



Balancing biodiversity and agriculture: Conservation scenarios for the Dutch dairy sector



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ABSTRACT

Biodiversity is declining and current strategies to halt biodiversity loss have not succeeded. In preparing the EU's Biodiversity Strategy 2030, it is essential to unravel different visions about conservation targets for agriculture, and to understand potential trade-offs with food production. In this research, we translated the narratives of experts into two conservation scenarios on a case study area resembling the Dutch dairy sector. The scenarios reflected a targeted versus a generic approach towards conservation. In the targeted conservation (TC) scenario, extensive grassland, reduced drainage and delayed mowing were applied in core areas to enhance meadow bird abundance, whereas in the generic conservation (GC) scenario, networks of nature and extensive agriculture were created and no feed was imported, which required a change in local agricultural land use. Subsequently, total feed and food (milk and meat) production and potential impacts on biodiversity were assessed, using the total energy and protein value for dairy, dairy productivity and the potentially disappeared fraction (PDF) of plant species richness. Land use changed on 6% of the case study area in the TC scenario, and 69 % in the GC scenario. Feed production per ha (net energy for lactation) was reduced by 3% for the TC and 41 % for the GC scenario. Food production on the case study area reduced to the same extent in TC, and to a larger extent (by about two thirds) in GC because no feed was imported. In consequence, biodiversity increased, thus reducing the PDF from 0.17 in the baseline scenario to 0.16 in the TC scenario and 0.10 in the GC scenario. In both scenarios, extensive grassland offset part of the loss in plant species richness caused by cropland and intensive grassland. Implementing these opposing scenarios requires different policy approaches or incentives for the dairy sector. Moreover, judging whether measures are worth the expected benefits for biodiversity depends on stakeholders' values. Lastly, potential displacement of food production and associated impact on biodiversity needs to be considered.

1. Introduction

Agriculture is widely recognised as a main driver of global biodiversity loss (Tilman et al., 2017). More than a third of the terrestrial area is used by agriculture, of which 83 % is used for livestock production (FAO, 2018; Poore and Nemecek, 2018). Conversion of natural land into agricultural land, as well as changes in agricultural land use and intensity, result in habitat loss and fragmentation and directly impact biodiversity (Joppa et al., 2016; Kleijn et al., 2009; Morton et al., 2006). Indirectly, agriculture affects biodiversity via its contribution to acidification, eutrophication, climate change, freshwater use and ecotoxicity (Curran et al., 2011).

Although agriculture is a driver of biodiversity loss, it is also recognised as a major contributor to Europe's biodiversity (Batáry et al., 2015; Herzog et al., 2012; LEAP, 2015). The value of specific

agricultural landscapes for biodiversity is acknowledged, for example, in high nature value farmland, which includes semi-natural areas (e.g. moorland, saltmarsh), extensive mosaic landscapes, and areas that host species of conservation concern (e.g. wintering wild fowl, farmland birds) (Andersen et al., 2003; Lomba et al., 2014). Increasing intensification and abandonment of less productive agricultural land have reduced the area of high nature value farmland (Lomba et al., 2014). Moreover, despite conservation efforts, the decline of biodiversity on agricultural land is widespread and particularly sharp (Gregory et al., 2005). For example, populations of farmland birds have more than halved over the last three decades (EBCC, 2018).

Reducing agriculture's impact on biodiversity is one of the Aichi Targets agreed upon by the Convention of Biological Diversity (CBD, 2010), which at a European level was translated into the 2020 Biodiversity Strategy (EC, 2011). The 2020 Biodiversity Strategy aims to halt

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the loss of biodiversity in the European Union (EU) and reduce the EU contribution to global biodiversity loss. With regard to agriculture, which represents 39 % of the terrestrial area (Eurostat, 2018), it proposes to increase the contribution of agriculture to biodiversity, mainly through maximisation of agricultural area under conservation measures (EC, 2011). Mid-term evaluations of the 2020 Biodiversity Strategy concluded that the current measures are not successful in halting biodiversity loss, and that more stringent environmental protection is needed to meet biodiversity targets (Batáry et al., 2015; EC, 2015; ECA, 2017; IPBES, 2019; Pe'er et al., 2014). Moreover, the post-2020 Biodiversity Strategy should be enhanced or not be not less ambitious to address biodiversity loss (CBD, 2019; EC, 2019).

Despite the general aim to halt biodiversity loss, the Biodiversity Strategy does not define clear conservation targets. Biodiversity is a broad concept, with a multitude of indicators reflecting aspects of biodiversity (Kok et al., 2020). In addition, there are multiple approaches towards conservation, for example focussing on conservation of threatened species versus conservation of landscapes (EC, 2011). The type and the extent of conservation measures will depend on the specific conservation target, but all approaches will require conservation measures of some sort on agricultural land. Applying conservation measures on agricultural land is likely to cause a trade-off with food production. Practices that allow higher levels of biodiversity on agricultural land typically have lower yields (e.g. Gabriel et al., 2013). The magnitude of this potential trade-off will depend on the type of conservation measures envisioned and the extent to which they need to be implemented. Potential benefits of conservation measures and trade-offs for agricultural production can be assessed using alternative land use scenarios (Lindborg et al., 2009; Tuomisto et al., 2012; Verhagen et al., 2018).

In preparing the EU's Biodiversity Strategy 2030, it is essential to unravel different visions about biodiversity conservation and understand the potential effects on other land uses (e.g. agricultural land). The Dutch dairy sector is an important livestock sector in terms of land use and economic value, with 1.6 million dairy cows that produced 14 billion kg milk in 2019 (CBS, 2020; RVO, 2020). The Netherlands is the fifth largest exporter of dairy products in the world (ZuivelNL, 2019) with an export value of 7.9 billion euro. The objective of this study was to translate two narratives for biodiversity conservation by experts into specific conservation scenarios, and assess the implications of these scenarios for food production and biodiversity, using dairy production in the Netherlands as a case study. The case study comprised about 794,000 ha of agricultural land (45 % of the Dutch agricultural area; CLO, 2020) that is currently used for dairy production. This land is considered important for general farmland biodiversity and abundance of meadow birds (Berendse, 2016; Kentie et al., 2016; Melman and Sierdsema, 2017).

