Measures for Nature-based agriculture

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Summary

This memorandum provides a definition of nature-based agriculture and an overview of measures that contribute to it. Nature-based agriculture is a form of sustainable agriculture which makes optimal use of ecological processes and integrates them into farming practice. It is based on a healthy biodiverse soil, produces food within the boundaries set by the living environment and has positive effects on biodiversity and climate.

Based on scientific literature and practical experience, the effects of nature-based measures on arable agriculture and dairy farming systems are assessed in terms of biodiversity and environmental, climatic and economic aspects. The measures for arable agriculture include expanding the crop rotation plan, conservation tillage, green manure crops, winter coverage and field margins. Those for dairy farms have to do with permanent grassland and herb-rich grassland, grazing and manure management. Various aspects of the impact of landscape elements are also assessed.

Although nature-based agriculture ideally requires integrated management at farm or even regional level, with several measures being applied in conjunction with each other, we focused on the analysis of effects of individual measures. This is because the decision as to which combination of measures is suitable depends on the ambition of the farmer and the circumstances and environment of the farm. Individual measures provide a basis for making a distinction between various levels of ambition, thus enabling farmers to set to work on nature-based agriculture on a step-by-step basis.

The analysis of the effects shows that most of the measures have a positive effect on one or more of the aspects for biodiversity, the environment and climate. In the short term this will require a variety of additional investments in machinery and land management leading to lower economic returns. In the long-term, however, the financial benefits for the farmer are set to increase.

The overview also includes ‘no regret’ measures, which can always be applied in a cost-effective manner. Examples include measures for soil management and the optimisation of nutrient cycles. Nature-based management requires farms to acquire more biological and agronomic knowledge and adjust their approach as regards methods and management compared with working with chemical agents and making maximum use of technology. Greater knowledge needs to be acquired through research, participatory approaches and practical experience.

1 Introduction

In the Netherlands, nature-based agriculture is starting to gain attention in the public consciousness as a form of sustainable agriculture. However, as it is open to multiple interpretations people are not clear on which measures are available for nature-based agriculture, nor on the effects of those measures.

Commissioned by the Dutch Ministry of Economic Affairs, in this document the Louis Bolk Institute and Wageningen Environmental Research provide a clear definition and an overview of measures for nature-based agriculture which farmers can take at their farms, and also show the effects of those measures.

Based on existing scientific literature and practical experience, the effects are assessed in this memorandum in terms of different aspects, including environmental aspects, biodiversity, costs and benefits. The analysis is limited to measures and an assessment of their effects at farm level. The following approach was used:

- To start with, we formulated a definition of the term 'nature-based agriculture'.
- We then selected measures of relevance to nature-based agriculture which farmers can take at their farms. Although these measures can be taken separately, in practice they will be combined, depending on the characteristics of the farm and the farmer's level of ambition.
- Next, we presented a qualitative overview of the effects of the measures on the different aspects in a summary table. This overview is based on existing scientific literature and practical experience. We compared the positive and negative effects of measures with a situation where no measures were taken. The table does not contain scores for the interaction between the measures.

This memorandum will deal first with the definition of nature-based agriculture as applied here. Thereafter, we will explain the approach to the assessment of the measures and their effects on a number of aspects. Finally, we will amplify the nature-based measures and their impact on arable and dairy farming, and make recommendations on how farmers can adopt the concept of nature-based agriculture and the measures presented here.

2 What is nature-based agriculture?

2.1 Definition

Nature-based agriculture is a form of sustainable agriculture and part of a resilient ecosystem and food system. It makes optimal use of ecological processes and integrates them into farming practice. Nature-based agriculture also directly contributes to the quality of the natural environment itself, producing food within the boundaries set by the environment and having a positive impact on biodiversity. It can be described using the following three dimensions (Van Doorn et al., 2016):

- A resilient agriculture and food system is based on biodiversity, which makes essential contributions to farming practice, including natural prevention of disease and pests, pollination, the supply and treatment of water, natural soil fertility and a good soil structure. This is known as functional agro-biodiversity. Nature-based agriculture starts with the conservation, improvement and exploitation of this functional agro-biodiversity and the ecosystem services it offers on the farm.
- By exploiting functional agro-biodiversity and ecosystem services and closing nutrient cycles aiming at a system of zero-emissions, more efficient use will be made of natural resources, and consequently the impact of farming practices on water, soil and air can be further reduced. As a result, the negative effects (including local, regional and global shift effects) of farming practice on the natural environment can be kept to a minimum. In turn, this also has positive consequences for specific species on the farm and in the surrounding countryside.
- Finally, there is the matter of landscape maintenance and the conservation of specific species on the farm. A green infrastructure at farms can be maintained through the construction and conservation of landscape elements (important for flora and fauna). Landscape elements, in turn, also play a role in improving the functional agro-biodiversity on the farm. Agricultural environmental management contributes to the survival of meadow and farmland birds and other farmland species.

There are various connections and interactions between these dimensions. They refer to the four interconnected elements described in the conceptual framework for biodiversity in sustainable dairy farming (Erisman et al., 2014), see Figure 1:

1. Functional agro-biodiversity (aimed primarily at soil quality, mineral cycles and plants)
2. Landscape diversity (in particular landscape elements on the farm itself, of benefit to functional agro-biodiversity)
3. Source areas and wildlife corridors (in particular, measures at landscape scale, coordination between Nature Network Netherlands, management, exchanges between areas, etc.)

4. Specific species (additional measures for species conservation and support).

Figure 1. The four elements of biodiversity in dairy farming (Erisman et al., 2014)

Nature-based agriculture requires a link between functional agro-biodiversity and natural values, such as landscape and specific target species.

Healthy soil which is capable of holding and delivering water, which can contribute to the supply and management of nutrients and which sequesters carbon and uses it to maintain soil life is essential (first element - Figure 1). The role of healthy soil in agriculture is supported by landscape elements which have a dual function: they form the basis for functional agro-biodiversity, like pollination and pest control, and support specific target species. These are species (such as farmland birds and meadow birds) which represent the natural quality of the agricultural landscape and are dependent on specific habitats (second element - Figure 1). Nature and landscape quality can be further enhanced through proper coordination within a region (third element - Figure 1).

The foundation is thus laid for both a productive farm and for target species. However, additional measures, including postponed mowing dates for grass at the expense of production on the farm, are also needed in order to protect and support those species (fourth element - Figure 1).

It is possible to spend much energy on functional agro-biodiversity with ultimately a limited impact on specific species (such as meadow birds, Montagu's harrier and the European hamster). However, you can also do a great deal for specific species without using functional agro-biodiversity on farms (current practice of agricultural nature conservation). The aim of nature-based agriculture is to achieve a win-win situation, where functional agro-biodiversity is accompanied by reduced pressure on the environment resulting from, for example, reduced use of pesticides combined with the creation and management of landscape elements, as well as creating and maintaining habitats for promoting specific species. Nature-based agriculture is not simply a matter of agriculture serving nature, but an agricultural practice which uses ecological processes optimally, reducing pressure on the environment. Both functional biodiversity and specific species benefit as a result (see Figure 2).

Finally, it is important that every type of farm - including nature-based farms - has a commercially sound business model and that there is sufficient financial scope, taking into account the additional costs incurred as a result of the measures (Figure 2).

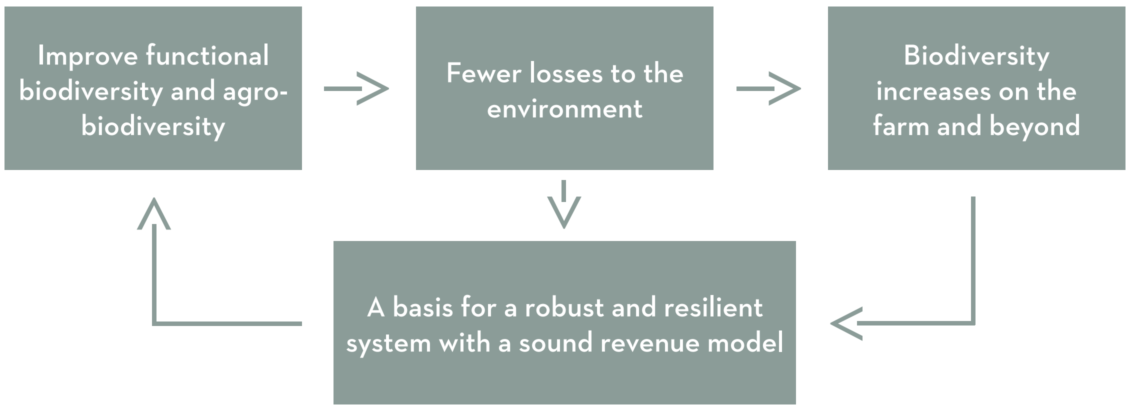


Figure 2. Links and interactions of nature-based agriculture (Erisman et al., 2014)

2.2 Characteristics of nature-based agriculture: resilient, diverse and comprehensive

In principle, nature-based agriculture is soil-bound because it is founded on healthy soil. This does not mean that intensive livestock breeding sectors cannot also work with natural processes. Consider, for example, natural development of the farmyard and limiting the impact on the environment of livestock breeding systems, and greenhouse horticulture where much use is already being made of natural pest control. How the term soil-bound agriculture is defined is important for nature-based agriculture. It may mean the land surrounding the farm, but also a collaboration between arable farming and livestock farming in the region where the farm is located, for example. However, it does not cover intensive livestock farming which is dependent on feed imported from other countries. We make a distinction between arable farming and dairy farming (grassland) because, in practice, there are different measures for the two sectors. The effects are comparable for other soil-bound sectors (including open-field vegetable production, fruit production and bulb cultivation). Measures for landscape elements are generally not classified in one of the sectors because the effects of the measures are not dependent on the farming system. One exception, however, is the integration of field margins at arable farms.

