature does not, while timber yields from Dutch forests are limited. Ecosystem services generate some additional income, but this is not sufficient to make it possible for land users to adopt proper sustainable soil management practices. In the current situation, farmers do not necessarily benefit in the short term from good soil management. Moreover, if they have no-one to take over the farm when they retire, it is questionable whether investments in soil management can be recouped in the price of the land.

Bouma et al. (2020) say that nature-inclusive farming, which is inextricably linked with sustainable soils, will only be scaled up if smart financial incentives are provided. Because soils – including natural and forest soils – will have to perform multiple functions, the Council thinks it is only logical that payment should be made for these functions. Where farmers, foresters and conservation managers can demonstrate from the results of the national measurement method that they are on the right track, they should be eligible for remuneration. Appropriate arrangements will have to be worked out in detail. Another approach is the creation of added value through regional branding, such as dairy products from the Weeribben area – niche products from a region where organic farmers produce higher-valued dairy products. Such regional approaches can be pursued through area-based strategies. Additional training could be encouraged by awarding farmers CAP bonus points for training.

All this would result in multiple remuneration possibilities to support sustainable soil management. This is equivalent to the CPIs proposed in the Delta Plan for Biodiversity Recovery (Agrifirm et al., 2018). Eco-schemes under the CAP could be integrated into these remuneration packages (Rli, 2019).

3.3.4 Restoration measures

Recommendation 6 to the authorities: Stimulate restoration work in forests and natural ecosystems.

The Integrated Approach to Nitrogen programme (*Programmatische Aanpak Stikstof* – PAS) contains 1,847 measures to bring about the restoration of nitrogen-sensitive ecosystems in 118 Natura 2000 sites. These measures are to be completed by 2021. Various funds were made available, some of which are for management (Box 11). The provinces and three ministries – Agriculture, Nature and Food Quality; Infrastructure and Water Management; Defence – are responsible for implementing these measures. The programme is on schedule (BIJ12, 2019): 516 measures have been completed (as of 31 March 2019) and 1,255 measures are still being implemented.

Box 11: Finance

‘In the Nature Pact (*Natuurpact ontwikkeling en beheer van natuur in Nederland*) the national and provincial governments have agreed that funds made available for the provinces under the Pact will be used by them for restoration management and hydrological measures in Natura 2000 sites under the PAS programme and also for the management of Natura 2000 sites in general. These funds are an additional €100 million for 2014 and 2015, €300 million for 2016 and 2017, and €200 million for the remaining years. The Minister of Agriculture, Nature and Food Quality has also made funds available for the programme as part of the original €120 million intensification of the programme as stated in the coalition agreement of the Rutte I Government. These funds amount to €29.9 million for 2014 and €13.5 million for 2015–2018’ (Rijksoverheid, 2017 – translated from the Dutch). In February 2020 an additional €125 million was made available for a regulation on targeted measures for habitat restoration and reducing the nitrogen sensitivity of ecosystems by conservation management organisations (Tweede Kamer, 2020e). In addition to this, in the period 2021–2030 investments will be made each year in specific areas to ensure the most effective restoration measures are taken, up to a total amount of €300 million (Tweede Kamer, 2020f).

Protecting nitrogen-sensitive ecosystems in Natura 2000 sites is just one element of the measures that are needed to restore forest and natural soils. Many areas of natural and forest soils on the ‘higher sandy soils’ (including some outside Natura 2000 sites) have been irreversibly altered by deposition of sulphur compounds (until the 1990s) and ammonia (until the present and near future). All the nutrients that have leached from soils as a result of these depositions will not be replenished naturally and so specific measures will have to be developed and implemented. This means that the damage to the soil system that has been done over the past 60 to 70 years will have to be restored.

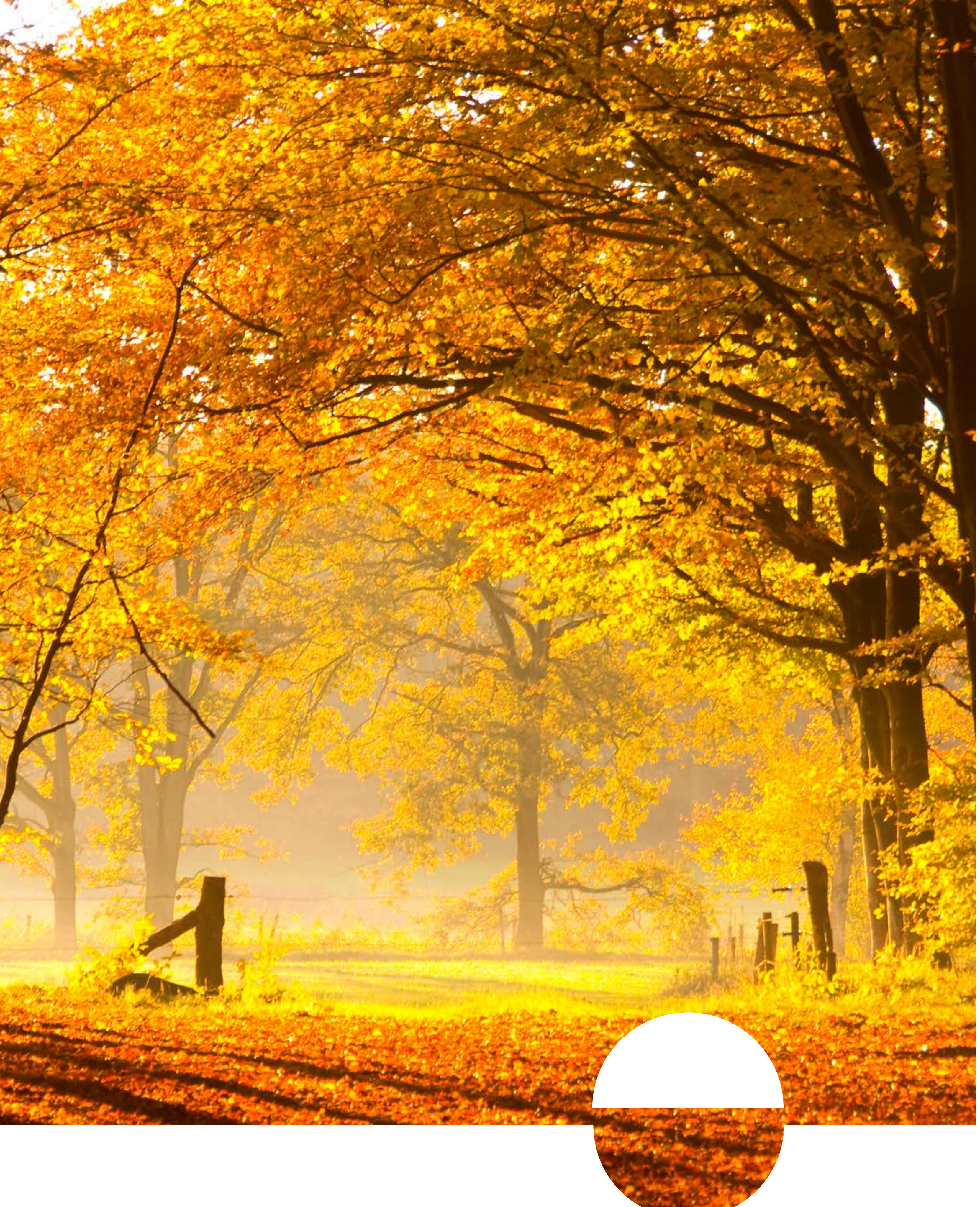
The Council advises the government to take active measures for the restoration of forest and natural soils, including soils that are not covered under the PAS programme, and to make subsidies available for ecosystem and soil restoration. It is important that the restoration measures include the necessary climate change adaptations, with a key role for the OBN Knowledge Network for Nature Restoration and Management. This independent knowledge network was established by the Ministry of Agriculture, Nature and Food Quality, BIJ12 (on behalf of the twelve provinces) and the Dutch Forest and Nature Reserve Owners Association (VBNE) and generates strategies and measures for a structured approach to ecological restoration and management. This knowledge is used for the implementation of important policy items such as Natura 2000, species conservation policy, the development and management of cultural landscapes and the conversion to nature of newly acquired agricultural land.

PART 2 | ANALYSIS

READER'S GUIDE

This second part of the advisory report gives background information on various topics discussed in Part 1.

Chapter 1 explains the properties of a soil that determine whether or not it is sustainable and gives an overview of the state of these properties in the different types of soil. The properties are organic matter content, soil chemistry, soil biodiversity, and soil structure. Chapter 2 describes the land uses and functions that depend on sustainable soils: agriculture, forestry, nature, water quality and the storage of water and carbon. Chapter 3 gives an explanation of the how agriculture has become intensified in the Netherlands. Chapter 4 describes several aspects of the regulatory framework that hinder the move towards sustainable soils.



1 PROPERTIES OF SUSTAINABLE SOILS

Soil sustainability is under pressure. The sustainability of a soil is the result of a complex set of interactions between soil structure, soil chemistry, soil biodiversity and organic matter content. In sustainable soils these properties are in a state of equilibrium, which allows them to fulfil several vital functions, but the interactions between these properties have been disrupted and soils are becoming unstable (see Table 2). Agriculture is dependent on the use of fertilisers and pesticides, but these also have adverse effects on the soil and on other land uses.

The differences between soils, and even between neighbouring fields, can be large.

Table 2: Overview of the status of soil properties in the Netherlands

	Agricultural soils	Forest soils	Natural soils
Area/% soil in NL (total includes water) (CBS, 2018a and 2020)	2,220,806 ha (54%) of designated agricultural land, of which 1,816,319 ha is actually under agricultural use	341,270 ha (8%)	95,055 ha (2%)
Soil structure (Van den Akker, 2019)	50% is compacted; arable land is more compacted than grassland, particularly due to the high wheel loads of agricultural vehicles	Increasing compaction caused by timber harvesting from production forest, especially the use of flail mowing[9] and the high wheel load of harvesting machines	Unknown
Soil chemistry (Beltman et al., 2019 and CLO, 2019)	Addition of nutrients, heavy metals, pesticides and other substances (e.g. lime) through the application of manure, nutrients and pesticides; current status of chemical soil fertility (nutrients and heavy metals for food production) is good to high in the Netherlands in relation to the standards that apply	Addition of nutrients, heavy metals and other substances via atmospheric deposition (particularly sulphur and nitrogen), via groundwater and surface water, and sporadically through the addition of fertilisers (e.g. rock dust in forests on poor sandy soils)	Addition of nutrients, heavy metals and other substances through atmospheric deposition (particularly sulphur and nitrogen), via groundwater and surface water, and sporadically through the addition of fertilisers
		92% critical load for nitrogen deposition exceeded	72% critical load for nitrogen deposition exceeded
Organic matter content (Koopmans & Van Opheusden, 2019)	Arable land 3–4%, maize fields 4–5% and grassland 7–9%; large regional differences and differences between fields within a farm, with some fields below the critical threshold of 1.5%	Depending on the soil type: sandy, loamy and wetland soils 5–10%, clay and peat soils 12–16%	Depending on the soil type: poor sandy soils 1%, peat soils 40%
Soil biodiversity (Van der Putten, 2019)	Nutrient balance is disrupted, allowing bacteria to become too dominant, leading to a reduction in soil sustainability	Nutrient balance is disrupted, allowing bacteria to become too dominant, leading to a reduction in soil sustainability	Nutrient balance is disrupted, allowing bacteria to become too dominant, leading to a reduction in soil sustainability

9 Mulching rough vegetation with the use of high-speed rotating steel drum-type cutters.

1.1 Soil structure

Soil compaction is defined as densification and deformation of the soil structure (Figure 6). It is particularly problematic in agricultural soils and in forest soils where timber is harvested. The subsoil in about 50% of agricultural soils in the Netherlands is compacted, and arable soils are generally more compacted than grassland soils. Compaction is caused mainly by mechanical stress from the wheel loads of agricultural and forestry vehicles. Wet soils are weaker and more susceptible to compaction than dry soils. Compaction reduces porosity due to the compression of the soil volume. It deforms the soil, causing a loss of structure that disrupts the continuity of the flow of air and water through the drainage channels (macropores) and leads to a homogenous and structureless material. Compaction considerably degrades vital soil properties such as water and air permeability, infiltration capacity, water storage, rootability and oxygenation. Reduced infiltration capacity and permeability to water increase the risk of soil erosion and nutrient losses due to runoff and denitrification[10] (Van den Akker, 2019).

There is a difference between the effects of compaction in topsoil and subsoil. Most of the root mass and soil organisms are found in the topsoil. This is where most water and nutrients are extracted, and where most of the formation and exchange of oxygen and other gases with the atmosphere take place. The topsoil absorbs rainwater and wind, retains water and transfers excess water to deeper layers, thus preventing surface runoff. In dry periods some plant roots have to penetrate into the subsoil to extract water and nutrients. It is also important that the soil contains channels through which water can travel from the topsoil to deeper layers. Compaction of the subsoil adversely affects both rooting depth and infiltration capacity (Van den Akker, 2019).

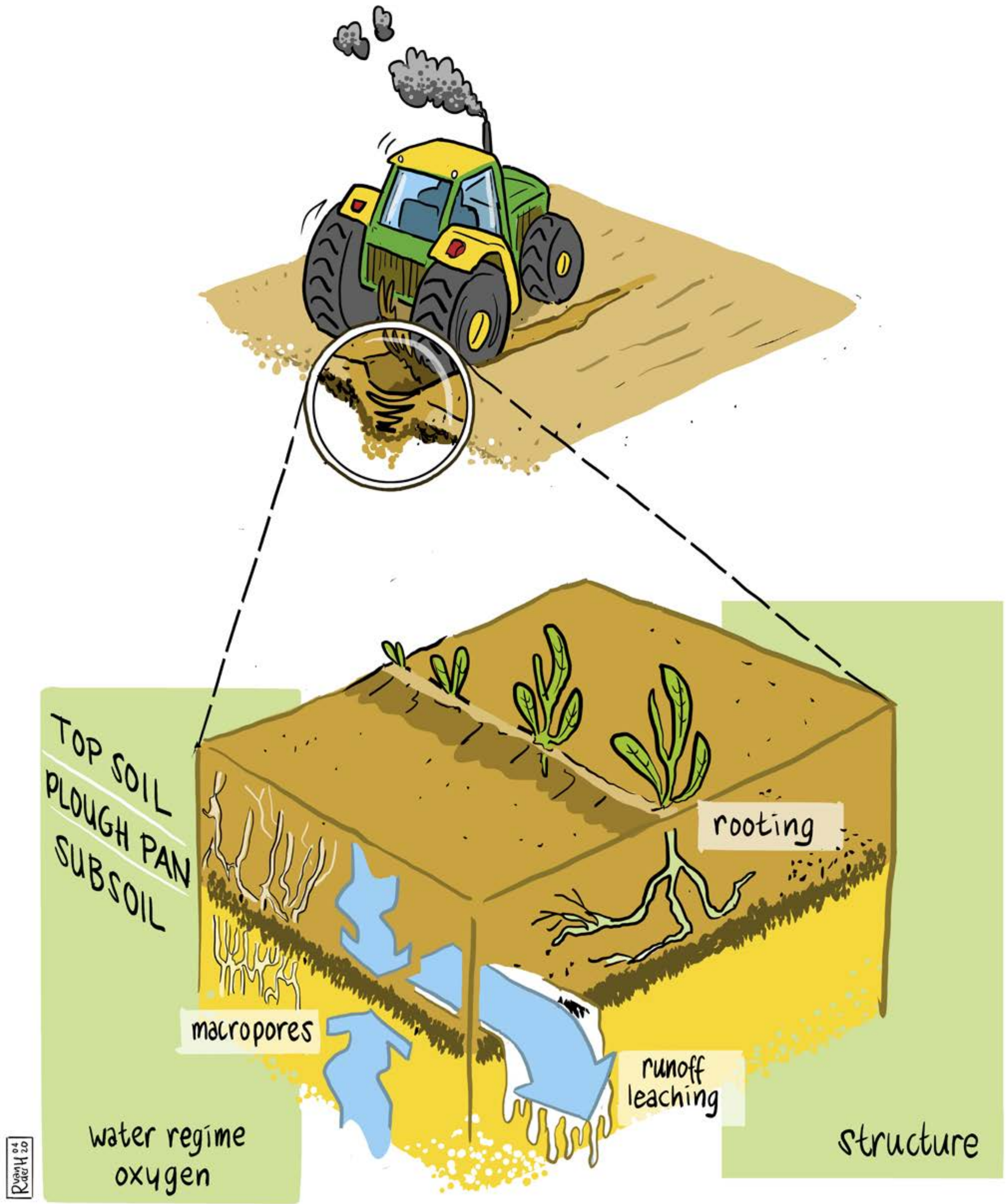
10 'Denitrification, a microbial process in which nitrate is broken down into gaseous nitrogen compounds, occurs in soils under anaerobic conditions in the presence of biodegradable organic matter' (Beltman et al., 2019).

