A Net Positive Impact on Nature for the Dutch Dairy sector: methodology

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Wild Business Ltd and Metabolic for Duurzame Zuivelketen (a programme financed by ZuivelNL)

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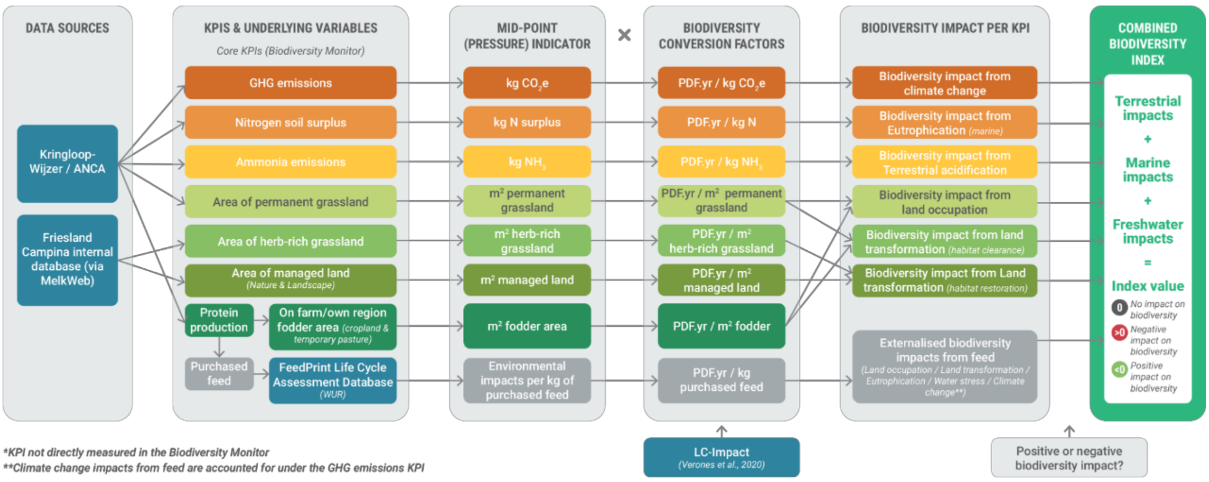
EXECUTIVE SUMMARY

An increasingly important question for nature conservation globally is which (if any) economic sectors can find ways to counterbalance biodiversity losses with substantial gains, to the extent that a 'net positive impact' is achieved overall. On the one hand agriculture can be implemented in ways that support biodiversity recovery, on the other it is one of the leading global causes of biodiversity loss. Here, we report on the outcomes of an exploration into whether a net positive impact on biodiversity might be achievable for the Dutch dairy sector. The exploration is structured around the concept of the biodiversity impact mitigation hierarchy: that is, biodiversity impacts caused in the process of dairy production are quantified, then avoided or reduced where possible, and finally over-compensated for; leading to a net positive impact for biodiversity in the aggregate. This work was carried out by Wild Business Ltd and Metabolic for the Dutch Sustainable Dairy Chain, Duurzame Zuivelketen (DZK).

The project focuses on the dairy sector as a whole, but is underpinned by farm-level environmental performance data collected via the Dutch Biodiversity Monitor for Dairy Farming; developed with the goal of enabling dairy farmers in the Netherlands to define and improve biodiversity on their own farms, whilst ensuring sustainable revenue. The anonymized farm data were analysed using established methodologies within Life Cycle Impact Assessment. The approach taken for the project involved four stages: 1) developing an integrated biodiversity index, drawing upon the 7 Key Performance Indicators (KPIs) in the Biodiversity Monitor, for monitoring impacts and progress towards a net positive goal; 2) establishing a set of safeguards, that accompany the index to ensure it does not result in unintended undesirable outcomes; 3) calculating a biodiversity impact baseline, against which to determine whether net positive is achieved; and, 4) outlining broad strategies to take the sector the current impacts towards net positive. In this subset of the overall report, we outline the methods taken i.e. stages (1) and (2).

The main biodiversity index developed during **stage 1** is measured in terms of 'Potentially Disappeared Fraction of species with time' (PDF.year), which is indicative of the contribution made by dairy sector activities towards increasing or decreasing global species extinction risks.

***Figure ES.1**: a process diagram for the incorporation of Biodiversity Monitor Key Performance Indicator data into a single aggregated biodiversity index, measured in 'PDF.year'*



In **stage 2** of the project, we developed the 'safeguards' to be implemented in conjunction with the **stage 1** biodiversity index at the sector-level, through literature review and stakeholder consultation. These safeguards were defined as standards "put in place to ensure that – in seeking to meet the goal of Net Positive Impact on biodiversity – there are no unintended, undesirable, or perverse outcomes for biodiversity". Safeguards include biophysical limits on environmental pressures from dairy activities, but also e.g. value judgements around appropriate means for biodiversity offsetting. In the full project report (not included in this document) we report on the outcomes of **stages 3 and 4**.

INTRODUCTION

Agriculture is one of the leading global causes of biodiversity[1] loss (Maxwell et al., 2016, Nature), is a major contributor to other environmental impacts (Poore & Nemecek, 2018, Science), and will play a key role in whether or not the Paris Agreement on climate change can be achieved (Clark et al., 2020, Science). However, agriculture could also play an important role in biodiversity recovery – not only through reduction of impacts, but through restorative practices (FAO, 2019). Key to realizing this potential will be: (a) developing improved frameworks for monitoring biodiversity impacts associated with agriculture; (b) setting Specific, Measurable, Attainable, Relevant, and Timebound (SMART) targets for mitigating and reversing those impacts; and, (c) laying out strategies for how agricultural actors, on multiple scales, can achieve those targets.

Dairy farming in general has the potential to play an important role in restoring biodiversity in grassland areas in the Netherlands: a landscape with grazing cows in herb-rich grasslands, interspersed with certain well-connected landscape elements, could feasibly provide habitat for a substantial diversity of wild species. Such landscapes have diminished globally because of a focus on dairy production efficiency and because dairy farmers are mainly paid for the milk that is sold on a competitive global market where their contribution to biodiversity is not rewarded.

Here, we report on the outcomes of an exploration into how a ‘net positive impact’ on nature might be achieved for the Dutch dairy sector. It is emphasized that these would apply to the dairy sector overall, and not to individual farms. The report is the outcome of work carried out by Wild Business Ltd and Metabolic for the Dutch Sustainable Dairy Chain Duurzame Zuivelketen (DZK).

Net Positive Impact

There has been an increasing interest in recent years – on the part of both governments and industry – in biodiversity conservation based on net outcomes (Bull et al., 2020, Nature Ecology & Evolution). The principle is that biodiversity impacts caused by economic development are quantified, reduced where possible, and otherwise compensated or over-compensated for; leading to ‘no net loss’ or a ‘net positive impact’ for biodiversity overall. The idea of ‘net biodiversity outcomes’ now forms the basis of established or emerging policy in over 100 countries worldwide, a growing conservation portfolio, and forming environmental markets worth billions of dollars (Deutz et al., 2020). Many of the theoretical challenges associated with achieving a net positive impact have already been explored in the scientific literature (Bull et al., 2022, Nature) – the current challenges are more related to practical considerations, monitoring, implementation, and demonstration in practice. Of all the key sectors in the global economy, agriculture is one that has arguably seen the least application of net outcomes approaches, and so the concept of exploring net positive impact for a national dairy sector is cutting edge. An emerging means for structuring efforts towards achieving net positive impact is the Mitigation and Conservation Hierarchy (Milner-Gulland et al., 2021, One Earth), which builds upon decades of experience with the site-level mitigation hierarchy and extends the concept to the strategic landscape-scale. The Mitigation and Conservation Hierarchy is a structured framework that combines efforts to mitigate biodiversity impacts of economic activities (normally involving measures to avoid, minimize, restore and offset impacts), alongside proactive conservation actions more broadly.

We note here the rapidly increasing popularity, in sustainability circles, of the term ‘nature positive’ as a goal; and that this is <u>not</u> the goal currently pursued by DZK. Though ‘nature positive’ has yet to be formally described in the scientific literature (this academic preprint[2] provides useful reflections on the

[1] ‘Biodiversity’ can be defined as per the Convention on Biological Diversity: “"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”.

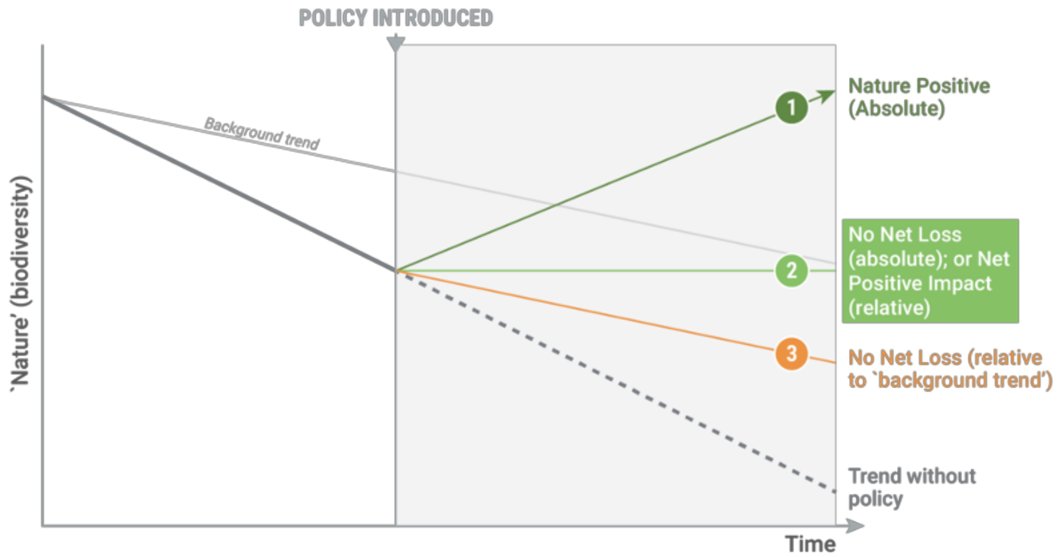
[2] Zu Ermgassen et al (2022) https://osf.io/preprints/socarxiv/rq6z2/

term), for clarification here, we distinguish between two different types of possible net biodiversity goal (Figure 1):

1. 'Nature Positive': The Dutch Dairy sector could be described as Nature Positive if the cumulative biodiversity impacts incurred since a fixed baseline year (e.g., 2020) had been avoided, mitigated, compensated, and complemented with additional restorative actions such that a substantial overall net gain in biodiversity was achieved in absolute terms (relative to the baseline year). In this scenario, Dutch dairy would have become a genuine driver of overall nature restoration, and contributor towards global conservation policy goals; or

2. 'Net Positive Impacts'/'Biodiversity Net Gain': The Dutch Dairy sector could be described as achieving Net Positive Impacts (also known as Biodiversity Net Gain) when annual impacts had been avoided, mitigated, and compensated such that there is a marginal net gain in biodiversity relative to a given counterfactual scenario. That is, biodiversity gains would be relative, directly reactive to the sector's impacts only, and overall biodiversity could still be declining in absolute terms.

