



DETERMINING ECOLOGICAL THRESHOLDS FOR DAIRY

A pilot for setting science-based targets for nature

EXECUTIVE SUMMARY



WWF is working with these partners to protect global environments.



COLOPHON

This project was commissioned by Bel Group and WWF France.

STEERING COMMITTEE:

Brian Shaw (Metabolic)
 Louisa Durkin (Metabolic)
 Ciprian Ionescu (WWF France)
 Emilie Ortolina (WWF France)
 Juliette Pugliesi (WWF France)
 Floor Ambrosius (WWF Netherlands)
 Simon Bonnet (Bel Group)
 Roelof Wijma (Bel Group)
 Elsa Dellièrre (Bel Group)
 Elodie Parre (Bel Group)

AUTHORS & REVIEWERS:

Louisa Durkin (Metabolic)
 Nadette Embregts (Metabolic)
 Brian Shaw (Metabolic)
 Alfons Beldman (Wageningen University)
 Juliette Pugliesi (WWF France)
 Alizée Masson (WWF France)

RESEARCH & DEVELOPMENT:

Louisa Durkin (Metabolic)
 Brian Shaw (Metabolic)
 Pieter Willem Blokland (Wageningen University and Research)
 Alfons Beldman (Wageningen University and Research)
 Joseph Bull (Wild Business, University of Kent)
 Julie Phillips (Metabolic)
 Katerina Bakousi (Metabolic)
 Nadette Embregts (Metabolic)
 Kristiina Marquardt (Metabolic)
 Vittorio Coletti (Metabolic)

ADDITIONAL CONTRIBUTORS:

Anne van Doorn (Wageningen University)
 Pieter Willem Blokland (Wageningen University and Research)
 Daniel Metzke (Potsdam Institute for Climate Impact Research (PIK))
 Jan Willem Erisman (Leiden University)

DESIGN:

Cassie Björck (Metabolic)
 Twin de Rooy (Metabolic)

SPECIAL THANKS TO:

The SBTN community including:
 Malcom Starkey (The Biodiversity Consultancy)
 Oscar Sabag (SBTN)
 Samantha McCraine (SBTN)
 Chris Weber (formerly SBTN)
 Jess McGlyn (SBTN)
 Alain Vidal (SBTN)
 Erin Billman (SBTN)
 Craig Beatty (WWF US)
 Sarah Baussmith (SBTN)
 Emma Mardsen (SBTN)
 Pamela Collins (Conservation International)
 Sam Putt del Pino (WWF International)
 Jill Schlechtweg (WWF International)
 Enrique Prunes (WWF US)
 Rebekah Church (WWF Germany)



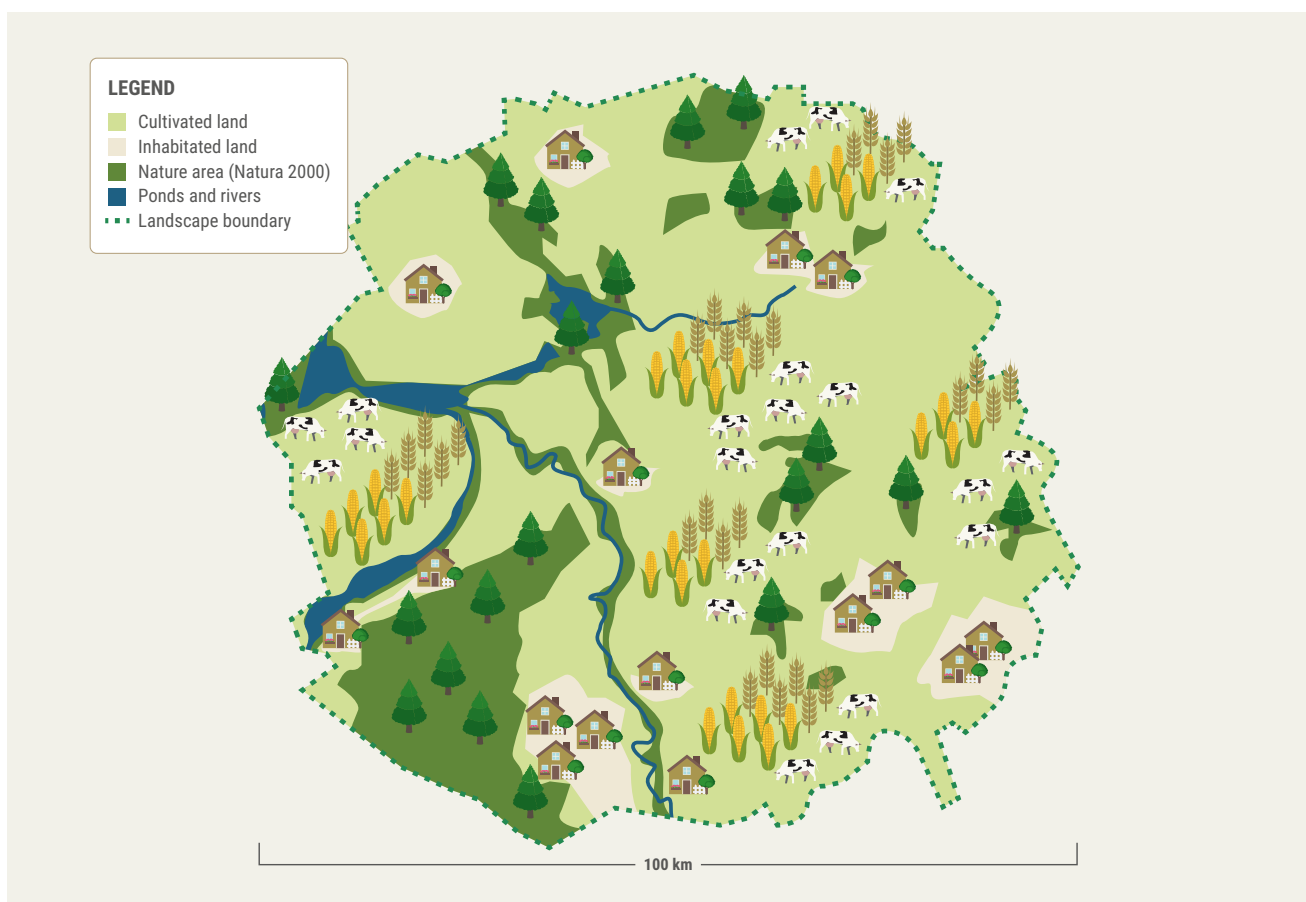
This publication benefited of the support of the MAVA Foundation, through the program Economics for Nature

EXECUTIVE SUMMARY

It has become increasingly clear that ecosystems and nature are in decline. Pressure on nature threatens its ability to provide the ecosystem services that we as a society rely on to prosper. The Science Based Targets Network (SBTN) was developed in response to nature's decline. The SBTN is a movement of international environmental nonprofit organizations, international agencies, and mission-driven entities working to turn science into targets for companies to tackle nature loss.

