Accounting for biodiversity and farmland birds in the Netherlands (2013–2020)

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1 Introduction

This report consists of two main parts. In the first part a partial update of the SEEA-EA Biodiversity account for the Netherlands is presented. The update is partial in the sense that it (1) focuses on species diversity only and (2) excludes a number of indicators for which no updated data is available (mainly ecosystem quality as measures by mean species abundance). A full description of context and methodology can be found in Bogaart et al. (2019).

The second part focuses on farmland bird indicators, and two selected pressure indicators (grazing intensity and manure application)

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2 SEEA-EA Biodiversity account

2.1 Threatened species

The Dutch Red lists contain species that are decreasing in population size and/or distribution range. As species become increasingly rare, they are categorized as "*Near Threatened*", *"Vulnerable*", *"Endangered"*, *"Critically Endangered"*, or *"Extinct"* (CLO 1052). Figure 1 shows the Red List status of 18 species groups that have been compiled for the Netherlands. The Red Lists are updated approximately every ten years per species group (Table 1). However, the Red Lists for three species groups of flies, as well as molluscs and flatworms still stem from 2005.

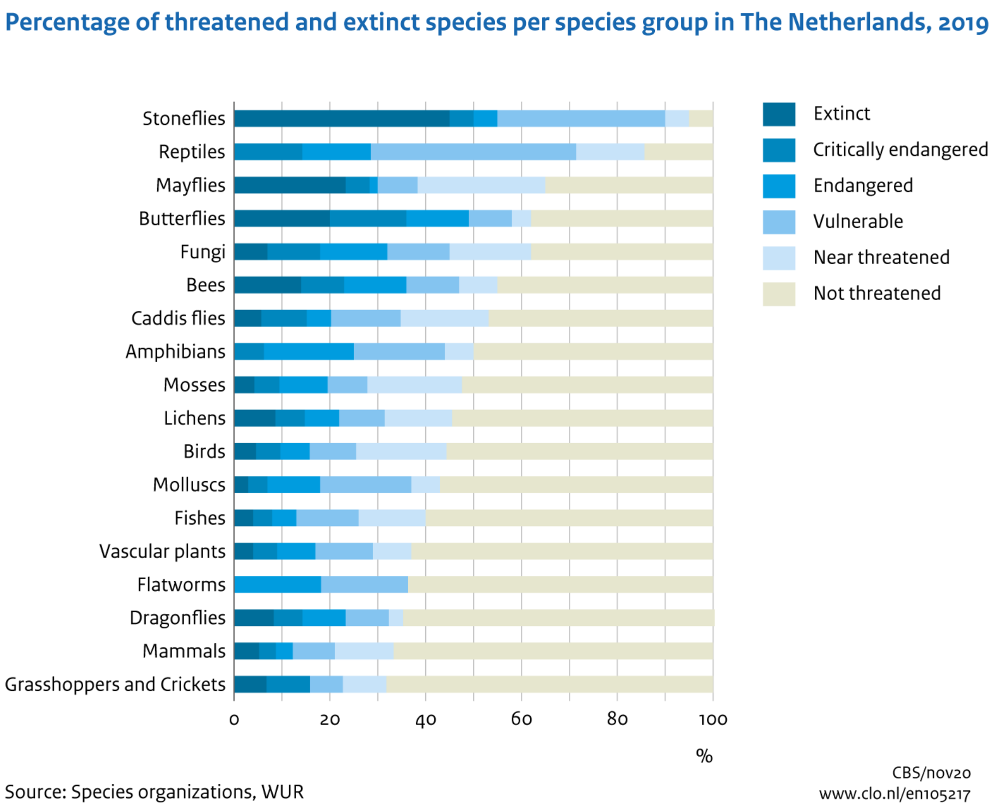

Figure 1. Percentage of threatened species per species group in the Netherlands, 2020 (adapted from CLO-1052)

Recently the official Red List of the mammals species group has been updated (LNV, 2020). Fewer mammals are listed in 2020 than in 2009. For example, the otter (*Lutra lutra*) is now no longer listed on the official Red List after a successful introduction and population increase since 2002 (Norren et al., 2020).