Mechanical pressure from machinery often leads to the formation of a plough pan, a less permeable layer in the upper subsoil. This effect depends among other things on the size of the tractor tyres, the wheel load and the tyre pressure. Roots and water are less able to penetrate this hardpan and reach the subsoil below. The subsoil is not broken up each year because this is costly and working the soil to this depth requires dry conditions. This compaction of the subsoil is therefore a cumulative process which eventually leads to a partially permanent homogenous compacted subsoil. Repairing subsoil compaction is a lengthy process.

Topsoil compaction can be repaired by ploughing, although this has adverse effects on the soil organisms. These can be avoided through the use of non-inversion tillage, a ploughing method in which the topsoil is loosened by a ripper.[11] Another method is to use machinery equipped with lower pressure tyres or tracks. Natural methods of recovery are frost, freeze drying, desiccation shrinkage, swelling, rooting and soil organisms (Van den Akker, 2019).

11 Rippers are agricultural machines with long tines that can be used to break up compacted soil (Wikipedia.nl, 2017).

Figure 6: Half of all agricultural soils are compacted



1.2 Soil biodiversity

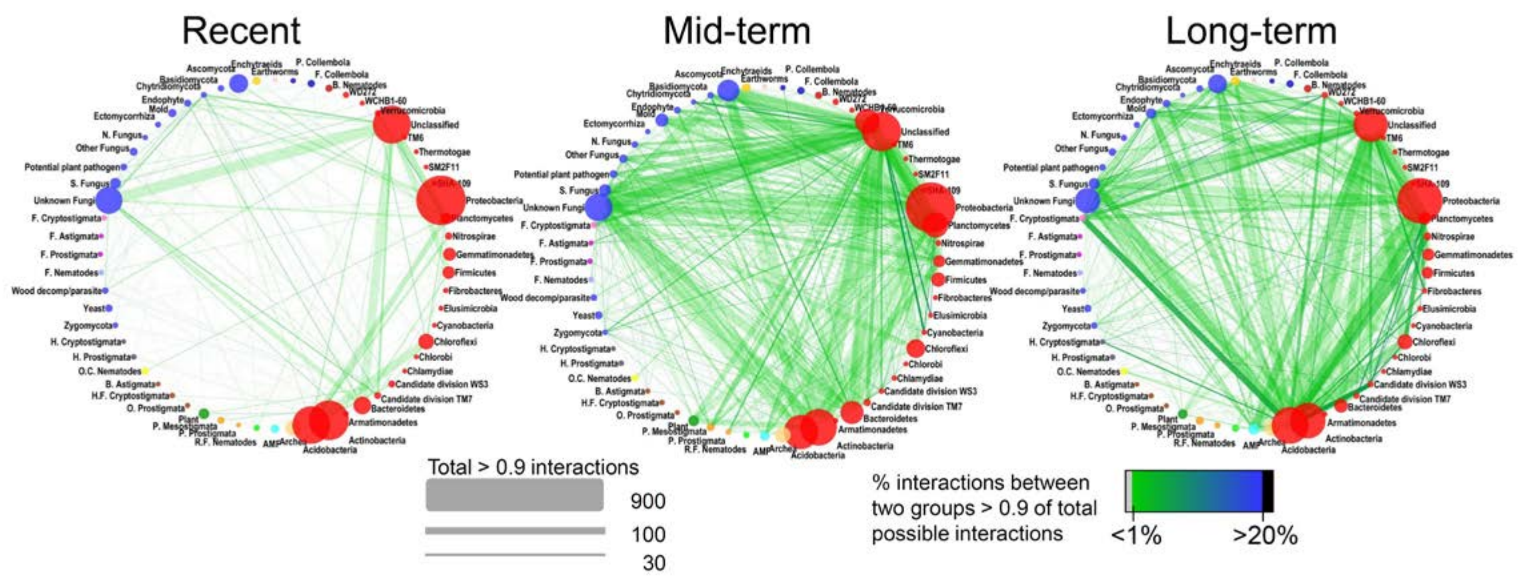
Sustainable soils contain a wealth of organisms. A handful of soil can contain as many as 5,000 species and the total number of soil organisms is about the same as the number of people on the planet (about 7 billion). In comparison, there are 1,400 native plant species in the Netherlands; if garden plants are included the total comes to around 4,000 to 5,000. Most soil organisms belong to one of four groups: bacteria, fungi, Archaea and Protisten. Other types of organisms found in the soil are viruses, nematodes, tardigrades, potworms, springtails, mites, isopods, spiders, earthworms, moles and other invertebrates and vertebrates.

Sustainable soils contain a food web in which many species of organisms interact with each other. Bacteria and fungi break down organic matter and are eaten by protozoa, nematodes, potworms, springtails and mites. This releases nutrients such as nitrogen and phosphate, which are taken up by plants. The soil organisms are in turn eaten by other organisms, which again releases nutrients (De Ruiter et al., 1995). Eating and being eaten ensures that nutrients are continually being released into the soil to support plant growth and helps to improve soil structure. The more interactions there are between species, the more stable the food web becomes. A soil food web with many links between species is more sustainable than a food web in which there are few links between organisms (Figure 7).

A good relationship between fungi and bacteria increases the resilience of the soil to diseases, pests and extreme weather conditions. Fungi break down organic matter more slowly (slow food consumers) than bacteria (fast food consumers) and consume less oxygen. This slower rate of decomposition allows other organisms to take up more of the released nutrients. In soils where bacteria have become too dominant, the organic matter is broken down too quickly and the nutrients are more readily leached from the soil, which in turn has consequences for biodiversity. In soils where the relationship between bacteria and fungi is disrupted there are fewer interactions between species. The soil food web then regresses from a fully evolved system to an unstable pioneer system (Van der Putten, 2019).

Intensification of land use leads to a decline in soil biodiversity, in the complexity of the soil food web and in the biomass of most groups of soil organisms. Only herbivorous organisms sometimes increase in number (Van der Putten, 2019). These effects on soil biodiversity also have consequences for the above-ground biodiversity (Part 2, section 2.4). Biodiversity is also important for agriculture (Erisman & Slobbe, 2019).

Figure 7: Development of networks of soil organisms in agricultural soil in the South Veluwe region that were taken out of production in the following three periods in the past: Recent (5–10 years ago), Mid-term (10–25 years ago) and Long-term (>25 years ago). The dots on the edges of the circles represent soil organisms (bacteria, fungi, springtails, mites, potworms, nematodes, earthworms, plants). The green lines between the species groups indicate that species occur together (correlated). Multiple and thicker lines indicate higher numbers of correlated species. The diagrams show that correlations between species in soil communities increase rapidly between the Recent and Mid-term time periods. Increasing correlation indicates a more efficiently functioning soil food web.



Source: Morriën et al. 2017

1.3 Soil chemistry

Organisms need nutrients to grow, especially nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and sulphur (S), and the trace elements boron (B), molybdenum (Mo), manganese (Mn), copper (Cu), cobalt (Co), selenium (Se), zinc (Zn) and iron (Fe). The soil supplies these nutrients (Figure 8). In agricultural soils the loss of nutrients is made up by applying chemical fertiliser and manure.

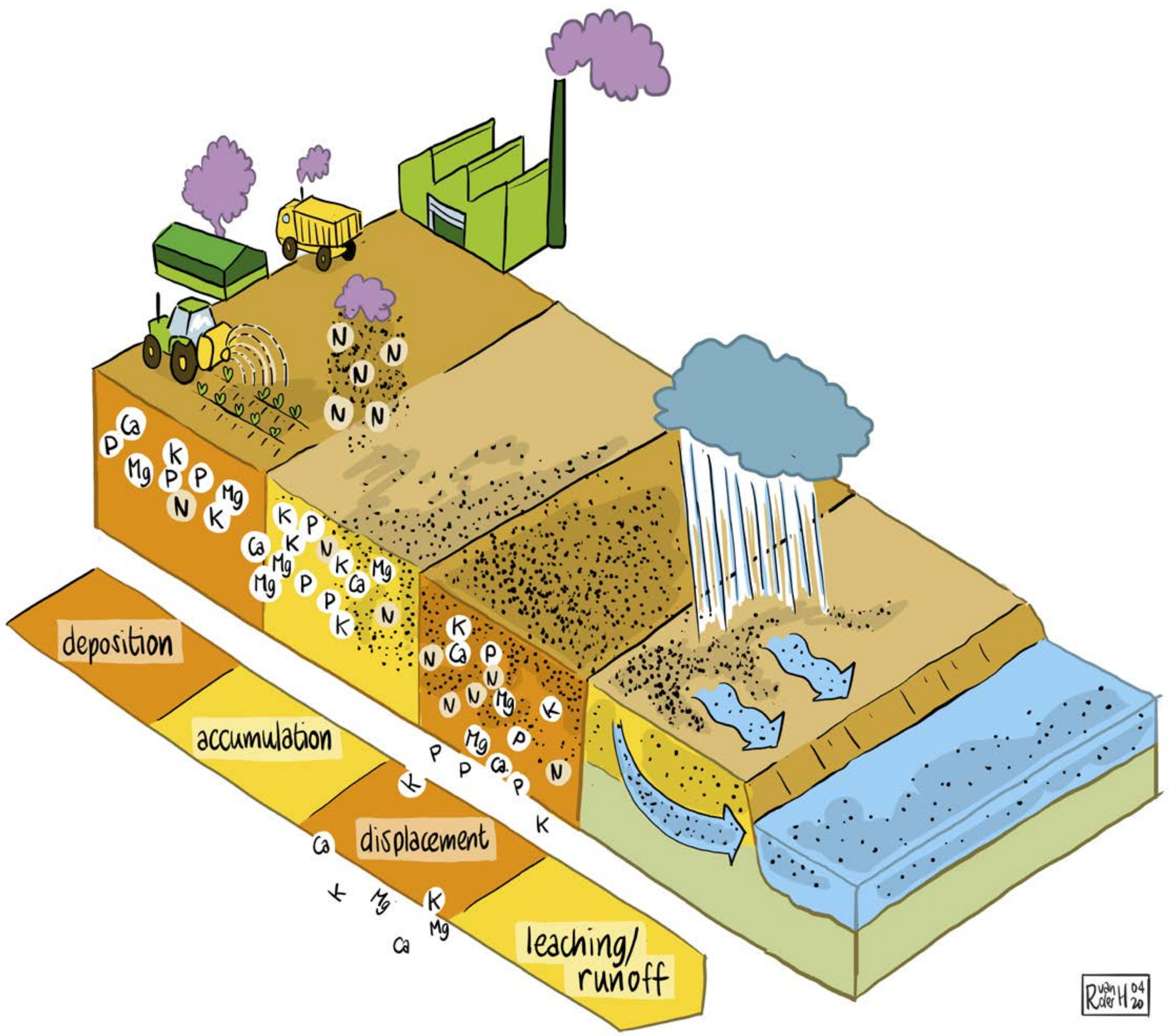
The long-term deposition of nitrogen and sulphur compounds on Dutch forest and natural soils has disturbed the chemical composition of these soils. The accumulation of nitrogen has led to nitrogen-saturated soils, with nitrogen present in excessive amounts in relation to other important nutrients and trace elements. The consequence of this is persistent acidification of these soils and lower availability of other nutrients such as calcium (Ca), potassium (K), magnesium (Mg) and phosphorus (P). Acidification can also lead to the release of toxic soluble aluminium ions in soil moisture in forested sandy soils. The effects of nutrient imbalances are directly visible in the vegetation and biodiversity and are exacerbated by drought (Beltman et al., 2019). In addition, in forests on dry sandy soils, where branches and top wood are harvested as well as timber, there is a chance that more nutrients are lost than are replenished by the conversion of organic matter. This leads to further impoverishment of the soil (Vereniging van Bos- en Natuurterreineigenaren, 2017).

The chemical soil fertility (nutrients and heavy metals) of Dutch agricultural soils is good to high for agricultural purposes (Beltman et al., 2019).

However, the soil chemistry is being disrupted by the application of fertilisers, nutrients and pesticides. Besides the desired effect of increasing yields, this disruption of soil chemistry – as well as compaction of the soil – also leads to negative effects, such as impacts on nature and leaching and runoff of nutrients and pesticides to groundwater and surface water. The bulk of nutrients in surface water bodies have come from leachate (via groundwater) and runoff (over or through the soil) from agricultural soils: 54% of the nitrogen and 56% of the phosphorus. A considerable part of this leaching is caused by the accumulation of nitrogen and phosphate in the soil from fertiliser applications in the past: 68% of the nitrogen and 33% of the phosphorus (Van Galen & Van Grinsven, 2017). As a result, the quality standards for surface water and groundwater in the WFD, the Groundwater Directive and the Nitrates Directive are not being met. Although the policy for phosphates has in fact led to a fall in phosphate levels in some arable soils, the stocks in the soil are still high and so this has so far not caused any problems for agricultural production (Beltman et al., 2019).

An unknown factor in soil chemistry are the rising levels of hazardous and ‘new’ substances such as pesticides, per- and polyfluoroalkyl substances (PFAS), nanoparticles, microplastics and veterinary and human medicines. The effects of these substances on nature and agriculture are often unknown (Beltman et al., 2019).