In general, today's agricultural production is highly specialised, concentrating on just a few crops. The availability of chemical products, fossil fuels and mechanisation has given rise to farming systems which place substantial pressure on the environment and where there is little biodiversity and therefore a sharp reduction in nature-based farming practices (Erisman et al., 2016, Tsiafouli et al., 2015). This specialisation has resulted in farms becoming more susceptible to, among other things, diseases and pests. In conventional agriculture, this is controlled by means of external inputs. Chemical products replace natural processes. The overuse of external inputs is often the cause of societal problems such as poor water quality, antibiotic resistance, etc. Diversity of soil organisms, specific species and landscape, by contrast, are elements which lead to more resilient agricultural systems. They also reduce dependence on interventions in the system (i.a. Tscharntke et al., 2005; Van Eekeren et al., 2015; Erisman et al., 2016).

The transition to nature-based agriculture and the accompanying objective of closing nutrient cycles could mean the advent of more mixed farms or mixed regions with dairy farms and arable farms working in close cooperation. The opportunities this offers, compared with specialised farms or regions, if put properly into practice, are that those farms will have a more resilient system and ecosystem (diversity), will make more efficient use of natural resources and will be able to close cycles by having more feed available from their own farms or regions. Such opportunities have been implemented in organic agriculture (Prins et al., 2004). The locations and spatial scale where co-operation between dairy farms and arable agriculture is possible are determined by various factors, such as cultural history, the type of region (peat grazing, marine clay), economy, regulations, etc. Further research is required into the scale on which cycles can be closed, where cooperation offers added value, and what effects this will have on nature-based agriculture.

A nature-based farming strategy not only has a major impact on the ecology of a farm but also potentially affects its economy. Key economic opportunities include:

- higher quality and healthier products through, among other things, an improved mineral and microbial cycle (Halweil, 2007; Benbrook, 2009); and
- an economically stronger, more resilient business model through diversification in products.

Nature-based farms turn out to be financially resilient farms in practice: they are low-risk because of the low financial burden and are more resilient at all levels (ecological and also economic), according to an initial assessment (Bestman et al., 2016). It is relevant that such farms do not have a short-term vision, but rather focus on the long term.

A form of integrated management which optimally uses the ecology of the system but also takes account of the societal aspects within the food chain can be seen in many agro-ecological systems such a permaculture, forest gardens, ecosystem restoration and community/consumer supported agriculture (CSA) (de Nooy van Tol, 2016). Many of those forms of agriculture take the soil as their starting-point and are distinguished by the fact that they use several layers in vegetation and produce products at the same time, close mineral cycles and use permanent ground cover, carbon sequestration and nutrient supply through biological fixation. Consequently, their performance is comparable and sometimes even superior to that resulting from the measures included here, not least because they are integrated concepts. Since they are still far away from conventional practice, they have not been included as measures in this study. However, we can learn a great deal from these systems.

2.3 Nature-based agriculture and climate

The climate is changing owing to human influences such as greenhouse gas emissions, air pollution, changing landscapes and all manner of interactions in the biosphere. The sea level is rising, temperatures are rising and we are experiencing drier and also wetter periods as a result of climate change. The extremes have become greater. We are experiencing the consequences of climate change already and with greater intensity than previously thought. Examples include the consequences of the heavy rainfall in South-East Brabant in June 2016.

Climate requires an integrated approach and a wide focus on soil and landscape quality. Nature-based agriculture can play an outstanding role here. As outlined in Figure 1, the first three elements form the basis for a farming system which can adapt to climate change and which is less susceptible to drought and excessive rainfall. Greater carbon sequestration can also help to reduce the CO^2 concentration in the air. A resilient and healthy soil combined with a diverse and green landscape can play a very important role in reinforcing agriculture's capacity to adapt and has a positive impact on climate because it has a cooling effect in the region concerned. In addition to its potential to help with climate adaptation, soil is fundamental to many other themes such as making agriculture sustainable, food, biodiversity, the living environment, water quantity and quality.

The capacity to adapt can be reinforced through efforts aimed at resilience and diversity, according to a mechanism with which we are familiar from ecology: diverse systems are more resistant to external influences. Resilience can be achieved by improving soil quality in terms of structure, composition (minerals, dry matter and compost) and soil life. Resilient soil is less susceptible to drought, excessive rainfall, diseases and pests and can therefore adapt to climate change.

Agriculture is partly to blame for climate change, but also has the potential to be part of the solution because it takes up more than 60% of the land area. Carbon sequestration in soil plays a key role in soil management in relation to food and water quality and quantity.

3 Method: overview of measures and effects

Nature-based agriculture requires an integrated management system aimed at a resilient food supply system, and a sound business model that includes nature and landscape conservation. An integrated approach is preferred over a set of individual measures because it is when they are combined that the nature-based approaches provide added value. In addition, many farmers will tend to apply several measures in an integrated way on their farms. That said, this report deals with individual measures only. The main reason for this is to provide farmers using conventional methods with an achievable outlook so that they can start with an accessible single measure and go on to build on it gradually. Added to that is the fact that a range of alternative combinations of measures is available for each farm, with the result that the associated effects differ substantially and are difficult to assess.

A selection of measures and aspects of relevance to nature-based agriculture was made for this survey. The selection is based on relevance, current application and also on earlier studies on agro-biodiversity and the biodiversity monitor for dairy farming (i.a. Erisman et al., 2014; van Eekeren et al., 2015; Geertsema et al., 2006; Zijlstra et al., 2016; Zaanen, 2017, http://biodiversiteitsmonitormelkveehouderij.nl, Laarhoven et al., 2017; Zijlstra et al., 2016).

Table 1 contains the measures assessed and the aspects used in the assessment of the effects. The summary table containing the scores for each measure is presented in Annex 1. The list of measures is not exhaustive and the details are discussed only for some of the selected measures, but for all measures the sources have been quoted. The measures are used in practice and most are applied on the scale of a plot or a farm. In addition to individual measures, we have included two farming systems (a farm with fully grass-fed livestock, and wet agriculture with cattle breeds adapted to the conditions in peat grazing areas).

The effects of the measures are assessed for a number of aspects (see Table 1 and the top row in the summary table in Annex 1). The aspects are grouped by theme, including functional agro-biodiversity, limiting environmental pressure factors (losses to and effects on the environment and climate) and specific biodiversity. Two aspects which reveal something of other societal benefits are also included. Since economic aspects are obviously very important for agriculture, the following aspects have also been included in the table: yield, financial investment, operating costs and income (not including investment costs for land, buildings and machinery), with a distinction made between the short and long term.