In this project, a subset of SBTN partners developed an approach with Bel Group for setting Science Based Targets (SBTs) for nature in a single dairy farming landscape. We developed a proof of concept for determining ecological thresholds that can be used as the basis for setting science-based targets for nature within a Dutch dairy landscape. We worked with the Initial Guidance of the SBTN, and used the Biodiversity Monitor for the Dairy Farming Sector (Biodiversity Monitor) (an instrument developed through a collaboration of FrieslandCampina, Rabobank and the Dutch chapter of the WWF) as the basis for target and Key Performance Indicator (KPI) development.

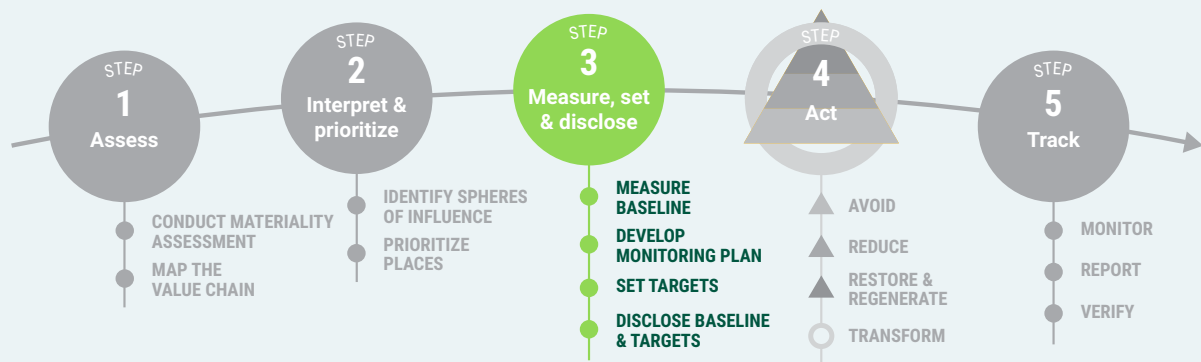
Our global food system, and in particular animal agriculture, is one of the leading causes of biodiversity loss globally (Benton et al., 2021). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) champions transformative change to protect biodiversity (IPBES, 2019). The SBTN framework builds upon the drivers of biodiversity loss as identified by IPBES. For agribusinesses looking to contribute to a nature-positive future, setting SBTs for nature is a key exercise. In this report, Bel Group fulfills its commitments: "(1) Defining local ecological thresholds by participating in research projects and (2) Working to measure their overall impact on biodiversity, in collaboration with experts in a prospective approach, across their entire value chain, to ensure that their activities are sustainable." Bel fulfills this by developing a proof of concept. The next step for Bel Group is to complete a value chain assessment, identify the material impacts on nature across their business, and implement them within landscapes as outlined in the methodology in this proof of concept.



In the first step, we specified which dairy basin to examine, determined the landscape boundary, and the most material impacts on nature within the landscape. Next, we contextualized these material impacts and addressed how to allocate the responsibility of these impacts on nature to dairy farming. In the next step, we set the ambition level for nature, i.e. determining what is really needed to enable ecosystem resilience/avoid collapse, according to science-based and societal-based references in the context of the selected landscape. We then assessed the gap between the current baseline and

that ambition. Next, we mapped mitigation activities to understand what options exist to close the gap. Finally, we contextualized the activities with business cases, to show how farmers can be supported in the transition toward nature positive farming.

The project objective was to develop a proof of concept for the approach, with the intention of applying it to other European dairy basins in the future. Throughout the report, we have detailed where the methodology should delve deeper when implemented on a landscape or farm level.



Phase 1: Define Landscape and Scope

In the first phase of the project, we determined the landscape boundary, and completed a local materiality assessment for the landscape.

Phase 2: Define Material KPIs

Next, we refined the materiality assessment further based on the local landscape and determined the relevant KPIs to move forward with. We then defined the technique used to determine allocation of impact.

Phase 3: Measure and Set Targets

In the third phase, we set the ecological threshold for each of the KPIs using the following decision-tree:

1. Is there a set approach to downscale a planetary boundary?
2. Is there a science based societal goal available to inform the target?
3. Is there an established societal goal with less clear scientific foundations?
4. Is the most bottom-up and ambitious societal goal being used?

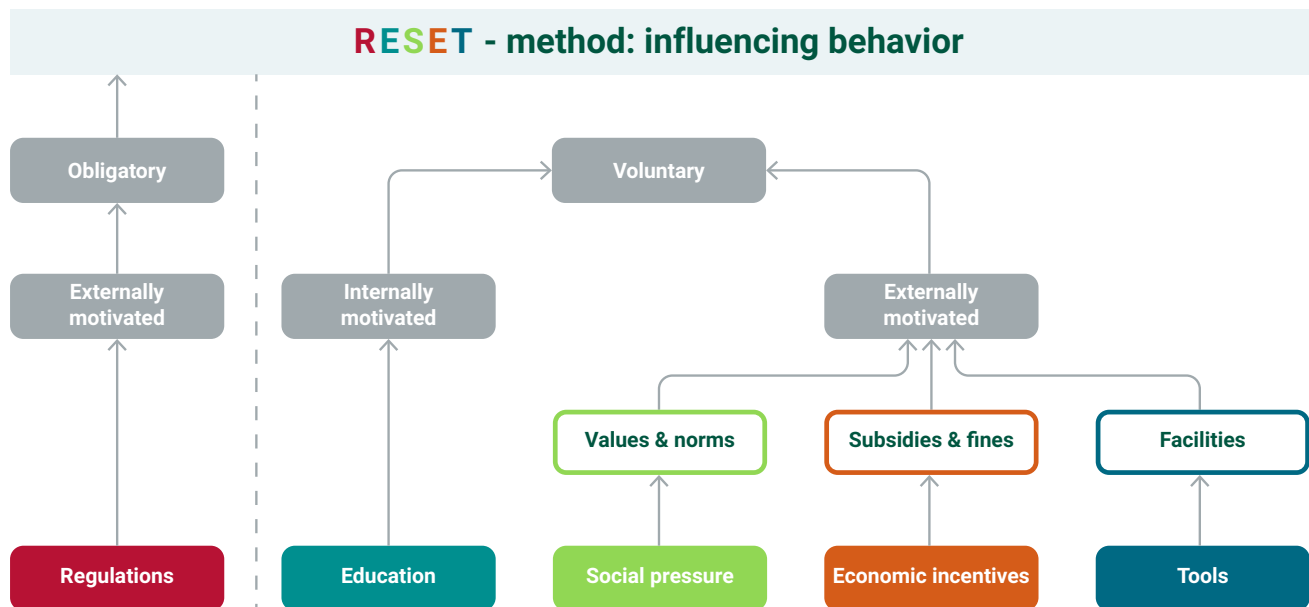
We then applied the ecological thresholds as targets and performed a gap analysis using empirical baseline data on the farm level. We performed the analysis distinguishing between two types of farms within the landscape: intensive (higher than 17000 kg Fat and Protein Corrected Milk (FPCM) per hectare) and extensive (lower or equal than 17000 kg FPCM per hectare).