Figure 8: Effects of disruptions to the soil chemistry



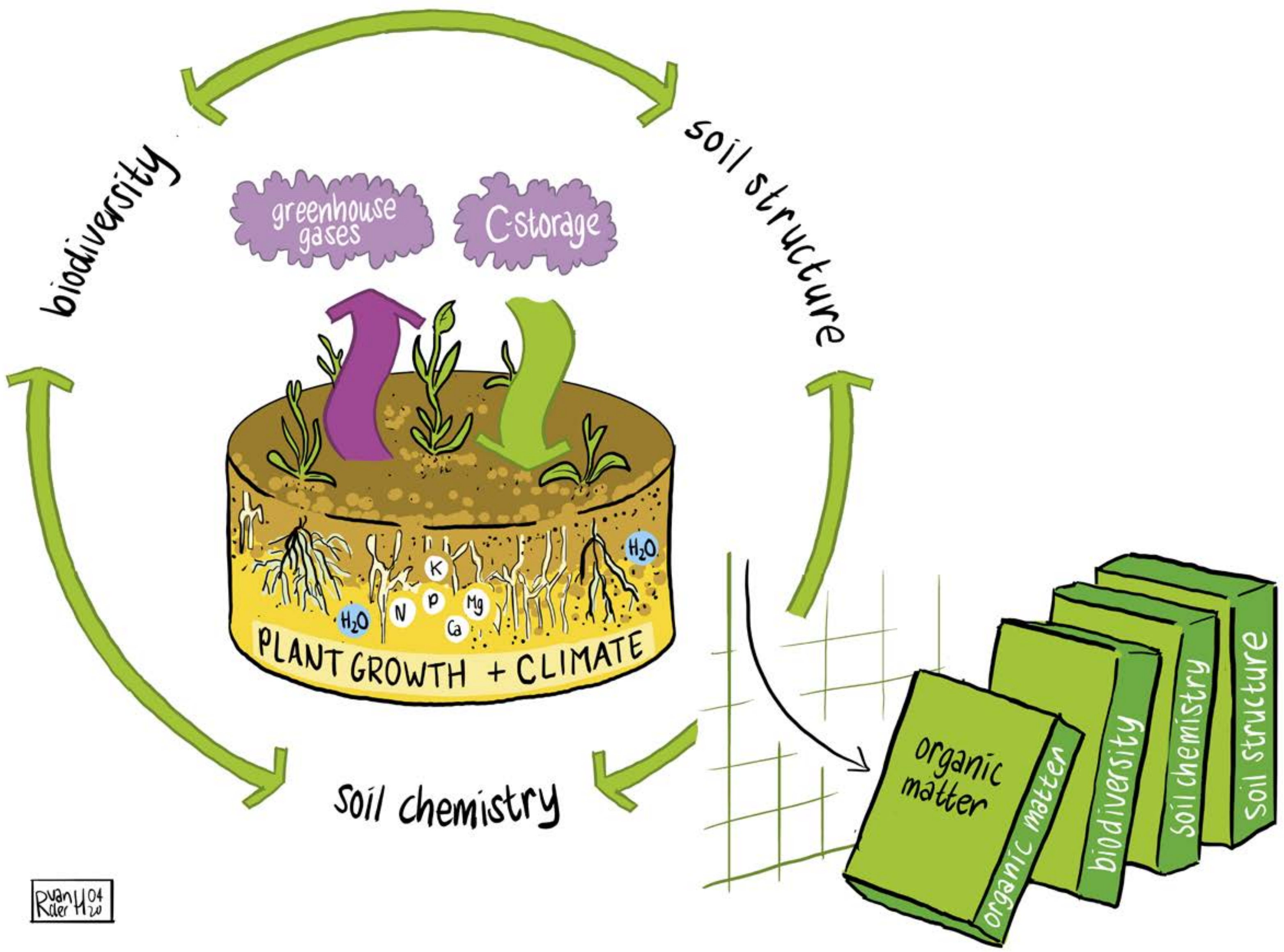
Precision agriculture, which is based primarily on ecological principles and reinforces natural processes, can help to build sustainable soils on agricultural land. Supplementary resources are only needed to combat pests and diseases if necessary. Precision agriculture enables more precise measurement of soil quality and more efficient administration of pesticides and nutrients. As a consequence, leaching of nutrients to water is reduced, which in turn reduces the impact on forest and natural soils. Precision agriculture also opens up the possibility of using less heavy machinery, which means less compaction.

In forests experiments are being conducted with applying rock dust to reduce the effects of high nitrogen concentrations. A degree of recovery appears to be possible, although this is accompanied by the release of mobile nitrates from the organic matter in the soil, which then leach into the groundwater.

1.4 Organic matter

Soil organic matter is an umbrella term for various types of material of organic origin, 40–65% of which consists of carbon (Koopmans & Van Opheusden, 2019). It consists of both dead organic material, such as undigested plant residues, and living organic material, such as roots, bacteria and other soil organisms (Koopmans & Van Opheusden, 2019; Figure 9).

Figure 9: Properties of soil organic matter

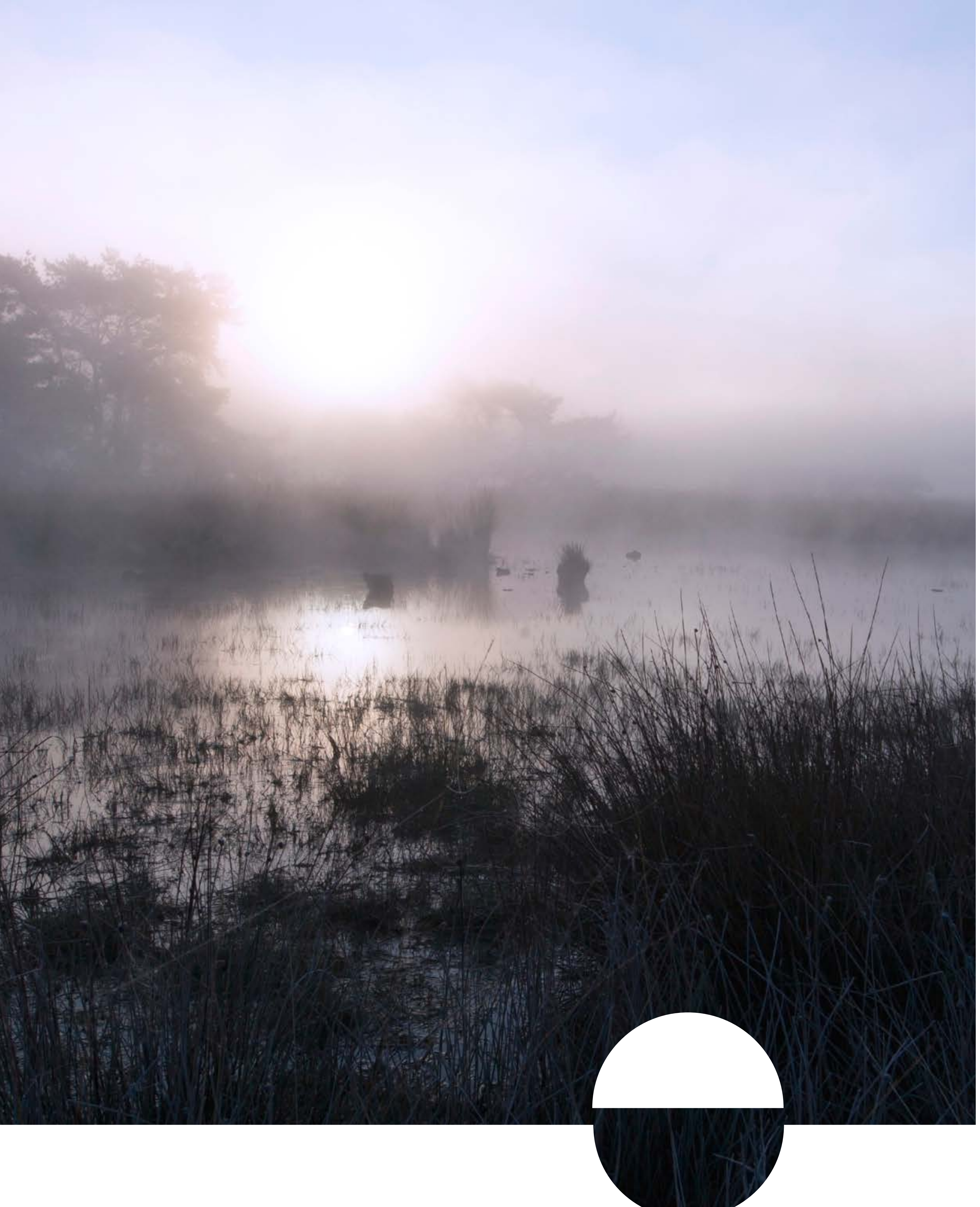


Organic matter plays an important part in the supply of food to soil organisms, in the retention and release of water, in the breakdown of greenhouse gases and in the storage of carbon. The organic matter content of the soil has a positive relation with soil biodiversity, soil structure, the water regime, nutrient balance, soil acidity, and pest and disease control. The amount of organic matter in the soil (expressed as carbon) is about twice the total amount in the atmosphere and in vegetation combined. A small change in the build-up and decomposition of soil organic matter can have a substantial effect on variations in the atmospheric concentration of greenhouse gases such as carbon dioxide and methane (Lehman & Kleber, 2015). Organic matter is broken down by soil organisms in the presence of oxygen and through mineralisation. The organic matter content of the soil and the rate at which it is built up and broken down are affected by the level of the water table, which determines the depth to which oxygen can penetrate the soil, and by the presence (or not) of residual organic matter on and in the soil after crops are harvested (the supply of organic matter), the soil biodiversity and the way the soil is worked (Koopmans & Van Opheusden, 2019).

The organic matter content of Dutch soils varies according to soil type and the crop being grown in the soil. The organic matter content of agricultural soils depends primarily on the use of the land. Arable land has an average organic matter content of 3–4%, or 4–5% where maize is grown, and grassland has an average organic matter content of 7–9%. There are large regional differences as well. The organic matter content of forest and natural soils is closely related to the type of soil. The average organic matter content of sandy, loamy and wetland forest soils is about 5–10% and of clay and peat soils is 12–16%. The organic matter content of natural soils varies from less than 1% in poor sandy soils to more than 40% in peat soils (Koopmans & Van Opheusden, 2019). A risk analysis indicates that in 50 years' time there is a chance that the carbon content of arable soils will reach the critical limit of 1.5%. Below this limit the amount of organic matter is insufficient to ensure that the soil can perform all its functions. This has already happened in some places, such as the north-western part of the province of Flevoland (Conijn and Lesschen, 2015). Climate change is increasing the rate of decomposition of organic matter. The loss of organic matter content is greater in arable soils, while in grasslands the rate of fixation is lower. According to model calculations, a 2°C increase in temperature will lead to an average reduction in the annual carbon balance of 290 kg per ha per year. To compensate for this an additional 0.6 t of effective organic matter is needed (Conijn & Lesschen, 2015).

Organic matter can decompose at different rates and thus perform different functions. In general, the higher the content of critical nutrients in relation to the amount of carbon in the fertiliser or crop residues, the faster the organic matter will be broken down. Decomposition of organic matter releases nutrients and greenhouse gases such as carbon dioxide, methane and nitrous oxide. These greenhouse gases escape to the atmosphere and the nutrients are taken up by the crop or leach to the groundwater or surface water. Lehman & Kleber (2015) talk of a soil continuum model in which biological, physical and chemical processes convert dead plant and animal material into organic compounds. Microorganisms play an important part in breaking these materials down. Decomposition releases nutrients and some of the decomposition products leach to water bodies or are released to the atmosphere in the form of carbon dioxide or methane. Another process that takes place at the same time is the binding of organic decomposition products to soil minerals, which holds the organic matter in the soil so that little or none of it is lost. The outcome of these biological and chemical processes in the soil is a continual flow from larger to smaller organic compounds and back again. At the same time, physical processes in the soil ensure a continual binding and release of organic matter with soil minerals, which maintains a dynamic buffer stock of mineral-bound organic matter. Lavallee et al. (2019) stress the complexity of organic matter decomposition and storage processes in soils and make a distinction between organic matter particles and mineral-bound organic matter. Both fractions are fundamentally different in terms of formation, persistence and function in the soil. The average residence time of organic matter particles is about ten years and of the mineral-bound fraction is ten to a hundred years. In European agricultural and forest soils both these fractions have demonstrably declined and must be increased again if soil fertility and the carbon reservoir are to be raised (Lavallee et al., 2019). There appears to be a reasonably stable balance between the input and output of organic matter in Dutch soils. However, little account has yet been taken of the relations between the different fractions of organic matter, which is necessary to ensure that the soil can perform all its functions.

Various measures have the potential to contribute towards increasing the organic matter content of soils. Agricultural measures that can be considered promising are delaying the ploughing of grassland, non-inversion tillage for maize cultivation following grassland, the inclusion of additional break crops in cropping plans, and greater use of solid manure and compost. The effects of specific measures will depend on the initial state of the soil, the type of soil, the crop rotation, the fertilisation plan, weather conditions, etc. Moreover, it often takes many years for a really stable organic matter fraction to be formed. Trees and shrubs make an extra contribution to the build-up of organic matter in the soil (Koopmans & Van Opheusden, 2019).



2 FUNCTIONS DEPEND ON THE SOIL

A sustainable soil is a sustainable resource that provides all the functions necessary to support agriculture, forestry, nature, water quality and the storage of water and carbon.

In 2015, the Dutch territory was 12% built-up area (infrastructure and buildings), 54% agriculture (excluding greenhouse horticulture), 8% forest, 2% terrestrial ecosystems, 9% inland waters and 10% coastal waters (CBS, 2018a). Built-up areas and waters can also play a part in the performance of these functions, but this advice does not include these areas.

2.1 Agriculture

Dutch agricultural soils are currently highly productive and deliver safe food in sufficient quantities. Maintaining soil quality is a necessary condition for continuing to meet the demand for safe food in future.

Agricultural soils around the world are becoming increasingly short of micronutrients (boron, iron, copper, manganese, molybdenum, zinc and selenium), including Dutch soils. However, this reduction has not yet led to a reduction in plant growth, partly because they are replenished through the application of manure and chemical fertilisers (Hospers-Brands et al., 2016).

On the other hand, the stocks of some minerals used in chemical fertilisers are limited. Known phosphate reserves are enough for 100 to 370 years and potash reserves are sufficient for 300 years. However, the reserves of some micronutrients will run out in a much shorter period of time. Zinc reserves are sufficient for just another 21 years and copper for 39 years. The reserves of boron, manganese, molybdenum and selenium will be depleted within a few decades (Table 3) (Udo de Haes et al., 2012; Hospers-Brands et al., 2016; Bastein & Van Bree, 2012).

Minerals (copper, magnesium, calcium, sodium, iron, potassium) are not only being depleted from soils, but a decrease in potato, vegetable and fruit products has also been observed, both nationally and internationally. Possible causes are the high crop yields, which can lead to a dilution of minerals and vitamins in the produce, fertilisation methods (e.g. displacement) and declining amounts in the soil (see Tables 4, 5 and 6) (Hospers-Brands et al., 2016).

Table 3: R/P ratios for various minerals
(R = known reserves (tonnes); P = production (tonnes/year))

	R/P (years)
Nitrogen	n.a.
Phosphate	370
Potash	288
Copper	39
Zinc	21
Boron	60
Manganese	48
Molybdenum	42
Selenium	39
Iron	75
Calcium	n.a.
Magnesium	430

Source: Udo de Haes et al., 2012; Hospers-Brands et al., 2016

Because the amounts of minerals in food (fruit and vegetables) have declined over the years, consumers obtain fewer nutrients via their food. This is most pronounced for vitamins A, B, E, D and the minerals calcium, iron, phosphorus, magnesium, selenium and zinc. As a result of this, people in Asia, Africa and South America may suffer from deficiency diseases. In the Netherlands this is not yet the case (see Table 7) (Hospers-Brands et al., 2016).

Table 4: Trends in the nutrient content of fruit and vegetables

Vitamins & Minerals		Results			Differences	
		1985	1996	2002	1985-1996	1985-2002
Broccoli	Calcium	103	33	28	-68%	-73%
	Folic acid	47	23	18	-52%	-62%
	Magnesium	24	18	11	-25%	-55%
Beans	Calcium	56	34	22	-38%	-51%
	Folic acid	39	34	30	-12%	-23%
	Magnesium	26	22	18	-15%	-31%
	Vitamin B6	140	55	32	-61%	-77%
Potatoes	Calcium	14	4	3	-70%	-78%
	Magnesium	27	18	14	-33%	-48%
Carrots	Calcium	37	31	28	-17%	-24%
	Magnesium	21	9	6	-57%	-75%
Spinach	Magnesium	62	19	15	-68%	-76%
	Vitamin C	51	21	18	-58%	-65%
Apples	Vitamin C	5	1	2	-80%	-60%
Bananas	Calcium	8	7	7	-12%	-12%
	Folic acid	23	3	5	-84%	-79%
	Magnesium	31	27	24	-13%	-23%
	Vitamin B6	330	22	18	-92%	-95%
Strawberries	Calcium	21	18	12	-14%	-43%
	Vitamin C	60	13	8	-67%	-87%

Source: Herbalvitality.info (n.d.), Hospers-Brands et al., 2016

Table 5: Percentage of products (38 vegetables) whose nutrient content has increased, remained the same or decreased between 1980 and 2014

	Energy	Protein	Carbohydrate	Sodium	Potash	Calcium	Phosphate	Iron	Vitamin B1	Vitamin B2
Increase	87	18	13	0	8	21	8	11	18	18
No change	0	55	47	49	57	55	68	51	71	68
Decrease	13	26	39	51	35	24	24	38	11	13

Source: Hospers-Brands et al., 2016

Table 6: Median daily habitual intake of selected micronutrients from foods and dietary supplements by Dutch adults aged 19 to 30 years in 2003 and in 2007–2010

		Men		Women	
		2003	2007-2010	2003	2007-2010
Calcium	mg	1,164	1,091	968	918
Iron	mg	12,9	11,8	10,5	9,8
Magnesium	mg	400	378	289	292
Phosphorus	mg	1,839	1,753	1,308	1,329
Selenium	µg	54	53	42	42
Zinc	mg	11.8	12.2	9.3	9.6
Vitamin B6	mg	2.4	2.4	1.8	2.0
Folic acid	µg	246	288	205	249
Vitamin D	µg	4.0	3.7	3.0	2.9
Vitamin E	mg	13,9	15,6	10,6	12,2

Source: Van Rossum et al., 2011; Hospers-Brands et al., 2016

Table 7: Minerals reported as declining in soils, foodstuffs and/or human food

	Declining in the soil	Declining in foodstuffs	Shortage in human food
Boron	X		
Calcium	X	X	X
Iron	X	X	X
Phosphorus	X		X
Potash	X	X	
Copper	X	X	
Magnesium		X	X
Manganese	X		
Molybdenum	X		
Sodium		X	
Selenium	X		X
Zinc	X		X
Sulphur	X		

Source: Hospers-Brands et al., 2016

2.2 Water storage and water quality

Sustainable soils are important for water systems. They act like sponges, absorbing and retaining water in wet periods and releasing water in dry periods. This prevents flooding in wet periods and desiccation in dry periods. In addition, nutrients and other chemical compounds leach more quickly from soils with a poor water holding capacity (e.g. because they are compacted or contain too little organic matter), which leads to eutrophication and pollution of groundwater and surface waters.