Measures		Aspects used to assess the effect	
Arable agriculture	**Dairy farms**	**subject**	**aspect**
Conservation tillage	Herb-rich grassland Outdoor grazing	Functional agro-biodiversity	Soil life Pest control/Combating diseases Pollination Soil quality (functions and structure)
Extend the cultivation plan for fields	Build a marshland system	Limit the impact of pressure factors	CO^2/carbon sequestration Mineral cycle Losses to the environment
Green manures, buffer crops, keeping fields green all year round	Wet agriculture and other cattle breeds in saturated peat grazing areas	Specific species	Biodiversity (above ground) and specific species
Reduction in the use of plant protection products	Farm with fully grass-fed livestock	Other societal benefits	Landscape quality and appreciation Climate adaptation and mitigation Food quality
Flourishing field mar-gins		Financial costs and benefits (farm)	Yield Investment (in euros) Operating costs and income: short-term Operating costs and income: long-term
Landscape elements	Landscape elements		

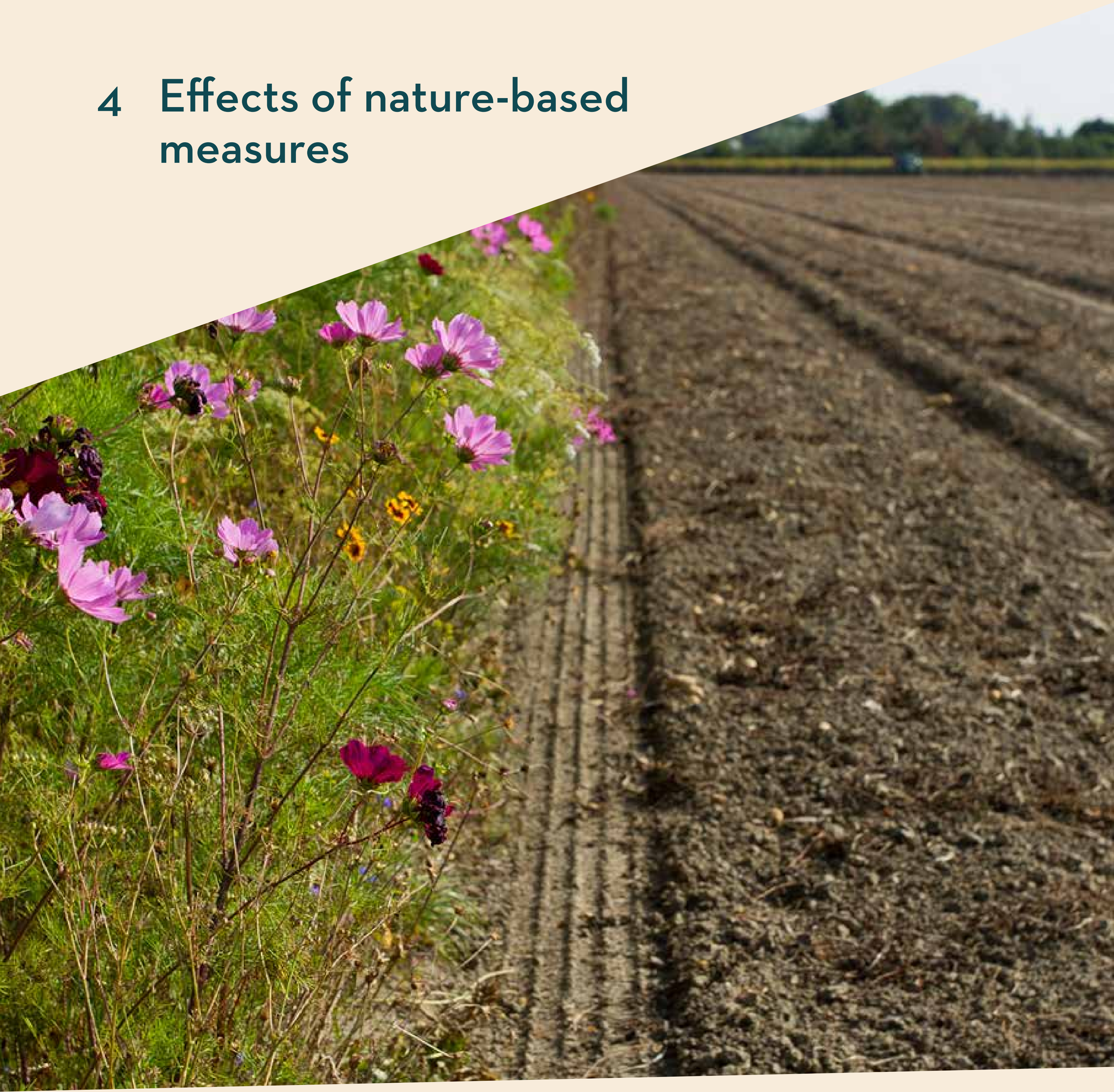
Table 1: List of measures for nature-based agriculture and aspects used to assess effects (elaborated further in Annex 1).

The principal objective for each measure is described and the positive and negative effects of the measures are assessed in the table. This is a qualitative assessment based on literature, expert knowledge and practical experience. Knowledge of the measures and their effects varies. For instance, a relatively large amount of knowledge and literature about mineral cycles and field margins is available, but very little is known about the effect of various nature-based measures on soil quality, losses to the environment or about the added value for the entire production system.

Positive and negative effects of the measures are determined by means of a comparison with a situation where no measure was taken. As for the economic parameters, we opted to identify at farm level the investments and short-term and long-term yields: lower, equal or greater than in a situation where no measure was applied. The change in societal benefits and its costs is not included, though. Many measures could possibly bring about a positive cost-benefit ratio in their own right if the societal benefits (in euros) were included. However, this does not provide a revenue model for individual farmers since the societal benefits and costs are not clearly quantified and captured.

The effect of a measure is seldom limited to the purpose for which it was taken. Nearly all measures also have side-effects; they are explained in the text. The predominant direction of the effect is indicated with a colour for each aspect: an improvement compared with a situation where the measure had not been implemented is green, a mixed or limited effect is yellow and a worsening of the situation is red. Since most of the measures serve several purposes and have effects and side-effects, the analysis of the effects of measures is complex, especially when complete farming systems which have implemented several measures simultaneously are examined. In addition, the effect of an individual measure on the overall business model is only partially taken into account by examining the ratio between operating costs and operating income. Farms will often combine several measures: their applicability will depend on the conditions, including the market conditions, experienced by the farm.

4 Effects of nature-based measures



4.1 Arable farming

In arable farming we distinguish between measures applied to crop fields, measures applied to field margins and a combination of the two. To increase nature-based agriculture on the field themselves, a combination of measures is required in order to generate similar yields in the longer term in comparison with those produced by conventional farming practice (De Haan et al., 2016). They will, however, require investment in the short term. This will involve a combination of extending the cultivation plan, conservation tillage, nitrogen fixing and cover crops. This will help to improve soil quality and productivity, and will also enhance the habitat of species such as farmland birds. Manure quality in relation to soil quality is important for nature-based agriculture. The same applies to dairy farming, as is explained in more detail in the section on dairy farming (4.2).

Extending the cultivation plan

Today's conventional arable farming is based on external products (fertiliser, pesticides and heavy machinery) which makes it possible, using a limited cultivation plan, to obtain substantial yields on large plots with just a limited number of crops (grains and root crops). However, limited crop rotation makes the system susceptible to weeds and the outbreak of diseases caused by fungi and nematodes, and soil quality will decline. Extending the cultivation plan with a rest crop such as clover or field beans alternating with (winter) cereals, catch crops, potatoes, etc. can substantially improve soil quality and increase organic matter. In short, this means an improved structure and also nitrogen fixation by legumes. A more comprehensive cultivation plan could also reduce the use of pesticides, provided there is proper coordination with other measures (conservation tillage, fertilisation using compost and/or fresh manure). It will enable the same yields to be achieved from the next cereal or root crops grown with reduced input of nutrients and pesticides. An extended cultivation plan and fewer external nutrients have a positive effect on biodiversity (Geiger et al., 2010). Economic gain for the farmer is obtained through soil-improving measures and reduced spending on manures, fertilisers and pesticides.

Conservation tillage

In conventional farming, arable land is frequently ploughed, a process known as turning the soil. Such intensive turning of the soil on arable land encourages the decomposition of organic matter. With conservation tillage or minimum tillage, organic matter is preserved and crop residues are retained in top soil (Holland, 2004). The effects of tillage on soil biodiversity are not clear, though, and depend on organisms and soil types. A recent review of German research into the effect of tillage intensity shows that the quantity and diversity of earthworms increase where there is less tillage (van Capelle et al., 2012). Earthworms, in particular, help to increase the pore volume in the soil, strengthen its carrying capacity through the formation of aggregates, and also help to increase water infiltration and water-holding capacity owing to the presence of more organic material in the soil. As a consequence, they perform a number of important functions for the agriculture system.

Green cover/buffer crops/green manures

Once a crop has been harvested, it is important that farmland enters winter covered. This can be achieved through nitrogen fixing, through the use of catch crops or through the cultivation plan (for example, sowing winter cereals). Such crops can be used to ensure nitrogen fixation in the soil, and the rooting has a positive impact on the soil structure and soil life. On the other hand, planted arable land offers few sources of food for birds in the winter because the crop residues have been incorporated (Holland, 2004). However, when combined with conservation tillage, there are opportunities here, although a catch crop is more interesting for specific species such as seed-eating birds. The experience of the Dutch Skylark Foundation shows that this measure is profitable in the long term. After 15 years, growers who apply soil-related measures and other sustainability measures obtained yields which are more stable and less susceptible to weather influences, and increase their revenue as well.