2. Material and methods

Conservation scenarios were developed for land currently used for dairy farming (Table 1). To identify potential conservation scenarios, recent policy reports and publications addressing biodiversity conservation in the Netherlands were studied. This yielded two opposing approaches to biodiversity conservation: a targeted conservation of meadow bird species (Melman and Sierdsema, 2017), and a generic change in agricultural land use to allow general conservation of biodiversity (Berendse, 2016). The contrast in the two claims is that one aims to conserve a specific species, whereas the other aims to conserve space under suitable conditions to support a dynamic set of species. The two recently postulated conservation narratives, together with interviews with their authors, were used to develop conservation scenarios. Interviews took place in person in October and November 2018. The interviews were semi-structured and aimed to clarify and gather in-depth knowledge regarding the concrete implementation of conservation narratives. Impacts on dairy production and biodiversity were

subsequently assessed for the current situation (baseline) and conservation scenarios.

2.1. Case study area and baseline scenario

The conservation narratives for targeted meadow bird conservation and generic conservation were formulated for the Netherlands and aimed at nationwide implementation. We applied the derived conservation scenarios to a fixed case study area of 793,899 ha of agricultural land (i.e. 45 % of total agricultural area; CLO, 2020), representing 75 % of all on-farm land use by farms with grazing animals (CBS, 2018e). This area corresponds to the Dutch area of grassland and forage maize on farms with grazing animals, mainly dairy, receiving derogation from the EU Nitrates Directive, i.e. allowing the Netherlands to surpass the limit of 170 kg nitrogen per hectare, averaged over 2014–2016 (RIVM, 2018). The case study area was limited to farms receiving derogation because of data availability. Moreover, the case study area consisted of five regions based on the dominant soil type: clay, sand 230, peat, sand 250, and loess (RIVM, 2018). Sand 230 and sand 250 correspond to sandy soils in different regions of the Netherlands and differ in the amount of nitrogen from animal manure that can be applied under derogation legislation (230 vs 250 kg nitrogen per hectare). Soil type was included because this influences the possibilities for both agricultural production and biodiversity conservation (CLO, 2005). For example, targeted meadow bird conservation is focused on clay and peat soils (Melman and Sierdsema, 2017); and peat soils are generally unsuitable for crop production other than grassland (Van Kernebeek et al., 2016). Soil type suitability was considered in the targeted conservation scenarios. In the generic conservation scenarios, a distribution of conservation management was applied in proportion to soil type, assuming a uniformly distributed uptake throughout the case study area.

As baseline scenario (BL), we used the average distribution of grassland and forage maize on the case study area between 2014 and 2016 (RIVM, 2018). Land use for other forage crops was not taken into account, because it represented only 0.6 % of total land use for forage cultivation (CBS, 2018f).

2.2. Targeted conservation of meadow birds

2.2.1. Narrative

In the Netherlands, meadow birds are considered important targets for biodiversity conservation (Melman and Sierdsema, 2017). Dutch agricultural grasslands are internationally important breeding habitat for several meadow bird species. In case of the black-tailed godwit (*Limosa limosa*), 87 % of the global population is estimated to breed in the Netherlands (Kentie et al., 2016), which adds international responsibility for their conservation. In addition, meadow birds have a high amenity value, i.e. people enjoy the sight of meadow birds in grassland (Melman, personal communication, October 2018).

To facilitate decision making regarding meadow bird conservation, a report was commissioned by the Dutch ministry of economic affairs (Melman and Sierdsema, 2017). The report details several conservation scenarios and associated targeted conservation measures (Melman and Sierdsema, 2017). The conservation measures aim to achieve a sustainable population of 40,000 breeding pairs of black-tailed godwits, in line with the species' conservation target as envisioned by the Dutch Society for the Protection of Birds ('Vogelbescherming Nederland') (Melman and Sierdsema, 2017).

Conservation efforts are concentrated on the most promising areas to use scarce financial resources for conservation measures most efficiently. Melman and Sierdsema (2017) distinguished 4 factors that determine the basic conditions or potential habitat quality for meadow birds: soil moisture, landscape openness, vegetation density, and landscape features associated with predation or human disturbance (referred to as disturbance). In addition to these factors, specific

Table 1
Summary of the baseline (BL) and conservation scenarios (TC, TC+, GC and GC+) and assumed biodiversity gains.

Scenario	Summary of measures
Baseline scenario (BL)	Current land use of (89 %) grassland and (11 %) maize on the case study area of 793,899 ha.
Targeted Conservation (TC)	Assumed biodiversity gain: sustainable population of 40,000 breeding pairs of black-tailed godwits Based on Melman and Sierdsema (2017) : To reach this, conservation measures to enhance meadow bird abundance are implemented on roughly 66,000 ha of grassland in the case study area (mainly on clay and peat soils). Measures bring vegetation density, soil moisture, and meadow bird management to optimal conditions (defined in Appendix 1 Table A1.1) to sustain meadow birds.
Targeted Conservation + (TC+)	TC scenario and additionally, the total area of extensive grassland in the case study area is increased to 200,000 ha
Generic conservation (GC)	Assumed biodiversity gain: give 70 % of wild species in the Netherlands a sustainable future, compared with the amount of species the Netherlands could harbour in an undisturbed state (Berendse, 2016) Based on Berendse (2016) : other land uses (e.g. urban) will grow at the expense of the agricultural area (Appendix 1 Table A1.2). On the remaining agricultural area, 30% protected nature is realised through creation of areas of nature combined with “biodiversity-friendly” agriculture (‘nature networks’, with organic-like crop production and low-productive dairy cows). Imports of feed are stopped, thus the crop production is adapted to locally produce rations to feed dairy cows (Appendix 1 Table A1.3).
Generic conservation + (GC+)	GC scenario and additionally, the productivity of the dairy cows in the regular agricultural area is reduced (from 8,000 to 7,000 kg fat-and-protein-corrected milk per lactation). This lower production level allows for a smaller share of energy-dense feedstuffs and a larger share of extensive grassland in the ration (Appendix 1 Table A1.3).

meadow bird management can be applied, which in the report was defined as delayed mowing (after June 15, compared with first mowing in April). Of the 66,000 ha agricultural area targeted for meadow bird conservation, 96 % was considered to be not optimal with respect to soil moisture, and less than 1% of the area was considered optimal for soil moisture, vegetation density and meadow bird management (Appendix 1 Table A1.1). According to the authors, to reach the target of 40,000 breeding pairs of black-tailed godwits, basic and management conditions should be brought to optimal levels throughout this area.