A revision frequency of 10 years does not reflect the actual situation and trends in the years between revisions. Using annual monitoring data, 'virtual' Red Lists are compiled in the years between official publications (see Red List Indicator below).

Table 1. Update frequency of official Red Lists of threatened species.

	Group name	(in Dutch)	1995	2005	2009	2015	2017	2018	2019	2020
Animals	Stoneflies	(Steenvliegen)		●						
	Reptiles	(Reptielen)	●	●	●					
	Butterflies	(Dagvlinders)	●	●	●				●	
	Mayflies	(Haften)		●						
	Bees	(Bijen)		●				●		
	Caddis flies	(Kokerjuffers)		●						
	Amphibians	(Amfibieën)	●	●	●					
	Molluscs	(Weekdieren)		●						
	Fishes (fresh water)	(Zoetwatervissen)	●	●		●				
	Mammals	(Zoogdieren)	●	●	●					●
	Birds	(Vogels)	●	●			●			
	Flatworms	(Platwormen)		●						
	Dragonflies	(Libellen)	●	●		●				
	Grasshoppers and Crickets	(Sprinkhanen en krekels)	●	●		●				
Plants	Macrofungi	(Paddestoelen)	●	●	●					
	Mosses	(Mossen)		●		●				
	Lichens	(Korstmossen)	●	●		●				
	Vascular plants	(Vaatplanten)		●		●				

2.2 Red list indicator (RLI)

The Red List Indicator reflects changes in the number of species on the Red List and the degree to which they are under threat (CLO-1521). The number of threatened species is reflected by the RLI *length*, while the degree of threat is reflected by the RLI *colour*. The RLI includes seven species groups: mammals, breeding birds, reptiles, amphibians, butterflies, dragonflies and vascular plants.

During the accounting period 2013-2020, the RLI length shows an increase from 675 to 694 (+2.8%) endangered species. This is the highest number of species on the Red lists since the first measurement in 1995 (Figure 2). The newly endangered species consist mostly of vascular plants, as well as some dragonflies and breeding birds. Between 2016 and 2017 the method for determining the degree of threat for vascular plants was updated, hence the notable increase in this species group.

2.2.1 RLI per species group

Looking at the separate groups of species (Figure 3) it can be seen that only the species group butterflies has clearly improved during the accounting period 2013-2020. The number of butterfly species on the Red List has decreased, as well as the average level of threat to the remaining butterfly species. Conversely, breeding birds and dragonflies have become more threatened. RLI color has improved somewhat for mammals and amphibians as well.