Phase 4: Determine Action Targets

During the fourth phase of the guidance, we determined the actions available to farmers and other stakeholders to reach the targets.

Phase 5: Business Case

Finally, we assessed the appropriate paths forward contextualizing the action targets with clear business objectives. Though the business case is important, it is clear that a whole-of-society approach is truly necessary for transformation change and this is outlined in the RESET model, as represented in the figure below.



RESET model to influence farmers' behavior (adapted from Jansen et al., 2016)






RESULTS

Within the report, we were able to identify the KPIs that are measurable and meaningful. We calculated the gap between the 2020 baseline and the identified ecological thresholds (Tables 1 & 2). This approach was developed in a specific dairy landscape, however, the methodology is replicable and scalable to others. The farm data was split into two typologies: extensive (lower or equal than 17000 kg Fat and Protein Corrected Milk (FPCM) per hectare) and intensive (higher than 17000 kg FPCM per hectare). In this dairy landscape, there were gaps (in at least one of the typologies) for: ammonia emissions,

chemical (pesticide, herbicide, fungicide) inputs, nitrogen soil surplus, percentage of own (or local) protein production, and percentage of natural habitat. For both farm typologies they have reached the goal of 60% permanent grassland. We examined pathways to improve the business case for farmers that want to close the gap on any farm level targets not being met (Table 3). Additionally, by using the RESET model, we have identified how a whole-of-society approach can support and incentivise farmers in making the transformation toward farming that contributes to improving biodiversity/nature.



Table 1: Gap between the thresholds/targets and the current state. We have used the above empirical KPIs as indicators used to determine the current state of nature on the farms within the target boundary as well as the gap between the target or threshold and the current state. There are two types of farms that are examined: intensive operations (higher number of cows per HA) and extensive operations (fewer cows per HA).

| KPI | THRESHOLD | | TARGET | | EXTENSIVE | | INTENSIVE | |
|---|---------------------------------|------------------------------|---------------------------------|--|----------------------------------|----------------------------|----------------------------|----------------------------|
| | Value | Source | Value | Source | Current Data | Performance Gap | Current Data | Performance Gap |
|  Chemical inputs (pesticides, herbicides, fungicides) | 0.03-0.1 µg/L active matter/ha* | (Drinkwaterbesluit, 2018) | | | 0.64 µg/L active matter/ha | 0.54 µg/L active matter/ha | 0.53 µg/L active matter/ha | 0.43 µg/L active matter/ha |
|  Nitrogen soil surplus | 20-30 kg N/ha | (Bobbink et al., 2011) | 3.57 kg N/ha reduction per year | Koekoek, 2021 | 122 kg N/ha | 92 kg N/ha | 146 kg N/ha | 116 kg N/ha |
|  Ammonia emissions | 47 kg NH ₃ /ha | Regulation (EU) No 1307/2013 | 27 kg NH ₃ /ha | Regulation (EU) No 1307/2013 | 52 kg NH ₃ /ha | 5 kg NH ₃ /ha | 68 kg NH ₃ /ha | 21 kg NH ₃ /ha |
|  % Natural habitat | 10% | European Commission, 2020 | | | 1.29% | 9% natural habitat | 0.80% | 9% natural habitat |
| % Permanent grassland icon" data-bbox="98 499 148 536"/> % Permanent grassland | | | 60% permanent grassland | Regulation (EU) No 1307/2013 van Doorn et al. 2019 | 78% permanent grassland | n/a (target met) | 65% permanent grassland | n/a (target met) |
|  Landscape diversity (green/blue) | | | | | 1.21 types of landscape elements | | 0.84 | |
| % Own protein icon" data-bbox="98 633 148 670"/> % Own (or local) protein production | | | 65-100% own protein | Commissie Grondgebondenheid, (2018) | 65% own protein | n/a (target met) | 52% own protein | 13% own protein |

● Ecological threshold well surpassed ● KPIs within ecological threshold

* Specific chemical inputs - Pesticides (individual): 0.1 µg/L (microgram / L) - per matter; Aldrin, dieldrin, heptachlor and heptachlorepoxyde: 0.03 µg/L; Pesticides (sum): 0.5 µg/L (microgram / L) (sum of individual pesticides with a concentration that is higher than the detection limit)

Landscape level KPIs

Table 2: Ambient monitoring index values for landscape level KPI data over time



| KPI | MEASUREMENT TECHNIQUE | SOURCE | CURRENT | TARGET |
|---|------------------------------|---------------------------|-------------------|--|
|  Landscape fragmentation | CAI_AM index | (McGarigal & Marks, 1994) | 53.8199 | Equal to or greater than the current value |
|  Species composition change | Mean Species Abundance (MSA) | (Alkemade et al., 2009) | 0.3307 (out of 1) | Equal to or greater than the current value |