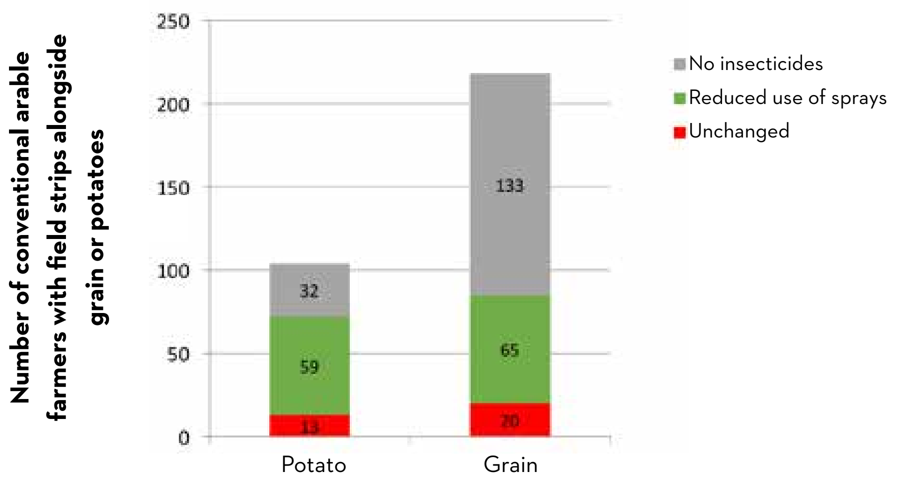
Field margins

In a recent literature review, Bos et al. (2014) provided a list of the advantages of field margins. They made a distinction between scientific status and practice (Table 2). The findings of Bos et al. (2014) have been used to assess the effects in the summary table.

Service	Sub-objectives	Demonstrated?		Main objective	Demonstrated?	
		Science	Practice		Science	Practice
Buffer functions	• Less leaching of nutrients and sediment run-off • Less pesticide drift	+ +	o o	• Cleaner surface water	o	±
Plant protection	• Greater diversity and numbers of natural enemies in field margins • Greater diversity and numbers of natural enemies in the crop • Greater predation of pest organisms in the crop	+ + +	± + o	• Lower pest pressure in crops • Less damage to crops by pests • Reduced use of insecticides in crops	+ o o	+ o ±
Crop pollination	• Greater diversity and numbers of pollinating insects in field margins • More visits to flowers by polli-nating insects • More fruiting in the crop	+ o o	+ o o	• Improved harvest or seed production	+	o
Nature conservation	*Too many different sub-objectives owing to substantial differences between ultimate goals.*			• Greater biodiversity in flora and fauna • An increase in the popula-tions of vulnerable species	+ +	± +
Landscape appreciation	• Improved landscape diversity owing to the field margins present • Improved landscape quality owing to visually attractive field margins	+ +	o o	• Greater satisfaction among local residents owing to improved appreciation of the landscape • More recreation and more income from it	o o	o o

Table 2: The services field margins provide for society and their sub-objectives and end goals and/or effects are demonstrated using research (science) or monitoring (practice) (+ = demonstrated positive effect; ± = a positive effect is sometimes demonstrated/sometimes no positive effect is demonstrated; o = not researched or monitored) (Bos et al., 2014).

Within the Flourishing Farm project (www.bloeiendbedrijf.nl), work on field margins for integrated plant protection through the exchange of knowledge and experience was carried out for three years involving roughly 600 farmers. The results of that project showed that 75% of the participants reduced their use of plant protection products (see Figure 3).



Source: 2013 Field Strip Report

Figure 3 Changes in the use of plant protection products for potatoes and grain within the Flourishing Farm project (after three years)

It is clear that field margins, provided they are properly constructed and maintained, have a very positive effect on buffer functions, reduced use of pesticides, pollination and landscape appreciation (see Bos et al., 2014). Field margin management for endangered bird species or to reduce the use of insecticides can be used to improve the situation of both, but have never been used in combination to date (Bos et al., 2014). Construction and management increase the arable farmer's costs and reduce production because part of the field is used as a margin. Generally speaking, the reduced costs of plant protection and the other functions producing an economic benefit are small compensation at present. However, there are recent examples of field margins having had a positive impact on yields (Pywell et al., 2015).

4.2 Dairy farms

Manure quality

Manure has a beneficial impact on the biological quality of soil through the organic matter it supplies (Faber et al., 2009). To ensure good quality soil it is essential that high-quality manure is applied in a manner such that the soil structure is preserved (fresh manure, lightweight machinery).

High-quality manure can be used to stimulate specific soil organisms which serve a variety of functions for the farm. The quality of manure has a major impact on the microbial cycle on a farm. Straw in fresh manure and also the fibres in the viscous fraction of slurry stimulate earthworms (van Eekeren et al., 2009; 2016). They, in turn, have a positive impact on the soil structure in the top layer and are thus conducive to water infiltration. Litter in fresh manure also serves as nesting material for meadow birds for which earthworms are an important source of food.

Grassland

Good soil quality and the extent to which the activities are soil-bound form the basis for the feed supply on nature-based dairy farms. One factor for determining the extent to which activities are soil-bound can be expressed in the number of livestock units (LU) per hectare or milk production per hectare, but also in the percentage of protein from the farm's own land and the grazing. Protein is an important part of the rations provided to dairy cows. At present, it is largely sourced from grass and concentrate crops, including soya. The percentage of protein produced on the farmer's own land is related to the biodiversity on the dairy farm itself and biodiversity in the regions where soya is produced. Many dairy farms combine grassland with arable land (often used for the production of silage maize). Farms which meet the requirements for derogation of the EU Nitrates directive have at least 80% grassland and a maximum of 20% arable land. As far as functional agro-biodiversity at a dairy farm is concerned, grassland, in principle, is preferable to arable land (Reidsma et al., 2006). For example, grassland contributes to raising levels of soil organic matter. Generally speaking, arable land has a diminishing or slightly stabilising effect on organic matter content. The organic matter content in the soil has an impact on soil biodiversity and functional biodiversity (Faber et al., 2009). It is important that the organic matter content of arable land remains stable. This can be monitored using the organic matter balance on arable land, which will also allow an assessment of soil biodiversity.

Reidsma et al. (2006) defined a value for the ecosystem quality of an arable farm or region based on the losses to the environment and the effect on biodiversity set off against natural areas (value set at 100). According to Reidsma et al. (2006) the value for the ecosystem quality of extensively managed grassland is 40%, 25% for extensively managed arable land, 20% for intensively managed grassland, and 10% for intensively managed arable land. Land which is used intensively, such as arable land, results in food supply systems which are less well-developed as regards the number of species, but also in less diversity in functional groups (Tsiafouli et al., 2015) and to fewer links between organisms (Creamer et al., 2015). The larger the amount of grassland in the farming system, the better this is for organic matter and soil biodiversity and, ultimately, for functions such as grass production (nitrogen-delivering capacity), environmental functions (including water regulation), climate (CO^2 sequestration) and biodiversity (including meadow birds) (van Eekeren et al., 2008; van Eekeren et al., 2010). This makes the amount of grassland an indicator of functional biodiversity on the dairy farm.

Herb-rich grassland

Herb-rich grassland accompanied by the various functional groups (grasses, legumes and herbs) is one of the key components of functional agro-biodiversity on a dairy farm. In addition, it is extremely important to specific species such as meadow birds. At present, herb-rich grassland is mainly linked to objectives related to meadow birds combined with a reduction in the use of fertiliser and a postponed mowing date. Although little account has thus far been taken of the fact that herb-rich grassland is functional to the practice of farming, there is no doubt that it contributes to animal health, drought tolerance and stability of production (Wagenaar et al., 2017).
Herb-rich grasslands are old grasslands and there is evidence showing that; the older the grassland and the lower the level of cultivation, the less degradation of the ecosystem and the greater the likelihood of diversity above and below ground. Since the soil is not cultivated, a stable environment is created below the soil offering sufficient nourishment, and soil biodiversity increases. Research conducted by Van Eekeren et al. (2008) shows that the diversity of earthworms, nematodes, fungi and bacteria is greater in soil below old grassland (36 years) than temporary grassland (3 years). The organic matter content also increases in older grassland. This is linked to the increase in soil biodiversity and functional biodiversity (Faber et al., 2009) and to the net CO^2 emissions pressure factor. The above-ground botanic composition is also partly linked to the age of the grassland, but is determined to a large extent by the management (including the grass species used when sowing, the use of herbicides and fertiliser) and the type of land.