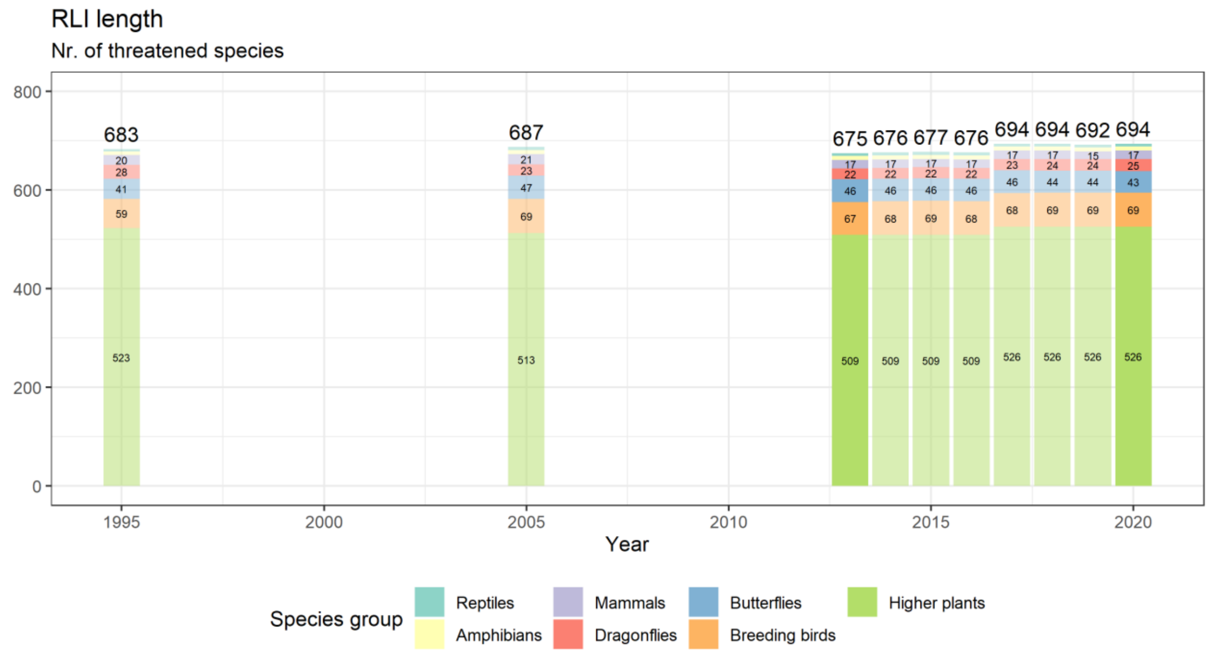

Figure 2. Red List lengths for seven species groups. Focal years 2013 and 2020 are highlighted.

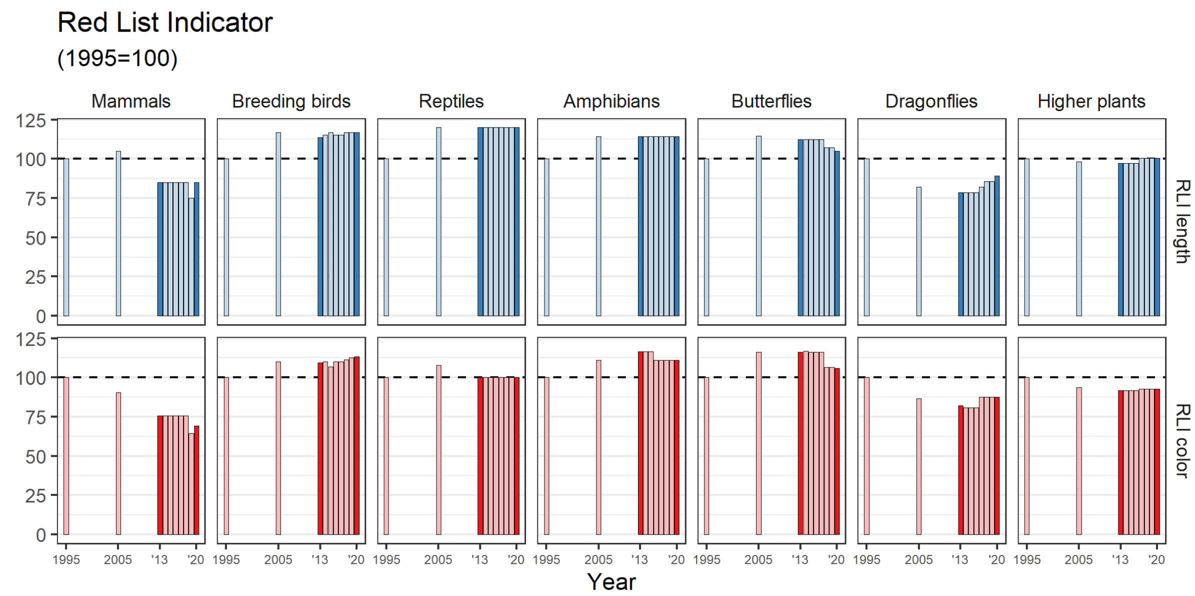

Figure 3. Red List Indicators per species group. Focal years 2013 and 2020 are highlighted.

2.2.2 RLI per ecosystem

Species can be clustered into terrestrial fauna and freshwater/wetland fauna (CLO-1573). During the accounting period 2013-2020 the terrestrial fauna have become more threatened than freshwater/wetland species The degree of threat to freshwater/wetland species (RLI color) shows a lot of variation between years. (Figure 4 and Table 2).