Figure 1*: illustrative examples of Nature Positive, Net Positive Impact and No Net Loss (adapted from Maron et al., 2018, Nature Sustainability)*



Our analyses here are underpinned by data collected using the Dutch Biodiversity Monitor. The Biodiversity Monitor for Dairy Farming was developed by FrieslandCampina, Rabobank and WNF (the Dutch chapter of the World Wide Fund for Nature/WWF), with an overarching goal to enable dairy farmers in the Netherlands to improve biodiversity on their own farms and beyond, whilst ensuring sustainable revenue. The Biodiversity Monitor uses integrated Key Performance Indicators (KPIs) to measure the influence of individual dairy farms on biodiversity, making it possible to monitor the role of dairy farmers in the preservation of the landscape and the environment using a standardized system. In addition to providing metrics for assessing the impact on the environment (both positive and negative), the monitor proposes specific measures dairy farmers can take to improve biodiversity. The Monitor consequently provides the basis of a system for calculating losses and gains of biodiversity towards a 'net positive impact' type goal. Though this project focuses on the sector overall (and not individual farms), the Monitor provides an underlying and pre-determined set of KPIs on which to base biodiversity metrics by aggregating across farms, with associated datasets for calculating baselines.

The approach taken for the project involved four stages: 1) developing a biodiversity index, to be used for monitoring impacts and progress towards a net positive goal; 2) establishing biodiversity safeguards, to accompany the index; 3) calculating the impact baseline, against which it can be determined whether net positive is achieved; and, 4) outlining broad strategies to take the sector from the current impacts towards the goal of net positive. This subset of the final overall report captures stages (1) and (2), i.e. the methods, development of the integrated biodiversity index, and the proposed safeguards.

STAGE 1: BIODIVERSITY INDEX

The biodiversity index

Firstly, we developed a single sectoral biodiversity index for tracking progress towards a net positive biodiversity target. This was necessarily based upon the KPIs monitored via the Biodiversity Monitor (see 'Introduction'); not only as these have been agreed as relevant for DZK through a lengthy process of stakeholder engagement, but also as these reflect data that are collected and therefore available to track long-term progress towards net positive.

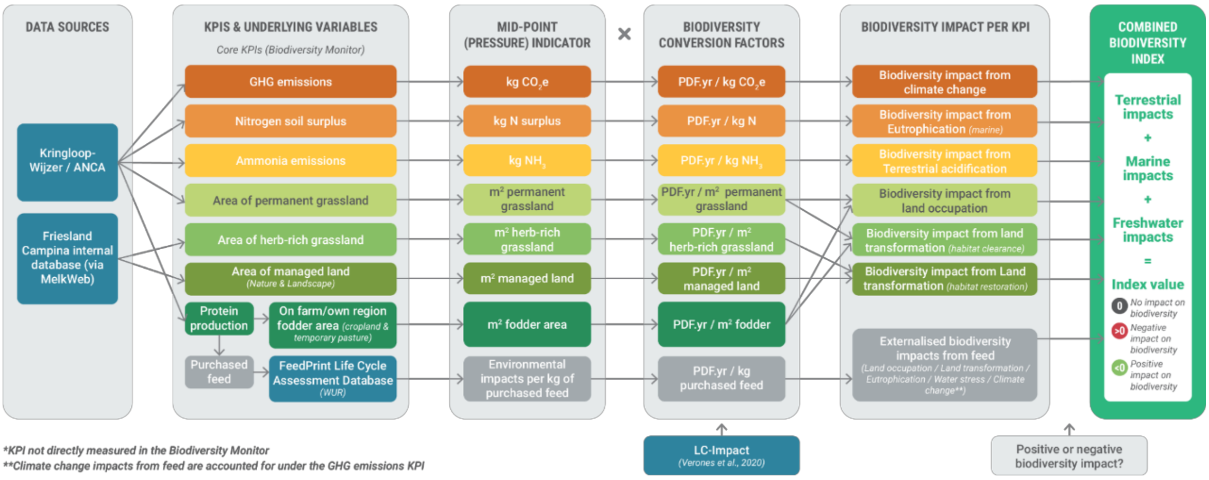
We start by considering some important characteristics for biodiversity indices; in general, and also specifically for this application with DZK. A biodiversity index developed for the project should:

- Be an effective proxy for measuring and monitoring biodiversity impacts;
- Capture both negative and positive impacts (losses and gains in biodiversity) and enable progress to be tracked towards a net biodiversity target (e.g., 'Nature Positive');
- Represent the pressures on biodiversity captured in the Biodiversity Monitor;
- Be pragmatic in terms of input data required while being a robust measure of biodiversity impact;
- Be communicable and meaningful to non-specialists;
- Avoid incentivising perverse outcomes for nature as much as possible; and,
- Be responsive to changes in biodiversity over the relevant temporal and spatial scales.

Next, we outline a proposed approach for calculating a biodiversity index to track progress against the net biodiversity goal (steps visualised in Figure 2):

1. Gather input data for KPIs (measures of environmental pressure). This focuses on the 7 KPIs described in the Biodiversity Monitor (see Fig. 2). For completeness, we note 3 additional KPIs that are not currently included in the Biodiversity Monitor (and are therefore out of scope for this project) but which the project team felt would be potentially worthy of consideration for incorporation into future iterations of the Monitor, as this could capture a broader range of biodiversity impacts from dairy farming;
2. Convert each KPI value into a biodiversity impact score per anonymised farm – to then be aggregated up to the sector level – using characterisation factors from the LC-Impact Life Cycle Impact Assessment methodology. This is measured using the unit: 'Potentially Disappeared Fraction of species over time' (PDF.year), which should be interpreted as an indicator for species extinction risk (Verones et al., 2020). Here, species are used to provide a proxy indicator for combining and comparing biodiversity impacts across a range of pressures/KPIs;
3. Sum PDF.year values across farms to calculate a sector-level biodiversity index per year.

***Figure 2**: visualisation of the proposed biodiversity index framework. A process diagram for the incorporation of Biodiversity Monitor Key Performance Indicator data into a single aggregated biodiversity index, measured in 'PDF.year'.*



Underlying KPI inputs to the index

To provide more detail on the KPIs used in the index calculation: we include the seven KPIs described in the Biodiversity Monitor, which are:

- greenhouse gas emissions;
- nitrogen soil surplus;
- ammonia emissions;
- area of permanent grassland;
- area of herb-rich grassland;
- area of managed land (Nature & Landscape); and,
- protein produced on own land/in farmer's own region.

The KPIs required for the biodiversity index use the underlying information from the Biodiversity Monitor KPIs (e.g., actual area of different land use types rather than percentage values, or absolute CO_2(e) values rather than CO_2(e)/ha) in order to calculate a combined sectoral index value. The KPI 'protein produced on own land/in farmer's own region' is an indicator for the level of self-sufficiency (e.g., feed produced on own land) and also the size of the footprint in other parts of the world (e.g., global impacts generated from ingredients like soy in concentrate feeds): the biodiversity index accounts for both of these underlying elements related to protein production. To calculate the environmental impacts associated with purchased feed, we make use of the FeedPrint NL database developed by Wageningen University & Research, Blonk Consultants, and GFLI.

For completeness, we note 3 additional KPIs that are not currently included within the Monitor but which the project team felt would be potentially worthy of consideration for incorporation into future iterations, as this could capture an even broader range of biodiversity impacts from dairy farming: pesticide use, water consumption, and phosphorus soil surplus. A full discussion of these points is beyond scope of the current project. Rather, we note the importance of considering these issues on an ongoing basis (see also appendix 1).

Biodiversity losses and gains through different KPIs

Crucial to this project is understanding where biodiversity gains could be achieved in principle, as otherwise a net positive outcome will not be possible. Therefore, to eventually be able to sum the net biodiversity impacts of each KPI, we consider which of these has the capacity to generate a biodiversity gain (positive impact on biodiversity).

Some KPIs can only result in losses of biodiversity (negative impacts) and cannot generate absolute gains. For example, pesticides can either be applied to the land (negative impact) or not applied (zero impact). Biodiversity gains are only possible for certain KPIs – namely land transformation and CO_2 emissions. This is further described in Table 1 below.

NB: annual *relative* biodiversity gains (i.e. year-on-year improvements) are possible in principle for all KPIs.

***Table 1**: List of KPIs, with their potential for generating biodiversity gains*

KPI derived from the Biodiversity Monitor	***KPI definition***	***Potential for biodiversity gains? (Y/N)***	***Justification (for the possibility of generating biodiversity gains)***
GHG emissions (kg CO_2e)	Total emissions of CO_2, CH_4, and N_2O from 'cradle to gate' (i.e., the entire supply chain up to and including the dairy farm)	**Y/N**	It is possible to sequester/capture more carbon than the sector emits globally. Any carbon sequestration beyond Net Zero (i.e., sequestering another sector's carbon) could count as a net gain because it would be tackling global biodiversity impacts from climate change that are additional to those caused by the Dutch Dairy sector.
Nitrogen soil surplus (kg N surplus)	N supply per cultivation type minus N removal (crops) and emissions to air.	**N**	Impacts from N surpluses are more localised (e.g., compared to CO_2). There is either a surplus (negative impact) or no surplus (zero impact/fully circular nutrient flows). There is no clear possibility of 'sequestering' additional N surplus to achieve biodiversity gains.
Ammonia emissions (kg NH_3)	Total emissions of ammonia from the barn, manure storage, grazing, fertilisation using animal manure, use of fertiliser.	**N**	We assume that, as with N or P soil surplus, NH_3 emissions could mainly only be reduced to zero and not become negative (i.e. be extracted from the environment)
Area permanent pasture (grassland) (ha)	Total area of permanent grassland - defined as a plot of grassland not included in the farm's crop rotation for a minimum of 5 years.	**Y**	Permanent grassland would have a *relative* biodiversity gain compared to cropland or temporary pasture, but could still be considered productive land with small impacts from ongoing occupation (e.g., by maintaining a lower diversity of grass species with some grazing pressure). Conversion of permanent grassland to herb-rich grassland or to nature & landscape would represent an absolute biodiversity gain (captured as increases in those KPIs).
Area herb-rich grassland (ha)	Total area of herb-rich grassland (permanent grassland with a mix of at least 8 types of grass and herbs, often >10 types), including both extensive and productive herb-rich grassland, weighted according to its biodiversity value (DZK, 2020).	**Y**	Increase in herb-rich grassland can be interpreted as gain of biodiversity rich grassland (noting that the KPI captures diverse types of herb-rich grassland which are already weighted in terms of their value for biodiversity).
Area Nature & Landscape	Total area of managed land under different nature & landscape packages/elements,	**Y**	Increase in area managed or set aside for nature can be interpreted as a biodiversity gain.