2.2.2. TC and TC+ Scenario

The proposed measures for targeted conservation of meadow birds focus on a specific area of roughly 66,000 ha agricultural grassland and 80,000 ha nature area ([Melman and Sierdsema, 2017](#)). In the Targeted Conservation (TC) scenario, the entire agricultural area considered for conservation measures was assumed to be located within the case study area. The nature area required for conservation was not on agricultural land and therefore not included in this study.

The agricultural area considered for conservation measures was implemented on the appropriate soil type, i.e. mostly on the clay and peat soils, in regions that are most suitable to create habitat for meadow birds and where meadow birds are already present ([Sierdsema, 2018](#)). Of the five elements of meadow bird conservation identified by [Melman and Sierdsema \(2017\)](#), (i.e. vegetation density, soil moisture, meadow bird management, landscape openness and disturbance), only the three first were considered to affect food production and biodiversity and were included in this study. In case these elements were suboptimal in the BL scenario, they were converted to optimal conditions (defined and quantified in Appendix 1 Table A1.1).

In brief, this meant that in the TC scenario,

- Area without optimal vegetation density (i.e. intensive grassland) was converted to extensive grassland (about 50,000 ha). If land use was converted from intensive to extensive grassland, it was assumed that adjustments to create optimal soil moisture or meadow bird management did not further affect dry matter yield or nutritional value of the grassland
- In areas with optimal vegetation density but without optimal soil moisture (about 15,500 ha), rewetting was implemented and assumed to change dry matter yield and nutritional value (Appendix 2, [Van Bakel et al., 2005](#)).
- In case of optimal vegetation density but no optimal management (about 9500 ha, of which about 9000 ha was also rewetted), delayed mowing (i.e. June 15) was assumed to reduce the energy content of the grass ([Vellinga, 1991](#)).

In the more extreme TC + scenario, the TC scenario was extended

by increasing the total area of extensive grassland in the case study area to 200,000 ha. The increase in the area of extensive grassland was assumed to occur proportionally over the different soil types. The TC + scenario is based on a campaign by the Dutch Society for the Protection of Birds, which aims to create 200,000 ha of extensive grassland throughout the Netherlands by 2020 ([Vogelbescherming Nederland, 2018](#)).

2.3. Generic conservation of species

2.3.1. Narrative

[Berendse \(2016\)](#) reasoned that targeted conservation measures on agricultural land are insufficient to achieve substantial biodiversity benefits, based on the observation that past nature conservation on agricultural land was largely ineffective. In his essay, [Berendse \(2016\)](#) therefore proposed generic conservation measures for a more robust nature conservation in the Netherlands by 2050. Aside from biodiversity measures, [Berendse](#) accounted for projected increases in water bodies, urban area and infrastructure in the Netherlands by 2050, that will increase at the expense of agricultural area (Appendix 1 Table A1.2).

In contrast to meadow bird conservation, conservation targets are not linked to a pre-defined population size of any species. Rather, [Berendse \(2016\)](#) argued that nature is inherently dynamic, with fluctuations in species composition. His conservation measures aimed to give 70 % of wild species in the Netherlands a sustainable future, compared with the amount of species the Netherlands could harbour in an undisturbed state. Based on the species-area relationship ([Darlington, 1957](#)), [Berendse \(2016\)](#) stated that nature conservation on 30 % of the area of the Netherlands is required to conserve 70 % of overall species richness. He proposed to realise this 30 % protected nature through the creation of well-connected areas of nature combined with “biodiversity-friendly” agriculture (‘nature networks’) (Appendix 1 Table A1.2). Moreover, 5% of the agricultural land should consist of permanent landscape elements, both in nature networks and regular agriculture ([Berendse, personal communication, November 2018](#)). In addition, [Berendse \(2016\)](#) identified nitrogen deposition; pesticide persistence ([Geiger et al., 2010](#); [Hallmann et al., 2014](#)); and disturbance from recreation ([Bijlsma, 2006](#)) as pressures that reduce biodiversity. Therefore, [Berendse \(2016\)](#) proposed that nitrogen input (from artificial fertiliser use and imported feed) and pesticide use should be stopped within the nature networks, and drastically reduced in regular agriculture. Regarding disturbance from recreation, he proposed an increase in recreational area, to reduce disturbance in the nature networks.

Table 2

Land use categories used, with their estimated yields, energy and protein content, and characterisation factors (CF) for relative plant species richness.

Land use category	Yield ¹ (ton/ ha*)	Energy content (VEM / kg*)	Protein content (DVE / kg*)	CF (PDF / m ²)
Intensive grassland	9.2 – 11.0 ^{a,b,c}	901 ^d	62 ^d	0.12 ^e
Extensive grassland	6.2 ^f	710 ^g	44 ^g	– 0.12 ^e
Grass-clover	7.6 – 12.4 ^h	845 ^g	66 ^g	0.09 ^e
Intensive cereals	8.8 ⁱ	1006 ^g	95 ^g	0.60 ^e
Extensive cereals	5.5 ^j	1006 ^g	95 ^g	– 0.09 ^e
Forage maize	16.2 – 17.5 ^{a,b,c}	988 ^k	53 ^k	0.60 ^e
Lupines	3.0 ^l	1120 ^g	135 ^g	0.60 ^e
Permanent landscape elements	–	–	–	– 0.02 ^e
Nature and forest	–	–	–	0 ^e
Recreational area	–	–	–	0.09 ^e

¹in case of a range of yields, yield differs between soil types (Appendix 3).

*Expressed in dry matter of conserved product in case of forages (assuming 5% conservation loss; van Schooten et al., 2017) and in mass at 16 % moisture in case of grains.

VEM = feed units for milk production (1000 VEM = 6.9 MJ of net energy (Van Es, 1975)); DVE = intestinal digestible protein; PDF = potentially disappeared fraction of plant species richness.