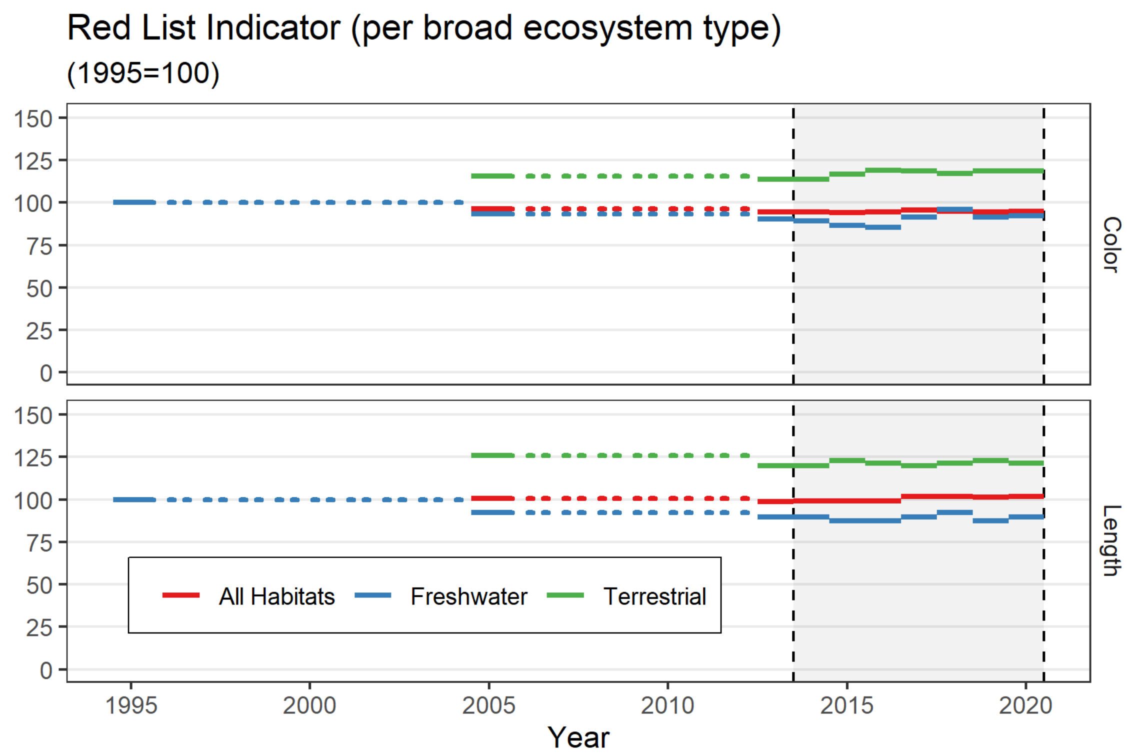

Figure 4. Red List Length and Color for all species considered, and for two major ecosystem types (terrestrial and freshwater/wetlands).

Table 2. Red List Indicator account for 2013-2020. Indicator values for other years are included for reference.

		All ecosystems		Terrestrial / dry nature		Freshwater / wetlands	
	Year	**RL Length**	**RL color**	**RL Length**	**RL color**	**RL Length**	**RL color**
	1995	100.0	100.0	100.0	100.0	100.0	100.0
	2005	100.6	96.5	125.8	115.5	92.3	93.2
Opening stock	**2013**	**98.8**	**94.4**	**119.7**	**113.8**	**89.7**	**90.3**
	2014	99.0	94.5	119.7	113.8	89.7	89.3
	2015	99.1	94.1	122.7	116.7	87.2	86.4
	2016	99.0	94.3	121.2	119.0	87.2	85.4
	2017	101.6	95.5	119.7	118.4	89.7	91.3
	2018	101.6	94.9	121.2	117.2	92.3	96.1
	2019	101.3	94.6	122.7	118.4	87.2	91.3
Closing Stock	**2020**	**101.6**	**94.8**	**121.2**	**118.4**	**89.7**	**92.2**
Net change		2.8	0.4	1.5	4.6	0.0	1.9

2.3 Threatened species account

Using the virtual Red Lists to map changes in the Red List status a threatened species account was created (Table 3). This account shows the mutation types that took place during the accounting period. Most new additions to the red list take place in the category ‘Near threatened’, this category therefore has a net number of additions. While the net change in the other categories is very low, there are some status changes between these categories, mostly between “Endangered” and “Vulnerable”.