(ha)	weighted for its biodiversity value (DZK, 2019).		
Protein/ feed production (purchased feed (kg) and feed produced on own land/in own region (ha))	Purchased feed: Total quantity and type of purchased feed (concentrates, roughage, by-products). Feed from own land/region: Total area of land on own farm used to produce feed (e.g., fodder crops, grassland etc)	**Y/N**	A reduction in land used to produce feed in the Netherlands or overseas could be interpreted as biodiversity gain, if that released agricultural land was allowed to restore to natural habitat. This cannot necessarily be assumed unless the same dairy production levels could be maintained on less land. Other impacts – e.g., reduction of overseas eutrophication impacts, or improving circularity in N/P nutrient flows within the Netherlands could be reduced/improved to zero but not achieve biodiversity gains (NB: embedded GHGs from feed would be included in the GHG emissions KPI).
Possible additional KPIs	***KPI definition***	***Potential for biodiversity gains? (Y/N)***	***Justification (for the possibility of generating biodiversity gains)***
Chemical pesticide use (kg)	Total quantity of chemical pesticide applied (including herbicides, fungicides, and insecticides)	**N**	Chemical pesticide is either applied and causes damage to biodiversity (negative impact) or is not applied and does not damage biodiversity (zero impact). NB: the use of natural enemies/IPM could in theory generate biodiversity gains, but that is not currently included within this KPI.
Water consumption (m^3)	Total freshwater usage (e.g., ground water + surface water + mains water)	**N**	Freshwater is either consumed (e.g., for irrigation or steeping), or not consumed within a basin. Freshwater that is returned to one basin would incur a loss in another basin.
Phosphorus soil surplus (kg P surplus)	P supply per cultivation type minus P removal	**N**	Impacts from P surpluses are more localised (e.g., compared to CO_2). There is either a surplus (negative impact) or no surplus (zero impact/fully circular nutrient flows). There is no clear possibility of ‘sequestering’ additional P surplus to achieve biodiversity gains.

Some important index-specific assumptions

Reversing characterisation factors: The characterisation factors provided in the LC-Impact methodology (Verones et al., 2020) are based on models that predict biodiversity losses per functional unit in terms of global species extinctions. In order to estimate biodiversity gains associated with certain activities (e.g., Nature & Landscape management), we assume it is meaningful to apply these factors in reverse. This is necessary since, as far as we are aware, there are no comparable methods that model biodiversity gains from such a broad range of activities. However, by reversing the LC-Impact models, we are theoretically reversing species extinctions. Given that global extinctions are irreversible, the magnitude of the positive impact may therefore be an overestimate.

Applying biodiversity gains to the ‘Nature & Landscape’ and ‘Herb-rich grassland’ KPIs: we apply the above characterisation factors for biodiversity gain directly to the areas of Nature & Landscape management and herb-rich grassland. We recognise and include that these KPIs represent a range of different land management regimes (e.g., meadow bird management, landscape management, soil management etc), which have been weighted according to their value for biodiversity (Duurzame Zuivelketen, 2019).

Weighting of KPIs: again, the biodiversity index is calculated by farm (without identifying individual farms), and then summed across all farms to obtain a single sectoral index value, which can be used to track progress towards net positive. We do not add any additional weightings at this stage - i.e., we assume that biodiversity gains across all farms have equal weight. We do not, for example, consider spatial elements of where biodiversity gains are being created (e.g., we do not add in multiplicative factors to account for strategic placement of biodiversity gains as part of core areas or corridors – mainly because detailed spatial data would not be available as part of the index inputs). Our estimate of biodiversity net impact is therefore conservative.

Interactions between KPIs: there may be some double counting of impact across KPIs. Where there is overlap between the KPIs (e.g., between protein produced on own land, permanent pasture, and herb-rich pasture), this will be accounted for in the final biodiversity index score. Some double counting of impacts may also occur due to the method employed in LC-Impact. For example, characterisation factors that quantify the biodiversity impact of 'land occupation' (e.g., associated with cropland or pasture occupation) are calculated based on the GLOBIO database, comparing species assemblages between disturbed and undisturbed land. Some of the impacts associated with land occupation will therefore be driven by pressures like fertiliser use and pesticides, which in this framework are also quantified as separate KPIs. Again, this means our estimates will be conservative. Other than double counting, we assume no further interactions between the KPIs with regard to their impact on biodiversity, beyond those that are already captured in the Biodiversity Monitor.

The full methodology proposed for calculating the integrated biodiversity index, on the basis of KPI data collected under the Biodiversity Monitor, is captured in appendices 1 – 3.

STAGE 2: SAFEGUARDS

A challenge in seeking to meet a target biodiversity net outcome measured using a single composite index is that there is the potential for the index to mask undesirable outcomes. For example, good performance against the index overall could reflect excellent performance across 6 KPIs, and unacceptable performance against the 7^{th}. Consequently, we develop a set of safeguards to be implemented in conjunction with the DZK biodiversity index.

In the context of this project, based on internal discussion and stakeholder consultation, we define a 'safeguard' as: *a standard put in place to ensure that – in seeking to meet the goal of Net Positive Impact on biodiversity – there are no unintended, undesirable, or perverse outcomes for biodiversity*. Safeguards are important both to avoid perverse outcomes and to define a safe operating space.

Function of safeguards: setting a 'net outcomes' target (such as achieving net positive impacts on biodiversity) works on the basis that certain unavoidable biodiversity impacts may occur, with the requirement that these losses are adequately compensated for (e.g., through biodiversity restoration offsets). Safeguards help us to specify which biodiversity losses are permittable and what 'adequate' compensation looks like. This can be based both on empirical biophysical limits as well as socio-political values. Safeguards are particularly important when using a single, integrated biodiversity index (as is proposed for this project), to correct for limitations of the index which could potentially mask unacceptable impacts on components of biodiversity – if implemented without safeguards. For example, a safeguard might specify that achieving net positive impacts on biodiversity should not be based on a strategy which includes deforestation of pristine rainforest through the Dutch dairy sector's feed supply chain, or one that leads to levels of nutrient pollution within the Netherlands that are unhealthy for humans or wildlife.

Defining a safe operating space: it is unlikely that values can be maximised for all Biodiversity Monitor KPIs. For example, there may be farm-level trade-offs between KPIs (such as between protein produced on own land and nitrogen soil surplus if intensity is increased) or local constraints that limit performance. Safeguards help to define the safe operating space for the sector as a whole, allowing farm-level constraints and trade-offs to be navigated while striving for a genuine Net Positive impact on biodiversity at the sector-level. Safeguards therefore need to be comprehensive enough to prevent perverse outcomes for nature, but practical enough to ensure feasibility when designing strategies towards a Net Positive target.

Proposed safeguards for DZK NPI

In developing safeguards for this project, we draw upon existing good practice guidance around achieving 'net outcomes' goals (such as net positive impacts on biodiversity), and associated topics (e.g. biodiversity offsetting). This includes peer-reviewed articles (e.g., Maron et al., 2016), business and financial institution standards and guidance (e.g., IFC Performance Standard 6, UK BNG Good Practice Principles), policy guidance (e.g., EU biodiversity strategy, Dutch Natuurpunten), and stakeholder consultation sessions (see appendix 4). These resources exhibit some common themes, which potentially serve as a good basis for determining categories of safeguard (Table 2).

***Table 2**: Proposed safeguard categories based on Net Positive Impact principles*

Principles for achieving Net Positive Impact	Brief Description	Proposed safeguard category for Net Positive Impact from Dutch dairy
Applying the mitigation hierarchy	Prevention (avoidance or reduction) of impacts on biodiversity should be prioritised before considering ecological compensation (restoring or offsetting biodiversity impacts). This is because prevention of impacts is the least risky approach for safeguarding biodiversity. Impacts on irreplaceable biodiversity should always be avoided.	1. **Avoiding irreplaceable losses.** For example, large impacts should be avoided in highly biodiverse regions – such as deforestation caused by soy or oil palm in feed. DZK have expressed a goal that: "*In 2025, dairy farming will be land-based in accordance with the advice of the Land-based Dairy Farming Committee (Advies Commissie grondgebondenheid*)." This advice includes a proposed reduction in imports of soy and palm products used in feed by two thirds by 2025 relative to 2018. DZK also require 100% responsibly sourced soy (RTRS or equivalent) and use of responsible palm kernels in animal feed (RSPO or equivalent).
Setting biophysical limits for unacceptable impacts	Related to (1) above, limits should be defined for the relevant components of biodiversity beyond which compensation for negative impacts is not acceptable.	**2. Biophysical safeguards.** These limits would be *sector-level* thresholds for each of the Biodiversity Monitor KPIs. They could be established using the farm-level values calculated by van Doorn et al. (2019) as a starting point (see Table 3).
The spatial proximity principle	Biodiversity gains should be located close to where impacts are occurring (e.g., in the same province, region, country, or ecoregion), and ideally contribute to locally strategic nature networks. In turn, this means that a biodiversity gain in one region should not compensate for a biodiversity loss in other regions. This spatial element also concerns the benefits people get from nature: the same people that lose access to nature should ideally benefit from biodiversity gains (or be compensated in other ways).	**3. Geographic/spatial safeguards.** Unavoidable impacts within the Netherlands should ideally be compensated within the region where they occurred (e.g., by restoring habitats and contributing to the National Ecological Network). Similarly, unavoidable impacts in locations where feed is sourced from should ideally be compensated within those regions. This could mean setting a minimum proportion of biodiversity gains that need to be achieved within the Netherlands, or within countries where feed ingredients are sourced, based on observed impacts from the sector.
Ensuring ecological equivalence	Biodiversity losses and gains should be equivalent (or 'in-kind'): Habitats that have been lost should be replaced 'like-for-like' or better (in terms of conservation value). For example, an area of forest that has been cleared might not be compensated for by creating grassland.	**4. Habitat type safeguards.** In the context of this project, impacts on aquatic habitats (e.g., from nutrient runoff or leaching) should not be compensated for by restoring terrestrial habitats (e.g., on-farm biodiversity). This may mean that aquatic impacts can only be reduced or avoided, but not restored or offset.