Quality of groundwater and surface water bodies (text from the Council's advisory report 'Sustainable and Healthy', 2018)

'Under current policy, in 2027 the targets for nitrogen and phosphorus will be met in about half of all surface water bodies. As a result, in most surface waters the 2027 ecological targets will not be achieved. If there is no change in policy, in 2027 the nitrate concentrations in the groundwater in the southern sandy soils area are expected to exceed the 50 mg/l standard by 20%, which will affect drinking water quality.

Water quality standards

The Dutch river basin management plans for implementing the WFD contain specific standards for surface water quality. The goal of the WFD is to improve water quality with the aim of restoring and maintaining its chemical and ecological health. The high concentrations of nitrogen and phosphorus in Dutch surface water bodies are an impediment to achieving the WFD ecological targets. About 55% of the nitrogen and phosphorus comes from the fertilisation of agricultural land, mostly with manure from livestock farms (PBL et al., 2017). Other sources of nutrients are the deposition of ammonia (via the air), the drainage of peaty soils and surface seepage from deep, nutrient-rich groundwater. The Nitrates Directive regulates the use of agricultural fertilisers with the aim of preventing and reducing water pollution by manure and fertilisers. It contains a use standard for the application of nitrogen in manure. The maximum application rate for all crops is 170 kg nitrogen per hectare from animal manure, unless a Member State has received a derogation. The Netherlands has a derogation for grazing livestock farms (230 kg nitrogen per hectare in/on sandy soils in the south of the country; 250 kg nitrogen per hectare elsewhere). This derogation is subject to certain conditions, including an obligation to monitor the effects of manure application and report on this annually and to restrict total manure production to within a manure production ceiling (equal to the 2002 level).

The Dutch government has transposed the Nitrates Directive into the Act on Manures and Fertilisers. The Act on Manures and Fertilisers includes provisions on the total amounts of nitrogen and phosphate that may be applied to arable land and grassland via chemical fertilisers and manures and the methods that must be used to apply them.

Exceedances of nitrogen and phosphorus standards in surface water
Problems with water quality resulting from manure application are largely regional in nature and depend on the composition of the soil and subsoil (clay and peat soils, sandy soils) and land use.

- *Phosphorus/phosphate in surface water*
  The WFD has been transposed into Dutch law with different standards for phosphate concentrations per surface water type and region: flowing waters and streams are found mainly in the higher lying areas of the country where the soils are usually sandy; ditches, lakes, canals and waterways are found mainly in the lower lying areas of the country with either clay or peaty soils. The average phosphorus concentrations in the water bodies affected by agricultural activities in the sandy soil regions are twice as high as the WFD standard of 0.11 mg P per litre. The average phosphorus concentrations in the clay and peaty soil regions are more than three times as high as the WFD standard of 0.22 mg P per litre. Under continuation of the current policy, the proportion of regional water bodies that meet the standards for nitrogen and phosphorus will rise from about 45% in 2013 to 50% in 2027, due primarily to emission reduction measures at sewage treatment plants (PBL, 2017b). Persistent replenishment of phosphorus from soils laden with excess concentrations and from phosphate-rich groundwater seepage (only in the lower lying regions of the country) are the main reasons why phosphorus concentrations in surface waters are hardly being reduced. The gradual tightening of use standards for phosphate in the Act on Manures and Fertilisers between 2006 and 2014 has now put a halt to and reversed this accumulation of phosphate in soils. But it will be only after 2027 that this decrease in the phosphorus stocks in soils will actually lead to an improvement in the quality of regional surface waters (PBL, 2017).
- *Nitrogen/nitrate in surface water*
  The nitrogen standards also depend on the type of water. After an initial decrease in the period 2012–2015, average nitrogen concentrations in the sandy soils regions are still about 40% above the standard of 2.3 mg N per litre. Concentrations in the clay and peaty soils regions are about 20% above the WFD standard of 2.4 mg N per litre (PBL, 2017). Although concentrations are declining, it is expected that under continuation of current policy in 2027 the WFD targets will not have been achieved in 50% of surface waters.

Groundwater

Besides the standards for surface water, the EU has also set quality standards for groundwater. The Groundwater Directive sets a maximum concentration for nitrate in groundwater of 50 mg per litre. This quality standard is met in most areas and is exceeded only in the southern sandy soils region, where average nitrate concentrations in the shallow groundwater layer are around 80 mg per litre. It is expected that without a change in policy, the decrease in nitrate concentrations in the southern sandy soils region will not be enough to achieve the nitrate target by 2027 and that concentrations will still be 10 mg per litre too high (PBL, 2017).

The degradation of nitrate in the groundwater can lead to an increase in the concentrations of heavy metals and sulfate and an increase in the hardness of the water. As a consequence, quality standards for drinking water may also be exceeded. In the period from 2000 to 2015 this occurred in water from 89 drinking water abstractions in the sandy soils region. According to PBL, these cases are probably a consequence of higher applications of chemical fertilisers and manures in the past (PBL, 2017).'

2.3 Carbon storage

Sustainable soils are crucial for meeting climate targets. Soils contain twice as much carbon as there is in the atmosphere and three times as much as in living organisms (*Technische Commissie Bodem*, 2016). Increasing soil organic matter content is one of the measures we can use to combat climate change. However, it is not only a climate mitigation measure, but also an adaptation measure for coping with the consequences of climate change and extreme weather conditions. Soils that contain more organic matter are more resistant to more frequent extreme weather conditions, such as longer periods of drought (moisture retention) or much heavier rainfall (soil structure).

EU legislation states that in 2021–2025 and 2026–2030 the balance of CO_2 emissions and sequestration in grassland and agricultural soils must be zero. When calculating this, the reference amount (the average in 2005–2009) may be deducted, which means that a net emission is permissible, but no more than took place in the reference period. The reference amount may not be subtracted for 'forested land' or 'deforested land' (where there has been a change of use), but it may be deducted from the emissions from managed forests. If the resulting emissions are larger than in the reference period, the EU regulation permits countries to offset the totals for forests and soils, either within the same land use or within the 'non-ETS sectors' (European Parliament and the Council, 2018; Arets et al., 2019).

The Netherlands is committed to the 4‰ initiative under the Global Climate Action Plan (GCAP), which contributes towards the goal of a land-degradation-neutral world. The idea is to raise the soil carbon stock in the top 30–40 cm of soil by 4‰ per year (Verenigde Naties, 2015b).

The 2019 National Climate Agreement (Tweede Kamer, 2019b) states that the government aims for a soil carbon sequestration rate of 0.5 Mt CO_2 per year by 2030. This could offset about 5% of the current CO_2 emissions from agriculture, giving the soil a climate mitigation function. The ability of the soil to perform this function depends on the soil organic matter content. This appears to be stable at the moment, but a significant decline is expected in the long term (Koopmans & Van Opheusden, 2019).

2.4 Nature

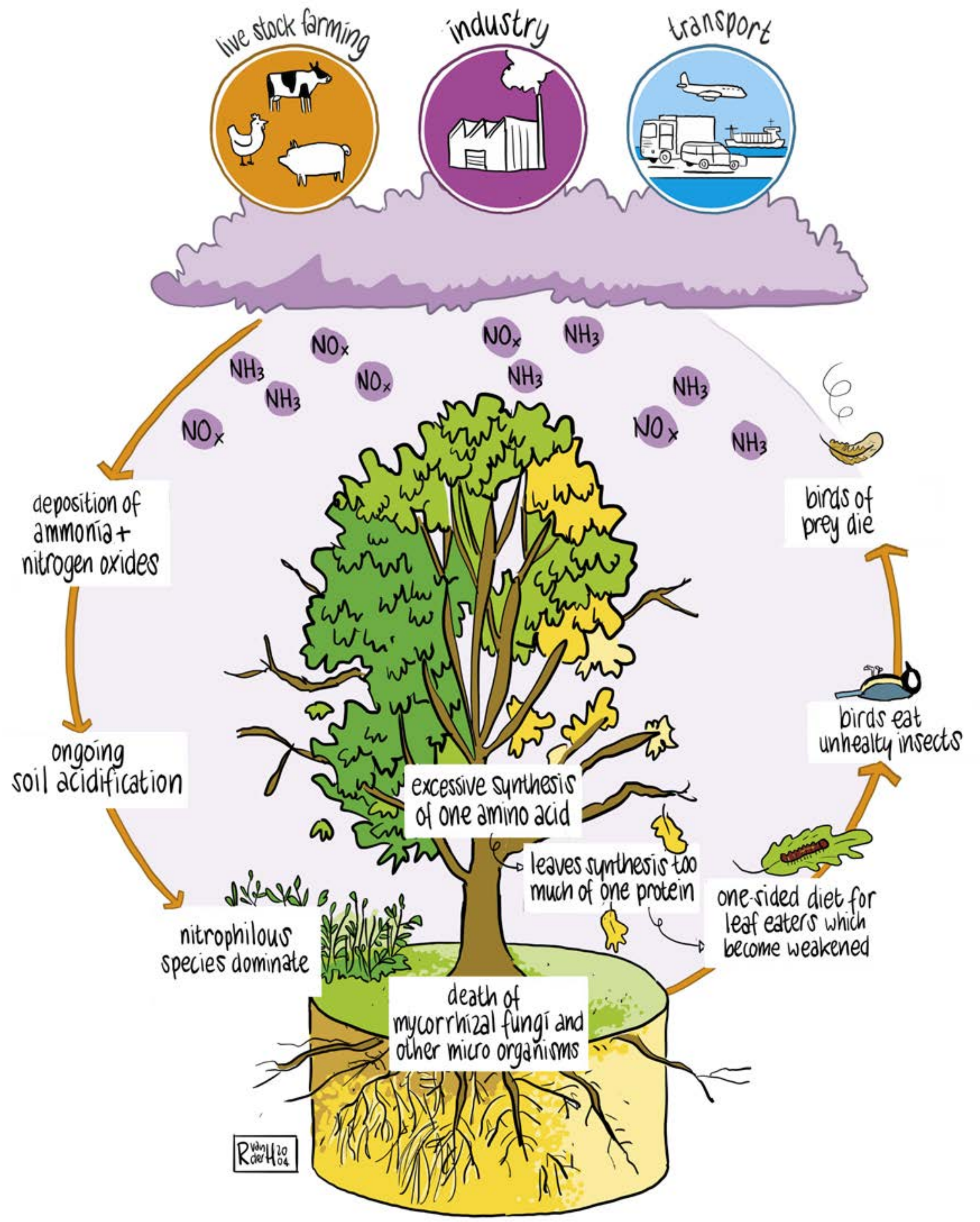
Sustainable soils are essential for the conservation and restoration of nature. Changes in soil biodiversity have consequences for biodiversity above ground and disrupt the whole ecosystem (Figure 10).

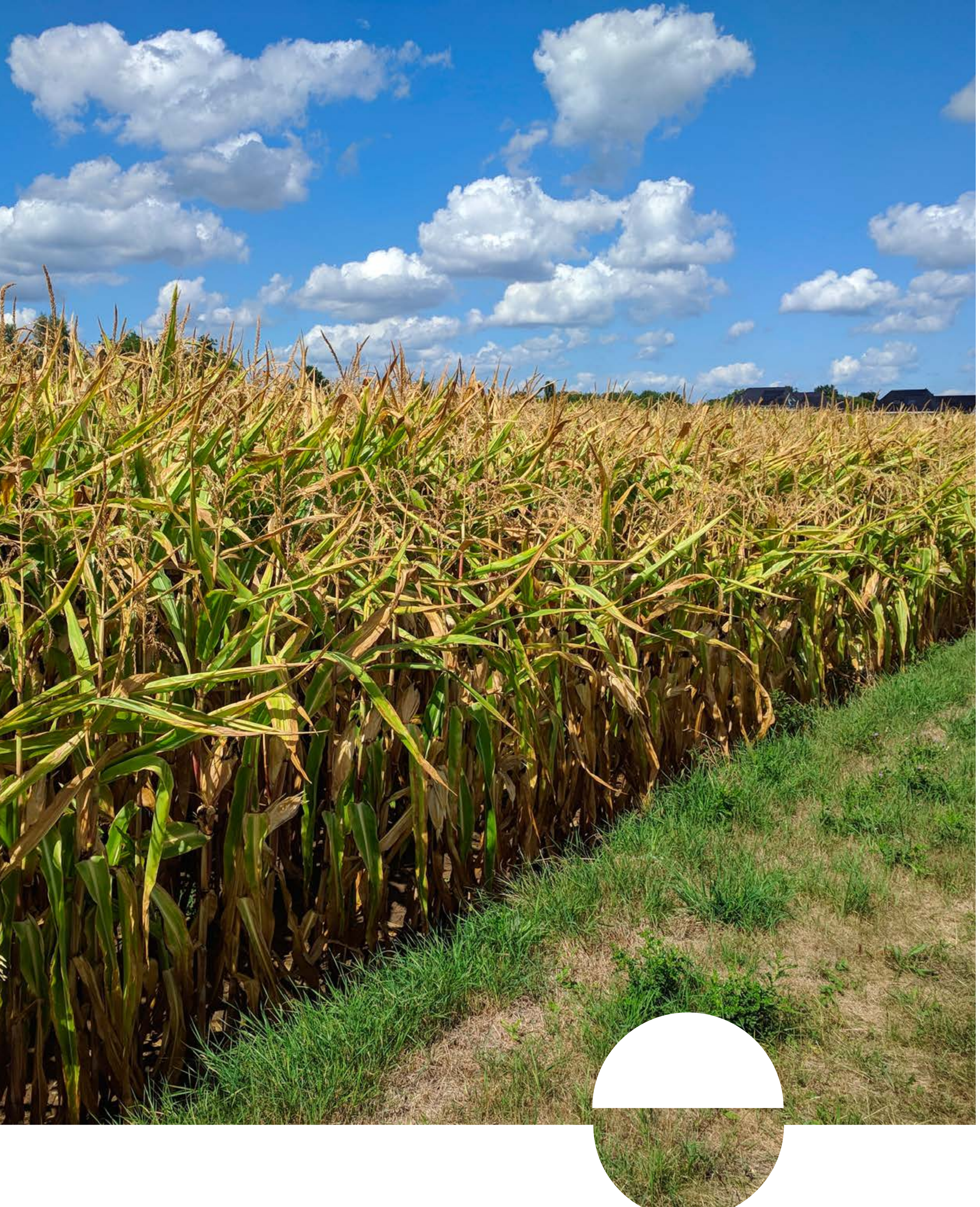
Soil biodiversity is the foundation of the food pyramid. Soil organisms not only ensure there are sufficient nutrients available for plant growth (including crops and trees), but of course are themselves a source of food for organisms higher up the food chain. That is why insufficient soil biodiversity has consequences for biodiversity above ground level.