Table 3. Threatened species account for the Netherlands, 2013-2020. Grey cells denote logical impossibility.

		Red List categories							
		Extinct	Critically endangered	Endangered	Vulnerable	Near threatened	**Total Red List**	Least concern	**Total**
Opening stock (2013)		85	105	149	209	127	**675**	1096	**1771**
Additions									
	Local extinctions	2					**2**		**2**
	Rediscoveries of local extinct species		1	0	0	2	**3**	1	**4**
	From lower threat categories		5	11	5		**21**	0	**21**
	From higher threat categories			3	13	5	**21**		**21**
	New additions to list		0	2	6	22	**30**		**30**
	Removals from list							10	**10**
	Total additions	2	6	16	24	29	**77**	11	**88**
Reductions									
	Local extinctions		2	0	0	0	**2**	0	**2**
	Rediscoveries of local extinct species	4					**4**		**4**
	To lower threat categories		6	11	4		**21**		**21**
	To higher threat categories		0	2	13	6	**21**		**21**
	New additions to list							30	**30**
	Removals from list		1	2	4	3	**10**		**10**
	Total reductions	4	9	15	21	9	**58**	30	**88**
Closing stock (2020)		83	102	150	212	147	**694**	1077	**1771**

While the previous accounting period 2006-2013 showed an improvement in the amount of threatened species (Bogaart et al. 2020), this trend reverses between 2013 and 2020. Since there are more years recorded in the period 2013-2020 there is more certainty on the deterioration of the status of threatened species.

2.4 Living Planet Index

The Living Planet Index (LPI) of the Netherlands reflects the average trend of almost all native species of breeding birds, reptiles, amphibians, butterflies and dragonflies, as well as a significant part of the mammals and freshwater fish species (CLO-1569). During the accounting period 2013-2020 the overall LPI slightly declines, but there is no significant change between the start and end of the period (Figure 5). The Environmental Data Compendium (CLO) does report a moderate decrease in the overall LPI for the last 12 years (Table 4).

Besides the overall LPI, indices are available for species groups, as well as habitat-related sub-groups.

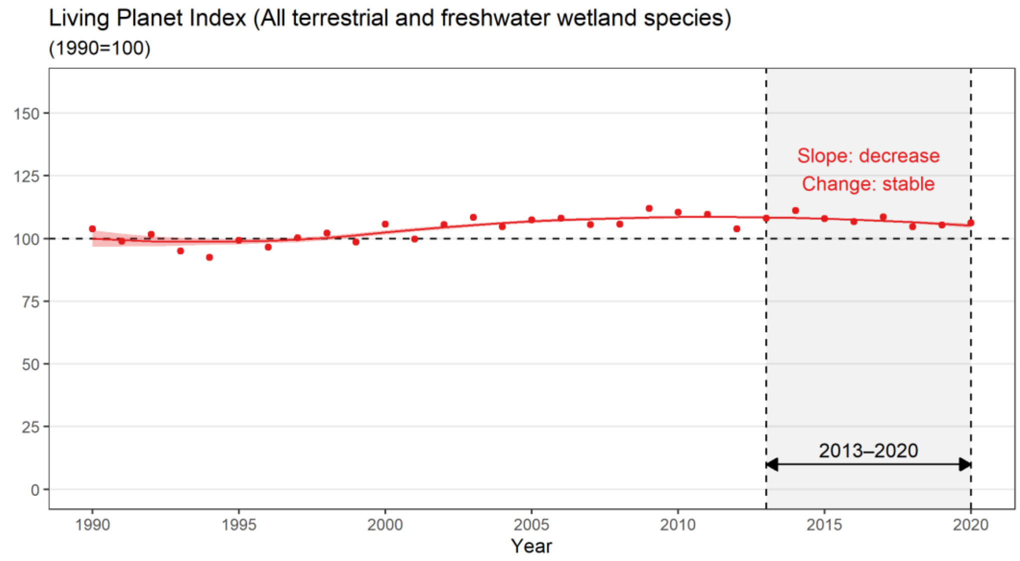

Figure 5. Living Planet Index for the Netherlands, total of all terrestrial, freshwater and wetland ecosystems. Points indicate the index value for individual years, while the solid line indicates a smoothed trend and its associated 95% confidence band.