Ensuring ecological compensation is timely and lasts	Limit the length of any time lags between causing biodiversity losses and implementing biodiversity gains. Ensure that biodiversity gains are designed to be maintained for a minimum amount of time.	**5. Temporal safeguards.** This is all about the timing of restoration measures. E.g., minimising time lags by setting a maximum number of years after biodiversity losses have occurred during which compensation for those impacts can be initiated (e.g., <5 years after negative impacts occur). Require biodiversity restoration measures to last at least as long as the impacts they are compensating for, and ensure long-term habitat monitoring and management plans are in place.

Table 3 lists proposed values for each safeguard category defined in Table 2 above. These are defined at sector level (not for individual farms) and categorised into two groups, which apply at different points of the mitigation hierarchy.

Safeguards for impact prevention: Safeguards (1) and (2) define the minimum impacts that should first be avoided or reduced (i.e., the 'unacceptable' impacts on biodiversity). These are determined from 'static' goals or standards – such as the goal to buy 100% responsibly sourced soy, or to adhere to nitrogen standards as set out in the Nitrates Directive.

Safeguards for impact compensation: Safeguards (3), (4), and (5) define how unavoidable impacts should be compensated in line with best practice for biodiversity (e.g., through restoring or offsetting). These are more dynamic, as they are determined by the kinds of impacts that have taken place (e.g., the habitat types and locations that have been affected), as well as when those impacts occurred.

***Table 3**: proposed values/approach for sector-level safeguards*

Safeguard Category	Basis for safeguard	Proposed sector-level safeguard value	Notes on calculation for sector-level safeguard
Safeguards for impact prevention			
1. Avoiding irreplaceable biodiversity losses	Advice Committee on Land-Relatedness ('Advies Commissie grondgebondenheid'): A proposed **two thirds (2/3) reduction in the amount of soy and oil palm products used relative to 2018 levels.**	Less than or equal to ~150 million kg soybean meal/flakes, ~6 million kg soy shells/hulls, and ~140 million kg of palm kernels.	Values are approximations calculated by using the total annual quantity (million kg of product) per feed type for soy and oil palm products listed in Table 8 of the Commissie Grondgebondenheid report (2018), which gives average values for 2016, based on a total of 1.7 million cows. We therefore scale these values to the number of cows in 2018 (approx. 1.6 million according to ZuivelNL, 2018), as this is stated as the baseline year for comparison, and reduce by a third to calculate the safeguard value. Soy and palm oil are not necessarily the only possible safeguard to employ here, but are arguably those for which the most information is available.
	DZK 2030 Goal for **100% use of responsible soy (RTRS or equivalent) and use of responsible palm kernels in animal feed (RSPO or equivalent).** Responsibly sourced soy and palm products are assumed to incur no impacts from deforestation (land use change). It is also worth noting that dairy companies setting Science Based Targets for FLAG greenhouse gas emissions are also required to publicly commit to zero deforestation (SBTi, 2022).	100% of soy and oil palm products in feed certified as RTRS/RSPO or equivalent.	Note that a 'book & claim' method is currently used when buying responsible soy, although DZK aim to shift to a 'mass balance' balance approach (including working with dairy sectors across Europe).
2. Biophysical safeguards for the Biodiversity Monitor KPIs Using van Doorn *et al.* (2019) as a basis)	**KPI1: Percentage of permanent grassland** (>5 years no tillage) Based in the CAP-GAEC (Common Agricultural Policy - Good Agricultural and Environmental Conditions)	>62%	In van Doorn et al. (2019), it is noted that nationally, the percentage of permanent grassland of the total area on dairy farms in 2017 was 62% (based on RVO data; noting that according to the RVO grassland becomes permanent grassland in the 6th year after 5 years of no tillage). This is used as the baseline from which permanent grassland should not decline. At the farm-level, van Doorn et al (2019) recommended limits depending on the soil type (60,75, and 80% for sandy, clay and peat soils, respectively). However, it is the overall sector value that is relevant here. Further, the research team is currently analysing farm data to determine what constitutes best current practice on this KPI (which informs feasibility).

	KPI2: Percentage of protein from own land/region (<20 km) Based on the Advice Committee on Land-Relatedness ('Advies Commissie grondgebondenheid')	>65%	The DZK 2030 goal is for at least 65% of the protein in the cow's ration must come from own land or within the local region of the dairy farmer. This is in order to reduce reliance on feed imported from other regions (linear nutrient flow) and stimulate greater proportions of grassland.
	KPI3: Nitrogen soil surplus Based on the Nitrates Directive Water Quality Standards (Target values are based on Water Framework Directive Ecological Standards)	If based on human health standards of the Nitrates Directive: <**105,000 tonnes of N soil surplus** If based on ecological standards of the Water Framework Directive: **<8,700-35,000 tonnes of N soil surplus** (depending on soil type breakdown)	van Doorn et al. (2019) calculated an average N soil surplus value for farms in locations where the Nitrates standard (50 mg NO3/l) was being met. This average value was equal to 120 kg N/ha, which (as our focus is the sectoral level) we assume that we can multiply by the total area of land use for Dutch dairy in 2020 (870,880 ha, CBS (2022)) to give an order of magnitude indication for the safeguard value. A more detailed estimate could be achieved in future by calculating a weighted total based on soil and crop type (both of which influence the amount of N leached into water bodies). NB: the value in van Doorn et al. (2019) is based on the nationally transposed human health standards of the EU Nitrates Directive. We note that a safeguard value for biodiversity might ideally be determined on the basis of ecological standards (such as those as set out in the Water Framework Directive, at a value of 10-40 kg N/ha) but recognise that this would set a very stringent safeguard for Nitrogen soil surplus.
	KPI4: Ammonia emissions Based on the National Emissions Ceiling Directive (NECD) & Netherlands PAS Agreement ('programmatic approach to Nitrogen').	<44,000 tonnes of NH_3	van Doorn et al. (2019) calculated a sector-level value for ammonia emissions based on the NEC ceiling (21% reduction compared to 2005 levels) plus an additional 5,600 tonnes NH_3 reduction based on the PAS Agreements. This was equal to 44,000 tonnes NH_3. A similar value (41,000 tonnes NH_3) was arrived at by Beldman et al. (2020), based on a national 26% reduction target for Nitrogen deposition. We understand there is some debate as to whether this value is sufficiently low to safeguard ecosystems against NH_3 emissions, but use it in the absence of an alternative and documented quantitative value.
	KPI5: Greenhouse gas emissions Based on the Forest, Land, and Agriculture (FLAG) Science Based Target Setting Draft Guidance (Science Based Targets Initiative, 2022): General pathway for FLAG sectors (see Table 9 of the draft guidance).	35% reduction relative to 2020 levels	van Doorn et al. (2019) give a value of 12 million tonnes of CO_2 equivalents as the sectoral limit for greenhouse gas emissions, based on dairy targets in the Netherlands Climate Agreement (Klimaatakkord). However, this value is limited in scope to on-farm methane emissions within the Netherlands (from enteric fermentation and manure management). In order to account for the global scope of emissions from Dutch dairy and align with a 1.5ºC scenario, a science-based target approach is preferred. The proposed 35% reduction in absolute CO_2 equivalents serves as a starting point, based on the general sector-level recommendations in the Forest, Land and Agriculture (FLAG) draft

			guidance published by SBTi (SBTi, 2022 – see Table 9). This would need to be further elaborated for all scopes of emissions through setting detailed Science Based Targets for the sector; and we note also the draft status of these recommendations (i.e. they therefore may still be subject to change).
	KPI6: Percentage of herb-rich grassland Based on the ANLb (Agricultural Nature and Landscape Management) - preconditions for meadow bird habitat quality	15-20%	Here we apply the same percentage range as the farm-level value provided in van Doorn et al. (2019). This was calculated based on habitat requirements for meadow birds - specifically, the black-tailed godwit. The assumption is made that, outside of areas with habitat potential for black-tailed godwits (~67,000 ha - or ~8% of total dairy land in 2020 – based on Melman and Sierdsema (2017)), the 15-20% value would have similar benefits for other species groups (e.g., pollinators, other meadow bird species, soil biota etc). It also recognises that herb-rich grassland inherently increases diversity of plant species (relative to more intensive grasslands and cropland). However, though making this assumption is the best option currently available, this safeguard should be updated through further research so that the evidence base explicitly extends to other species groups and regions. Relevant research is ongoing (coordinated by the Louis Bolk Institute), with results anticipated in 2023.
	KPI7: Percentage of Nature & Landscape elements Based on Cormont et al. (2016)	7-10%	Same percentage as average farm-level provided in van Doorn et al. (2019), based on research by Cormont et al. (2016) on the relationship between non-productive area and species richness on farmland. 7-10% of the total farm area is the value at which a ~50-60% increase in species richness is predicted, relative to a situation with no natural elements (noting that there is a lot of variation around this value).
Safeguards for impact compensation			
3. Geographic/spatial safeguards	Biodiversity gains (e.g., habitat restoration) should be located close to where impacts are occurring	Preliminary data analysis on location of impacts for 2020 indicates that approximately ~10-30% of biodiversity gains should be achieved in the Netherlands, and ~70-90% should be achieved overseas in regions where feed is sourced3	This safeguard would apply to biodiversity gains being implemented to restore or offset any unavoidable impacts on biodiversity from Dutch dairy. The values would be updated each year and would be determined by the extent of unavoidable biodiversity impacts per region. For example, preliminary analysis of biodiversity impacts from Dutch dairy suggest that approximately ~15% of impacts occurred within the Netherlands in 2020, and the remaining ~85% of impacts occurred overseas in locations where feed is sourced. Applying the geographic safeguard would mean that the same proportions should apply to biodiversity gains being implemented to compensate these impacts.