Grazing

At present, under the policy for grazing, conventional farms aim for a minimum of 120 days with six hours' grazing a day. It is not only the length of time spent grazing but also the surface being grazed and the start date on which animals are turned out for grazing that are important to functional agro-biodiversity and specific species. Among other things, grazing has a positive effect on the botanical composition (including white clover), which increases the functionality of natural nitrogen transformation in conditions where there is a low nitrogen content (van Eekeren et al., 2015). Grazing also has a positive effect on ammonia emissions (Hoving et al., 2014). In addition, cow manure offers breeding sites for earthworms (Versteeg et al., 2014), which digest the litter and improve the structure of the top soil. Those earthworms are also a source of food for meadow birds and the insects settling on cow dung are food for chicks (Versteeg et al., 2014).

Early grazing also stimulates the creation of growth steps (i.e. a mosaic), and prevent the first cut from being mowed entirely. The largely beneficial effects depend heavily on the way in which grazing takes place, with the intensity of grazing being particularly crucial.

In peat grazing areas, an increase of the water level results in improvements for a number of indicators. This measure is implicit in the table for wet agriculture and other cattle breeds in saturated peat grazing areas.

4.3 Landscape elements

Landscape elements are defined here as elements on farms comprising natural and semi-natural vegetation, such as hedgerows, rows of trees, copses, headlands with rough vegetation, banks of ditches and nature-friendly banks

No distinction between arable farming and dairy farming is made in the description of the effects of landscape elements on the various aspects. Many farms have a small percentage of landscape elements. The type of landscape feature varies among the different regions in the Netherlands (Geertsema et al., 2002). Many of those elements have been part of the landscape for decades and are emblems of regional identity. In the past, they played a more important role in farming; hedgerows, for instance, were used to mark plot boundaries, as a source of food or for pest control. Many landscape elements have disappeared as a result of the upscaling of agriculture and because they have ceased to be functional tools for production. The management of landscape elements varies, but often has zero priority in farming practice. Examples include the management of ditch banks (flailing, scraping). They are also affected by eutrophication and pesticide drift.

The characteristic feature of landscape elements still present today is that they are the stable factor in the production system. Management is far less intensive than on the plots themselves and the vegetation is made up of perennials. The landscape elements support diversity and gradients in today's agricultural landscape. They have a dual function (see Figure 1): they serve to strengthen both functional agro-biodiversity and habitats for specific species, and are also emblems of regional identity and landscape quality.

Landscape elements form a vital link in nature-based agriculture (Figure 2). They are a crucial source of food, nesting places or refuges for natural enemies of pest insects and also for pollinators and provide a habitat where natural enemies can overwinter. In spring, woody landscape elements come into bloom earlier than fields and field margins, supplying nectar and pollen for natural enemies such as wasps and hover flies and enabling them to build up their populations so that, when the crop starts to grow on the field, there is sufficient potential in the form of natural enemies to suppress pest populations (Van Rijn, 2016). In addition, landscape elements provide shade, which is important for livestock.

On the other hand, farmers can also view landscape elements as a source of pests. However, research shows that the benefits of natural enemies outweigh the pests (Bianchi et al., 2006). In other words, investing in landscape elements has a much stronger impact on the growth of natural enemies than on the growth of pest insects.

Landscape elements are the most important habitat for many plant and animal species in the agricultural countryside. This is true for all types of habitat, from damp, lush vegetation on ditch banks and dry dike slopes to hedgerows and rows of trees. Positive relationships between those habitats and the agricultural landscape are found for plants, birds and several insect groups (Billeter et al., 2008, Cormont et al., 2016). The network of features which can be created at landscape scale over several farms plays an important role in linking conservation areas and, consequently, in strengthening biodiversity (Grashof et al., 2009).

Reinforcing landscape elements in nature-based agriculture can be achieved through good management. For lush features (ditch banks and dikes) that means mowing (no more than once or twice a year) and the removal of biomass. Through phased mowing, a stable habitat is left for plants and animals.

Leaving the management aspect aside, in many cases increasing the number of elements or the size of existing ones is a way of raising the inclusion of nature. One example is the development of nature-friendly banks alongside ditches and reducing their depth. This results in a more stable water level, which is more resistant to extremes in precipitation (Van de Sandt & Goosen, 2011) and offers additional opportunities for biodiversity.

Effectiveness for functional agro-biodiversity and also for specific species depends on the spatial link at landscape scale (feature 3 in Figure 1). Investing in isolated landscape elements has less impact than investment in elements which show correlations in the landscape.

The management and creation of habitats to foster specific species also requires investments on the part of the farmer. However, this will largely generate societal benefits. Investment from society, or offsetting from the supply chain by charging more for products, is necessary to arrive at a balanced revenue model. Ponds and ditches could also feature in this list. They are an important habitat for aquatic species, but have only a very limited role in functional agro-biodiversity.

4.4 Ambition levels and scenarios

Ultimately, nature-based agriculture is more than the implementation of individual measures without considering the connections between them. It requires integrated management aimed at soil and landscape quality, production, including food production, and ecosystem services, at farm and even regional level. The descriptions and quantifications given here are generic, but we can make a distinction between various levels of ambition or scenarios for nature-based agriculture (Erisman et al., 2014). This makes it possible for farmers to set to work on nature-based agriculture on a step-by-step basis. It remains important to work on the basis of an integrated approach as far as possible and to bear in mind the sequential order of the related elements in Figure 1: start by working on the soil quality in relation to crops and fertilisation (cycles), and management and/or creation of landscape elements tailored to the surrounding area.

An incentive or reward system could be based on an ambition classification. Figure 4 provides an example of the variation in biodiversity for each farm in relation to yield (Erisman et al., 2016). Four ambitions are outlined in the figure, which gives the score for individual farms (red dots) for biodiversity in relation to intensity: the higher the intensity, the lower the biodiversity. In practice, biodiversity turns out to have a maximum for each intensity class. The blue line shows the highest scores for biodiversity and therefore represents the maximum biodiversity that can be achieved in that intensity class. The potential for individual farms can vary substantially where the management is the same. Yield can also increase substantially for most farms without the biodiversity level decreasing. Again, yield is partly dependent on the intensity level (not shown in the figure). The maximum biodiversity is fixed when a specific yield-intensity level is chosen. The combination of the absolute biodiversity level (the level the farm has already achieved) and the progress made on the way to the maximum biodiversity level achievable (blue dotted line) can be used to define ambition levels.
Note: The production and use of sustainable energy are, of course, also areas in which ambitions can be formulated, but they do not come within the scope of this study.

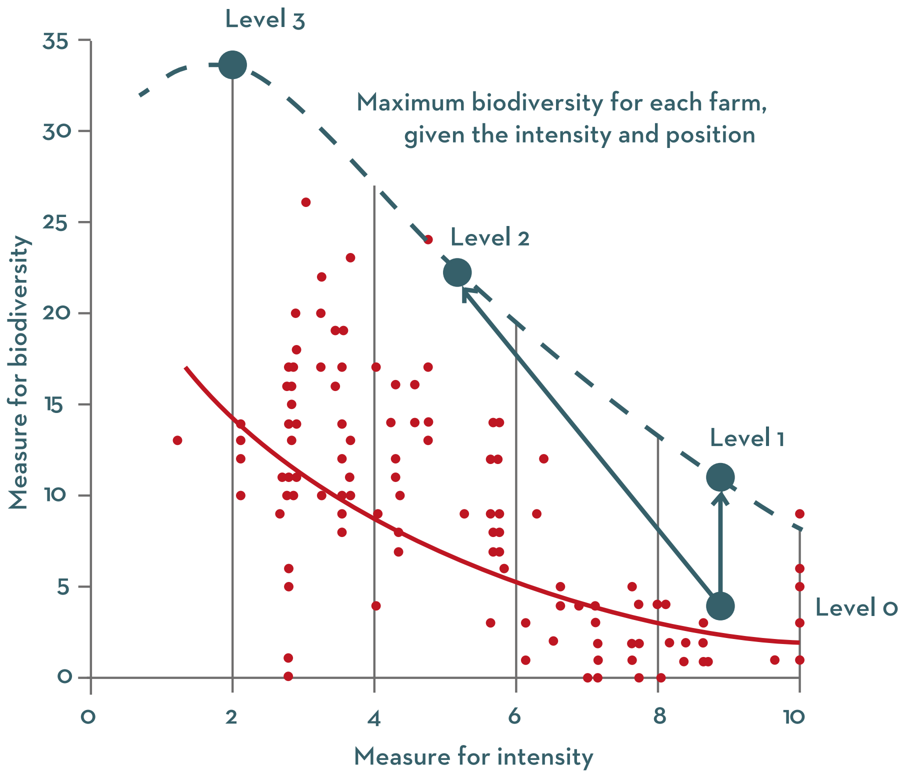


Figure 4. Variety of biodiversity for each farm (red dots) in relation to intensity. Intensity is determined by the combination of fertilisation, grazing and mowing. The blue dotted line shows the maximum amount of biodiversity per yield, determined by combining the highest points scored.