Sources: ^aRIVM, 2016, ^bRIVM, 2017, ^cRIVM, 2018, ^dEurofins Agro, 2018a, ^eKnudsen et al., 2017, ^fGeerts, 2014, ^gPlomp et al., 2010, ^hDe Wit et al., 2004, ⁱCBS, 2018a, ^jGeerts et al., 2018, ^kEurofins Agro, 2018b, and ^lPrins et al., 2007.

2.3.2. GC scenario and GC + scenario

In the Generic Conservation (GC) scenario, part of the case study area was converted from agricultural area to water, urban area and infrastructure, in proportion to the changes on national scale (Table 2). Next, three elements of nature conservation considered by Berendse (2016) were addressed: an increased area of protected nature, reduced disturbance from recreation, and reduced nitrogen input from imported feed and fertiliser. Nature area, recreational area, and agricultural area within nature networks were increased at expense of regular agricultural area (Appendix 1 Table A1.2).

Both agriculture within nature networks and regular agriculture included 5% permanent landscape elements. Subsequently, the type of agricultural land use was determined. Based on Berendse (2016) it was assumed that no feed was imported, and agricultural land use was therefore changed to support rations with feed ingredients grown in the case study area. However, ration composition depends on the required energy and feed intake capacity per day, and is thus partly determined by the productivity of a cow. Plomp et al. (2010) composed local rations for lactating dairy cows at three different production levels; we assumed that these rations were fed year-round (Appendix 1 Table A1.3). Agricultural land use within nature networks was based on the ration for 6000 kg fat-and-protein-corrected milk (FPCM) per lactation, to comply with the envisioned biodiversity-friendly character. This ration allowed for the largest proportion of extensive grassland and the lowest proportion of concentrates (Plomp et al., 2010). Moreover, 'extensive cereals' instead of conventional 'intensive cereals' were grown in nature networks. Finally, to comply with the ban on fertiliser use in nature networks, grass-clover instead of intensive grassland was used. In regular agriculture, land use was based on the ration for 8000 kg FPCM per lactation. Different categories of land use were distributed proportionally over the different regions, except that no additional crop production was applied on peat soils (Van Kernebeek et al., 2016).

In the GC + scenario, crop cultivation outside nature networks was based on the ration for 7000 kg FPCM per lactation instead of 8000 kg FPCM. The lower production level allows for a smaller share of energy-dense feedstuffs and a larger share of extensive grassland in the diet (Appendix 1 Table A1.3) (Plomp et al., 2010).

2.4. Evaluation of conservation scenarios

The baseline and conservation scenarios are summarized in Table 1. To evaluate consequences of the conservation scenarios for food production and biodiversity value, first the land use of each scenario was determined. Each land use was associated with a certain feed production and biodiversity value (Table 2).

Land use for each scenario was categorized by the type of crop or (semi)natural vegetation occupying the land, into the following categories: grassland, cereals, forage maize, lupines, permanent landscape elements, nature and forest, and recreational area. In addition, grassland and cereals were divided in an intensive and extensive category because these crops vary largely in the yields that are obtained, that depend on intensity at which they are managed, and the associated biodiversity (Geerts et al., 2018, 2014). Extensive grassland was based on a type of herb-rich grassland that was studied during a recent (2012–2014) project among farms with grazing animals (Geerts et al., 2014), and actively promoted for meadow bird conservation by the Dutch Society for the Protection of Birds (1818). The category extensive cereals describes continuous cropping of spring cereals followed by overwintered stubbles, which was based on a recent (2015–2018) project for bird conservation on arable land (Geerts and Korevaar, 2016).

2.4.1. Feed and food production on case study area

The baseline and conservation scenarios on the case study area were evaluated in terms of food production and biodiversity value. The case study area was used for feed production for the Dutch dairy sector. The only feed production that is compared is the production on the case study area; imported concentrate is not included. To relate this feed production to food production, we analysed land use in terms of its value as feed for dairy production. Feed value was determined in terms of energy and protein value, because these are the two main components dairy feed requirements are based on (CVB, 2012). Total energy yield in feed units for milk production (VEM, 1000 VEM = 6.9 MJ of net energy; (Van Es, 1975)), and total protein yield, expressed in intestinal digestible protein (DVE) were computed from the land use distributions under the different conservation scenarios. Dry matter yields and associated energy and protein content were either taken from Dutch averages over 2014–2016 or from literature (Table 2). For intensive grassland, grass-clover and forage maize, dry matter yields were differentiated between soil types (Appendix 3). In case of meadow bird management, the energy for lactation reduced by 15 VEM per kg dry matter (Vellinga, 1991).

Feed production in the case study area was computed for all scenarios. In case of the GC and GC + scenario, however, part of the changes in feed production could not be attributed to measures to increase biodiversity, but merely accounted for increases in urban area, infrastructure and water bodies. To assess the impact of conservation scenarios in the case study area on food production, therefore, feed production was expressed per hectare, from which urban area, infrastructure and water bodies on the former agricultural area in the case study area were excluded. This way, all conservation scenarios could be compared in terms of productivity. Moreover, to be able to relate the intensity of agricultural production and its biodiversity impact, the production per unit of agricultural land (including only grassland, cropland and permanent landscape elements) was calculated for the GC and GC + scenario (GC_{agr} and GC_{agr}).

Food production in terms of milk production and meat production from culled cows was estimated using the total energy production in VEM from the case study area, and additional concentrate. Additional concentrate was assumed to be 25 % of the energy of the ration of dairy cows in the BL, TC and TC + scenario (CBS, 2019), and zero in the GC and GC + scenario. Total energy requirements were computed for dairy cows, including requirements for growth, maintenance, milk production, and gestation, and for rearing of replacement heifers (CVB, 2012),

assuming a replacement rate of 0.29 (CBS, 2019). Annual milk production was assumed to be 8800 kg/ cow in the BL, TC and TC + scenario (CBS, 2019), and 6000/ 7000/ 8000 kg/ cow in the GC and GC + scenario as explained in section 2.3.2. Culled cows were assumed to have a slaughter weight of 650 kg (CBS, 2019), and a dressing percentage of 60 % (Rutten et al., 2014).