3 ***Note****: These percentages apply to the unit used for the Stage 1 biodiversity index ('PDF.year') which essentially measures the contribution to proportional global species losses predicted to result from activities. Because of the way these values are calculated (e.g., including weighting for species vulnerability – see LC-Impact for info) these percentages would not directly translate into percentages of habitat restoration area. A given biodiversity gain (as measured using the biodiversity index score) could be achieved by restoring different absolute areas of habitat, depending on the location (i.e., a m^2 of habitat restoration in the Netherlands will have a different value in the biodiversity index to a m^2 of restoration in Brazil).*

4. Habitat type safeguards to ensure ecological equivalence	Biodiversity gains should be ecologically equivalent to biodiversity losses in order to achieve NPI.	Values determined year on year, based on specific impact areas.	Related to geographic safeguards, this safeguard would apply to biodiversity gains being implemented to restore/offset unavoidable impacts on biodiversity. The value(s) would be updated each year (dynamic) and would be determined by the extent of unavoidable biodiversity impacts per broad habitat type. For example, if, in a particular year, 20% of biodiversity losses occurred within wetland habitats, then 20% of biodiversity gains should also be within wetland habitats. In reality, the KPIs of the Biodiversity Monitor and associated biodiversity index (Stage 1) are too high-level to determine exact types of habitat that would need to be compensated, so this may need to be based on average habitat types per region, or require additional monitoring.
5. Temporal safeguards	Time-lags between biodiversity losses and gains should be avoided.	Implementation of compensation should ideally be provided in advance (e.g., through biodiversity banking) or commence at the same time as impacts accrue. However, if there is some delay between ecological impacts and compensation, a multiplier will be added into gains requirements (as per Laitila et al., 2014). In any case, due to practical feasibility around multiplier size, it is recommended that any time lag is **no greater than 5 years.**	See the work in Laitila et al. (2014) as referenced already, as well as the discussion on multipliers by Bull et al. (2017). We incorporate further consideration of this into the document for Stage 3.
	Ensure longevity of biodiversity gains	Are long-term management/monitoring plans in place for biodiversity gains? **(Categorical: Yes or No).**	Long term in this case could be taken as ‘equal to or greater than one typical generation’, and certainly for the time frame for which the DZK strategy is to be defined i.e., ~ 30 years. Long term management/monitoring of offset gains is a key offset design principle (see e.g., Bull et al., 2013), and the use of a 30 year period is often cited, including in some policy. Further, one proposal is for DZK to align NPI targets with the CBD post-2020 strategy, seeking net gain for around 2050; which would also mean monitoring for at least ~30 years.

In practice, the safeguards listed in Table 3 should be thought of as a 'checklist' to be used alongside the Biodiversity Index. In principle, to achieve Net Positive Impacts, the Dutch Dairy sector must achieve a positive net score on the index while also meeting each of the safeguards; although this depends to some extent on the degree of flexibility considered permissible by DZK (see **Stage 4**). To expand: in the scenario in which the result was that more biodiversity was gained than lost overall, but one or more of the safeguards were not met, an overall 'net positive impact' could not be claimed. Conversely, if more biodiversity was gained than lost overall and every minimum safeguard was met, the result *could* be considered a 'net positive impact'.

CONCLUSIONS: methods

The implementation of the Biodiversity Monitor has resulted in a useful dataset, which allows a reasonable quantitative estimate of the Dutch dairy sector's biodiversity and emissions impacts to be calculated. Here, we have developed an approach for doing so, which makes possible an integrated biodiversity index based on established methodologies for Life Cycle Impact Assessment (estimating the contribution to global species extinction risks). It is crucial to bear in mind that any biodiversity metric, including the integrated index proposed here, is potentially useful as an indicative guide – but cannot represent every important aspect of biodiversity impacts. This in turn is why the safeguards outlined here are such a crucial outcome of the project.

That being said, the results of the overall study will help identify key areas for targeting biodiversity impact reduction, and allow strategies to be proposed that could seek to eventually achieve a net positive impact against the proposed metric per annum. Any strategy must, importantly, be guided by efforts to meet the suite of safeguards outlined here – both biophysical and social – identified through literature review and stakeholder consultation. For further information on stages 3 and 4 of the project (baseline impacts, and positive net positive strategies), the reader should refer to the full project report.

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APPENDICES

Appendix 1: detailed methods

Gathering and preparing KPI data on environmental pressures

Data attributes

Data were provided to the project team at farm-level for 14,686 farms in total, with values spanning the time period 2018-2020. However, 2020 was the only year for which comparable data was available across all of the KPIs collected under the Biodiversity Monitor; hence, this was the year chosen as the focus for analysis.

Data on the herb-rich grassland and Nature & Landscape KPIs were sourced from Royal FrieslandCampina (RFC), with data on the remaining KPIs and contextual data provided from the KringloopWijzer (KLW) database from ZuivelNL. Datasets were matched based on unique farm identifiers, but all farms were anonymised.

All variables used in this analysis are listed in appendix 2 (the 'index spreadsheet'). This appendix contains information on the methods, and no results.

Data screening

Farm-level screening

Data were screened to remove farms that did not meet specific criteria on data quality and outlier values for each of the KPIs. Farms were removed from the analysis if they did not pass the initial screening (as indicated in the fully anonymized KLW dataset) developed for the KLW by Wageningen University & Research (WUR). Farms lacking key basic information necessary for converting KPIs into estimated biodiversity impacts (such as the total area of land or milk production) were also excluded. After screening, the final dataset consisted of 8,950 individual farms (62% of all dairy farms in the Netherlands, based on a total number of dairy farms recorded by CBS in 2020 of 14,542). RFC data was available for 8010 (89%) of these farms.

Variable screening

Further screening was applied to certain variables in order to remove outlier values. In some cases, the percentage of permanent grassland exceeded 100% (i.e., exceeded the total area of the farm) and were therefore removed. For herb-rich grassland and Nature & Landscape KPIs, values were similarly removed where the total (unweighted) area exceeded the total area per farm. For nitrogen soil surplus, negative values were not removed from the dataset but were capped at zero (0). This is because, while negative values are possible for this variable, it would not be considered accurate to translate these as a biodiversity gain when summing values across farms due to the localised nature of the impact.

Calculation of additional/modified KPIs

Converting relative KPIs into absolute values

In order to convert KPI values into a biodiversity index value for the sector as a whole, it was necessary to convert KPIs provided as relative values (e.g., kg CO_2e per kg milk, or kg NH_3 per ha, KPIs presented as percentage values) into total/absolute values per farm. This was achieved by multiplying by either the total farm area or total milk production per farm, depending on the KPI.

Accounting for other land-use types

In addition to other to the permanent grassland KPI, other land use types and intensities exist within the farm boundaries that needed to be accounted for. The total area of combined temporary grassland and cropland (combined, as these are often in rotation) was therefore estimated, by subtracting the area of permanent grassland from the total area of the farm. Areas of grassland/cropland were then adjusted to account for areas provided for Nature & Landscape (described further below). The yard area was not considered in this analysis.

Areas of Nature & Landscape management (unweighted) provided in the RFC dataset were separated into four categories, based on the type of land the measure would be applied to (e.g., grassland, cropland, or landscape element – based on the Cumulatie and Grondgebruik table provided by Boerennatuur) and also based on the biodiversity weighting per management package, (provided in the Beheerpakketten Biodiversiteitsmonitor (BBM) documentation and associated appendices). These categories are shown in Table A1 below. The distinction between these four categories was necessary for the biodiversity index calculations (see section 2 below), as it separates areas of low-intensity farming (which would have a relatively lower biodiversity impact compared to more intensive areas) from farmland habitats capable of generating absolute biodiversity gains. It was necessary to exclude certain management packages from calculations in order to avoid double counting of areas.4

Areas of permanent grassland and combined areas of temporary grassland/arable land were adjusted to account for areas of low impact grassland/arable land, herb-rich grassland, and Nature & Landscape areas.

Combined values for these different land-use types often exceeded the total area per farm, and conversations with DZK project members indicated that overlap between these areas was possible.

However, it was not always possible to determine from the dataset which land use types were overlapping (e.g., whether HRG was included under temporary or permanent grassland). The following assumptions were therefore made:

Area of HRG was subtracted from the total area of permanent grassland.

Areas of low impact grassland/arable land and Nature & Landscape areas were subtracted from the assumed arable/temporary grassland area. If these values exceeded the arable/temporary grassland area, the remainder was subtracted from permanent grassland areas.

While this involves making several assumptions, it was considered necessary and reasonable as a means to account for potential double counting of areas.

***Table A1**: Categorisation of Nature & Landscape and herb-rich grassland areas*

Category	Description/definition	Examples	Type of impact on biodiversity	Relevant environmental pressure
Herb-rich grassland	Packages under the Grassland Management (Graslandbeheer) category of the BBM	Extensive herb-rich grasslands, herb-rich grassland borders, Botanical grassland, old grasslands (>20 years) with herbs, etc.[5]	Absolute biodiversity gain	Land Transformation and Restoration
Nature & Landscape areas	Nature & Landscape packages with a BBM weighting of >1	Hedges, groves, coppice areas, 'plas-	Absolute biodiversity gain	Land Transformation

4 Specifically – BBM107 and BB107 ('Bodemverbetering grasland met ruige mest', 'Bodemverbetering bouwland met ruige mest', 'Bodemverbetering met ruige mest', 'Chemie en kunstmestvrij land') as they are applied in combination with other management packages.

[5] Note: Productive and transitional herb-rich grassland (BBM100 & BBM141) would also be included under this category (with the relevant weighting applied), but none were recorded in the dataset provided.

		dras' (wet grassland habitat), orchards etc		and Restoration
Low-impact arable land	Nature & Landscape packages with a BBM weighting of <1, typically applied to arable land	Stubble areas ('stoppelland'), arable land with nesting field birds, arable land with clutch management, etc	Relative biodiversity gain compared to more intensive farming	Land Occupation
Low-impact grassland	Nature & Landscape packages with a BBM weighting of <1, typically applied to grassland	Grassland with rest period, extensive grazing, controlling water levels for meadow birds, etc	Relative biodiversity gain compared to more intensive farming	Land Occupation

For the 2020 analysis, areas of land transformation / restoration were calculated using the change in area of herb-rich grassland or Nature & Landscape management per farm relative to the previous year (2019). This calculation was only made when data were available for both years, which was the case for 1237 farms for herb-rich grassland (14% of the dataset, 9% of all farms in the Netherlands), and 3753 farms for Nature & Landscape areas (42% of the dataset, 26% of all farms in the Netherlands).

Estimating environmental pressures from feed using FeedPrint

<u>FeedPrint overview</u>

In order to estimate biodiversity impacts associated with purchased feed, it was necessary to convert data provided on quantities of feeds into an estimated level of environmental pressure.

We did this using the Life Cycle Analysis (LCA) database FeedPrint6. FeedPrint is also referred to in the calculation guidance for the KLW, particularly when calculating greenhouse gas emissions associated with feed (included in the fully anonymized KLW dataset). We therefore use FeedPrint as a consistent source for estimating other environmental pressures.

FeedPrint provides ingredient- and country-level breakdown for a broad range of dairy feeds, and calculates the associated environmental pressures using the PEFCR-Feed methodology.

We exported environmental data for feed components per country, with the following (default) parameters selected:

***Figure A1**: parameters selected when using FeedPrint*

6 Written consent was provided by the owners for this project.

Selecting relevant feed data and avoiding double counting

Data was provided to the project team for feed produced on the farm and feed purchased by the farm. Feeds included concentrates, other roughage & by-products, maize, grass silage, and milk powder (see list of variables contained in Appendix 1).