In terms of the degree of nature-based farming practices, we distinguish the following levels:

Level 0: minimum use is made of biodiversity at the farm; all it does is comply with the regulations, for example, grazing in accordance with the relevant minimum requirements.

Level 1: biodiversity is advanced by taking measures for one part of the farm for specific species, for example, by blocking off part of the land and leaving it unmanaged, by creating a marshland system or herb-rich field margins, by taking account of mowing and fertilising through a mosaic structure or ditch bank management, but also by putting up nest boxes or through farmyard vegetation. Organic pest control in greenhouses is also included at this level.

Practical example: Level 1 is in fact implemented by conventional farms which are currently taking part in the Agricultural Nature Conservation programme[1] and taking measures to preserve or encourage species.

Level 2: this is a step concerning the extent to which activities are soil-bound: activities on the farm are geared towards enhancing functional biodiversity by improving soil, crop and animal cycles, for example by using a combination of the measures discussed in this publication, as well as giving scope for animals to behave as nature intended, managing landscape elements as a means of assisting functional agro-biodiversity and measures in respect of specific species.

Level 3: the farm has an adaptive system and is fully soil-bound, cycles are optimised and attention is paid to, for example, herb-rich grassland and robust cattle breeds. The creation and maintenance of landscape elements and measures in respect of specific features are also taken into account. Participation in a regional cooperative with ambitious regional management plans in respect of an interlacing network of ecosystems and water and species management can improve the results.

Practical example: Few farms qualify as level 3. One example is a dairy farm with fully grass-fed livestock, see: http:www.zogroenalsgras.com

A higher biodiversity ambition will be accompanied by different costs in the short and long term, and yields will differ too. The first farm ambition incurs the lowest costs as regards investments in biodiversity measures and the highest crop yields in the short term. This system approximates the 'control model': these are farms where the use of external inputs means little use is made of natural processes. They are largely dependent on external and technical aids such as fertiliser, plant protection products, irrigation, antibiotics, etc. with the associated costs. In the long term, the costs involved with this model rise because the risks of climatic influences, resistance to antibiotics and feed and milk price fluctuations increase.

At level 0, the costs for investments in biodiversity are greater, but the differences in yields as compared with level 1 are limited. Level 2 offers the greatest stability in income in the medium and long term because extensive use is made of natural processes instead of external inputs to address disruptions caused by diseases and pests. This results in great steps being made towards sustainability, but not in the greatest biodiversity profit. Level 3 is the most attractive from the point of view of sustainability and also biodiversity, but only offers the prospect of cost-benefit ratios comparable with those achievable at level 0 in the long term (a minimum of ten years). This is because managing, optimising and testing natural processes and the agro-ecosystem takes a great deal of time.

[1] The added value of the collective system for Agricultural Nature and Landscape Conservation is that the collectives monitor regional consistency between the measures taken by individual farms.

5 Conclusions

5.1 Many positive effects, with investments and knowledge required

The table containing measures and effects (see Annex 1) shows that the majority of the measures have a positive impact on one or more aspects for functional agro-biodiversity and specific biodiversity. However, it is also clear that investments are required, certainly in the short term. The long-term picture will be quite different and the financial benefits are set to increase.
An improvement in indicators generally leads to an increase in societal benefits and a reduction of societal costs – the outcome nature-based agriculture aims at. Were this to be offset against the financial costs and benefits, many measures could prove cost-effective in their own right.

Most of the measures serve several goals. Furthermore, several measures often have the same effects or side effects, such as an improvement in soil quality, the quality of the landscape and promoting species. Farms will often combine several measures. Control exercised within nature-based agriculture can help to implement the measures based on an integrated approach successfully and consistently. The conceptual framework in Figure 1 can be used as a tool: start by working on soil quality, crops and the mineral cycle, enhance them with landscape elements, reinforced within a region. The attractiveness of a revenue model depends on the combination of measures, but also on physical aspects (size, soil, etc.) and the socio-economic circumstances (e.g. distance to a town or city) of a farm. This makes a generic analysis of the translation of several nature-based measures for each farm into a farming system where measures are taken on an integrated basis extremely complex. It is not a simple sum total of costs and benefits.

Ultimately, nature-based agriculture requires an integrated approach and the implementation of measures, but the implementation must be such that the measures reinforce each other. Depending on the ambition level, farmers can determine for themselves how attractive an option nature-based agriculture is to them. Greater awareness of its benefits and the potential new revenue models that can be developed can result in the ambition level being raised.

Working with biodiversity and natural processes requires farms to acquire different knowledge and to take a different approach as regards methods and monitoring from that required when working with chemical agents and technology. That knowledge needs to be acquired through research and practical experience. What are known as frontrunner farms are essential in this process as we can learn from them, they can indicate an effective approach, and we can quantify the results as for the indicators in the summary table. The overview given here is still highly qualitative. Quantifying the effect of measures (hectares, species, densities) using indicators (how many additional species, how many more pests have been suppressed, how much less use is made of products) and costs and benefits can enable the next step to be taken. This will also immediately reveal the knowledge gaps.

This overview can be used to specify which ‘no regret’ measures can always be taken in a cost-effective manner. They include soil management measures and optimising nutrient cycles.

5.2 Concluding observations

The table containing measures and scores for different aspects of sustainability presented in Annex 1 can be used as a tool. Nature-based agriculture is not limited to an individual measure but is a different, more integrated system of agricultural practice. It is a farming concept which is put into practice using different levels of ambition in various areas and can lead to sustainable results, aimed at quality, ecosystem services and an adequate food supply in the long term. This will require a transformation of farming practice and/or gradual implementation and, possibly, additional market development for specific products. Farmers can set to work on it now. Further development and quantification will also be required in order to develop the concept and test it in practice. This will make it possible to demonstrate the benefits, further develop the system and explore areas where government support is required.

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Annex 1

Overview of measures and effects within Nature-based Agriculture - Landscape elements

positive	neutral	negative

			Functional agro-biodiversity			Limiting the impact of pressure fa
Land use	**Measures**	**Purpose/function**	**Soil life**	**Pest control / combating disease**	**Pollination**	**Soil quality (functions and structure)**
Arable land and grass-land	**To modify manure quality and diversity (fresh manure, limit the use of fertiliser, manure quality)**	Structure of organic matter, to limit emissions, stimulate soil life, food and nesting opportunities for specific species	Increases and has the effect of improving soil structure, water management, mineral use and pest control	The role played by soil life is enhanced and pest pressure reduced	No effect	Encourage use of minerals, Organic matter, Foster soil life, Improve soil structure
Arable land	**Conservation tillage**	To keep crop residues in topsoil, reduce decomposition of organic matter, ensure that there is a greater food supply and less disruption of soil life	Increases and has the effect of improving soil structure and resistance to disease	Pest pressure is reduced	No effect	The quantity of organic matter increases, soil life activity increases, soil structure is improved and CO_2 emissions decrease
	Extend the cultivation plan for fields	Organic matter structure, improvement of soil structure and increased disease resistance	Increases and plays a part in pest control	The role played by soil life is enhanced and pest pressure reduced	No effect	Soil structure and water management is improved
	Use of catch crops, cover crops and nitrogen fixing crops	To fix nutrients, stimulate soil life, improve soil structure and organic matter production	Increases and has the effect of improving soil structure and resistance to disease	The role played by soil life is enhanced and pest pressure reduced	Is improved	Improvement of soil structure
	Reduction in the use of plant protection products	Less disruption of the food web for specific species; product quality	Less interference with soil life	More natural control	Is substantially improved	No impact on physical structure
	Flourishing field margins	Buffer functions, plant protection, crop pollination, nature conservation (including specific species such as farmland birds) and landscape appreciation	Has an impact only on a broad margin	Greater diversity and numbers of natural enemies in field margins Greater diversity and numbers of natural enemies in the crop Greater predation of pest organisms in the crop, when managed well (seed mix) means a substantial reduction in the use of pesticides. Flourishing Farm project (60 farmers) showed a reduction of up to 70%	Greater diversity and numbers of pollinating insects in field margins More visits to flowers by pollinating insects More fruiting in the crop	Has an impact only on a broad margin