2.4.2. Biodiversity value of case study area

The impact of the different scenarios on biodiversity was assessed using the indicator potentially disappeared fraction (PDF) (De Schryver et al., 2010), in an attempt to compare the relative biodiversity value. The PDF expresses the species richness of vascular plants under a specific land use compared with a reference situation of semi-natural woodland (Knudsen et al., 2017). The mean impact on biodiversity across land use types in each scenario was expressed as mean PDF (per m²), calculated as:

$$PDF = \frac{\sum_{i=1}^n (CF_i * A_i)}{\sum_{i=1}^n A_i}$$

with CF being a characterisation factor expressing PDF of plant species richness, and A the area occupied (in m²) by land use *i*.

The CFs for different land use categories (Table 2) were used from Knudsen et al. (2017), who used data from six European countries to calculate CFs for different land use and management types. In this study, CFs for Germany were used, because they best represented intensive agricultural production in an area dominated by dairy farming. Intensive grassland was regarded as the category 'conventional monocotyledons pasture'; herb-rich grassland as 'mixed organic pasture'; and grass-clover as 'mixed conventional pasture' because of its high mowing frequency (on average five cuts a year (De Wit et al., 2004)). Moreover, silage maize, intensive cereals, and lupine were all regarded as 'conventional arable crops', and extensive cereals as 'organic arable crops'. Permanent landscape elements were regarded as 'conventional hedgerows'. The CF for conventional hedgerows was based on the mean CF of Austria, Switzerland and Wales, because no CF for Germany was available. Nature was assumed to be forest with the CF of 'temperate broadleaf forest'. Knudsen et al. (2017) used temperate broadleaf forest as reference vegetation, so its CF is by definition 0. Finally, all recreational area was assumed to be 'conventional mixed pasture' (Knudsen et al., 2017).

To relate the impact on biodiversity to total food production, the impact of feed production on biodiversity was expressed as the damage score per unit energy produced (DS_{kVEM}), calculated as:

$$DS_{kVEM} = PDF * \frac{A_{tot}}{Yield_{tot}}$$

with A_{tot} (in m²) being the total land use and Yield_{tot} the total energy yield (in kVEM) of the case study area.

In the GC and GC + scenario, similar to the assessment of feed production, the increase of urban area, infrastructure and water bodies were excluded from the calculations, to assess only the impact of the conservation scenarios only. In addition, to be able to relate the intensity of agricultural production and its biodiversity impact, the PDF and the DS_{kVEM} per unit of agricultural land (including only grassland, cropland and permanent landscape elements) were calculated for the GC and GC + scenario (GC_{agr} and GC_{agr} +).

3. Results

3.1. Land use

Implementation of conservation scenarios resulted in changes in land use in the case study area (Fig. 1). In the TC scenario, land use changed from intensive to extensive grassland in 6% of the case study area compared with the BL scenario, and on an additional 2.3 %

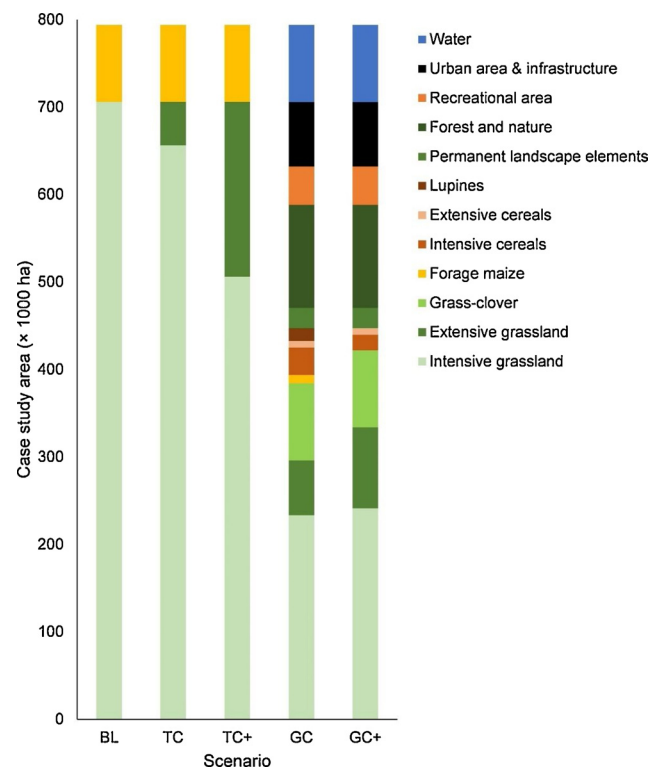


Fig. 1. Land use distribution in the case study area of the baseline (BL), targeted conservation (TC and TC +) and generic conservation (GC and GC +) scenarios.

drainage status and mowing regime were changed. These changes occurred in specific areas that are most suitable to create habitat for meadow birds and where meadow birds are already present, which were mainly on peat and clay soils (Fig. 2). In the TC + scenario, the additional target for 200,000 ha extensive grassland increased land use change compared with the BL scenario to 25 %. In the GC scenario, land use changed on 69 % of the case study area. Excluding the expected increases in water and urban area and infrastructure (i.e. 20 % of the case study area) the case study area was mainly divided between agricultural area (70.7 %) and forest and nature (18.6 %), with smaller areas for recreation (7.0 %) and permanent landscape elements (3.7 %; i.e. 5% of the 74.4 % agricultural area including these permanent landscape elements). In the GC + scenario, the shift to a dairy cow with a lower productivity and associated ration shift resulted in a land use change on 70 % of the case study area compared with the BL scenario. The GC + scenario allowed for more extensive grassland than the GC scenario, at the expense of forage maize, cereals and lupines.

3.2. Feed and food production

The case study area under the BL scenario realised a total energy yield of 8.14×10^{12} VEM and a total protein yield of 5.40×10^{11} DVE. Energy yield was reduced by 3% in the TC scenario, 13 % in the TC + scenario, 41 % in the GC scenario and 43 % in the GC + scenario (NB: Excluding the urban area, infrastructure and water bodies in the GC and GC + scenarios; Table 3). Expressing yields of the GC and GC + scenarios per unit agricultural land (including permanent landscape elements; GC_{agr} and GC_{agr} +) shows the effect of conservation measures on agricultural land, without the effects from conversion of agricultural land into other land uses. Agricultural land uses GC_{agr} and GC_{agr} + resulted in a 21 % and 23 % lower energy yield than the BL scenario, respectively. Reductions in protein yields were largely similar to those in energy (Table 3).