It was assumed that all feeds 'produced' by the farm were accounted for by other environmental KPIs for which actual/known environmental values were provided (e.g., areas of grassland, total area of farm, $N/NH_3/CO_2e$ emissions associated with growing fodder etc). Using the known environmental values was considered a more reliable approach than estimating environmental pressures based on the kilograms of produced feed, therefore 'produced' feeds were excluded from further analysis to avoid double counting.

It was also assumed that 'purchased' grass and maize silage were produced on other farms within the dairy sector (i.e., the Dutch dairy sector selling grass/maize back to itself), and were therefore also excluded to avoid double counting across farms (since all were included in the sector total). This could potentially result in underestimating biodiversity impacts (for example, if grass or maize silage is sourced from areas outside of the scope of the dairy sector).

Purchased concentrates and other roughage and by-products were assumed to be additional (i.e., sourced from other sectors and/or other countries). The analysis of purchased feeds therefore focuses on these two types of composite feeds.

Ingredient- and country-level breakdown of environmental impacts

Calculating biodiversity impacts requires knowing where environmental pressures are occurring (i.e., where ingredients are sourced), which in turn requires knowing which component ingredients make up composite feeds such as concentrates or the broad category 'other roughage & by-products'.

To estimate this for concentrates, we used 'concentrate dairy standard' as a reference product, taking the ingredient and country-level breakdown directly from the FeedPrint database.

'Other roughage & by-products' is a much broader category of feed ingredients, which was more difficult to determine. To determine the ingredient breakdown associated with this category, we referred to data published by Blonk Consultants (Broekema & Kramer, 2014), which provided an in-depth Life Cycle Inventory for Dutch semi-skimmed milk and semi mature cheese. We referred specifically to Table 3-10 of this report, shown in Figure A2 below (note that we used the most up-to-date dry matter estimates provided within FeedPrint, sourced from CVB).

The country-level breakdown for each of the composite ingredients was then sourced from FeedPrint.

These values can be viewed in the feed-related tabs of the biodiversity index spreadsheet (appendix 1), or directly withing the FeedPrint database software.

Figure A2*: Table taken from Broekema & Kramer (2014) to determine breakdown of 'other roughage & by-products'*

Table 3-10: LCI for the mix of wet by-products fed to dairy cows.

Products	Quantity	Unit	Comment
Dairy wet by-product feed NL	100	kg	As fed
Materials/fuels			
Brewers' grains (22% dm) NL	18	kg	22% dry matter, Handboek Melkveehouderij 2012, chapt 6, table 6.24
Potato pulp pressed fresh+silage NL	14	kg	16% dry matter
Sugarbeet pulp SUG 150-200 NL	23	kg	22% dry matter
Soybean meal CF 45-70 CP 0-450 NL	18	kg	16% dry matter
Rapeseed meal Mervobest NL	9	kg	88% dry matter
Wheat NL	9	kg	87% dry matter
Maize NL	9	kg	87% dry matter
Transport, lorry 20-28t, fleet average/CH U	5	tkm	
Transport, barge tanker/RER U	5	tkm	

Environmental values per kilogram of ingredient per country were exported for: Land occupation, freshwater eutrophication, marine eutrophication, and water consumption.

Carbon values from FeedPrint were not used in order to avoid double counting, as these were assumed to be accounted for under the GHG emissions KPI (following the KLW guidance).

Estimating area of land transformation (land use change) associated with feed

While the area of land occupation was provided directly in FeedPrint, the area of land transformation (also known as land use change; LUC) was not provided. However, FeedPrint does provide estimates of carbon emissions associated with LUC, calculated using the PAS 2050 methodology. Therefore, in order to calculate the area of LUC (i.e., the area of habitat destruction for conversion to agriculture), we reverse this calculation using the same factors (provided in Annex C of the PAS2050:2011 guidelines). These factors are in the form of tonnes CO_2e / ha / year (available in appendix 1), and are provided at local level for a set of countries. For countries not included in this list, we used the continental average.

The area of LUC was calculated for all feed ingredients except for those derived from soybean products. Soy was assumed to have no impacts associated with LUC due to the sector sourcing 100% certified sustainable soy (RTRS or equivalent). Other environmental pressures from soy (land occupation, eutrophication etc) were included, however.

Converting KPI data on environmental pressures into an assumed impact on biodiversity

KPIs used in the biodiversity analysis

The following are the final list of KPIs/environmental pressures used in the biodiversity analysis for 2020 – as depicted in Figure 2 of the main report (these refer to total values per farm):

- GHG emissions (kg CO_2e)
- Nitrogen soil surplus (kg N)
- Ammonia emissions (kg NH_3)
- Area of permanent grassland occupation (m^2)
- Area of arable land/temporary grassland occupation (m^2)

- Area of low-impact grassland occupation (m^2)
- Area of low-impact arable land occupation (m^2)
- Area of herb-rich grassland (m^2)
- Area of Nature & Landscape (m^2)

Environmental impacts (land occupation, freshwater eutrophication, marine eutrophication, and water consumption) associated with quantities of purchased concentrates and other roughage & by-products.

Choice of biodiversity metric (LC-Impact)

There are several biodiversity metrics currently available for use in impact analysis (e.g., see those listed in the SBTN guidance, or the EU Business @ Biodiversity Platform report), and none that are widely accepted as standard. However, LCIA is the only approach that would allow us to incorporate such a broad scope of environmental pressures (KPIs), and enable us to convert these KPI 'mid-points' (pressures) into an estimated aggregated end-point impact on biodiversity.

LC-Impact software in particular was chosen because it is one of the most recently developed LCIA methodologies (developed as part of an EU FP7 project, via a collaboration between 14 partners). It incorporates spatial differentiation for environmental impacts where relevant, as well as levels of species vulnerability and endemism – both of which are lacking to some degree in other LCIA methodologies.

LC-impact measures biodiversity impacts using the unit: 'Potentially Disappeared Fraction of species over time' (PDF.year), which should be interpreted as an indicator for species extinction risk (Verones et al., 2020). Species are used to provide a proxy indicator, for combining and comparing biodiversity impacts across a range of pressures/KPIs.

Applying LC-Impact to estimate biodiversity impacts per KPI

General choices

LC-Impact provides a set of characterisation factors (CFs), which estimate biodiversity impact (in PDF.year) per unit of environmental pressure – for example, PDF.year per kg CO_2e emitted, or PDF.year per m^2 of land occupation. These CFs are based on a set of models from the scientific corpus which link the KPI to biodiversity via a particular 'impact pathway' (e.g., climate change, eutrophication, acidification, habitat conversion etc).

Users of the LC-Impact software can choose to use either the 'core' or 'extended' set (with the latter including more uncertain impacts), and also whether to use CFs calculated via an average/linear method, or a marginal method (see Verones et al., 2020 for further details).

Here, we have applied the core set of CFs, using average/linear CFs wherever these are available. Notably, LC-Impact does not provide average/linear CFs for estimating terrestrial acidification impacts linked to ammonia emissions and we therefore use the marginal CF in this instance.7

In the case of the KPIs for CO_2e emissions and NH_3 emissions, these could be combined directly with the relevant characterisation factors (specific factors are detailed in appendix 1). For other KPIs, further adjustments were made before combining KPIs with the characterisation factors, which are described in the following sections, along with any other relevant assumptions and limitations.

7 Marginal CFs calculate the biodiversity impact of an additional kilogram of ammonia (as opposed to the average effect of a kilogram of ammonia).

Nitrogen soil surplus

Nitrogen soil surplus describes the balance between supply (e.g., from fertiliser, manure, fixation etc) and removal (e.g., via crops or emissions to air) of nitrogen compounds on farms. As such, it is possible to have a negative value for nitrogen soil surplus (i.e., where removals outweigh the supply).

However, given the localised nature of nitrogen soil surpluses, it was not considered appropriate to sum negative and positive impacts from nitrogen. That is, if a negative nitrogen surplus value is achieved in one location, that would not translate into a positive impact that compensates for negative impacts elsewhere. Furthermore, because impacts are determined based on models of eutrophication, it would be incorrect to apply the CFs in reverse in this instance - i.e., eutrophication impacts can be reduced to zero, but not reversed to achieve a biodiversity gain (see Table 1 of the main report). This was a point raised and discussed during both stakeholder consultations.

Therefore, we 'cap' negative nitrogen soil surplus values at zero before combining values with the biodiversity CFs.

A second point to note is that the CFs for nitrogen model eutrophication are based on a commonly applied (e.g., see Morelli et al., 2018) assumption of nutrient limitation – that is: nitrogen is assumed to be the limiting nutrient in marine ecosystems and phosphorus is assumed to be the limiting nutrient in freshwater ecosystems. As such, the impact of nitrogen soil surplus is modelled in terms of eutrophication of marine systems8 rather than of freshwater systems.

This could lead to impacts from nitrogen soil surplus being underestimated in the index – although there is evidence that phosphorus is a primary driver of freshwater eutrophication, including within the Netherlands (e.g., Lürling & Mucci, 2020; Schindler et al., 2016 & 2012), and that nitrogen limitation tends to be stronger in marine systems (Elser et al., 2007). Furthermore, relatively low levels of phosphorus soil surplus are reported for Dutch dairy farms – which would translate into a biodiversity impact from freshwater eutrophication several orders of magnitude lower than other KPIs ($\sim1.4\times10^{-08}$ PDF.year, based on an average of 7kg P2O5 recorded on the WUR Agro & Food portal).

Here, we have used the best method currently available. Nevertheless, we acknowledge that this is a simplified approach (particularly given high percentages of eutrophic freshwater bodies in the Netherlands - RIVM, 2021), which would ideally be improved by CFs that take into account site-specific nutrient limitation and synergistic effects of nitrogen and phosphorus (Maberly et al., 2020; Henryson et al., 2018).

Land occupation – grassland and arable land

For the land aspects of the biodiversity index, instead of applying the land factors provided via LC-Impact (based on a 2015 analysis), we substitute these for CFs calculated by Chaudhary & Brooks (2018). Following consultation with the authors of these analyses, the 2018 factors were determined to be a more reliable data source, which can be directly substituted into the LC-Impact methodology and allow differences between three levels of land use intensity (minimal, light, intense) to be accounted for.9

CFs for 'light use' pasture were applied to areas of permanent grassland, whereas CFs for 'minimal use' cropland and pasture were applied to areas of low-impact grassland/arable land.

8 This takes into account a generic soil leaching fraction for the Netherlands and nutrient transport via river systems – see Verones et al. (2020) for more information.

9 Definitions for each of the land use categories can be found in the supplementary material of Chaudhary & Brooks (2018).