Agricultural intensification and scaling up of production has led the number of characteristic animal species in farmland to decline by almost 50%. A similar percentage reduction has been observed in open ecosystems due to desiccation and excess nitrogen concentrations. Ecosystems on sandy soils are the most vulnerable, particularly where nitrogen deposition is high. No decline in the average population sizes of characteristic animal species has been found in forests, but animal species of heathland ecosystems, the most nutrient-poor soils, have on average been less successful (WNF, 2020).

There are twenty international targets for nature conservation (Aichi Biodiversity Targets). The Netherlands National Report published in 2019 shows that the Netherlands has made progress towards all twenty Aichi targets, but that in most cases the targets have not yet been reached. However, neither can it be said that biodiversity is improving as the report indicates that progress is often frustrated by poor environmental conditions (Tweede Kamer, 2019e and 2019f). The national evaluation of the Habitats Directive (Tweede Kamer, 2019e and 2019f) indicates that 46 of the 52 protected ecosystems in the Netherlands have a moderate to bad conservation status.

Figure 10: Nitrogen deposition: soil biodiversity and above-ground biodiversity are inseparably linked





3 AGRICULTURAL GOVERNANCE

This chapter gives a brief description of current agricultural governance and why this pays little attention to the soil and other land uses (Figure 11). After the Second World War, government policy was aimed at economic recovery and modernisation, with agriculture to provide enough food for everyone as well as products for export. Since then the overall level of welfare and prosperity has risen sharply and as incomes have risen, so have labour costs. To allow farmers and growers to profit from this increase in prosperity and prevent high labour costs from stifling the sector, labour productivity had to be increased. This was achieved in part by making products with higher added value (e.g. seed potatoes for export instead of table potatoes, and niche products such as *boerenkaas* – artisanal cheese made on the farm), by scaling up production (which means fewer farmers because farms require more land), by mechanisation, by specialisation and above all by intensification of production. In livestock farming this intensification was achieved by holding more animals on a smaller area of land, by outsourcing feed production to other continents, by producing high-protein food, and by breeding higher yielding animals (more milk, more meat or more eggs per animal). Animal housing was adapted and solid manure replaced with slurry. In arable farming, this process was driven by mechanisation with larger and heavier machines, by more intensive cropping plans with high-yield crops in short succession and fewer break crops, and through the use of chemical fertilisers, pesticides and improved varieties to raise yields.

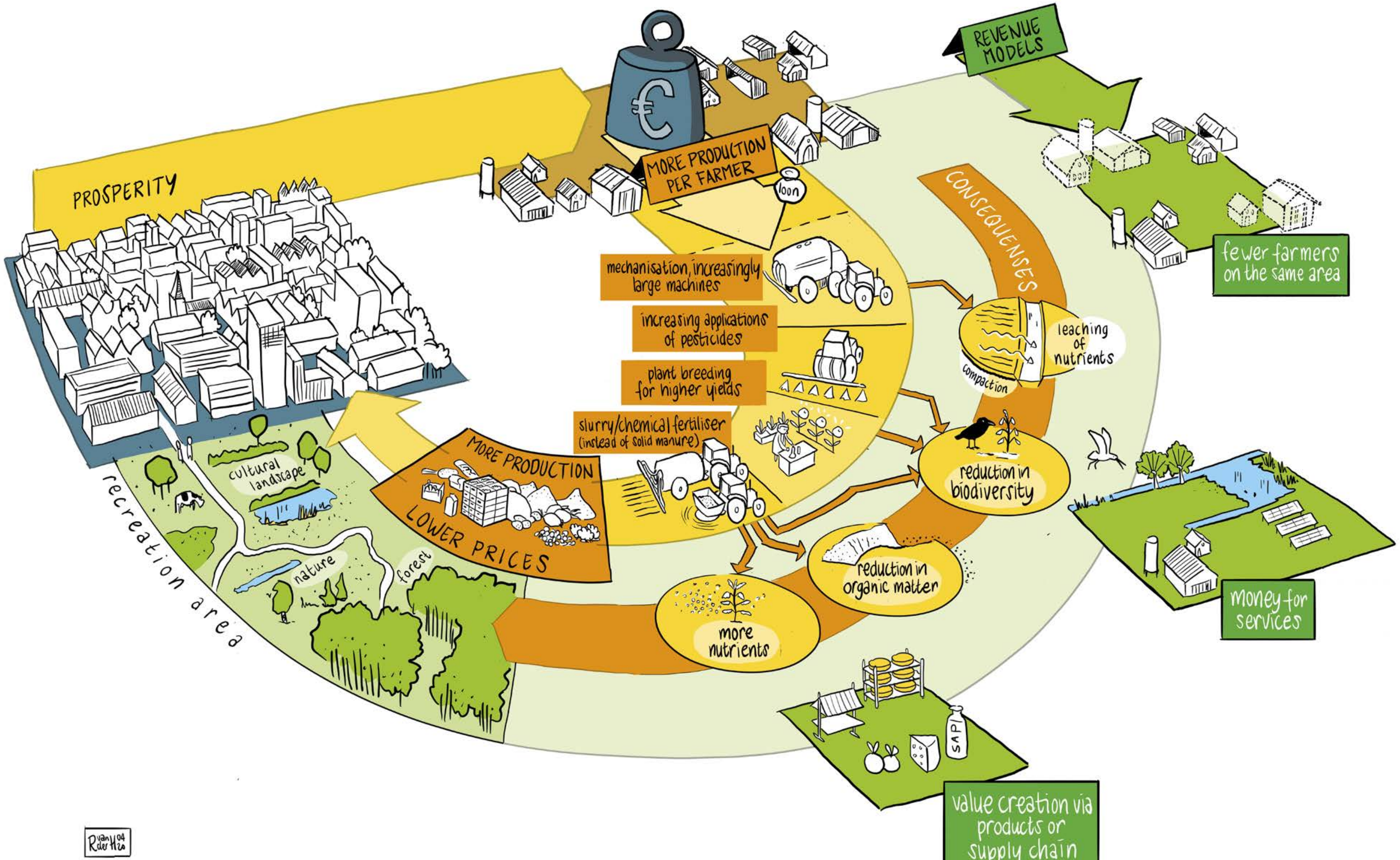
The increasing labour productivity was accompanied by a need for more land per worker and therefore to higher land prices, which can only be afforded by a limited number of farmers. This stimulates them – particularly those farmers who are least able to buy land – to further intensify production.

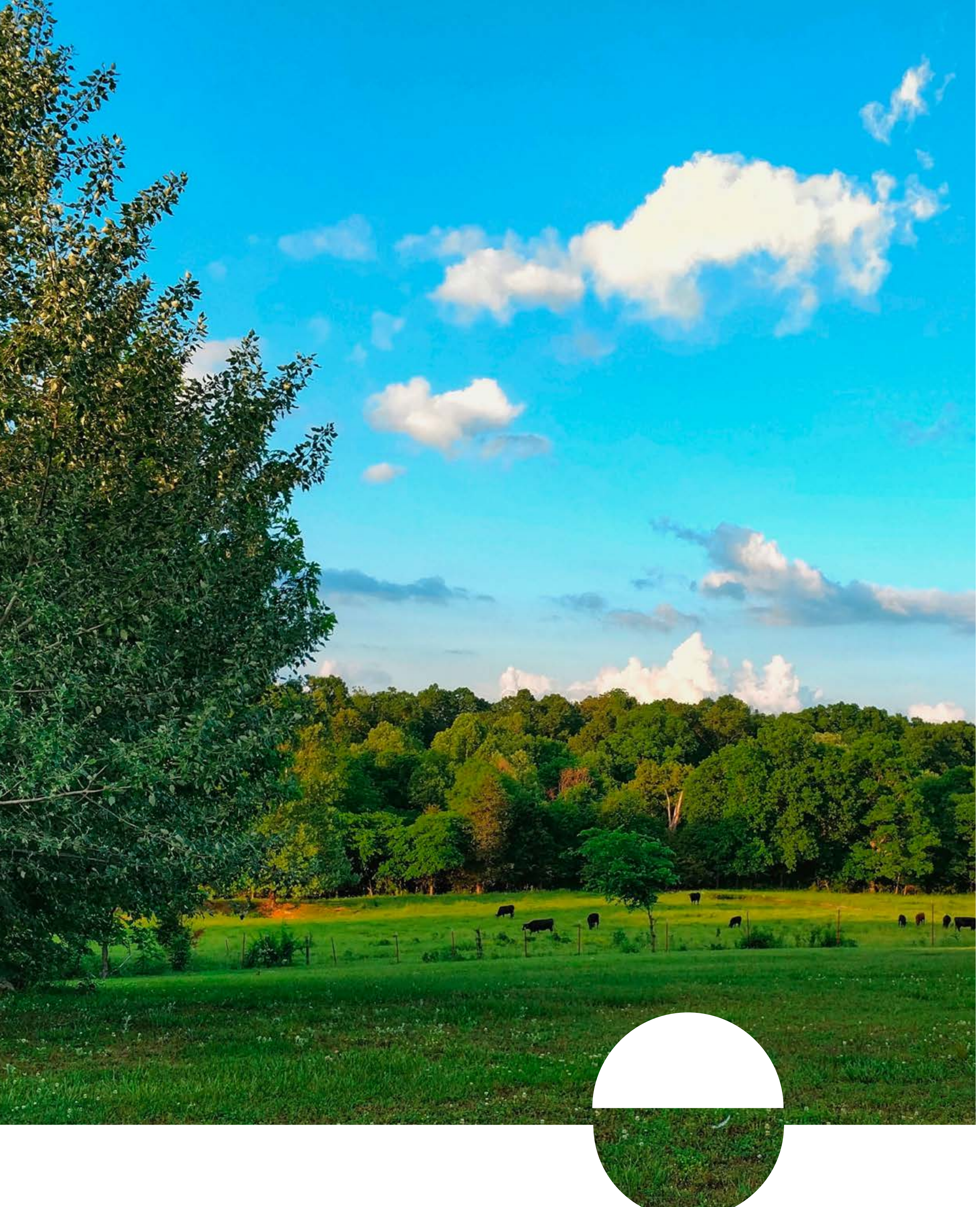
The whole value chain is geared to this process. As part of this, the agricultural knowledge system has become liberalised. Whereas once the independent national agricultural extension service played an important role in acquiring and sharing knowledge with land users, this role has now been taken over by agricultural suppliers and advisers. However, they sell seeds, fertilisers and pesticides or are in the business of contracting production. The knowledge and advice they provide, therefore, is not independent and is fragmentary; it is limited to the product being sold or to a specific crop and is therefore not comprehensive enough to be relevant for a whole soil management regime. Moreover, advice is limited to short-term recovery measures that increase harvest security.

At the macroeconomic level, this has led to significant exports of agricultural products and the development of an agricultural supply and processing industry that has acquired a strong position in international markets. The innovations at the core of this process have driven the export of machines and knowledge and led to considerably lower food prices. This continual pressure on prices drives a vicious circle of further upscaling and intensification, which leads to the adverse impacts on the soil described in Chapter 2 of Part 1.

The focus has been on agricultural production, which means that changes in the use and management of the soil have not automatically taken account of other functions of the soil, such as nature, water quality, and water and carbon storage. The resulting optimisation of agricultural value chains, the rising exports and the pressure on retail prices are putting farmers' incomes under pressure. In recent years, farmers have just been able to maintain sufficient margins by reducing costs and increasing production, which also makes it difficult for them to bear the costs of sustainable production methods. Decisions that are good for agriculture are clearly not always good for other functions of the soil. If the interests of these other functions are to be included in decision-making, policy will have to be adjusted accordingly. After all, sustainable soils are also in the interests of agriculture and there are already signs of vulnerabilities due to poor soil sustainability (Part 1, Chapter 2).

Figure 11: Agricultural governance illustrated





4 THE REGULATORY FRAMEWORK

Soil governance is based on the regulatory framework. This chapter explores several aspects of the regulatory framework that hinder the move towards sustainable soils: fertiliser policy, agricultural tenancy policy, tax regulations and the CAP. The Council realises that this is not the complete picture. Nevertheless, this chapter is an attempt to reveal how current soil governance can hinder progress towards sustainable soils that are suitable for multiple functions.

4.1 Agricultural tenancy policy

Control over the management of agricultural land is governed by the agricultural tenancy legislation. As high-yielding crops such as Brussels sprouts, carrots, flower bulbs and tree nursery plants require a wide crop rotation, growers that specialise in these crops have to rent land from colleagues. Exchanging grassland for arable land to grow potatoes is also a common practice. Although this is less sustainable for grassland, it can increase the sustainability of the soil used for growing potatoes, vegetables and ornamental crops. To accommodate these practices the agricultural tenancy legislation has been liberalised to permit short-term lease contracts. Including conditions in these contracts specifying which crops may be grown on the land need not be problematic (and is sometimes even better for the land than long-term leases), but it can also lead to a far too intensive use of the land if the landowner is only interested in obtaining the best possible rent on the market.

Many parties have strategic land holdings, including provincial governments, water authorities and Staatsbosbeheer (the government conservation management agency). Such land holdings could be used to favour activities that put less of a burden on the soil when land is leased. At present, it is often impossible to impose sustainable soil use requirements or dissolve contracts if the tenant does not manage the soil according to sustainability principles. In a ruling on a lease drawn up by the provincial government of Noord-Brabant, the Central Agricultural Tenancies Authority (Centrale Grondkamer) stated that the need for additional conditions regarding the use of pesticides should be determined for each individual agricultural lease (Centrale Grondkamer, 2020). However, the Regional Agricultural Tenancies Authority for the South has rejected the inclusion of a prohibition on the use of pesticides in lease agreements (Maas, 2020). This raises doubts about whether the proposal by the Vilsteren Estate to set conditions on sustainable management for liberalised leasehold will withstand the scrutiny of the Agricultural Tenancies Authority (see Box 12). The Council's opinion is that the landowner's right to impose conditions on soil management should in fact be strengthened. Where the legislation prevents such proposals for the sustainable management of land holdings in agricultural leases, it should be amended to make this possible. Taking this further, conditions on sustainable soil management could be made obligatory in liberalised lease agreements, which would obviate the need to debate the pros and cons of short-term and long-term tenancies. The idea that it only makes sense to include conditions for sustainable soil management in long-term lease agreements would no longer be relevant, and high-yield crops could also be grown under sustainable conditions.

Box 12: Examples of leasing arrangements

'14 sustainable conditions for liberalised leases

The Vilsteren Estate has drawn up 14 special conditions for leasehold land. Each condition is worth at least one point and farmers must obtain at least 10 points.

- For every 10 cows there must be at least 1 hectare of grazing land. Farmers receive 1 point for 720 hours grazing per year and 2 points for 1,440 hours.
- At least 60% of the leasehold must be permanent pasture. Farmers receive 2 points if this applies to all land on the farm.
- A 3-metre wide fertiliser-free and spray-free strip must be maintained along watercourses to reduce runoff. Farmers receive 2 points if they implement this across the whole farm.
- Non-inversion tillage of arable land. Farmers receive 2 points if they implement this on all the arable land on the farm.
- No applications of fertiliser. Farmers receive 2 points if no chemical fertiliser is used at all on the farm.
- At least 50 trees or shrubs are planted each year. Farmers receive 2 points if this measure is applied across the whole farm.

- At least 5% of the land must be herb-rich pasture, arable field margins or managed landscape elements. These may include strips along watercourses. Farmers receive 2 points if this measure is applied across the whole farm.
- At least 65% of feed protein must be produced on the farm (no contracts with neighbouring farms).
- The nitrogen surplus in the soil must not exceed 150 kg per hectare.
- Ammonia emissions must not exceed 75 kg per hectare.
- The organic matter balance is at least neutral.
- Use or self-generation of green electricity.
- The farm receives visitors or participates in cooperative arrangements on the estate.
- The farmer takes courses on sustainable farming, soil management and biodiversity.'