Estimated milk and meat production supported by the forage grown on the case study area (and additional concentrates in case of BL, TC,

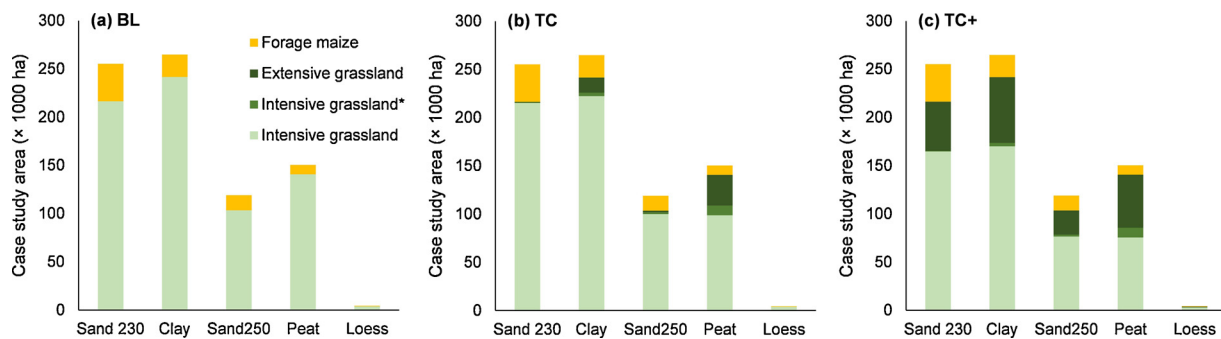


Fig. 2. Land use distribution across soil types of the case study area (a) for baseline (BL), (b) targeted conservation (TC) and (c) targeted conservation + (TC+) scenario.

and TC+) is depicted in Table 4. In the BL scenario, annual milk production of the case study area is about 12.7 billion kg. In the TC and TC+ scenarios, milk production is reduced to the same extent as energy production on the case study area, by 3% and 13% respectively. In this case, concentrates use is reduced likewise, and explained by the smaller herd size supported. In the GC and GC+ scenarios, however, the reduction in energy production on the total case study area is combined with a stop on imported concentrates, which reduces estimated milk production compared with the BL scenario by 67% and 70%, respectively. Estimated meat production from culled cows is affected to a lesser extent (60% reduction in GC and GC+ compared with BL), due to the increased meat to milk ratio (i.e. lower milk production) of the cows in the GC and GC+ scenario.

3.3. Impact on biodiversity

In the BL situation, the mean PDF of the case study area was 0.17 of reference plant species richness (i.e. an expected species richness of 83% compared with the reference situation; Table 3). In the TC and GC scenarios, the mean PDF decreased to 0.16 and 0.10, respectively (i.e. the expected species richness increased to 84% and 90% compared with the reference situation). In the TC+ and GC+ scenarios, the mean PDF further decreased to 0.11 and 0.06, respectively. The mean PDF of GC_{agr} and GC_{agr}+ was 0.13 and 0.07, respectively. Thus, comparing the impact of agricultural production only on the case study area, the TC+ scenario results in a greater increase in plant species richness than the GC_{agr} scenario. The damage score per unit of energy produced (DS_{kVEM}), which is the product of the biodiversity impact per unit area and the area required to produce a unit of energy, was 0.17 in the BL scenario. The DS_{kVEM} decreased in all conservation scenarios compared with the BL scenario, except in the GC scenario. In the GC scenario, a lower impact per unit land (PDF of 0.13 vs 0.17 in the BL scenario) resulted in the same DS_{kVEM} due to a larger area required to produce a unit of energy than the BL scenario (1.66 vs 0.98 m²). The DS_{kVEM} was lowest for the GC+ scenario, despite the largest area

Table 3

Energy yield (kVEM/m²), protein yield (DVE/m²), and impact of scenarios¹ on the potentially disappeared fraction (PDF) of plant species richness, and the damage score (DS) per kVEM.

	kVEM/ m ²	Change (%)	DVE / m ²	Change (%)	PDF/m ²	m ² / kVEM	DS _{kVEM}
BL	1.02	Ref.	68	Ref.	0.17	0.98	0.17
TC	0.99	-3	65	-4	0.16	1.01	0.16
TC+	0.89	-13	58	-15	0.11	1.12	0.13
GC	0.60	-41	44	-35	0.10	1.66	0.17
GC _{agr}	0.81	-21	59	-13	0.13	1.23	0.16
GC+	0.58	-43	42	-38	0.06	1.71	0.11
GC _{agr} +	0.79	-23	56	-17	0.07	1.27	0.10

¹Baseline (BL), targeted conservation (TC and TC+) and generic conservation (GC and GC+) scenarios. GC_{agr} and GC_{agr}+ depict results for GC and GC+ scenarios per unit of agricultural land only. Assumed biodiversity gain TC scenario: sustainable population of 40,000 breeding pairs of black-tailed godwits; assumed biodiversity gain GC scenario: give 70% of wild species in the Netherlands a sustainable future.

Table 4

Estimated number of cows, milk production and meat production of baseline (BL), targeted conservation (TC and TC+) and generic conservation (GC and GC+) scenarios.

	Cows (mln)	Milk production (bln kg/ year)	Meat from culled cows (mln kg/ year)
BL	1.44	12.7	166
TC	1.40	12.3	160
TC+	1.26	11.1	145
GC	0.57	4.2	66
GC+	0.58	3.9	66

required to produce a unit of energy.

Fig. 3 shows the contributions of different land use categories to the mean PDF value through their damage scores (i.e. CF_i × A_i). It demonstrates how land use categories with a relative gain in plant species richness (i.e. CF < 0, such as for extensive cereals, extensive grassland and permanent landscape elements) offset some of the loss in plant species richness caused by the other land use categories. The land use category 'nature and forest' is not visible in this graph because its relative plant species richness is 0, as it is the reference vegetation, but is accounted for in the average PDF in the GC and GC+ scenario.

4. Discussion

In preparation for the EU Biodiversity Strategy 2030, it is essential to determine targets for biodiversity conservation for agriculture, and to understand their potential trade-offs with food production. In this research, we evaluated the implications of targeted and generic conservation scenarios for dairy production and biodiversity on a case study area of Dutch agricultural land.