2.4.1 LPI per species group

There is great variation in LPI trends for the separate species groups (Figure 6). There is a decline in the LPI of butterflies and reptiles (CLO-1386, CLO-1384). Other species groups appear mostly stable, though within groups there can be contrary trends for different ecosystems subgroups. The overall LPI trend for dragonflies is improving, while this is not true for the subgroup of dragonfly species living in bog habitats (CLO-1387). The LPI of breeding birds living in forest habitats is improving while the other breeding bird subgroups are stable (CLO-1381). The increase in the LPI of mammals that was reported for the previous accounting period 2006-2013 does not continue in the more recent years. The LPI trend for amphibians has improved since the last report, whether the fire salamander is included or not matters less for the period 2013-2020 than it did earlier.

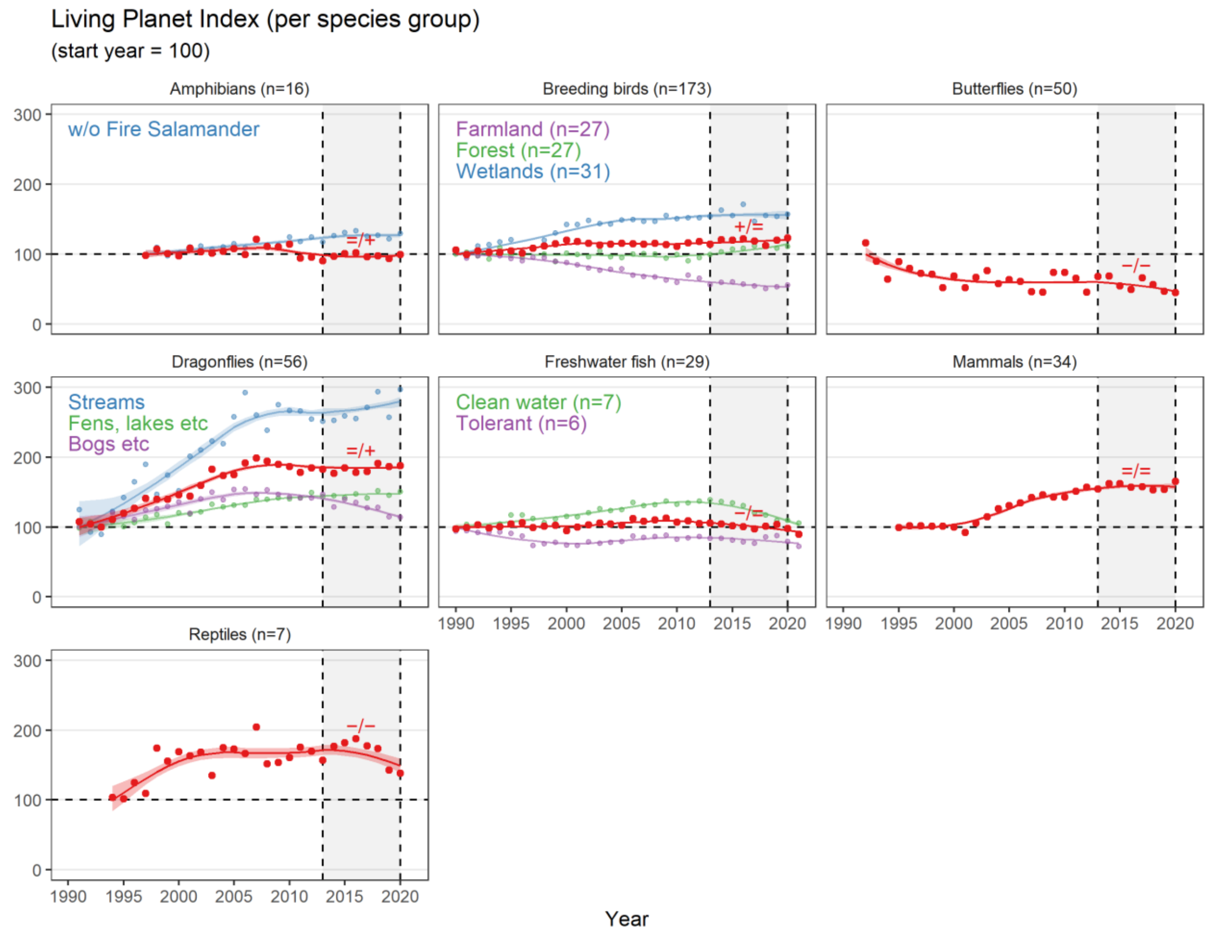

Figure 6. LPI for separate species groups (in red) and for selected habitat-specific sub-groups (other colours). Symbols like "+/=" indicate the trend during the focus period (first symbol) and comparison between 2005 and 2013 (second symbol). Symbols indicate an increase (+), decrease (−), stable (=), or uncertain(?).

Table 4. Trend estimates for all LPI indicators, for the accounting period (in red) and other time intervals.

							Whole data period 1990–2020			Pre-accounting period 1990-2013			Accounting period 2013-2020		Last 12 yr 2008-2020
					CLO ID	nr. species	CLO-trend	trend	change	trend	change		trend	change	CLO trend
Overall LPI terrestrial and freshwater					1569	351	+	+	+	+	+		-	=	-
(Sub)-ecosystem type	Terrestrial				1579	214	-	-	-	-	-		-	=	-