ctors				Specific species	Other societal benefits		
	CO_2/carbon sequestration	**Mineral cycle**	**Losses to the environment**	**Biodiversity (above ground) and specific species**	**Landscape quality and appreciation**	**Climate adaptation and mitigation**	**Food quality**
	Facilitates carbon sequestration	To close cycles and improve minerals by fostering soil life, improve soil structure, improve water management and rooting	Decreasing where minerals are properly managed	To simulate soil life and ensure better accessibility of food for meadow birds, for example (Deru et al.)	Limited direct impact	Mitigation: carbon in the soil, reduction in the use of fossil fuel in the production of fertilisers	Good balance of food and minerals
	Organic matter decomposition is reduced, net CO_2/carbon sequestration	More stable mineralisation in soil resulting in better use of nutrients	Decreasing where minerals are properly managed	More insects and feed in winter, causing the farmland bird population to increase		Adaptation: more organic matter in the soil increases its water-retention capacity, extreme drought and extreme rainfall has less of an impact; broad cultivation plan spreads the risks of extreme weather	
	CO_2/carbon sequestration	Improvement when green manures and buffer crops are used and the use of fertiliser is limited	To reduce the use of plant protection products	To include specific crops such as lucerne and clover for farmland birds	Changing landscape, land cover	Adaptation: better soil structure improves penetration of ground water (benefiting deep-rooting crops, for example) and helps to prevent flooding during extreme rainfall; crops which are suited to higher temperatures are likely to succeed; as well as saline agriculture	More diverse production and food quality
	CO_2/carbon sequestration	Reduction in emissions	Decreasing where minerals are properly managed	Possible increase in the insect population. The incorporation of crop residues may mean less food for surface fauna	Changing landscape, land cover	Mitigation: carbon in soil Adaptation: soil's water-retention capacity	
	Reduction in emissions owing to reduced production; crops absorb less CO_2 when there is less growth (because of disease or pests)	Reduction in emissions	Decreasing where minerals are properly managed	More insects and feed in winter, causing the farmland bird population to increase	Increases owing to a rise in the number of species, depending on alternative measures	Mitigation: less energy is required for the production of chemical agents	Few plant protection products in or on food
	Limited	Limited	95% of surface emissions of plant protection products, reduced loss and run-off of minerals owing to lower levels of fertiliser and buffer function	Helps farmland birds. Improvement in the food web and growth of chicks	Improved landscape diversity owing to the field margins present Improved landscape quality owing to visually attractive field margins	Limited	Limited

Annex 1
Overview of measures and effects within Nature-based agriculture – Arable land

positive	neutral	negative

		Financial costs and benefits (farm)			
Land use	**Measures**	**Yield**	**Investment (in euros)**	**Operating costs and income: SHORT-TERM**	**Operating costs and income: LONG-TERM**
Arable land and grass-land	**Modify manure quality and diversity (fresh manure, limit fertil-iser, manure quality)**	Will increase	Depends on the modifica-tion of existing housing system and machinery	Higher operating costs for the use of manure	Higher in the long term owing to higher yield
Arable land	**Conservation tillage**	Improvement in structure with the possibility of an increased yield	Investment in the mod-ification of machines	Short-term invest-ment	Higher in the long term
	Extend the cultivation plan for fields	Targeted yield increase for top cash crops		Net result of the cultivation plan taken into account rather than the net result of the crop	Net result of the cultivation plan taken into account rather than the net result of the crop
	Use of cover crops, catch crops and nitrogen fixing crops	5% yield poten-tial in next crop	Limited invest-ment	Cultivation of crop leads to higher costs.	Higher in the long term because of higher yield
	Reduction in the use of plant protection products	Heavily de-pendent on alternative meas-ures (soil, field margins, crop rotation, etc.)		Greater risk if no alternative meas-ures are taken; reduction in costs for the use of products	Reduction in costs for the use of products
	Flourishing field margins	lower owing to non-productive margins and greater weed pressure else-where	Construction and conser-vation	Conservation costs, production loss and weeds elsewhere	Conservation costs and produc-tion loss

Annex 1
Overview of measures and effects within Nature-based agriculture – Arable land

Land use	Measures	References
Arable land and grass-land	**Modify manure quality and diversity (fresh manure, limit fertil-iser, manure quality)**	Balen, D. van, C. G. Topper, W.C.A. van Geel, J.J. de Haan, M.J.G. de Haas, D.W. Bussink. Effecten bodem- en structuurverbeteraars, onderzoek op kleigrond. Final report for the Province of Flevoland. PPO-agv & NMI. 63. Koopmans, C.J. and A. Zwijnenburg. 2015. Reststromen veilig en duurzaam inzetten in de akker-bouw. Louis Bolk Institute, Driebergen 28 p. Faber, J.H., G.A.J.M. Jagers op Akkerhuis, J. Bloem. J. Lahr, W.H. Diemont, L.C. Braat. 2009. Eco-systeemdiensten en transities in bodemgebruik; Maatregelen ter verbetering van biologische bodemkwaliteit. Wageningen, Alterra, Alterra report 1813. 150 pages Haan, J. de Het belang van organische stof; organische stof, meer waard dan je denkt. Presentation at Grond om te boeren, Papendal, 8 December, 2015.
Arable land	**Conservation tillage**	Cooper, J.M., M. Baranski. et. al. 2014. Effects of reduced tillage in organic farming on yield, weeds and soil carbon: Meta-analysis results from the TILMAN-ORG project. Proceeding at OWC, Istanbul, 2014. Powlson, D.S., et.al. 2011. Soil management in relation to sustainable agriculture and ecosystem services. Food Policy 36: S72-S87. Lijster, E. de., J van de Akker, A. Visser, B. Allema, A. van der Wal and H. Dijkman (2016). Waarderen van bodemwatermaatrgelen. CLM, Culemborg. 54 p.
	Extend the cultivation plan for fields	Dijk, H. van, Spruijt, J., Runia, W., & van Geel, W. (2012). Verruiming vruchtwisseling in relatie tot mineralenbenutting, bodemkwaliteit en bedrijfseconomie op akkerbouwbedrijven. Prakti-jkonderzoek Plant & Omgeving, Business Unit AGV, Lelystad. Van de Sandt, K. & Goosen, H. 2011. Klimaatadaptatie in het landelijk gebied. KvK044/2011, KvR040/2011
	Use of cover crops, catch crops and nitrogen fixing crops	Van de Sandt, K. & Goosen, H. 2011. Klimaatadaptatie in het landelijk gebied. KvK044/2011, KvR040/2011
	Reduction in the use of plant protection products	Popp, J., K. Peto, J. Nagy. 2013. Pesticide productivity and food security. A review. Agronomy for Sust. Dev. Vol. 33. No 1:243:255
	Flourishing field margins	www.bloeiendbedrijf.nl Merijn M. Bos, C.J.M. Musters & G.R. de Snoo (2014) De effectiviteit van akkerranden in het vervul-len van maatschappelijke diensten. Een overzicht uit wetenschappelijke literatuur en praktijk-ervaringen. (An overview based on scientific literature and practical experience) CML Report 188, Department Conservation Biology, Institute of Environmental Sciences, Leiden University

positive	neutral	negative

Annex 1
Overview of measures and effects within Nature-based agriculture - Grassland

			Functional agro-biodiversity		
Land use	**Measures**	**Purpose/function**	**Soil life**	**Pest control/combating disease**	**Pollination**
Grassland	**Herb-rich grassland**	To improve soil, roughage, animal health and meadow birds	Soil life diversity	Reduced use of antibiotics	Depending on the botanical composition of permanent grassland, this will increase
	Outdoor grazing	Animal welfare and health, to close cycles and limit ammonia	Greater grazing losses and cowpats stimulate soil life	Greater resilience in cows	High-manure patches mean lusher growth in the pasture
	Creation of a marshland system	Encourage meadow birds	Quantity will decrease	Liver fluke infestation can increase	N/A
	Farm with fully grass-fed livestock	Grassland has a positive impact on soil quality (organic matter and soil life), nutrient and plant protection product emissions into surface water [are limited] and biodiversity in topsoil	Soil life numbers, activity and increased diversity	The role played by soil life is enhanced and pest pressure reduced	Depending on the botanical composition of permanent grassland, this will increase
	Wet agriculture and other cattle breeds in saturated peat grazing areas	To limit CO_2 emissions in peat grazing areas, cleaner water, water storage, biodiversity/birds, landscape	N/A	N/A	Depending on the crops, this may increase