However, since areas of low-impact arable/grassland consisted of a broad range of measures, with varying benefits for biodiversity (e.g., applied at certain times of the year, covering different spatial scales etc), we also account for this by applying the BBM weightings (see appendix 4).

It is worth noting that for land occupation, some double counting of impacts may also occur due to the method employed in LC-Impact. For example, characterisation factors that quantify the biodiversity impact of 'land occupation' (e.g., associated with cropland or pasture occupation) are calculated based on the GLOBIO database, comparing species assemblages between disturbed and undisturbed land. Some of the impacts associated with land occupation will therefore be driven by pressures like fertiliser/manure, which in this framework are also quantified as separate KPIs. However, continued occupation of land is likely to cause important ongoing negative impacts not accounted for in other KPIs (e.g., from landscape fragmentation).

<u>Land transformation & restoration – herb-rich grassland and Nature & Landscape areas</u>

This section explores our approach to calculating negative (transformation) and positive (restoration) land use change (LUC) on dairy farms in the Netherlands.

As described in section 1.3.2. above, we only used the change per year to calculate impacts from transformation/restoration. Existing areas of herb-rich grassland or Nature & Landscape were given a 'zero' impact (i.e., an avoided loss of biodiversity).

Per farm decrease in area was assumed to represent a loss of habitat, applying the transformation factor for the Netherlands; conversely, per farm increase in area represented a gain of habitat, applied the transformation factors in reverse (multiplied by -1).

It is important to consider losses/gains separately, rather than simply using the overall net change summed across all farms: using an overall net value could mask the extent of losses that might have occurred, and potentially overestimate gains.

We acknowledge that using reversed CFs to estimate 'biodiversity gains' is not a typical use of these CFs – as if treated as anything other than representative would essentially mean that activities were reversing species extinction risk. This approach was taken only after consultation with some authors of LC-Impact, to confirm that the results could be considered meaningful for analysis on this scale. It was necessary to take such an approach since, as far as we are aware, there are no comparable methods that model biodiversity gains from such a broad range of activities (this is identified as an important area for further research in this approach).

Obviously, the results of the analysis are also reliant on the accuracy and completeness of the source data. There were many gaps/unknowns on farm-level increases/decreases in herb-rich grassland and Nature and Landscape features, and data were only available for RFC farms. Values are therefore indicative: accurate calculation of land restoration and transformation will depend on more comprehensive and consistent ongoing monitoring of farmland habitat areas. Also, new areas may not necessarily be newly created, just newly managed (or, indeed, no longer managed).

As is the case with low impact arable/grassland, herb-rich grassland and different types of Nature & Landscape management will have varying effects on biodiversity, which are reflected in the BBM weightings (see https://biodiversiteitsmonitor.nl/certificatie.html, also listed in appendix 4). In order for these weightings to function correctly with the biodiversity index, the values have been adjusted so that they do not overestimate biodiversity gains from these activities. To summarise – since the maximum possible proportional change in habitat restoration is 1 (i.e., 100% habitat recovery), the weightings were adjusted such that the maximum possible weighting was also equal to 1. This meant that the packages with the highest biodiversity weighting – in this case Landscape Management packages (weighting = 5 on the original scale) – were used as the reference (adjusted weighting = 1). Weightings for other packages were then adjusted in direct proportion to Landscape Management packages (all weightings and adjusted weightings are provided in appendix 4). This is also to be consistent with the approach for accounting for temporal risk (see section 3.2. below).

BBM weightings are again considered the best available approach in this case, although these are not without their limitations; for instance they are calculated in part on the degree of income lost from management activities – which in some cases will work – e.g., where greater effort/income lost means reduced human appropriated net primary productivity, in other cases it would be less accurate (e.g., an expensive action that has relatively limited benefits for biodiversity). As these weightings are further developed, their accuracy in this index will also improve.

Greenhouse gas emissions associated with land transformation/restoration

Areas undergoing land transformation/LUC or restoration would also be associated with a change in greenhouse gas emissions (emitted either through LUC, or sequestered through habitat restoration, respectively).

Excluding GHG emissions from LUC linked to feed (which would already be included within the total GHG values provided as part of the fully anonymized KLW dataset), losses of habitat area were associated with an increase in GHG emissions, calculated using the values provided in Annex C of the PAS2050:2011 guidance (as per section 1.4.4. above).

For any gains in habitat area (e.g., increases in herb-rich grassland or Nature and Landscape areas), GHG sequestration was calculated using the values provided by Table 3 of Schmidinger & Stehfest (2012), who calculate the average potential carbon sink per continental region and food product (based on the IMAGE model) and provide factors in kg $CO_2/m^2/year$.

Emissions and sequestration of GHGs were then combined with the relevant characterisation factor in LC-Impact to estimate this indirect effect on biodiversity.

Environmental impacts from feed

Environmental pressures from feed broken down by country were obtained from the FeedPrint database for each of the composite feeds (see section 1.4.3. above).

These were then multiplied by the relevant country-specific CFs from LC-Impact for land occupation, land transformation, freshwater eutrophication, marine eutrophication, and water consumption.

Combining farm-level values to calculate a sector-level biodiversity index per year

Accounting for additional positive impacts at the sector level

Released agricultural land – passive restoration

Agricultural land can be released from agricultural use through a reduction in the total sector area within the Netherlands, or a reduction in the total area of land occupation linked to feed. This released land could, in the absence of action by other sectors, passively restore to natural habitat over time (e.g., see Meli et al., 2017).

Responses from the first stakeholder consultation indicated that released land should be considered as an avoided loss of biodiversity, rather than a biodiversity gain from passive restoration, due to the uncertainty around what would happen to the released land in subsequent years as well as potential displacement effects if a reduction in land use also resulted in a reduction in milk production. This is consistent with literature on treatment of counterfactual scenarios in net outcomes policies for biodiversity (e.g. Maron et al., 2018).

However, the project team have also agreed to make the assumption that land will inevitably undergo passive restoration in the absence of further anthropogenic influence, and if that was not accounted for to some degree within the biodiversity index, it would mean potentially penalising the Dutch dairy sector for actions undertaken by other sectors. Therefore, passive restoration of released land is included in the biodiversity index model, but only in the scenario where the total sector milk production remains the same or increases, alongside the reduction in land use.

Further – given the lack of directed active management for restoration outcomes – we apply a higher temporal risk multiplier to land assumed to undergo passive restoration (described further in section 3.2. below).

Biodiversity offsets

Biodiversity offsets are measurable conservation outcomes (e.g., restoring species and habitats) that are intended to compensate for significant residual negative impacts on biodiversity (see e.g. BBOP).

While no offsets were accounted for in the 2020 analysis, as these are not currently a component of the sectoral strategy, the index includes an option to calculate biodiversity gains linked to biodiversity restoration offsets by inputting the country and area of habitat restored. As in section 2.3.4. above, areas of restored habitat are multiplied by the relevant country-specific CF for land transformation (multiplied by -1).

Applying multipliers to account for temporal risk for biodiversity gains

Time lags are important in conservation (Maron *et al.* 2012). Impacts such as land use change may result in immediate biodiversity losses, but ecological gains from compensatory restoration activities may take time to accrue. Time lags are undesirable – particularly if species/habitats are threatened, or when the existence of biodiversity provides some ongoing ecosystem service that is diminished during the time lag.

A common approach is to apply a multiplier to areas being restored, in order to account for uncertainties around immediate/certain losses being compensated by delayed/uncertain future gains. The multiplier can be considered a ratio between damaged and necessary compensated amounts of biodiversity. It would be applied here as a factor to biodiversity gains, to calculate gains that account for these temporal uncertainties.

For example, Laitila *et al.* (2014) propose a method to calculate minimum temporal multipliers associated with biodiversity restoration offsets, which we apply to the biodiversity gains shown in Figure 4 in the main text. The method is based on a set of parameters, which can be entered into an Excel tool developed by Laitila *et al.* (2014) to determine the multiplier/ratio value. The parameters include:

Time taken to restore different habitats (in number of years);

The change in habitat condition (e.g., the proportional increase in biodiversity that is achieved by the restoration activity);

A discount rate, which mathematically determines the currently perceived value of biodiversity gains that are not achieved until future years ('net present value' – see Laitila *et al.* (2014) for further detail); and,

Permanence of the positive and negative impacts (i.e., how long will biodiversity restoration activities be maintained?)

The values applied for each parameter for different types of relevant restoration activities are described in Table 4. The 'permanence of impacts' parameter is assumed to be 30 years for all habitats, based on this being approximately equivalent to one generation (and therefore a feasible period of time for maintaining activities). Time lag values for habitat restoration are based on Meli et al. (2017) and on habitat management guidance provided by BoerenNatuur. Discount rates are based on Overton et al. (2013).

To calculate the change/improvement in habitat condition associated with the wide range of Nature & Landscape measures (including areas of herb-rich grassland), we make use of the existing biodiversity weightings that have been developed for the BBM and ANLb packages. In order for these weightings to function correctly with the biodiversity index, the values have been adjusted so that they do not overestimate biodiversity gains from these activities. In short – since the maximum possible proportional change in habitat restoration is 1 (i.e., 100% habitat recovery), the weightings were adjusted such that the maximum possible weighting was also equal to 1. This meant that the packages with the highest biodiversity weighting – in this case Landscape Management packages (weighting = 5) – were used as the reference (adjusted weighting = 1). Weightings for other packages were then adjusted in proportion to Landscape Management packages (Table A2).

***Table A2**: Parameters chosen for each of the three broad types of biodiversity restoration, and the final temporal multipliers calculated based on the tool/method provided by Laitila et al. (2014)*

Type of biodiversity restoration activity	*Values chosen for parameters*			**Final multiplier based on Laitila *et al.* (2014)**
	1. Assumed time taken for habitat restoration (#years)	**2. Proportional change in habitat condition**	**3. Discount rate**	
On farm biodiversity gains from Nature & Landscape management and herb-rich grassland (listed in Table 2)	10	Calculated based on the Nature & Landscape and herb-rich grassland weightings (see Appendix 3)	4%	1.48
Biodiversity restoration offsets	18	1 (assumes full habitat recovery)	4%	2.02
Passive restoration of released agricultural land	35	1 (assumes full habitat recovery)	10%	28.10

Factoring up biodiversity values to sector-level

After converting all KPIs to estimated biodiversity impacts using the range of approaches described above, biodiversity impact values (in PDF.year) were summed across all farms within the cleaned data sample. These total values were also extrapolated to estimate biodiversity impacts for the sector as a whole, based on known data coverage (number of farms) per KPI and total number of farms (14,542; CBS, 2022). Total values were then adjusted to match the total area recorded for the sector in 2020 (870,880 ha; CBS, 2022).