Table 3: The Action Targets and Farm Level KPIs associated through scientific evidence are mapped for the avoid/reduce and restore/regenerate categories. Action targets follow the ARRRT framework prioritizing first actions that avoid and reduce impacts, then actions that restore and regenerate, and all the while prioritizing transformative actions. Currently there is not sufficient evidence to report on the outcomes for transformative targets for them to be included here. (* Integrated pest management (IPM))

| KPI | | AVOID/REDUCE | | | | | RESTORE/REGENERATE | | | |
|---|-------------------------------------|---|---|---|---|--|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | |  |  |  |  |  |  |  |  |  |
| | | Soil management | IMP*/no spray | Organic inputs | Manure management | Flowering grass | Natural land | Woody biomass | Riparian areas | High impact grazing |
|  | Chemical inputs | | ✓ | | | | ✓ | | ✓ | |
|  | Nitrogen soil surplus | | | ✓ | | | ✓ | ✓ | ✓ | ✓ |
|  | Ammonia emissions | | | ✓ | ✓ | | | | | ✓ |
|  | % Natural Habitat | | | | | ✓ | ✓ | | ✓ | |
|  | % Permanent Grassland | | | | | ✓ | ✓ | | | ✓ |
|  | Landscape diversity (green/blue) | | | | | | ✓ | | ✓ | |
|  | Landscape fragmentation | | | | | ✓ | ✓ | | ✓ | ✓ |
|  | Species composition change | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ |
|  | % Own (or local) protein production | | | | | ✓ | ✓ | ✓ | | ✓ |

Sources: ¹ (Zabaloy et al., 2020) (Bowles et al., 2016) (Grab et al., 2018) (Ravetto et al., 2017) (Pulungan et al., 2019) ² (Albrecht et al., 2020) (Grab et al., 2018) (Ravetto et al., 2017) ^{3,4} (Zhang et al., 2019) (Byrne et al., 2020) (Groenestein et al., 2011) (AHDB, n.d.) (Journeaux et al., 2016) (Dijkstra, n.d.) (Howarth et al., 2016) ⁵ (Luoto et al., 2003) (Ravetto et al., 2017) (Goosey et al., 2019) (Wrage et al 2011) ⁶ (Grab et al., 2018) (Pulungan et al., 2019) ⁷ (Pumariño et al., 2015) (Rigueiro-Rodríguez et al., 2010) (Luoto et al., 2003) ⁸ (Wilcock et al., 2009) (Luoto et al., 2003) ⁹ (Ravetto et al., 2017) (Goosey et al., 2019) (Pulungan et al., 2019)

CONCLUSIONS

As more companies commit to SBTs for nature, it's critical that frameworks and precedents are in place which can guide them in addressing upstream and downstream impacts. In this work, we have shown that it is possible to assess upstream impacts by setting targets and thresholds within a landscape that will steer the system towards recovering and thriving nature. We have shown how approaches such as the Biodiversity Monitor provide a solid foundation for on-farm measurements, and how these can be linked to broader landscape outcomes. For these theoretical frameworks to become reality it will require on the ground work with stakeholders, data monitors, and the accountability and reward frameworks associated with the outcomes. Spheres of influence are particularly important, those within a local landscape have the ability to make transformative, lasting changes.

There is a limited but growing body of scientific literature defining regenerative response options, within which it is possible to qualify the connection between actions and outcomes. Further work on quantifying these connections are needed for widespread implementation. Additionally, it is clear there needs to be further work within the environmental community and SBTN to provide consistent guidance for ambient monitoring for nature and indicators going forward. As companies start to take action, we need to be sure that feedback is available for them to respond to.

We found that the basis for setting targets, according to scientifically derived planetary or regional boundaries, is not currently available for most issue areas. There

are expected outputs, such as those from the Earth Commission, that aim to provide these boundaries. In the absence of such, there are societal goals upon which to base targets. However, it is critical that both the goals chosen are sufficiently ambitious to deliver on what nature needs, and that as science evolves, organizations and other stakeholders adapt to more stringent targets.

As the field of accounting for nature is still in progress, it requires that companies continue to pilot and test approaches, and exchange knowledge with the broader community. The SBTN is a facilitator and continually adapts their guidance towards a solid set of best practices that will help to prevent nature loss.

A business case for farming within ecological thresholds will likely not be enough. Rather, there will need to be a whole-of-society approach where there are many incentives to bridge the gap for farmers. Therefore, farmer livelihoods are an essential consideration in the transition to dairy farming that reaches targets for biodiversity.

What comes next?

In order to see results, projects like this will need to be implemented and the nuance that is learned with implementation will need to be documented. For example, sector wide indices can be useful tools for implementation. Ideally, an index will look at the impact on the farm level for a combination of thresholds. Projects implementing the SBTN guidance are useful when broadcasted for others to utilize.



APPENDIX

REFERENCES

Albrecht, M., Kleijn, D., Williams, N. M., Tschumi, M., Blaauw, B. R., Bommarco, R., Campbell, A. J., Dainese, M., Drummond, F. A., Entling, M. H., Ganser, D., Arjen de Groot, G., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., ... Sutter, L. (2020). The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: a quantitative synthesis. *Ecology Letters*, 23(10), 1488–1498. <https://doi.org/10.1111/ele.13576>

Alkemade, R., van Oorschoot, M., Miles, L., Nellemann, C., Bakkenes, M., & ten Brink, B. (2009). GLOBIOS: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss. *Ecosystems*, 12(3), 374–390. <https://doi.org/10.1007/s10021-009-9229-5>

Agriculture and Horticulture Development Board. (n.d.). Ammonia emissions on dairy farms. Retrieved in August 2021, from <https://ahdb.org.uk/knowledge-library/ammonia-emissions-on-dairy-farms>.

Beldman, A., Polman, N., Kager, H., Doornewaard, G., Greijdanus, A., Prins, H., Dijkshoorn, M., & Koppenjan, J. (2019). Meerkosten biodiversiteitsmaatregelen voor melkvee- en akkerbouwbedrijven. <https://edepot.wur.nl/501680>

Benton, T. G., Bieg, C., Harwatt, H., Pudasaini, R., & Wellesley, L. (2021). (rep.). Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature. <https://www.chathamhouse.org/2021/02/food-system-impacts-biodiversity-loss>

Blumetto, O., Castagna, A., Cardozo, G., García, F., Tiscornia, G., Ruggia, A., Scarlato, S., Albicette, M. M., Aguerre, V., & Albin, A. (2019). Ecosystem Integrity Index, an innovative environmental evaluation tool for agricultural production systems. *Ecological Indicators*, 101, 725–733. <https://doi.org/10.1016/j.ecolind.2019.01.077>

Bobbink, R., Braun, S., Nordin, A., Power, S., Schütz, K., Strengbom, J., Weijters, M. & Tomassen, H. (2011). Review and revision of empirical critical loads and dose-response relationships: Proceedings of an expert workshop, Noordwijkerhoud, 23-25 June 2010. (Nr. 680359002). RIVM. <https://rivm.openrepository.com/bitstream/handle/10029/260510/680359002.pdf?sequence=3&isAllowed=y>

Bowles, T. M., Jackson, L. E., Loeher, M., & Cavagnaro, T. R. (2016). Ecological intensification and arbuscular mycorrhizas: a meta analysis of tillage and cover crop effects. *Journal of Applied Ecology*, 54(6), 1785–1793. <https://doi.org/10.1111/1365-2664.12815>

Buchhorn, M., Smets, B., Bertels, L., Roo, B. D., Lesiv, M., Tsendbazar, N.-E., Fritz, S. (2020). Copernicus Global Land Service: Land Cover 100m: collection 3: epoch 2019: Globe.