Trade-offs between biodiversity measures and dairy production were present in all scenarios, and were made explicit using the fodder yields and changes in the PDF indicator. Visualising results of Table 3 in

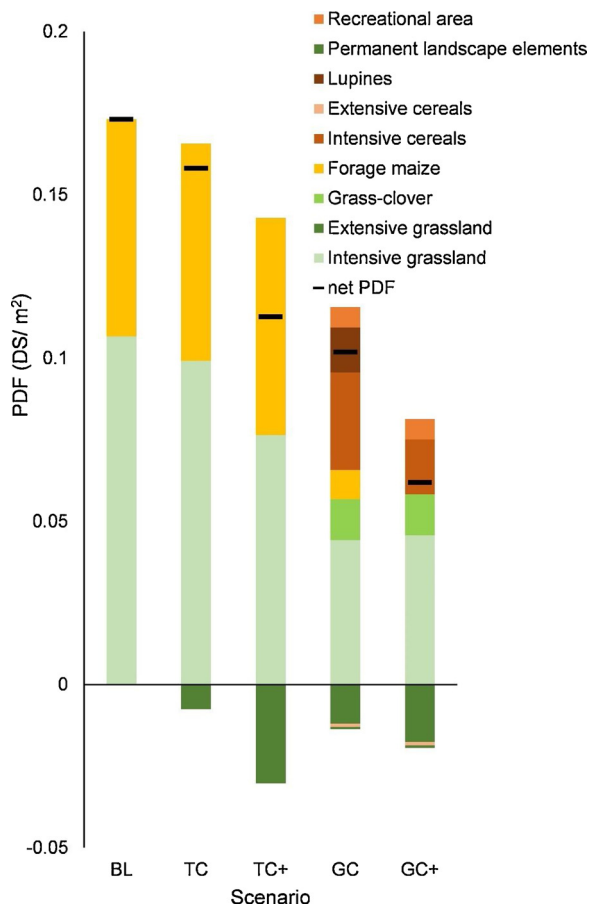


Fig. 3. Potentially disappeared fraction (PDF) of plant species richness in the baseline (BL), targeted conservation (TC and TC+) and generic conservation (GC and GC+) scenarios, showing contribution of different land use categories.

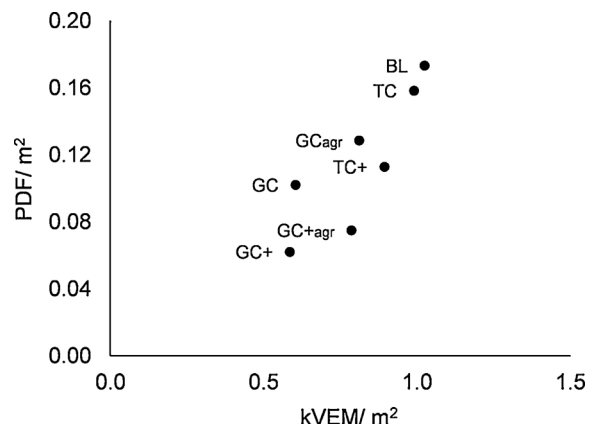


Fig. 4. Biodiversity value (in potentially disappeared fraction (PDF)) and feed production of the baseline (BL) and conservation scenarios. TC = Targeted Conservation; GC = Generic Conservation; In GC_{agr} and GC_{agr} only the agricultural area in the case study area is taken into account.

a scatter plot allows us to discuss the implications of moving from the BL scenario to conservation scenarios (Fig. 4). Feed energy yields per unit land decreased from BL to TC, TC+, GC, and GC+, while the biodiversity value of the land increased. From BL to TC and from TC to TC+, the larger share of extensive grassland affected food production and biodiversity in the same way (i.e. the three scenarios are on one line in Fig. 4). This shows that the impact of conversion from intensive to extensive grassland on food production is much larger than applying the other targeted measures in the TC scenario, regarding drainage and

delayed mowing. Thus, once the conversion to extensive grassland is made, these additional management factors make the land suitable for meadowbirds and associated biodiversity (Gregory et al., 2005) with a limited impact on feed production. Compared with the TC + scenario, the GC scenario resulted in a large reduction of local feed production and a relatively small improvement in biodiversity. In contrast, the change from a GC to GC + scenario slightly reduced feed yield (2% of BL), but lowered the PDF from the BL scenario considerably (Fig. 4). In other words, the GC + scenario (using lower productive dairy cows) appears to be better for local biodiversity than the GC scenario, with a limited difference in feed production, thus a smaller trade-off between biodiversity conservation and feed production. The comparison between the GC and GC + scenario illustrates that some changes may best be done in combination (i.e. internalisation of feed production AND lower productivity) to increase biodiversity. By integrating cows with a lower productivity level, more grass from extensive grassland can be integrated in diets, and fewer concentrates or energy-dense feedstuffs are required (Plomp et al., 2010; van Hal et al., 2019). The GC + cropping plan is only feasible without feed imports if lower productive dairy cows are used, because more concentrates – with a relatively large negative impact on biodiversity – would be required in the ration of higher producing cows. A lower share of concentrates in the ration, moreover, can have advantages in terms of avoiding feed-food competition (Van Hal et al., 2019) and a more favorable milk composition (Elgersma et al., 2006).