(Boerderij.nl, 2020 – translated from the Dutch)

22 hectares under new lease agreements

A group of farmers have signed a lease contract with the municipalities of Haaren and Vught. They are renting the leasehold land for six years. 'The dairy farmers and arable farmers receive a 200 euro discount on the rent for making significant improvements in the quality of the soil. This means that they turn land used to grow maize over to herb-rich grassland for three years. They receive a further 200 euro discount if in addition they take 5% to 15% of the arable field margins out of cultivation and sow them with a wildflower mixture.' The Louis Bolk Institute is monitoring and supervising the arrangement.

(Van der Meijden, 2020 – cited text translated from the Dutch)

DuurzameGronduitgifte.nl

'The Brabant Green Development Fund (Groen Ontwikkelfonds Brabant), Staatsbosbeheer, Stichting Brabants Landschap (Brabant provincial landscape foundation), Natuurmonumenten, the province of Noord-Brabant, Brabant Water, and the Aa and Maas, the Dommel and Rivierenland water authorities want their leasehold land to be put to more sustainable use. They have imposed conditions on the use of these land holdings, but are also considering new approaches).'

(DuurzameGronduitgifte.nl, 2019 – translated from the Dutch)

Analogous to sustainable procurement, public authorities could adopt a policy of sustainable agricultural tenancy. Instead of selecting the highest bidder when leasing land, the Central Government Real Estate Agency could employ sustainable procurement principles like all other government procurement contracts. Land would then only be leased on the condition that a sustainable soil management regime is maintained. The more sustainably farmers farm, the more chance they will have of obtaining a lease. This is also recommended in a report to the House of Representatives (Rijksoverheid, 2020), which proposes that the agricultural land leased by the national land agency should only be used for sustainable forms of agriculture.

4.2 Fertiliser policy

Current fertiliser policy sets a maximum limit on the amount of nutrients, particularly nitrogen and phosphate, that may be applied to the land. This policy encourages farmers to maximise fertiliser applications to the permitted limit because manure is abundant and they can earn money by applying manure from other farms. Farmers with a manure surplus benefit by applying the maximum permissible amount of manure on their land. In some regions they are required to have more than half of their manure surplus treated by manure processors (RVO.nl, n.d.). These farmers can pay other arable farmers and growers who have not used up their application limit to take the rest of their surplus manure. This is cheaper than having it processed. In certain farming sectors there are therefore strong financial incentives to apply as much manure as possible up to the permitted limit, regardless of the needs of the crops and the soil, or any consideration of the other vital functions of the soil. The same arable farmers apply chemical fertilisers as well because these are easier to dose than slurry. Some would prefer to use solid manure to stimulate the growth of soil organisms and build up the organic matter content of the soil. In addition, when manure tariffs are high, the recipient farmers benefit when the nutrient content of the manure is low because they can then apply larger quantities to their land (Luesink et al., 2007).

The fertiliser legislation can be used to provide clarity and a framework for action. For example, the quality of manure could be matched much better to the quality of the soil through the use of separate manure collection systems and improved application techniques. One solution would be to legislate for phasing out the use of slurry, with dates when specific percentage reductions must be achieved. The 20% reduction in phosphate application rights when farms are sold, which means a reduction in the size of the herd on the farm, could be used for this purpose. When applying this regulation a differentiated approach could be taken in which farmers who can demonstrate that they employ a sustainable soil management regime and limit other environmental impacts (nutrient losses, greenhouse gas emissions, and biodiversity loss) would be given more leeway in making these reductions, while farmers who cannot would be subject to more stringent measures. In other words, the Council argues for a bold approach to reducing emissions by setting targets backed by a policy aimed at changing farming practices and the agricultural structure rather than, as in the past, relying on price differentials resulting from supply and demand and related government measures (working manure into the soil, adaptations to animal housing, nutrient application standards, etc.).

4.3 Common agricultural policy

Whereas in the past the CAP led mainly to an intensification of agricultural production, nowadays there is a growing conviction that the aim should be to establish more sustainable farming systems. This is also stated in the Council's earlier advisory letter on the new CAP, which advised using the eco-schemes and the existing private sustainability schemes to pay for sustainable soil management (Rli, 2019). This means that Pillar I direct payments per hectare will be paid not only for good agricultural practice and meeting cross-compliance conditions, but additional payments per hectare will also be available for sustainable practices under the eco-schemes.[12] The CPIs can be used to determine when such payments can be made.

An example of a current legislative obstacle to the pursuit of a policy for more sustainable farming concerns the ploughing up of grassland. Farmers receive a subsidy for managing 'permanent' grassland on the condition that the relevant fields have been under grassland for longer than five years. The law states that grassland is considered to be permanent if it has been continuously under grass for longer than five years. It is then not permissible to use the land for arable crops. Farmers who want to avoid being committed to maintaining permanent grassland are forced to plough it up every five years. This releases carbon dioxide, which is not the best outcome for the climate function of grassland.

4.4 Tax legislation

The high price of land in the Netherlands leads to intense forms of land use. Farmers have to pay back the investments they make or are forced to work with too little land because they cannot afford to buy or rent the additional land they need. The current exemptions from income tax, corporation tax, inheritance tax and gift tax keep land prices high. These taxes have been designed with the continuation of existing farm businesses in mind, regardless of whether or not the soil is managed sustainably. The same goes for the six tax exemptions for forest management and conservation management (Table 8 and Box 13). One solution to this problem would be to transform these incentives so that they support desired forms of land use and management.

12 Cross compliance is meeting the provisions of existing EU directives in order to be eligible to receive CAP payments, including those in the Birds, Habitats, Nitrates and Groundwater Directives.

Table 8: Six tax exemptions for forested land and other natural areas

Scheme	Exemption
1. Forestry exemption	Income tax on profit & Corporation tax
2. Tax exemption on subsidies for forest and conservation management	Income tax on profit & Corporation tax
3. Tax exemption on income from savings and investments in forested land and other natural areas	Income tax: Box 3
4. Exemption from transfer tax on natural areas	Transfer tax
5. Exemption from transfer tax under the Rural Areas Development Act (Wet Inrichting Landelijk Gebied)	Transfer tax
6. Exemption on land acquisitions by the Land Management Service (Bureau Beheer Landbouwgronden, BBL)	Transfer tax

Source: Silvis & Van der Meulen, 2016

Box 13: 'Exemption from income tax and/or corporation tax

- The forestry exemption (*bosbouwvrijstelling*) stipulates that the profits made by a forestry business are not taxed. This applies to every entrepreneur and business that manages forest. The exemption provides indirect financial support for forest management by enterprises.

- The tax exemption on subsidies for forest and conservation management (*vrijstelling vergoeding bos- en natuurbeheer*) applies to subsidy schemes for the development and conservation of forest and other natural areas. The development and conservation of forest and natural areas depends to a great extent on the available subsidies and this tax exemption provides an additional boost. It is particularly relevant for converting land from agriculture to nature in certain areas, which involves large sums to compensate for the loss of assets. The exemption means that the relevant subsidies can remain lower while achieving the same effect.
- The tax exemption on income from savings and investments in forested and other natural areas (*vrijstelling bos- en natuurterreinen bij voordeel uit sparen en beleggen*) allows private individuals not to declare the value of their assets in Box 3 (income from savings and investment) of their income tax returns. This exemption makes private ownership of forest and natural areas more attractive.

Exemptions from transfer tax

- The exemption from transfer tax on natural areas (*vrijstelling overdrachtsbelasting natuurgrond*) exempts acquirers of natural areas from transfer tax. This exemption makes natural areas more attractive as an investment.
- The exemption from transfer tax under the Rural Areas Development Act (*vrijstelling overdrachtsbelasting Wet Inrichting Landelijk Gebied*) is a means to help realise structural improvements in rural areas. The exemption promotes the "smooth" transfer of property via the exchange of land parcels and the resubdivision of land without tax barriers. This makes it easier to build roads, watercourses and other infrastructure and for landowners to group their land holdings closer together.
- The BBL exemption (*vrijstelling verkrijging door Bureau Beheer Landbouwgronden*) is a generic exemption from transfer tax that applies to the Land Management Service as a body for acquisitions under government policy. Traditionally, this exemption has contributed towards structural improvements in rural areas and is fully in line with the needs of the BBL.'

(Tweede Kamer, 2017 – translated from the Dutch)

The tax exemptions for forests and other natural areas are motivated by nature policy and seek to further two strategic objectives: the sustainable use of nature and the conservation of biodiversity (Tweede Kamer, 2015). From this perspective a solution could be to make these exemptions conditional on sustainable soil management: good forestry practices or good conservation practices, comparable with good agricultural practices. These could include, for example, concrete actions to increase forest biodiversity and to increase organic matter reserves (e.g. by not removing branches and top wood), raising the water table and not flail mowing.

Another tax stumbling block is inheritance and gift tax. Whoever inherits or is gifted a farm business is subject to inheritance or gift tax. However, if the business is continued, use can be made of the ‘business succession scheme’, under which the inheritance/gift tax is reduced or waived. The scheme encourages farmers to keep the farm in the family, thus preventing the land from coming onto the market for farmers who want to farm more extensively or need to increase the size of their farms. This is not necessarily a bad thing if the soil is managed sustainably, but there is no incentive for successful continuation of sustainable soil management (Rosenboom et al., 2014).

The income tax exemption for agricultural businesses can also be an obstacle. This stipulates that if the management or designated use of the land remains the same, changes in the value of the land are not included in the profit and loss accounts of the business. This also makes it attractive for the farm to be passed on to the next generation, but at the same time this prevents the land from coming onto the market for farmers who want to extensify their production. As a result, land prices remain artificially high. Making this scheme conditional on a farm management regime geared to sustainable soil management could provide the required incentive. It would mean that farmers would only be eligible for the exemption if it can be demonstrated that sustainable soil management has been carried out for the past ten years (from the results of the proposed measurement method).

REFERENCES

Agrifirm, BoerenNatuur, Centraal Bureau Levensmiddelenhandel, Duurzame Zuivelketen, LTO Nederland, Naturalis Biodiversity Center, Natuur en Milieufederaties, Natuurmonumenten, Netherlands Ecological Research Network (NERN), Rabobank, Stichting Veldleeuwerik, De Vlinderstichting & Wereld Natuur Fonds (2018). *Deltaplan Biodiversiteitsherstel; In actie voor een rijker Nederland; Samen voor biodiversiteit*.

Akker, J. van den (2019). *Bodemverdichting: ondergrond en bovengrond*. Fact finding paper in opdracht van Raad voor de leefomgeving en infrastructuur.

Arets, E., Schelhaas, M-J. & J.P. Lesschen (2019). *Inschatting accounting onder de EU LULUCF verordening 841/2018*. Wageningen: Wageningen University & Research.

Baptist, M., Hattum, T. van, Reinhard, S., Buuren, M. van, Rooij, B. de, Hu, X., Rooij, S. van, Polman, N., Burg, S. van den, Piet, GJ., Ysebaert, T., Walles, B., Veraart, J., Wamelink, W., Bregman, B., Bos, B. & T. Selnes (2019). *Een natuurlijkere toekomst voor Nederland in 2120*. Wageningen: Wageningen University & Research.

Bastein, T. & Bree, T. van (2012). *Suppletie van micronutriënten uit de mijnbouw*. Delft: TNO.

Beltman, W., Boesten, J., Reinds, G.J., Reijneveld, A., Rietra, R., Römkens, P. & G. Velthof (2019). *Chemische Bodemkwaliteit in Nederland*. Fact finding paper in opdracht van de Raad voor de leefomgeving en infrastructuur.

BIJ12 (2019). *Rapportage voortgang uitvoering herstelmaatregelen 2019*. Utrecht.

Bobbink, R., Bouwman, J.H., Brouwer, E., Everts, F.H., Horsthuis, M.A.P., Kleef, H.H. van & A. Klimkowska (2013). *Preadvies kleine ecotopen in de hydrologische gradiënt*. Rapport nr. 23013/OBN173-NZBE. The Hague.

Boerderij.nl (2020). *Langjarige pacht als beloning voor duurzame boer*. Accessed 21 April 2020 via https://www.boerderij.nl/Home/Achtergrond/2020/2/Langjarige-pacht-als-beloning-voor-duurzame-boer-542241E/

Bokhorst, J., Leeuwen, Y. van & C. ter Berg (2008). *Bodem en bemesting in de bollenteelt*. Driebergen: Louis Bolk Instituut.

Bouma, J., Koetse, M. & J. Brandsma (2020). *Natuurinclusieve landbouw: wat beweegt boeren? Het effect van financiële prikkels en gedragsfactoren op de investeringsbereidheid van agrariërs*. The Hague: Planbureau voor de Leefomgeving.

Centraal Bureau voor de Statistiek (2018a). *Bodemgebruik; uitgebreide gebruiksvorm, per gemeente*. Accessed 13 February 2020 via https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70262ned/table?fromstatweb

Centraal Bureau voor de Statistiek (2018b). *Areaal bloembollen blijft groeien*. Accessed 9 April 2020 via https://www.cbs.nl/nl-nl/nieuws/2018/12/areaal-bloembollen-blijft-groeien

Centraal Bureau voor de Statistiek (2020). *Landbouw; gewassen, dieren en grondgebruik naar hoofdbedrijfstype, regio*. Accessed 6 March 2020 via https://opendata.cbs.nl/statline/#/CBS/nl/dataset/80783NED/table?fromstatweb

Centrale Grondkamer (2020). *Beschikking van 5 maart 2020, GP 11.812 [artikel 7:319 lid 1 aanhef en onder b BW] [artikel 7:397 lid 1 BW]*

Compendium voor de Leefomgeving (2018). *Kwaliteit grondwaterafhankelijke ecosystemen, 2017*. Accessed 13 February 2020 via https://www.clo.nl/indicatoren/nl1594-kwaliteit-grondwaterafhankelijke-ecosystemen

Compendium voor de Leefomgeving (2019). *Overschrijding kritische depositiewaarden voor stikstof op natuur, 1995–2016*. Accessed 18 December 2019 via https://www.clo.nl/indicatoren/nl2045-overschrijding-stikstofdepositie-natuur

Conijn J.G. & Lesschen J.P. (2015). *Soil organic matter in the Netherlands. Quantification of stocks and flows in the top soil*. Wageningen: Wageningen University & Research.

Dienst Landelijk Gebied en LOLA Landscape Architects (2010). *LOGBOEK, Landbouwontwikkelingsgebieden in beeld*. Velsen-Noord.

DHV (2009). *Plan-MER Structuurvisie Noord-Holland Erratum*. Zaandam.

Duinhoven, G. van (2019). *Wat doet een teveel aan stikstof in onze natuur?* Wageningen: Vakblad Natuur Bos Landschap, October 2019.

DuurzameGronduitgifte.nl (2019). *Hét inspiratieplatform voor duurzamer grond-gebruik*. Accessed 21 February 2020 via www.duurzamegronduitgifte.nl

Eerste Kamer (2019). *Memorie van antwoord bij Wijziging van de Omgevingswet en enkele andere wetten met het oog op het beschermen van de bodem met inbegrip van het grondwater, en het duurzaam en doelmatig gebruik van de bodem (Aanvullingswet bodem Omgevingswet). Brief van de minister voor Milieu en Wonen aan de Eerste Kamer van 22 november 2019*. Vergaderjaar 2019-2020, 34 864 nr. G.

Erisman, J.W. & R. Slobbe (2019). *Biodivers Boeren – de meerwaarde van natuur voor het boerenbedrijf*. Utrecht: Uitgeverij Jan van Arkel.

Erisman J.W. & F. Verhoeven (2019). *Presentatie KPI systematiek voor natuurinclusieve kringlooplandbouw*. Presentatie workshop Verdienmodellen. Driebergen: Louis Bolk Instituut.

European Environmental Agency (2019). *EEA greenhouse gas - data viewer*. Accessed 9 April 2020 via https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

Europees Parlement en Raad (1979). *Richtlijn inzake het behoud van de vogelstand: richtlijn 79/409/EEG van de Raad van 2 april 1979*. Brussels.