Byrne, M. P., Tobin, J. T., Forrestal, P. J., Danaher, M., Nkwonta, C. G., Richards, K., Cummins, E., Hogan, S. A., & O'Callaghan, T. F. (2020). Urease and Nitrification Inhibitors—As Mitigation Tools for Greenhouse Gas Emissions in Sustainable Dairy Systems: A Review. *Sustainability*, 12(15), 6018. <https://doi.org/10.3390/su12156018>

Commissie Grondgebondenheid. (2018). Grondgebondenheid als basis voor een toekomstbestendige melkveehouderij. Retrieved from NZO: <https://www.duurzamezuivelketen.nl/resources/uploads/2018/04/Grondgebonden-Melkveehouderij-2018.pdf>

Dijkstra, J. (n.d.). Changing the cow's diet reduces methane and nitrogen emissions. Wageningen University & Research. <https://www.wur.nl/en/article/Changing-the-cows-diet-reduces-methane-and-nitrogen-emissions.htm>

- Dinerstein, E., Joshi, A. R., Vynne, C., Lee, A. T. L., Pharand-Deschênes, F., França, M., Fernando, S., Birch, T., Burkart, K., Asner, G. P., & Olson, D.** (2020). A "Global Safety Net" to reverse biodiversity loss and stabilize Earth's climate. *Science Advances*, 6(36), eabb2824. <https://doi.org/10.1126/sciadv.abb2824>
- Dolman, M. A., Sonneveld, M. P. W., Mollenhorst, H., & de Boer, I. J. M.** (2014). Benchmarking the economic, environmental and societal performance of Dutch Dairy Farms aiming at internal recycling of nutrients. *Journal of Cleaner Production*, 73, 245–252. <https://doi.org/10.1016/j.jclepro.2014.02.043>
- Drinkwaterbesluit.** (2018, 1st of July) Retrieved from Overheid.nl: <https://wetten.overheid.nl/BWBR0030111/2018-07-01>
- Erismans, J., van Eekeren, N., de Wit, J., Koopmans, C., Cuijpers, W., Oerlemans, N., & J. Koks, B.** (2016). Agriculture and biodiversity: a better balance benefits both. *AIMS Agriculture and Food*, 1(2), 157–174. <https://doi.org/10.3934/agrfood.2016.2.157>
- European Commission.** (2000). The Environmental impact of dairy production in the EU: Practical Options for the Improvement of the Environmental Impact (DGXI). <https://ec.europa.eu/environment/agriculture/pdf/dairy.pdf>
- European Commission.** (n.d.a). Biodiversity strategy for 2030. Retrieved from European Commission: https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en#ecln-page-325
- European Commission.** (2019). The common agricultural policy at a glance. Retrieved from European Commission: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en#title
- European Commission.** (2020). EU Biodiversity Strategy for 2030: Bringing nature back into our lives. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0380>
- European Environment Agency.** (2020). Natura 2000 End 2019 - Shapefile. Retrieved from European Environment Agency: <https://www.eea.europa.eu/data-and-maps/data/natura-11/natura-2000-spatial-data/natura-2000-shapefile-1>
- Food and Agriculture Organization.** (2019). The State of the World's Biodiversity for Food and Agriculture. Food and Agriculture Organization <http://www.fao.org/3/CA3129EN/CA3129EN.pdf>
- Goosey, H. B., Smith, J. T., O'Neill, K. M., & Naugle, D. E.** (2019). Ground-Dwelling Arthropod Community Response to Livestock Grazing: Implications for Avian Conservation. *Environmental Entomology*, 48(4), 856–866. <https://doi.org/10.1093/ee/nvz074>
- Grab, H., Danforth, B., Poveda, K., & Loeb, G.** (2018). Landscape simplification reduces classical biological control and crop yield. *Ecological Applications*, 28(2), 348–355. <https://doi.org/10.1002/eap.1651>
- Groenestein, C. M., Smits, M. C. J., Huijsmans, J. F. M., & Oenema, O.** (2011). (rep.). Measures to reduce ammonia emissions from livestock manures; now, soon and later (pp. 1–48). <https://edepot.wur.nl/189371>
- Hillebrand, H., Donohue, I., Harpole, W. S., Hodapp, D., Kucera, M., Lewandowska, A. M., Merder, J., Montoya, J. M., & Freund, J. A.** (2020). Thresholds for ecological responses to global change do not emerge from empirical data. *Nature Ecology & Evolution*, 4(11), 1502–1509. <https://doi.org/10.1038/s41559-020-1256-9>
- Howarth, S., Journeaux, P.** (2016). Review of Nitrogen Mitigation Strategies for Dairy Farms - is the method of analysis and results consistent across studies? In: Integrated nutrient and water management for sustainable farming. (Eds L.D. Currie and R.Singh). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 29. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 13 pages.
- Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.** (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services. In *Population and Development Review* (Vol. 45, Issue 3). Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages. <https://doi.org/10.5281/zenodo.3553579>
- International Soil Reference and Information Centre.** (2017). Soils in the vicinity of Wageningen: Background information for participants of the ISRIC Spring School 2017. Retrieved in August 2021 from https://www.isric.org/sites/default/files/Wageningen%20soils%20background%20info_2017.pdf
- Journeaux, P.** (2016). Review of Nitrogen Mitigation Strategies for Dairy Farms - is the method of analysis and results consistent across studies? In: Integrated nutrient and water management for sustainable farming. (Eds L.D. Currie and R.Singh). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 29. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. (pp. 1-13)
- Kamer van Koophandel.** (n.d.). Dit is onze opdracht. Retrieved from KVK: <https://www.kvk.nl/over-kvk/dit-is-onze-opdracht/>
- McGarigal, K., Marks, B.J.** (1994). FRAGSTATS- spatial pattern analysis program for quantifying landscape structure.
- Zabaloy, K.N., Guan, M.C. & Villamil, M.B.** (2020). Do cover crops benefit soil microbiome? A meta-analysis of current research. *Soil Biology and Biochemistry*, 142. <https://doi.org/10.1016/j.soilbio.2019.107701>
- Klootwijk, C. W., Van Middelaar, C. E., Berentsen, P. B. M., & de Boer, I. J. M.** (2016). Dutch dairy farms after milk quota abolition: Economic and environmental consequences of a new manure policy. *Journal of Dairy Science*, 99(10), 8384–8396. <https://doi.org/10.3168/jds.2015-10781>
- Koekkoek, E.** (2021, 8th of July). Stikstofuitstoot Nederland: hoe zit het?. Retrieved in August 2021, from <https://www.kvk.nl/advies-en-informatie/innovatie/duurzaam-ondernemen/stikstofuitstoot-nederland-hoe-zit-het/>
- Koskamp, G.J. & van Kuik, J.A.M.** (2001). 'Typical Dutch' - Zicht op verscheidenheid binnen de Nederlandse melkveehouderij met betrekking tot: gewasbescherming, energie en broeikasgassen, zware metalen, water, natuur. Rapport 4a. Retrieved in August 2021, from <https://edepot.wur.nl/27507>
- Lammerant, J., Starkey, M., de Horde, A., Bor, A. M., Driesen, K., & Vanderheyden, G.** (2021, March). Assessment of Biodiversity Measurement Approaches for Business and Financial Institutions (Update 3). https://ec.europa.eu/environment/biodiversity/business/assets/pdf/EU%20B@B%20Platform%20Update%20Report%203_FINAL_1March2021.pdf
- Luoto, M., Pykälä, J., & Kuussaari, M.** (2003). Decline of landscape-scale habitat and species diversity after the end of cattle grazing. *Journal for Nature Conservation*, 11(3), 171–178. <https://doi.org/10.1078/1617-1381-00052>