The targeted and generic conservation scenarios inherently aimed at conserving or enhancing biodiversity, but their impact on biodiversity will differ. At least two biodiversity indicators have previously been used to model biodiversity loss linked to agricultural land use, the Mean Species Abundance (MSA) and the Potentially Disappeared Fraction (PDF) (Alkemade et al., 2009; De Schryver et al., 2010; Knudsen et al., 2017). Both indicators assess biodiversity loss compared with an undisturbed reference situation, either in terms of abundance or presence of each species. A main difference is that species that do not occur in the undisturbed reference situation are not accounted for in the MSA, whereas they add to biodiversity in the PDF (Kok et al., 2020). In our study, all species (i.e. independent of whether they occur in the reference situation) count for biodiversity in the generic conservation scenario, and meadow birds would likely be absent in the reference without agriculture, thus would not be accounted for in the MSA. The PDF only includes plant species, thus also does not account for meadow birds, however, it would account for the vegetation associated with the conservation scenario under extensive grassland that is absent in the reference situation. The PDF was therefore used in our attempt to compare the scenarios in terms of biodiversity (De Schryver et al., 2010; Knudsen et al., 2017). At the same time, however, this indicator reflects potential plant species richness, and does not measure the intended improvements in the target biodiversity (Gregory et al., 2005; Manning et al., 2015), i.e. abundance of meadow birds or overall species richness. Because no indicator reflects both the targeted and generic conservation scenarios' targets for biodiversity, comparing them using one indicator may not be a fair comparison (Kok et al., 2020). Keeping this limitation in mind, using biodiversity indicators can still be useful to increase understanding of trade-offs. The indicator will reflect aspects of the conservation scenarios that are positive for plant diversity too, such as extensive grassland (Knudsen et al., 2017; Manning et al., 2015). However, aside from a comparison between scenarios using indicators, stakeholders or a political decision are needed to decide if measures are worth the claimed benefits for biodiversity, and to determine the relative value of different conservation scenarios (Kok et al., 2020).

The Biodiversity Strategy for 2030 is currently under discussion and specific conservation targets for biodiversity have not been set yet. Conservation scenarios were therefore based on two recently postulated conservation claims (Berendse, 2016; Melman and Sierdsema, 2017). The scenarios reflect two opposing approaches to biodiversity

conservation: targeted conservation of species versus generic conservation of habitat on agricultural land. Both approaches may be realistic for future conservation targets. Targeted conservation is representative for past and ongoing conservation projects, and may be undertaken for any species of conservation concern (Berendse et al., 2004; Verhagen et al., 2018). As it is, the Netherlands has the international responsibility to conserve meadow birds (Kentie et al., 2016; Melman and Sierdsema, 2017). Generic conservation through the creation or conservation of larger nature networks resembles a more ambitious and proactive conservation movement (Noss et al., 2012; Wilson, 2016). Currently, only 13 % of the Netherlands is protected under the EU Birds and Habitats Directive (Natura 2000 areas; EC, 2018), whereas recent research indicates that the Aichi target to protect 17 % of the terrestrial area is insufficient to halt biodiversity loss (Larsen et al., 2014). More stringent measures are advocated for the Biodiversity Strategy 2030 (CBD, 2019; EC, 2019). The type and extent of conservation measures, however, is a political decision. Scenario studies like this one can give insight in the impact of such decisions and evaluate different conservation scenarios to identify possible synergies and trade-offs. As such, identifying targets and scenario studies go hand-in-hand. In light of these results, political processes should actively include all stakeholders and economic sectors that might be affected by the measures, especially the agricultural sector. The implementation of measures should be context specific and should consider compensation measures (e.g. payment schemes) and recognition (see below).

At the European level, targeted and generic conservation would require very different policies. A targeted species conservation, like the TC scenario, requires specific core areas to comply with specific conservation measures (Melman and Sierdsema, 2017; Verhagen et al., 2018). A generic conservation scenario may be achieved through conserving or restoring habitat on a certain amount of land. This land could be a share of each farms' arable area, through enforced policies such as the set-aside policy in the 1992 CAP reform (Gillings et al., 2010) and the Ecological Focus Areas in the current CAP (Pe'er et al., 2014), or through encouraging incentives, such as specific farmers' voluntary participation in development of nature networks through the EU framework for rural development programmes.

The extent of conservation may be reinforced by producers and consumers, for example through dairy products with biodiversity labels. Labels can incentivise farmers to have extensive grassland with meadow bird management or to apply generic conservation measures. Gradual generic changes to enhance biodiversity within the dairy sector in the Netherlands may be expected, especially in the light of recent developments in the sector. First, a commission appointed by the Dutch dairy organisation has given the binding advice to reduce imports of concentrate from outside Europe with two-thirds by 2025, compared with 2018 (Commissie Grondgebondenheid, 2018). Second, a 'Biodiversity monitor for dairy farming' is currently being developed to monitor and incentivize biodiversity (Van Laarhoven et al., 2017). The proposed biodiversity monitor includes indicators as percentage of herb-rich grassland and the share of permanent landscape elements on the farm, and the nitrogen surplus per hectare (Van Laarhoven et al., 2017). The generic conservation scenario is probably more radical than the gradual changes in the sector, with a ban on concentrate imports and the increase in nature networks (Berendse, 2016). Such conservation plans would require fundamental changes in the food system, agriculture and society, as illustrated by the 70 % land use change and the reduction of feed production in the case study area.

All conservation scenarios reduced overall feed production, and these reductions were largest for the GC + scenario. The case study area (excl. urban area, infrastructure and water) would sustain about 0.7 livestock units per ha in the GC + scenario, with lower productivity (i.e. 6000 kg FPCM per lactation in nature networks and 7000 kg FPCM per lactation in regular agriculture), compared with 2.3 livestock units per ha on the case study area in 2014–2016 (RIVM, 2018). Accounting

for the competing claims for agricultural land (Berendse, 2016), total food production would reduce even further. A loss of production due to conservation scenarios in a certain area of agricultural land is likely to trigger an increase of production and thus land use changes outside that area. For instance, locally, biodiversity conservation in one field or farm could result in intensification in another field or farm (Jouven and Baumont, 2008). Globally, a reduced production in the Netherlands could trigger production and increased environmental impact at the cost of biodiversity elsewhere (Morton et al., 2006). This would merely externalise or displace the impact of food production on biodiversity (Meyfroidt et al., 2010). At the same time, the GC and GC + scenarios would stop the use of additional concentrates; that currently amount to 4 billion kg for the Dutch dairy sector (CBS, 2019). Fundamental changes in production and consumption worldwide would be needed to avoid this externalisation of biodiversity loss, and enhance global biodiversity.

5. Conclusion

Targeted and generic conservation scenarios reduced feed and food production and increased potential plant species richness. The evaluation suggests that greater biodiversity benefits may be obtained with similar losses in feed and food production by combining multiple measures, as was shown for combining a reduction in imported concentrates with a cow with lower productivity. The extent and type of conservation measures is a political decision that should be made with involvement of stakeholders.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.agee.2020.107103>.

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