Europees Parlement en Raad (1991). *Richtlijn inzake de bescherming van water tegen verontreiniging door nitraten uit agrarische bronnen: richtlijn 91/676/EEG van de Raad van 12 december 1991*. Brussels.

Europees Parlement en Raad (1992). *Richtlijn inzake de instandhouding van de natuurlijke habitats en de wilde flora en fauna: richtlijn 92/43/EEG van de Raad van 21 mei 1992*. Brussels.

Europees Parlement en Raad (2000). *Richtlijn tot vaststelling van een kader voor communautaire maatregelen betreffende het waterbeleid: richtlijn 2000/60/EG van het Europees Parlement en de Raad van 23 oktober 2000*. Brussels.

Europees Parlement en Raad (2006). *Richtlijn betreffende de bescherming van het grondwater tegen verontreiniging en achteruitgang van de toestand: richtlijn 2006/118/EG van het Europees Parlement en de Raad van 12 december 2006*. Brussels.

Europees Parlement en Raad (2018). *Verordening inzake de opname van broeikasgasemissies en -verwijderingen door landgebruik, verandering in landgebruik en bosbouw in het klimaat- en energiekader 2030, en tot wijziging van Verordening (EU) nr. 525/2013 en Besluit nr. 529/2013/EU: verordening (EU) 2018/841 van het Europees Parlement en de Raad van 30 mei 2018*. Brussels.

FAO & WHO (2020). *Codex Alimentarius. International Food Standards*. Accessed 5 March 2020 via http://www.fao.org/fao-who-codexalimentarius/codex-texts/list-standards/en/

Galen, F. van & H. van Grinsven (2017). *Vijf vragen en antwoorden over nutriënten en waterkwaliteit*. The Hague: Planbureau voor de Leefomgeving.

Hack-ten Broeke, M.J.D., Rietra, R.P.J.J., Römkens, P.F.A.M. & F. de Vries (2008). *Geschikte of vruchtbare landbouwgronden in Nederland en Europa. Een overzicht en synthese van bestaande informatie*. Wageningen: Alterra.

Hanegraaf, M., Elsen, E. van den, Haan, J. de & S. Visser (2019). *Bodemkwaliteitsbeoordeling van landbouwgronden in Nederland – indicatorset en systematiek, versie 1.0*. Wageningen: Wageningen University & Research.

Helpdeskwater.nl (s.a.). *Verzilting*. Accessed 30 March 2020 via https://www.helpdeskwater.nl/onderwerpen/water-ruimte/waterkwantiteit/verzilting/

Herbalvitality.info (s.a.). *Comparison of Nutrients in Fruits and Vegetables*. Accessed 14 April 2020 via https://www.herbalvitality.info/articles/nutrients_in_food.html

Hooijboer A.E.J., Meer, R.W. van der, Fraters, B. & T.C. van Leeuwen (2014). *Scouting vollegrondsgroenten op zand (2007-2010), een verkennend onderzoek*. RIVM en LEI Wageningen UR.

Hospers-Brands, M., Staps, S. & P. Voshol (2016). *Trends in bodem- en gewaskwaliteit. Literatuurstudie*. Driebergen: Louis Bolk Instituut.

Interprovinciaal Overleg, het ministerie van Landbouw, Natuur en Voedselkwaliteit & BIJ12 (2019). *Vijfde Voortgangsrapportage Natuur. Natuur in Nederland. Stand van zaken eind 2018 en ontwikkeling in 2019*. The Hague.

Koopmans, C. & M. van Opheusden (2019). *Organische stof in de Nederlandse bodem. Feiten en discussie in perspectief*. Fact finding paper in opdracht van de Raad voor de leefomgeving en infrastructuur.

Kuper, J. (2019). *Natuurvolgend Bosbeheer*.

Lavallee, J.M., Soong, J.L. & M.F. Cotrufo (2019). *Conceptualizing soil organic matter into particulate and mineral-associated forms to address global change in the 21st century*. Global Change Biology 2020;26:261–273. https://doi.org/10.1111/gcb.14859 Wiley

Lehmann, J. & M. Kleber (2015). *The contentious nature of soil organic matter. Perspective*. Nature, vol. 528, 3 December 2015, doi:10.1038/nature16069

Lesschen, J.P., Reijs, J., Vellinga T., Verhagen, J., Kros, H., Vries, Jongeneel, R., Slier, T., Gonzalez Martinez, A., Vermeij, I. & C. Daatselaar (2020). *Scenariostudie perspectief voor ontwikkelrichtingen Nederlandse landbouw in 2050*. Wageningen: Wageningen University & Research.

Luesink, H.H., Blokland, P.W., Bosma, J.N. & M.W. Hoogeveen (2007). *Monitoring mestmarkt 2007*. Achtergronddocumentatie. LEI-Rapport 2008.

Maas, M. (2020). *Gemeente mag Roundup niet verbieden*. Binnenlands Bestuur, 27 January 2020, Accessed 20 February 2020 via https://www.binnenlandsbestuur.nl/ruimte-en-milieu/nieuws/gemeente-mag-roundup-niet-verbieden.12173284.lynkx

Meijden, D. van der (2020). *Boeren rond Margriet slaan duurzame weg in: ze luiden de klok als er straks pieren in de grond zitten*. Accessed 21 February 2020 via https://www.bd.nl/meierij/boeren-rond-margriet-slaan-duurzame-weg-in-ze-luiden-de-klok-als-er-straks-pieren-in-de-grond-zitten~a67d55938/?utm_source=twitter&utm_medium=social&utm_campaign=socialsharing_web

Methorst, R. (2016). *Farmers' perception of opportunities for farm development*. Promotieonderzoek. Aeres Hogeschool Dronten.

Meulen, H. van der (2019a). *Topinkomen bloembollentelers door stabiele markt*. Accessed 9 April 2020 via https://www.agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2234&themaID=2272

Meulen, H. van der (2019b). *Inkomen akkerbouwbedrijven daalt door afname opbrengsten*. Accessed 9 April 2020 via https://www.agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2233&themaID=2272

Morriën, E., Hannula, E.E., Snoek, L.B., Helmsing, N., Zweers, H., de Hollander, M., Bouffaud, MBuée, M., Dimmers, W., Duyts, H., Geisen, S., Girlanda, M., Griffiths, R.I., Bracht Jörgensen, H., Jensen, J., Plassart, P., Schmelz, R.M., Schmidt, O., Thomson, B.C., Tisserant, E., Uroz, S., Winding, A., Bailey, M., Bonkowski, M., Faber, J., Martin, F., Lemanceau, P., Boer, W. de, Veen, J.A. van & W.H. van der Putten (2017). *Soil networks become more connected and take up more carbon as nature restoration progresses*. Nature communications 8. DOI: 10.1038/ncomms14349.

Ontwikkeling + Beheer Natuurkwaliteit (s.a.). *Bodem in natuurbeheer*. Accessed 26 March 2020 via https://www.natuurkennis.nl/thema-s/bodem/bodem/bodem-algemeen/

Openbodemindex.nl (s.a.). *Open bodemindex*. Accessed 8 April 2020 via www.openbodemindex.nl

Planbureau voor de Leefomgeving (2017). *Evaluatie Meststoffenwet 2016: Syntheserapport*. The Hague.

Planbureau voor de Leefomgeving (2018). *Milieu- en ruimtelijke condities nog onvoldoende voor landnatuur*. Accessed 14 February 2020 via https://themasites.pbl.nl/balansvandeleefomgeving/jaargang-2018/themas/natuur/toestand-en-trends-milieu-en-ruimtelijke-condities-landnatuur

Planbureau voor de Leefomgeving (2019). *Klimaat- en Energieverkenning 2019*. The Hague.

Planbureau voor de Leefomgeving, Centraal Bureau voor de Statistiek & Wageningen University & Research (2017). *Compendium voor Leefomgeving*. www.clo.nl

Ploeg, M. (2019). *De bodem, je partner!* Amsterdam: Royal HaskoningDHV.

Pouwel, R & R. Henkens (2020*). Naar een hoger doelbereik van de Vogel- en Habitatrichtlijn in Nederland. Een analyse van de resterende opgave na 2027 voor het bereiken van een gunstige staat van instandhouding van alle habitattypen en VHR-soorten*. Wageningen: Wageningen University & Research.

Provincie Noord-Brabant (2017). *Uitvoeringsplan Vitale Bodem Noord-Brabant*. Den Bosch.

Provincie Noord-Brabant (2020). *Provincie hanteert koop-pacht-aanpak om natuurinclusief boeren te stimuleren*. Accessed 11 February 2020 via https://www.brabant.nl/actueel/nieuws/platteland/2020/provincie-hanteert-koop-pacht-aanpak-om-natuurinclusief-boeren-te-stimuleren

Provincie Fryslân (2019). *Geluk op 1. Vernieuwen in vertrouwen. Bestuursakkoord 2019-2023*. Leeuwarden.

Putten, W. van der (2019). *Bodembiodiversiteit in Nederlandse landbouw, bos en (droge) natuur.* Fact finding paper in opdracht van de Raad voor de leefomgeving en infrastructuur.

Raad voor de leefomgeving en infrastructuur (2014). *Doen en laten: effectiever milieubeleid door mensenkennis*. The Hague.

Raad voor de leefomgeving en infrastructuur (2016). *Verbindend landschap*. The Hague.

Raad voor de leefomgeving en infrastructuur (2018). *Duurzaam en gezond: samen naar een houdbaar voedselsysteem*. The Hague.

Raad voor de leefomgeving en infrastructuur (2019). *Europees landbouwbeleid: inzetten op kringlooplandbouw*. The Hague.

Raad voor de leefomgeving en infrastructuur (2020a). *Advies over bodemdaling in veenweidegebied het Groene Hart, in voorbereiding*. The Hague.

Raad voor de leefomgeving en infrastructuur (2020b). *Greep op gevaarlijke stoffen*. The Hague.

Rijksoverheid (2017). *Programmatische Aanpak Stikstof 2015-2021, zoals gewijzigd na partiële herziening op 18 december 2017*. The Hague.

Rijksoverheid (2020). *Tenminste houdbaar tot, Bewegen naar een duurzaam voedselsysteem. 28 februari 2020*. The Hague.

Roekel, A. van (2015). *Bollentelers werken aan herstel van bodemleven*. Accessed 9 April 2020 via https://www.nemokennislink.nl/publicaties/bollentelers-werken-aan-herstel-van-bodemleven/

Rosenboom, N., Smits, T., Buiren, K. van, Gerritsen, M. & C. Koopmans (2014). *Evaluatie fiscale regelingen gericht op bedrijfsoverdracht*. Amsterdam: SEO Economisch Onderzoek.

Rossum, C.T.M. van, Fransen, H.P., Verkaik-Kloosterman, J., Buurma-Rethans, E.J.M. & M.C. Ocke (2011). *Dutch National Food Consumption Survey 2007-2010. Diet of children and adults aged 7 to 69 years*. Bilthoven: RIVM.

Ruiter, P.C. de, Neutel, A.M. & J.C. Moore (1995). *Energetics, patterns of interaction strengths,and stability in real ecosystems*. Science, 269:1257-1260.

RVO.nl (s.a.). *Mestverwerkingsplicht voor de landbouwer*. Accessed 30 March 2020 via https://www.rvo.nl/onderwerpen/agrarisch-ondernemen/mestbeleid/mest/mestverwerkingsplicht/mestverwerkingsplicht-landbouwer

Silvis, H. & H. van der Meulen (2016). *Evaluatie fiscale vrijstellingen bos en natuur*. Wageningen: Wageningen Economic Research.

Smit, B. (2019a). *Belasting oppervlaktewater neemt verder af*. Accessed 9 April 2020 via https://www.agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2234&themaID=2275

Smit, B. (2019b). *Milieubelasting akkerbouw stabiliseert*. Accessed 9 April 2020 via https://www.agrimatie.nl/SectorResultaat.aspx?subpubID=2232&sectorID=2233&themaID=2275

Synbiosis.alterra.nl (s.a.). *Iteratio abiotiek in beeld*. Accessed 10 April via https://www.synbiosys.alterra.nl/iteratio/Iteratio.html

Technische Commissie Bodem (2016). *Advies Toestand en dynamiek van organische stof in Nederlandse landbouwbodems*. The Hague.

Tweede Kamer (2013). *Natuurbeleid. Brief van de staatssecretaris van Economische Zaken aan de Tweede Kamer van 18 september 2013*. Vergaderjaar 2013-2014, 33 576, nr. 6.

Tweede Kamer (2015). *Beleidsdoorlichting Economische Zaken. Brief van de staatssecretaris van Economische Zaken aan de Tweede Kamer van 24 december 2015*. Vergaderjaar 2015–2016, 30 991, nr. 29.

Tweede Kamer (2017). *Natuurbeleid. Brief van de staatssecretaris van Economische Zaken aan de Tweede Kamer van 6 juni 2017*. Vergaderjaar 2016-1027, 33 576, nr. 106.

Tweede Kamer (2018a). *Bodembeleid. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 23 mei 2018*. Vergaderjaar 2017-2018, 30 015, nr. 54.

Tweede Kamer (2018b). *Herziening van het gemeenschappelijk landbouwbeleid. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 15 maart 2018*. Vergaderjaar 2017-2018, 28 625, nr. 256.

Tweede Kamer (2019a). *Nationaal programma landbouwbodems. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 25 april 2019*. Vergaderjaar 2018-2019, 30 015, nr. 58.

Tweede kamer (2019b). *Kabinetsaanpak klimaatbeleid. Brief van de minister van Economische Zaken en Klimaat aan de Tweede Kamer van 1 november 2019*. Vergaderjaar 2019-2020, 32 813, nr. 400.

Tweede Kamer (2019c). *Biodiversiteit. Natuurbeleid. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede kamer van 11 februari 2019*. Vergaderjaar 2018-2019, 26 407 nr. 114.

Tweede Kamer (2019d). *Biodiversiteit. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 17 december 2019*. Vergaderjaar 2019-2020, 26 407, nr. 131.

Tweede Kamer (2019e). *Natuurbeleid. Voortgang Natura 2000. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 20 mei 2019*. Vergaderjaar 2018-2019, 33 576, nr. 163.

Tweede Kamer (2019f). *Zesde Nationale Rapportage Verdrag voor het behoud van de Biologische Diversiteit. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 17 juli 2019*. Vergaderjaar 2018-2019, 26 407, nr. 128.

Tweede Kamer (2019g). *De Nederlandse visie op datadeling tussen bedrijven. Rapport van de minister van Economische Zaken en Klimaat aan de Tweede kamer van 20 februari 2019*. Vergaderjaar 2018-2019, 2019D, nr. 07140.

Tweede Kamer (2020a). *Natuurbeleid. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 3 februari 2020*. Vergaderjaar 2019-2020, 33 576, nr. 186.

Tweede Kamer (2020b). *Nationale Omgevingsvisie. Brief van de minister van Binnenlandse Zaken en Koninkrijksrelaties aan de Tweede Kamer van 23 april 2020*. Vergaderjaar 2019-2020, 34682, nr. 48.

Tweede Kamer (2020c). *10-stappenplan natuurinclusieve kringlooplandbouw. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 9 maart 2020*. Vergaderjaar 2019-2020, 35 300, nr. XIV-71.

Tweede Kamer (2020d). *Voortgang stikstofproblematiek: maatregelen landbouw en verdere impuls gebiedsgerichte aanpak. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 7 februari 2020*. Vergaderjaar 2019-2020, 35 334, nr. 44.

Tweede Kamer (2020e). *Problematiek rondom stikstof en PFAS. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 7 februari 2020*. Vergaderjaar 2019-2020, 35 334, nr. 48.

Tweede Kamer (2020f). *Voortgang stikstofproblematiek: structurele aanpak. Brief van de minister van Landbouw, Natuur en Voedselkwaliteit aan de Tweede Kamer van 24 april 2020*. Vergaderjaar 2019-2020, 35 334, nr. 82.

Udo de Haes, H.A., Voortman, R.L., Bastein, T, Bussink, D.W., Rougoor, C.W. & W.J. van der Weijden (2012). *Schaarste van micronutriënten in bodem, voedsel en minerale voorraden – Urgenties en opties voor beleid*. Utrecht: Platform Landbouw, Innovatie & Samenleving.