- Mair, L., Bennun, L.A., Brooks, T.M. et al. A metric for spatially explicit contributions to science-based species targets. *Nat Ecol Evol* 5, 836–844 (2021).
- Mueller, N. D., Lassaletta, L., Runck, B. C., Billen, G., Garnier, J., & Gerber, J. S. (2017). Declining spatial efficiency of global cropland nitrogen allocation. *Global Biogeochemical Cycles*. Published. <https://doi.org/10.1002/2016gb005515>
- Natura 2000. (n.d.). Natura 2000. Retrieved in August 2021 from <https://www.natura2000.nl/>
- Pulungan, M. A., Suzuki, S., Gavina, M. K. A., Tubay, J. M., Ito, H., Nii, M., Ichinose, G., Okabe, T., Ishida, A., Shiyomi, M., Togashi, T., Yoshimura, J., & Morita, S. (2019). Grazing enhances species diversity in grassland communities. *Scientific Reports*, 9(1). <https://doi.org/10.1038/s41598-019-47635-1>
- Pumariño, L., Sileshi, G. W., Gripenberg, S., Kaartinen, R., Barrios, E., Muchane, M. N., Midega, C., & Jonsson, M. (2015). Effects of agroforestry on pest, disease and weed control: A meta-analysis. *Basic and Applied Ecology*, 16(7), 573–582. <https://doi.org/10.1016/j.baee.2015.08.006>
- Ravetto Enri, S., Probo, M., Farruggia, A., Lanore, L., Blanchetete, A., & Dumont, B. (2017). A biodiversity-friendly rotational grazing system enhancing flower-visiting insect assemblages while maintaining animal and grassland productivity. *Agriculture, Ecosystems & Environment*, 241, 1–10. <https://doi.org/10.1016/j.agee.2017.02.030>
- Regulation (EU) No 1307/2013 of the European Parliament and of the Council** of 17 december 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009.
- Reijs, J., Beldman, A., Zijlstra, J., Vrolijk, M., & Hoes, A. C. (2021). Building Farm-level Sustainability Programmes in Agribusiness: A 5 step cycle based on lessons from working with the dairy industry. Retrieved from <https://edepot.wur.nl/543101>
- Rigueiro-Rodríguez, A., Rois-Díaz, M., & Mosquera-Losada, M. R. (2010). Integrating Silvopastoralism and Biodiversity Conservation. *Sustainable Agriculture Reviews*, 359–373. https://doi.org/10.1007/978-90-481-9513-8_12
- Rijksdienst van Ondernemend Nederland. (2016). Natura 2000-Beheerplan De Borkeld (044). https://www.bij12.nl/wp-content/uploads/044_Beheerplan_De-Borkeld.pdf
- Rijksinstituut voor Volksgezondheid en Milieu. (2018). Wettelijke eisen aan drinkwater. Retrieved in August 2021, from <https://www.rivm.nl/drinkwater/drinkwater-en-regelgeving>
- Rockström, J., Steffen, W., Noone, K., Persson, S., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Foley, J. A. (2009). A safe operating space for humanity. *Nature*, 461(7263), 472–475. <https://doi.org/10.1038/461472a>
- Science Based Targets Network. (2020). Science-Based Targets for Nature, Initial Guidance for Business. Global Commons Alliance. Retrieved in August 2021, from <https://sciencebasedtargetsnetwork.org/wp-content/uploads/2020/09/SBTN-initial-guidance-for-business.pdf>.
- Schipper, A. M., Hilbers, J. P., Meijer, J. R., Antão, L. H., Benítez-López, A., Jonge, M. M., Zeist, W.-J. v. (2019). GLOBIO data downloads. Retrieved in August 2021, from <https://www.globio.info/globio-data-downloads>
- SoilGrids. (2020). SoilGrids – global gridded soil information. Retrieved in August 2021, from <https://www.isric.org/explore/soilgrids>
- Tóth, G., Montanarella, L., Stolbovoy, V., Máté, F., Bódis, K., Jones, A., Panagos, P. & Van Liedekerke, M. (2008). Soils of the European Union. JRC Scientific and Technical Reports. https://esdac.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/other/EUR23439.pdf
- van der Meulen, H. (2021). Agrimatie - informatie over de agrosector. Retrieved August 2021, from <https://www.agrimatie.nl/ThemaResultaat.aspx?subpubID=2232&themaID=2267&indicatorID=2106>.
- van Doorn, A., Melman, D., Erisman, J. W., de Wit, J., & Dijkman, W. (2017). *Methode voor bepaling drempel- en streefwaarden voor de KPI's van de Biodiversiteitsmonitor Melkveehouderij*.
- van Doorn, A., Erisman, J. W., Melman, D., van Eekeren, N., Lesschen, J. P., Visser, T., & Blanken, H. (2019). *Drempel- en streefwaarden voor de KPI's van de Biodiversiteitsmonitor melkveehouderij: Normeren vanuit de ecologie*.
- Van Laarhoven, G., Nijboer, J., Oerlemans, N., Piechocki, R. & Pluimers, J. (2018). Biodiversiteitsmonitor Melkveehouderij: Een nieuw instrument dat biodiversiteitsversterkende prestaties in de melkveehouderij eenduidig meetbaar maakt [Brochure]. http://biodiversiteitsmonitormelkveehouderij.nl/docs/Biodiversiteitsmonitor_nederlands.pdf
- Wageningen University & Research (2021). Nitrogen surplus on the soil surface balance in the Peat Region high through mineralization. Retrieved August 2021, from <https://www.wur.nl/en/Research-Results/Research-Institutes/Economic-Research/show-wecr/Dutch-Dairy-Farming-in-2030.htm>
- Wang, X., Blanchet, F. G., & Koper, N. (2014). Measuring habitat fragmentation: An evaluation of landscape pattern metrics. *Methods in Ecology and Evolution*, 5(7), 634–646. <https://doi.org/10.1111/2041-210x.12198>
- Wilcock, R. J., Betteridge, K., Shearman, D., Fowles, C. R., Scarsbrook, M. R., Thorrold, B. S., & Costall, D. (2009). Riparian protection and on farm best management practices for restoration of a lowland stream in an intensive dairy farming catchment: A case study. *New Zealand Journal of Marine and Freshwater Research*, 43(3), 803–818. <https://doi.org/10.1080/00288330909510042>
- Wrage, N., Scedilla, D. N., Hofmann, M., & Isselstein, J. (2011). Influence of stocking density on plant species richness and diversity in permanent grassland. (No. 20113347838). Department of Crop Sciences, Grassland Science, University of Göttingen.
- Zijlstra, J., Timmerman, M., Reijs, J., Plomp, M., de Haan, M., Sebek, L., & van Eekeren, N. (2019, December). Doelwaarden op bedrijfsniveau voor de KPI's binnen de Biodiversiteitsmonitor Melkveehouderij (No. 1151). Wageningen University.