Limiting the impact of pressure factors				Specific species
Soil quality (functions and structure)	**CO_2/carbon sequestration**	**Mineral cycle**	**Losses to the environment**	**Biodiversity (above ground) and specific species**
Diversity in rooting, soil biology and improved soil structure	To reduce the composition of organic matter, net CO_2/carbon sequestration	Lower level of fertilisers hence improved cycles	Limited owing to lower level of fertilisers	Healthier cattle and more meadow birds; reduced use of antibiotics with benefits in the chain
Less soil compaction, better moisture regulation, greater production capacity and capacity to recover	Greater supply of organic matter as a result of more losses through grazing than losses through mowing. CO_2/carbon sequestration. Reduced methane emissions as a result of grass silage being replaced with pasture grass. Reduced CO_2 emissions because less use is made of machinery. Nitrous oxide emissions will increase	Situation improves where there is proper integration in farming practice	Situation improves where there is proper integration in farming practice. Reduced ammonia emissions owing to the separation of urine and dung. Greater soil nitrogen uptake efficiency	Greater diversity in insects and plants, good for, among other things, meadow birds. Outdoor grazing encourages the use of grassland based on a mosaic pattern and ensures that not all the grass is mowed at once; it also provides cowpats = snack bar for meadow birds
The soil structure may deteriorate	The decomposition of organic matter can accelerate if the water level fluctuates	May deteriorate	Depending on the geography of the plot, concave or convex, the loss of nutrients to surface water may increase	An increase in the accessibility of soil life as food for meadow birds, as well as an increase in the insect population in marshland transition zones
Soil quality increases in permanent grassland	Permanent grassland increases the quantity of organic matter and CO_2 sequestration	Permanent grassland, a large quantity of organic matter, large nitrogen-supplying capacity, few losses to the environment	The mineral cycle will increase and there will be fewer losses when the use of fertiliser is reduced	Increasing the quantity of herb-rich grassland and controlled mowing (outdoor grazing) will result in healthier cattle and more meadow birds
Drop in soil quality	Fewer CO_2 emissions by limiting the decomposition of peat (raising the water level)	Use of minerals from water or soil: lower dosage	Possible increase in the short term, and improved water quality in the long term	Increase in biodiversity above ground, including in the meadow bird population

Annex 1
Overview of measures and effects within Nature-based Agriculture - Grassland

positive	neutral	negative

Land use	Measures	Other societal benefits Landscape quality and appreciation	Climate adaptation and mitigation	Food quality
Grassland	**Herb-rich grassland**	Cows spend more time at pasture, more meadow birds and flourishing grasslands	Mitigation: carbon in soil Adaptation: soil's water-retention capacity	Milk quality negative and positive
	Outdoor grazing	Cows spend more time at pasture, more meadow birds	Mitigation: carbon sequestration in soil, less methane, but nitrous oxide Adaptation: improved water management (penetration of groundwater and water retention)	More resilience in cows, more fresh grass, more unsaturated fatty acids in milk
	Creation of a marshland system	More attractive (varied) landscape with more meadow birds	Depending on the water level: where mineralisation is improved and CO_2 emissions increase: widened and, if appropriate, shallower water courses help to accommodate extreme precipitation	N/A
	Farm with fully grass-fed livestock	Cows spend more time at pasture, and (possibly) grassland that is richer in herbs	Mitigation: carbon in soil Adaptation: soil's water-retention capacity	More unsaturated fatty acids in milk
	Wet landscape and other breeds of cattle in saturated peat grazing areas	More attractive (varied) landscape with more meadow birds	Adaptation: water storage, water retention	N/A

Financial costs and benefits (farm)				
Yield	**Investment (in euros)**	**Operating costs and income: SHORT-TERM**	**Operating costs and income: LONG-TERM**	**References**
More stable	Creating herb-rich grassland	Net costs are higher because of reduced yield	Net costs are higher because of reduced yield	Altieri MA. 1999. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment 74: 19 31. See, for example, the Kruidenrijk grasland (Herb-rich Grassland) pamphlet: http://edepot.wur.nl/295728
Comparable	Depending on the farm's situation	Depending on the farming practice and the extent of outdoor grazing, outdoor grazing can have a positive impact on the operating result	Depending on the farming practice and the extent of outdoor grazing, outdoor grazing can have a positive impact on the operating result	Van den Pol – van Dasselaar, A. (Praktijkonderzoek Veehouderij; PV), W.J. Corré (PRI), H. Hopster: (ID), G.C.P.M. van Laarhoven (PV) and C.W. Rougoor (CLM) Belang van weidegang (2002) PV-PraktijkRapport Rundvee 14 82 p. ISSN 0169 – 3689 Allan et al. (2014) Interannual variation in land-use intensity enhances grassland multidiversity PNAS 2014 111 (1) 308-313; doi:10.1073/pnas.1312213111
Lower by removing hectares for production	Creation of a marshland system	Operating expenses and maintenance and loss of production	Operating expenses and maintenance and loss of production	Van de Sandt, K. & Goosen, H. 2011. Klimaatadaptatie in het landelijk gebied. KvK044/2011, KvR040/2011
Milk production levels per cow are lower		Depending on the LU, a higher net margin owing to lower veterinary costs and longer lifespan of the cows	Depending on the LU, a higher net margin owing to lower veterinary costs and longer lifespan of the cows	Grass-Fed Nation Getting Back the Food We Deserve - Graham Harvey Van Eekeren, N., L. Bommele, J. Bloem, M. Rutgers, R.G.M. D Good, D. Reheul, L. Brussaard (2008) Soil biological quality after 36 years of ley-arable cropping, permanent grassland and permanent arable cropping. Applied Soil Ecology. 40: 432-446. Eekeren, N.J.M. van, J.G. Bokhorst, J.G.C. Deru, J. de Wit. 2014. Regenwormen op het melkveebedrijf: Handreiking voor herkennen, benutten en managen. Louis Bolk Institute, Driebergen Eekeren, N.J.M. van, J.G.C. Deru, H. de Boer, B. Philipsen. 2011. Terug naar de graswortel: Een betere nutrientenbenutting door een intensievere en diepere beworteling. Report 2011-2011 LbD. Louis Bolk Institute, Driebergen. Wit, J. de, N.J.M. van Eekeren, W.J. Nauta, U. Prins, F.W. Smeding. 2008. Een plus een is drie.: Biodiversiteitsmaatregelen voor rendabele melkveehouderij. Louis Bolk Institute, Driebergen
Alternative revenue model	New farming system	Alternative revenue model is required	Alternative revenue model is required	Fritz et al. (2014) Paludicultuur – kansen voor natuurontwikkeling en landschappelijke bufferzones op natte gronden. Vakblad Natuur Bos Landschap. (Nature, Forest, Landscape journal) Riet, B. van de , R. van Gerwen, H. Grioen, N. Hogeweg. Vernatting voor veenbehoud, carbon credits en kansen voor paludicultuur en natte natuur in Noord-Holland. Landschap Noord-Holland, Heiloo. bufferzones op natte gronden. Vakblad Natuur Bos Landschap.

positive	neutral	negative

Annex 1

Overview of measures and effects within Nature-based Agriculture - Landscape elements

			Functional agro-biodiversity		
Land use	**Measures**	**Purpose/function**	**Soil life**	**Pest control/ comba-ting disease**	**Pollination**
Landscape elements	**Construction and management of grassy, dry features or standing overgrowth**	Functional agro-bio-diversity in the food web, natural value (species) and landscape	Stable habitat as a place of refuge for soil organisms (overwin-tering, for example), in particular in arable farming systems	Important for natural enemies as a means of completing the life cycle (overwintering, alternative food source for natural enemies, pollen, breeding habitat)	Important for polli-nators as a means of completing the life cycle (pollen, nesting habitat)

Limiting the impact of pressure factors				Specific species	Other societal benefits	
Soil quality (functions and structure)	**CO_2/carbon sequestration**	**Mineral cycle**	**Losses to the environment**	**Biodiversity (above ground) and specific species**	**Landscape quality and appreciation**	**Climate adaptation and mitigation**
Indirect: biomass from grass clippings, hedge clippings, incorporation (as compost) in the soil indirectly: margins as potential source of earthworms	Biomass incorporated (fresh or as compost), locks carbon into the soil, carbon in woody features	Is improved when features are used for feed (willow, for example)	Help to limit drift and leaching of nutrients and pesticides into surface water, planting around sheds reduces particulate matter emissions	Important for all kinds of plant and animal species in agro-ecosystems, variation in habitats, fragmentation and merging; important for functional biodiversity as a means of completing the life cycle (overwintering, alternative food supply, pollen, breeding habitat)	Crucial to landscape quality appreciation, among other things, by showing regional identity and variation in landscapes	Mitigation: carbon sequestration in standing overgrowth Adaptation: shade for cattle in high temperatures

Other societal benefits		Financial costs and benefits (farm)				
Land use	**Food quality**	**Yield**	**Investment (in euros)**	**Operating costs and income: SHORT-TERM**	**Operating costs and income: LONG-TERM**	**References**
Landscape elements	Improvement of the food supply web can have an impact	Lower where landscape elements take up a great deal of room, shade effect of towering landscape elements means reduced local production Functional in the longer term and greater stability in yields	Construction and management	Conservation and loss of production	Conservation and loss of production, potentially a more resilient system	Effects of landscape elements on various aspects of nature-based agriculture