When extrapolating, wherever possible, the total extrapolated values were compared against known CBS national statistics (e.g., on milk production) as a form of verification and sense check. This confirmed that none of the extrapolated values we derived were wildly different to those that figures already known, providing a degree of confidence in other extrapolated estimates (such as overall biodiversity impact).

We note also that there is a higher level of uncertainty around some KPIs – particularly herb-rich grassland and Nature and Landscape – since these had a lower data coverage (as discussed in section 1.3.2. above). We do not attempt to quantify those uncertainties here.

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<u>Appendix 2</u>: key calculations (index spreadsheet)

[The index spreadsheet accompanies this report as a separate file, which accompanies the full project report (not this document)].

<u>Appendix 3</u>: weightings for habitat components

Original and adjusted weightings for different Nature & Landscape and herb-rich grassland measures. Original N&L weightings are based on those developed for the BBM and ANLb packages. Weightings are adjusted using 'landscape management' measures as the reference point (all values are divided by 5). Adjusted weightings are used to estimate the change in biodiversity condition when calculating multipliers based on Laitila et al (2014) (see section ***). Measures with an original N&L weighting of <1 were categorised as 'other low-impact cropland/grassland' (displayed in Figure ***), and therefore as an avoided loss of biodiversity (rather than a biodiversity restoration measure).

Omschrijving (Dutch)	**Description (English, from Google Translate)**	**Categorie (Dutch)**	**Category (English)**	**Original N&L Weighting**	**Adjusted weighting**
Duurzaam slootbeheer: baggerspuiten	*Durable ditch management: dredging*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	2.50	0.50
Natuurvriendelijke oever	*Nature-friendly shore*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	5.00	1.00
Rietzoom en klein rietperceel	*cane hem and small reed plot*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	5.00	1.00
Duurzaam slootbeheer: ecologisch slootschonen	*Durable ditch management: ecological ditch cleaning*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	5.00	1.00
Bufferstroken	*buffer strips*	*Randenbeheer*	*Edge management*	1.00	0.20
Insectrijke en/of kruidenrijke graslandrand	*insect-rich and /or herbal grassland edge*	*Randenbeheer*	*Edge management*	1.00	0.20
Kruidenrijke akker	*herbal field*	*Akkervogelbeheer*	*Field bird management*	1.58	0.32
Wintervoedselakker	*winter food field*	*Akkervogelbeheer*	*Field bird management*	1.82	0.36
Vogelakker	*bird field*	*Akkervogelbeheer*	*Field bird management*	1.60	0.32
Biodivers inheems bouwland	*Biodiversity native arable land*	*Akkervogelbeheer*	*Field bird management*	1.86	0.37
Kruidenrijk graslandrand (extensief)	*Herb-rich grassland margin (extensive)*	*Graslandbeheer*	*Grassland management*	1.00	0.20
Bosje	*grove*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Poel en klein historisch water	*pool and small historic water*	*Landschapsbeheer*	*Landscape management*	5.00	1.00

Hakhoutbeheer	*coppice management*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Beheer van bomenrijen	*Tree row management*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Solitaire boom op landbouwgrond	*Solitary tree on farmland*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Houtwallen en houtsingels	*wooded banks and wood girths*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Half -en hoogstamboomgaard	*half - and standard orchard*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Knip- of scheerheg	*Cut - or shaving hedge*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Knotbomen	*knot trees (pollarding)*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Struweelhaag	*thicket hedge*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Hakhoutbosje	*coppice*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Struweelrand	*thicket rim*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Elzensingel	*Elzensingel*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Landschapskamers	*landscape rooms*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Snelgroeiend naaldbos	*Fast growing coniferous forest*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Griendje	*pilot*	*Landschapsbeheer*	*Landscape management*	5.00	1.00
Zandwallen	*sandbanks*	*Landschapsbeheer*	*Landscape management*	2.50	0.50
Stuwbeheer	*Weir management*	*Peilbeheer*	*Level management*	2.50	0.50
Water bergen op grasland	*Water mountains on grassland*	*Peilbeheer*	*Level management*	1.00	0.20
Beheer infiltratiegreppel	*Management infiltration ditch*	*Peilbeheer*	*Level management*	2.50	0.50
Kruidenrijk grasland	*Herb-rich grassland*	*Weidevogelbeheer*	*Meadow bird management*	1.00	0.20
Structuurrijk grasland	rich in structure grassland	Weidevogelbeheer	Meadow bird management	1.00	0.20
Kruidenrijk graslandrand	Herb-rich grassland edge	Weidevogelbeheer	Meadow bird management	1.00	0.20
Botanisch grasland	Botanical grassland	Weidevogelbeheer	Meadow bird management	1.00	0.20

Botanisch graslandrand	Botanical grassland edge	Weidevogelbeheer	Meadow bird management	1.00	0.20
(Greppel-) plas-dras	*(Ditch-) plas-dras*	*Weidevogelbeheer*	*Meadow bird management*	1.29	0.26
Nest- en foerageergelegenheid zwarte stern	*Nest and foraging facility black tern*	*Weidevogelbeheer*	*Meadow bird management*	3.21	0.64
Kruidenrijke akkerrand	*herbal field edge*	*Erf*	*Property*	1.80	0.36
Leibomen bij historische boerderijen	*espaliers at historic farms*	*Erf*	*Property*	2.50	0.50
Bouwland met doortrekkende en overwinterende akkervogels	*arable land with passing and wintering field birds*	*Soortenbeheer*	*Species management*	1.82	0.36
Foerageerrand bever	*Beaver foraging edge*	*Soortenbeheer*	*Species management*	2.02	0.40
Chemie en kunstmestvrij land	*Chemical and fertilizer free land*	*Botanisch beheer*	*Botanical management*	0.39	*Excluded from calculations to avoid double counting*
Bodemverbetering grasland met ruige mest	*Soil improvement grassland with rough manure*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	0.09	*Excluded from calculations to avoid double counting*
Bodemverbetering bouwland met ruige mest	*Soil improvement arable land with rough manure*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	0.09	*Excluded from calculations to avoid double counting*
Bodemverbetering met ruige mest	*Soil improvement with rough manure*	*Ecologisch water- en bodembeheer*	*Ecological water and soil management*	0.09	*Excluded from calculations to avoid double counting*
Stoppelland	*stubble areas*	*Akkervogelbeheer*	*Field bird management*	0.24	*Included in calculations as 'other low impact cropland/grassland'*
Ondiepe drainage	*Shallow drainage*	*Peilbeheer*	*Level management*	0.16	*Included in calculations as 'other low impact cropland/grassland'*
Peilgestuurde drainage	*Level controlled drainage*	*Peilbeheer*	*Level management*	0.16	*Included in calculations as*

					'other low impact cropland/grassland'
Beheer peilscheidingen	*Management sound separations*	*Peilbeheer*	*Level management*	0.16	*Included in calculations as 'other low impact cropland/grassland'*
Grasland met rustperiode	*Grassland with rest period*	*Weidevogelbeheer*	*Meadow bird management*	0.46	*Included in calculations as 'other low impact cropland/grassland'*
Legselbeheer	*clutch management*	*Weidevogelbeheer*	*Meadow bird management*	0.03	*Included in calculations as 'other low impact cropland/grassland'*
Hoogwaterpeil	*high water level*	*Weidevogelbeheer*	*Meadow bird management*	0.04	*Excluded from calculations to avoid double counting*
Extensief beweid grasland	*extensive grazed grassland*	*Weidevogelbeheer*	*Meadow bird management*	0.32	*Included in calculations as 'other low impact cropland/grassland'*
Nestgelegenheid en beplanting erfvogels	*Nesting site and planting farm birds*	*Erf*	*Property*	0.15	*Included in calculations as 'other low impact cropland/grassland'*
Bouwland met broedende akkervogels	*Arable land with nesting field birds*	*Soortenbeheer*	*Species management*	0.03	*Included in calculations as 'other low impact cropland/grassland'*
Gedooggebied met overwinterende ganzen	*Tolerance area with wintering geese*	*Soortenbeheer*	*Species management*	0.04	*Included in calculations as 'other low impact cropland/grassland'*

Gedooggebied dassen	*Tolerance area ties*	*Soortenbeheer*	*Species management*	0.04	*Included in calculations as 'other low impact cropland/grassland'*
Grasland met voorweiden	*Grassland with front pastures*	*Soortenbeheer*	*Species management*	0.17	*Included in calculations as 'other low impact cropland/grassland'*
Gedooggebied met overzomerende ganzen	*zone with oversummer geese*	*Soortenbeheer*	*Species management*	0.04	*Included in calculations as 'other low impact cropland/grassland'*
Kuikenvelden	*chick fields*	*Soortenbeheer*	*Species management*	0.45	*Included in calculations as 'other low impact cropland/grassland'*

Appendix 4: stakeholder consultation sessions

Throughout the development of this project, two stakeholder consultation meetings were organized. The objective of these consultations was to inform relevant stakeholders about the project, receive feedback on the proposed methodologies, and discuss topics which needed concrete decisions.

The stakeholder consultation meetings took place virtually on December 6th 2021, and May 25th 2022 (running for 2 hours in both cases). Where identified stakeholders were unable to attend the meeting, they were invited to provide feedback by email. Both consultations were hosted by the project team, Wild Business and Metabolic. Representatives from the following organizations participated in the stakeholder consultation:

- Duurzame Zuivelketen (DZK)
- IMAGEN
- LTO
- Staatsbosbeheer
- Stichting Biodiversiteitsmonitor
- Wageningen University & Research (WUR)
- WWF France
- WWF Netherlands (WNF)

The first consultation focused primarily upon the biodiversity index (stage 1), and the second consultation upon the safeguards (stage 2) and baseline (stage 3). Separate documents outlining the current status of work on stages 1 – 3 were provided in advance of the meeting to attendees. During both meetings, the project team (Wild Business and Metabolic) commenced by presenting a project update to inform stakeholders about the suggested approach and methodologies. Next, there was an open space for stakeholders to ask questions, provide feedback, and make suggestions on how to improve the approach and methods. At last, the project team hosted a focussed discussion about critical points where stakeholder input was essential to move forward with the project.

All stakeholder inputs were recorded and evaluated, and incorporated into refinements to the methodology where relevant and appropriate. The project team notes that not all feedback resulted in changes to the final outputs, as in some cases there was contradictory feedback that had to be resolved (which was achieved through discussions between the project team and DZK). Trade-offs have been made in order to achieve a comprehensive end product which is relevant, and complies with the needs of DZK at this stage. We recommend that DZK keep dialogue open with this group of stakeholders, in order to continue developing strategies for moving towards a nature-positive future in an effective and ambitious manner.