BIODIVERSITY MONITOR KPIS

Percent of permanent grassland (% of total acreage):

- **Calculation % of permanent grassland:** Total acreage of permanent grassland / total acreage of farm * 100%
- **Definition of permanent grassland:** A plot of grassland that has not been included in the farm's crop rotation for a minimum of five years.
- **Definition of farm's total acreage:** Acreage used or managed by the farm.
- **KPI in context:** The larger the amount of grassland in the farming system, the more favourable the outcome for organic matter, soil biodiversity and ultimately for ecosystem services. The share of grassland is therefore an indirect indicator of more functional biodiversity on the farm. Additionally, the age of the grassland is important. The older the grassland, the less soil cultivation, the more the ecosystem remains intact, and the greater the chances for biodiversity above and below the ground.

Percent of protein produced by own farm (less than 20 km):

- **Calculation % of protein produced by own farm:** % of protein produced on the farmer's own land / % N (1-N in purchased feed / N in total feed) * 100%
- **Purchased feed** = Purchase of concentrated feeds + roughage and by products
- **Total feed** = Concentrated feeds + roughage + by-products + meadow grass
- **KPI in context:** Firstly, the percentage of protein produced on the farmer's own land indicates the level of self-sufficiency in feed production, and is related to the intensity of dairy farms. It therefore indicates the size of the footprint from external suppliers. This affects biodiversity in other parts of the world. Thirdly, it indicates the share of grassland maintained by a dairy farm. Grassland scores higher in terms of biodiversity and its functions than agricultural land.

Percent of herbrich grassland (% of acreage):

- * No data available for this KPI *
- **Calculation of % herbrich grassland:** Total acreage of herb-rich grassland / total farm acreage * 100%
- **Definition of total acreage of herb-rich grassland:** Permanent grassland with a mix of at least four types of grass and herbs, but often more than 10 types (incl. Buttercups, cuckoo flowers, daisies, ordinary sweet vernal grass, crested dog's-tail, cuckoo flowers, Greater Yellow-rattle, water forget-me-not, red clover and plantain. The share of grass is lower than for production grass, and it has an open and diverse structure due to the numerous herbs, with their large number of stalks and little leafage.
- **Definition of total farm acreage:** Acreage used or managed by the farm.
- **KPI in context:** Herb-rich grassland strengthens the soil, leads to more stable production, is more resistant to drought, may have a positive impact on animal health, and helps reduce ammonia and methane emissions by ruminants. A diverse composition of grass also has a positive effect on aboveground biodiversity. Grassland with a rich variety of herbs, combined with a later mowing date, allows meadow birds to breed and raise their young in safety.

Nitrogen soil surplus (in kg N/ha):

- **Calculation of nitrogen soil surplus per cultivation:** Nitrogen supply - nitrogen removal - nitrogen emissions
- $[\% \text{ grassland} * \text{soil nitrogen surplus (grassland - kg N/ha)} + \% \text{ corn land} * \text{soil nitrogen surplus (corn land - kg N/ha)} + \% \text{ land used for other roughage - kg N/ha)} + \% \text{ land used for arable crops} * \text{soil nitrogen surplus (soil used for arable crops - kg N/ha)}] / 100\%$
- **Definition** Surpluses are defined as the difference between the nitrogen inputs into and outputs from the agricultural system 1
- **KPI in context:** Nitrogen surpluses are one of the greatest threats to biodiversity and resilient ecosystems. The nitrogen surplus in the soil provides an indication of the burden on the soil and water system. The nitrogen soil balance is determined by the supply of nitrogen through deposition, eutrophication, leguminous plants, mineralisation and purchased feed, and the amount of nitrogen evaporated into the air. The smaller the nitrogen soil surplus, the smaller the risks.