Verenigde Naties (1992). *Convention on biological diversity*. Rio de Janeiro.

Verenigde Naties (2015a). *Transforming our world: The 2030 agenda for Sustainable Development*. New York.

Verenigde Naties (2015b). *Paris Agreement, FCCC/cp/2015/add.1, decision 1/CP.21*. Parijs.

Vereniging van Bos- en Natuurterreineigenaren (2017). *Houtoogst in relatie tot nutriëntenvoorraden in bossen op droge zandgronden*. Driebergen.

Vogelzang, T.A., Smit. A.B., Kuiper, P.P. & C. Gillet (2019). *Grond in beweging; Ontwikkelingen in het grondgebruik in de provincie Flevoland in de periode tot 2025 en 2040*. Wageningen: Wageningen Economic Research.

Wereld Natuur Fonds (2020). *Living Planet Report Nederland. Natuur en landbouw verbonden*. Zeist.

Westerink, J., Boer, T.A. de, Pleijte, M. & R.A.M. Schrijver (2019). *Kan een goede boernatuurinclusief zijn? De rol van culturele normen in een beweging richting natuurinclusieve landbouw*. Wageningen: Wageningen University & Research.

Wikipedia.nl (2017). *Woeler*. Accessed 28 February 2020 via https://nl.wikipedia.org/wiki/Woeler

Wikipedia.org (2020). *Ecotope*. Accessed 14 April 2020 via https://en.wikipedia.org/wiki/Ecotope

Witte, J.P.M., Eertwegh, G. van den, Hoefsloot, P. & M. van Huijgevoort (2018). *Vitaliteit van natuurbodems in Noord-Brabant*. KWR 2018.105. In opdracht van de provincie Noord-Brabant.

RESPONSIBILITY AND ACKNOWLEDGEMENT

Advisory committee

Krijn Poppe, Council member and committeee chair

Prof. Koos Biesmeijer, external committeee member (Leiden University & Naturalis)

Wim Stegeman, external committeee member (Saalland advies & farmer)

Em. prof. André van der Zande, Council member

Project team

Dr Nicole van Buren, project leader

Linda van Asselt, project assistant

Dorien Derks (RoyalHaskoningDHV), project team member from 5 August 2019 to 14 February 2020

Yvette Oostendorp, project team member from 18 February 2020

Matthijs Veenkant, project team member from 26 June 2019 to 9 September 2019

Consultees

Individuals consulted

Jan van den Akker, Wageningen University & Research
Gert Jan Baaijens, Baaijens advies
Leon Boer, Farmfrites
Jelka Both, Staatsbosbeheer
Ton Breure, National Institute for Public Health and the Environment
Eric Brinckmann, Het Lankheet
Rob Comans, Wageningen University & Research
Jan Jacob van Dijk, Nationaal Programma Landbouwbodems
Nicole van Eeden, Association of Netherlands Municipalities (VNG)
Jan Willem Erisman, Louis Bolk Institute
Henk Everts, EGG Consult
Marieke Francke, Board of Government Advisers
Wessel de Gouw, Province of Noord-Brabant
Hens Gunneman, Farmfrites
Harrie Hekhuis, Staatsbosbeheer
Mark Hoevenaars, Association of the Provinces of the Netherlands (IPO)
Peter de Koeijer, ZLTO
Chris Koopmans, Louis Bolk Institute
Marjan Kuiper, Staatsbosbeheer
Petra Mesken, Association of Netherlands Municipalities (VNG)
Rob Messelink, Province of Overijssel
Frits Mohren, Wageningen University & Research
Peter van der Molen
Wim van der Putten, Netherlands Institute of Ecology
Gert Jan Reinds, Wageningen University & Research
Huib Silvis, Wageningen University & Research
Tjeco Smits, Staatsbosbeheer
Berno Strootman, Board of Government Advisers
Harrie Vissers, Province of Noord-Brabant
Shera van den Wittenboer, Board of Government Advisers
Geert van der Veer, Herenboeren
Gijs van Zandbrink, Wageningen University & Research
Renée Zijlstra, Verrijkende landbouw

Government departments

Charles Aangenendt, Ministry of the Interior and Kingdom Relations
Annet Bertram, Ministry of the Interior and Kingdom Relations
Hanneke Brouwer, Ministerie van Infrastructuur en Waterstaat
Margot de Cleen, Rijkswaterstaat
Gerrie Haenen, Ministerie van Landbouw, Natuurbeheer en Voedselkwaliteit
Mariska Harte, Ministry of Agriculture, Nature and Food Quality
Peter Heij, Ministry of Infrastructure and Water Management
Jochiem Hendriksen, Ministry of Agriculture, Nature and Food Quality
Matthijs van Huijgevoort, Ministry of Agriculture, Nature and Food Quality
Douwe Jonkers, Ministry of Infrastructure and Water Management
Henk Massink, Ministry of Agriculture, Nature and Food Quality
Arne Meeter, Ministry of Agriculture, Nature and Food Quality
Co Molenaar, Rijkswaterstaat
Rosie Oude Lenferink, Ministry of Economic Affairs and Climate Policy

Henrieke Paul, Ministry of Agriculture, Nature and Food Quality
Peter Petrus, Ministry of the Interior and Kingdom Relations
Marjolein Sonnema, Ministry of Agriculture, Nature and Food Quality
Charlotte Stein, Ministry of the Interior and Kingdom Relations
Keimpe Wieringa, Ministry of Agriculture, Nature and Food Quality
Wilbert van Zeventer, Ministry of Infrastructure and Water Management

Expert meeting held on 19 November 2019 in Utrecht
Erwin Al, Staatsbosbeheer
Pieter Brooijmans, Suikerunie
Lijbert Brussaard, Wageningen University & Research
Daan Henkens, Dutch Water Authorities
Arnold Michielsen, LTO Noord Provincie Flevoland
Henk Siebel, Natuurmonumenten
Erik Somsen
Petra Souwerbren, Gelderse Natuur- en Milieufederatie
Frans Verwer, Meststoffen Nederland
Marcel van Vulpen, Province of Drenthe
Gerben Zijlstra, Cumela

Expert meeting held on 10 December 2019 in Utrecht
Gea Bakker, Rabobank
Rob Eijsink, Vewin (national association of water companies in the Netherlands)
Willemien Geertsema, BoerenNatuur
Jan Reinier de Jong, farmer
Niels Louwaars, Plantum
Judith van de Mortel, HAS University of Applied Sciences
Harrie Vissers, Province of Noord-Brabant
Theo Vulink, Fedecom

Reviewers
Erwin Al, Staatsbosbeheer
Pieter Jelle Beers, DRIFT
Jan Willem Erisman, Louis Bolk Institute
Harrie Hekhuis, Staatsbosbeheer
Franciska de Vries, University of Amsterdam

Fact finding papers

Akker, J. van den (2019). Bodemverdichting: ondergrond en bovengrond.
Beltman, W., Boesten, J., Reinds, G.J., Reijneveld, A., Rietra, R., Römkens, P. & G. Velthof (2019). Chemische Bodemkwaliteit in Nederland.
Koopmans, C. & Opheusden, M. van (2019). Organische stof in de Nederlandse bodem. Feiten en discussie in perspectief.
Putten, W. van der (2019). Bodembiodiversiteit in Nederlandse landbouw, bos en (droge) natuur.

OVERVIEW OF PUBLICATIONS

2020

A Grip on Hazardous Substances. ['Greep op gevaarlijke stoffen']. February 2020 (Rli 2020/01)

2019

Towards a Sustainable Economy: The Governance of Transitions. ['Naar een duurzame economie: overheidssturing op transities']. November 2019 (Rli 2019/05).

Desirable Tourism: Capitalising on Opportunities in the Living Environment. ['Waardevol toerisme: onze leefomgeving verdient het']. September 2019 (Rli 2019/04).

European Agricultural Policy: Working Towards Circular Agriculture. ['Europees Landbouwbeleid: inzetten op kringlooplandbouw']. May 2019 (Rli 2019/03).

Aviation Policy: A New Approach Path. ['Luchtvaartbeleid: een nieuwe aanvliegroute']. April 2019 (Rli 2019/02).

The Sum of the Parts: Converging National and Regional Challenges. ['De som der delen: verkenning samenvallende opgaven in de regio']. March 2019 (Rli 2019/01).

2018

Warmly Recommended: Towards a Low-CO_2 Heat Supply in the Built Environment ['Warm aanbevolen: CO_2-arme verwarming van de gebouwde omgeving']. December 2018 (Rli 2018/07)

National Environment and Planning Strategy: Litmus Test for the New Environmental and Planning Policy ['Nationale omgevingsvisie: lakmoesproef voor de Omgevingswet']. November 2018 (Rli 2018/06)

Accelerating Housing Production, While Maintaining Quality ['Versnellen woningbouwproductie, met behoud van kwaliteit']. June 2018 (Rli 2018/05)

Better and Different Mobility: Investing in Mobility for the Future '[Van B naar Anders: investeren in mobiliteit voor de toekomst']. May 2018 (Rli 2018/04)

The Healthy City: Delivering Health Through Environmental and Planning Policy ['De stad als gezonde habitat: gezondheidswinst door omgevingsbeleid']. April 2018 (Rli 2018/03)

Sustainable and Healthy: Working Together Towards a Sustainable Food System ['Duurzaam en gezond: samen naar een houdbaar voedselsysteem']. March 2018 (Rli 2018/02)

Electricity Provision in the Face of Ongoing Digitalisation ['Stroomvoorziening onder digitale spanning']. February 2018 (Rli 2018/01)

2017

A Broad View of Heritage: The Interactions Between Heritage and Transitions in the Physical Environment ['Brede blik op erfgoed: over de wisselwerking tussen erfgoed en transities in de leefomgeving']. December 2017 (Rli 2017/03)

Energietransitie en leefomgeving: kennisnotitie. December 2017 (Rli 2017) [only available in Dutch]

Land for Development: Land Policy Instruments for an Enterprising Society ['Grond voor gebiedsontwikkeling: instrumenten voor grondbeleid in een energieke samenleving']. June 2017 (Rli 2017/02)

Assessing the Value of Technology: Guidance Document ['Technologie op waarde schatten: een handreiking']. January 2017 (Rli 2017/01)

2016

Faster and Closer: Opportunities for Improving Accessibility in Urban Regions ['Dichterbij en sneller: kansen voor betere bereikbaarheid in stedelijke regio's']. December 2016 (Rli 2016/05)

International Scan 2016: Emerging Issues in an International Context. November 2016 (Rli/EEAC)

The Connecting Landscape ['Verbindend landschap']. November 2016 (Rli 2016/04)

Challenges for Sustainable Development: Main Focus Areas Identified in Advisory Reports Published in the Past Four Years by the Council for the Environment and Infrastructure ['Opgaven voor duurzame ontwikkeling: hoofdlijnen uit vier jaar advisering door de Raad voor de leefomgeving en infrastructuur']. July 2016 (Rli 2016/03)

Beyond Mainports ['Mainports voorbij']. July 2016 (Rli 2016/02)

Notitie Systeemverantwoordelijkheid in de fysieke Leefomgeving. May 2016 (Rli 2016/01) [only available in Dutch]

2015

Reform of Environmental Law: Realize your Ambitions ['Vernieuwing omgevingsrecht: maak de ambities waar']. December 2015 (Rli 2015/07)

A Prosperous Nation Without CO_2: Towards a Sustainable Energy Supply by 2050 ['Rijk zonder CO_2: naar een duurzame energievoorziening in 2050']. September 2015 (Rli 2015/06)

Room for the Regions in European Policy ['Ruimte voor de regio in Europees beleid']. September 2015 (Rli 2015/05)

Changing Trends in Housing: Flexibility and Regionalisation Within Housing Policy ['Wonen in verandering: over flexibilisering en regionalisering in het woonbeleid']. June 2015 (Rli 2015/04)

Circular Economy: From Wish to Practice ['Circulaire economie: van wens naar uitvoering']. June 2015 (Rli 2015/03)

Stelselherziening omgevingsrecht. May 2015 (Rli 2015/02) [only available in Dutch]

Survey of Technological Innovations in the Living Environment ['Verkenning technologische innovaties in de leefomgeving']. January 2015 (Rli 2015/01)

2014

Managing Surplus Government Real Estate: Balancing Public Interest Against Financial Gain ['Vrijkomend rijksvastgoed: over maatschappelijke doelen en geld']. December 2014 (Rli 2014/07)

Risks Assessed: Towards a Transparent and Adaptive Risk Policy ['Risico's gewaardeerd: naar een transparant en adaptief risicobeleid']. June 2014 (Rli 2014/06)

Recovering the Costs of Environmental Damage: Financial Indemnity Requirements for High-Risk Companies ['Milieuschade verhalen: advies financiële zekerheidstelling milieuschade Brzo- en IPPC4-bedrijven']. June 2014 (Rli 2014/05)

International Scan 2014. Emerging Issues in an International Context ['Internationale verkenning 2014. Signalen: de opkomende vraagstukken uit het internationale veld']. May 2014 (Rli 2014)

The Future of the City: The Power of New Connections ['De toekomst van de stad: de kracht van nieuwe verbindingen']. April 2014 (Rli 2014/04)

Quality Without Growth: On the Future of the Built Environment ['Kwaliteit zonder groei: over de toekomst van de leefomgeving']. April 2014 (Rli 2014/03)

Influencing Behaviour: More Effective Environmental Policy Through Insight Into Human Behaviour ['Doen en laten: effectiever milieubeleid door mensenkennis']. March 2014 (Rli 2014/02)

Living Independently for Longer, a Shared Responsibility of the Housing, Health and Welfare Policy Domains ['Langer zelfstandig, een gedeelde opgave van wonen, zorg en welzijn']. January 2014 (Rli 2014/01)

2013

Sustainable Choices in the Implementation of the Common Agricultural Policy in the Netherlands ['Duurzame keuzes bij de toepassing van het Europese landbouwbeleid in Nederland']. October 2013 (Rli 2013/06)

Pulling Together: Governance in the Schiphol/Amsterdam Metropolitan Region ['Sturen op samenhang: governance in de metropolitane regio Schiphol/Amsterdam']. September 2013 (Rli 2013/05)

Safety at Companies Subject to the Major Accidents Risks Decree: Responsibility and Effective Action ['Veiligheid bij Brzo-bedrijven: verantwoordelijkheid en daadkracht']. June 2013 (Rli 2013/04)

Dutch Logistics 2040: Designed to Last ['Nederlandse logistiek 2040: designed to last']. June 2013 (Rli 2013/03)

Nature's Imperative: Towards a Robust Nature Policy ['Onbeperkt houdbaar: naar een robuust natuurbeleid']. May 2013 (Rli 2013/02)

Room for Sustainable Agriculture ['Ruimte voor duurzame landbouw']. March 2013 (Rli 2013/01)

2012

Keep Moving: Towards Sustainable Mobility. Edited by Bert van Wee. October 2012 (Rli/EEAC)

Original title
De bodem bereikt?!

Text editing
Ellen Segeren, Segeren Tekst, The Hague

Infographics
Ronald van der Heide, Studio Ronald van der Heide, Utrecht
(pages 8, 10, 39, 42, 43, 53, 56)

Photo credits
Cover: Ruud Morijn / Shutterstock
Page 5: Ralf Liebhold / Shutterstock
Page 14: Ruud Morijn / Shutterstock
Page 18: fotoJoost / Shutterstock
Page 36: Maxim van Asseldonk / Shutterstock
Page 46: Ronald Wilfred Jansen / Shutterstock
Page 54: StockShots / Shutterstock
Page 57: LCarlon / Shutterstock

Graphic design
Jenneke Drupsteen Grafische vormgeving, The Hague

Publication Rli 2020/02
June 2020

Translation
Derek Middleton, Zevenaar

Preferred citation
Council for the Environment and Infrastructure (2020). *Soils for Sustainability.* The Hague.

ISBN 978-90-77323-29-8
NUR 740