Ammonia emissions (kg NH₃/ha)

- **Calculation ammonia emissions per ha:** (Ammonia emissions from the barn + manure storage + grazing + fertilisation using animal manure + use of fertiliser) / total acreage of farm
- **Definition:** The effects of ammonia emissions are negative, and could be observed in aquatic ecosystems, forests, crops and cultivations. Where excessive emissions are recorded, increased acid depositions and excessive levels of nutrients in soil, rivers or lakes are observed 1.
- **Definition total farm acreage:** Acreage used or managed by the farm.
- **KPI in context:** Ammonia emissions account for approx. 70% of nitrogen deposition in the Netherlands. A total of 75% of this share originates from Dutch sources, with agriculture being the main contributor. This nitrogen deposition has an impact on the natural world, which results in a decline in biodiversity (see KPI: nitrogen soil surplus).

Nature & landscape (% of managed land based on management contract)

- **Calculation contribution of nature and landscape:** $\Sigma (O_i \times C_i \times 100\%) / T$
 - O = Total surface of nature and landscape elements (for type i)
 - C = Weighting factor (for type i)
 - T = Total farm acreage
- **Definition weighting factor:** Since different elements contribute to biodiversity in different ways, a weighting factor is used to determine the amount of land used for nature and landscape elements, including full-scale elements, line-shaped elements and point elements. These weighting factors are based on the amount of compensation paid and the effort required for management.
- **Definition farm acreage:** Acreage of land used or managed.
- **KPI in context:** Landscape diversity on the farm improves the quality of the landscape and people's perception of this landscape, along with biodiversity, and supports functional agrobiodiversity. This KPI is a composite indicator for landscape management and species management.

ADDITIONAL KPIS

Species composition change

- MSA values are retrieved by dividing the abundance of each species found in relation to a given pressure level by its abundance found in an undisturbed situation within the same study, truncating the values at 1, and then calculating the arithmetic mean over all species present in the reference situation
- Evaluating ecosystem functioning at the ecoregion level involves four steps:
 - (i) quantification of land-use biodiversity loss at the ecoregion level (calculation below)
 - (ii) defining safe operating space for each ecoregion, this part is based on the "nature needs half" (NNH), (see below);
 - (iii) deriving safe operating space for a country in each ecoregion based on a chosen effort sharing approach; (ex. ratio of population to global pop, or the Grandfathering approach using historical biodiversity loss data of the local region compared to the global equivalent)
 - (iv) evaluating if the environmental impact from (i) is within the safe operating space defined in (iii). according to <https://ecoregions2017.appspot.com/Netherlands> is in the Nature Could Recover stage
- Biodiversity loss footprint: Hectares of area in use * (1-MSA)
- MSA values may be found from the GLOBIO3

Landscape Fragmentation

- For genetic biodiversity, having connected landscapes is essential. Currently, there are limited ambient monitoring capabilities for measuring landscape fragmentation. We used the KPI from CAI_AM index to determine the current landscape and then set boundary to not reduce the current connectedness of the landscape due to the lack of societal goals or ecological thresholds associated this or any landscape fragmentation index.

Chemical Inputs (herbicide, pesticide, fungicide)

- The ecological threshold used are the levels of chemicals safe for drinking water. The specific chemical inputs thresholds for drinking water are as follows: Pesticides (individual): 0.1 µg/L (microgram / L) - per matter; Aldrin, dieldrin, heptachlor and heptachlorepoxide: 0.03 µg/L; Pesticides (sum): 0.5 µg/L (microgram / L) (sum of individual pesticides with a concentration that is higher than the detection limit).

GLOSSARY

Biodiversity monitoring: Determining the status of biological diversity at one or more ecological levels and assessing changes over time and space. This should include genetic, species, and ecosystem level of monitoring as well as multiple groups within each of these to have a complete picture of the changes of biodiversity in an area over time.

DPSIR: (Drivers, pressures, state, impact and response): A framework developed to describe the causative chain of environmental issues:

- Drivers: The values and behaviors of individuals, organizations and society as a whole. “Drivers” feed into “pressures”, which then fuel the degradation and loss of nature (measured in state variables) within the land, freshwater, and ocean realms.
- Pressure: Derived from the drivers (as per the DPSIR framework) of biodiversity loss as determined by IPBES .
- State of nature: a measurement of KPIs at a point in time that is used to benchmark impacts.
- Impact: Positive or negative contributions of a company or other actor toward the state of nature.

Materiality assessment: Assessment to determine issues which should influence decision making processes, or have the potential to do so and which should be included in corporate target setting. In a materiality assessment, we identify the main pressures on nature and the level of influence for the company to affect these pressures. Materiality can be assessed and reported in a number of ways, and in the case of our assessment we examine the material impacts on nature within our 50km radius landscape.

Key Performance Indicator (KPI): A metric used to measure the impact associated with a set of actions or outcomes. The indicators can be used on a broad, landscape level or more pinpointed at a dairy farm on biodiversity on the farm and beyond. In the case of this project, KPIs make it possible to benchmark and monitor the role of dairy farmers in the preservation of the landscape and the environment using a standardized system. Key criteria in the selection of KPIs are integrality and measurability. This means that the set of KPIs can be used to collectively quantify the performance of dairy farmers in an integrated manner with the objective of improving biodiversity:

- **Role of KPI:** KPIs ensure that there is across the board contraction of impact that lead to landscape level improvement of biodiversity outcomes
- **Input KPI:** KPIs that are related to initial load or use of a resource
- **Midpoint KPI:** KPIs that assess intermediary impacts between the impact and eventual decline in question (in this case biodiversity). It is important to measure midpoint KPIs because they appear before the endpoint, and can provide clear indication of how a system is behaving
- **End-point KPI:** KPIs that to the outcome or eventual goal are related to to target, and in this case, biodiversity monitoring

Threshold: defines a value for the boundary for an activity (i.e. nitrogen soil surplus) for which the landscape can remain within a safe operating space. Thresholds are applicable for some activities, but are not applicable for all activities.

Target: A science-based target for nature is a measurable, actionable, and time-bound objectives based on the best available science that allow actors to align with Earth’s limits and societal sustainability goals:

- **Action targets:** Are set to ensure that interventions are carried out appropriately to ensure that outcome targets and the goal will be realized
- **Outcome targets:** Are based on key results required to achieve the goal within a certain time period.
- **Target boundary:** A specific quantitative objective, usually nested under a goal, with defined measurement and an associated indicator. Defines the issue area (location) and/or aspects of a company’s operations, brands/product lines where targets will be set. Within the context of this project, the target boundary is the dairy basin of the Bel milk processing plant. We are looking at biodiversity impacts (CO2eq considerations are out of scope) on sandy soil farming operations.

Pressures: Five key pressures contribute most to the loss of nature globally: Land and sea use change; direct exploitation of organisms; climate change; pollution; and invasion of alien species.