		Nature areas			1581	86	-	-	-	-	-		-	-	-
			Forest		1162	37	=	-	-	-	-		=	=	=
			Open landscapes		1586	48	-	-	-	-	-		-	-	-
				Heathlands	1134	30	-	-	-	-	-		-	-	-
				Coastal dunes	1123	33	-	-	-	-	-		-	=	-
		Agricultural			1580	45	-	-	-	-	-		-	=	-
			Farmland birds		1479										
			Butterflies		1181										
		Urban environments			1585										
			Breeding birds												
			Butterflies												
	Freshwater and wetland				1577	136	+	+	+	+	+		-	=	=
(Sub-)species group	Breeding birds				1381	173	+	+	+	+	+		+	=	+
		Wetlands			1155	31	+	+	+	+	+		=	=	=
		Farmland			1479	27	-	-	-	-	-		-	=	-
		Forest			1618	27	+	+	+	-	=		+	+	+
	Freshwater fish				1578	29	=	=	=	+	+		-	=	-
		Clean water				7	+	+	=	+	+		-	-	-
		Tolerant				6	-	-	-	-	-		-	=	-
	Dragonflies				1387	56	+	+	+	+	+		=	+	=
		Streams					+	++	+	++	+		+	+	+
		Fens, marshes, etc					+	+	+	+	+		+	=	+
		Bogs etc					+	+	+	+	+		-	-	-
	Butterflies				1386	50	-	-	-	-	-		-	-	-
	Mammals				1571	34	+	+	+	+	+		=	=	+
	Amphibians				1077	16	-	-	=	=	=		=	+	-
		w/o Fire Salamander				15	+	+	+	+	+		=	+	+
	Reptiles				1384	7	+	+	+	+	+		-	-	=

2.4.2 LPI per ecosystem

Apart from average trends per species group, the LPI can be constructed per ecosystem type using the abundance of so called habitat specialists. Most ecosystem types show a small negative trend for the period 2013-2020, though the change is only significant for heathland ecosystems (Figure 7). The trends are very similar to the previous accounting period, apart from the forest LPI which has stabilized after a period of increase (CLO-1162). Looking at the long term trend since 1990, all reported ecosystem types except for freshwater/wetlands show a decline in LPI.

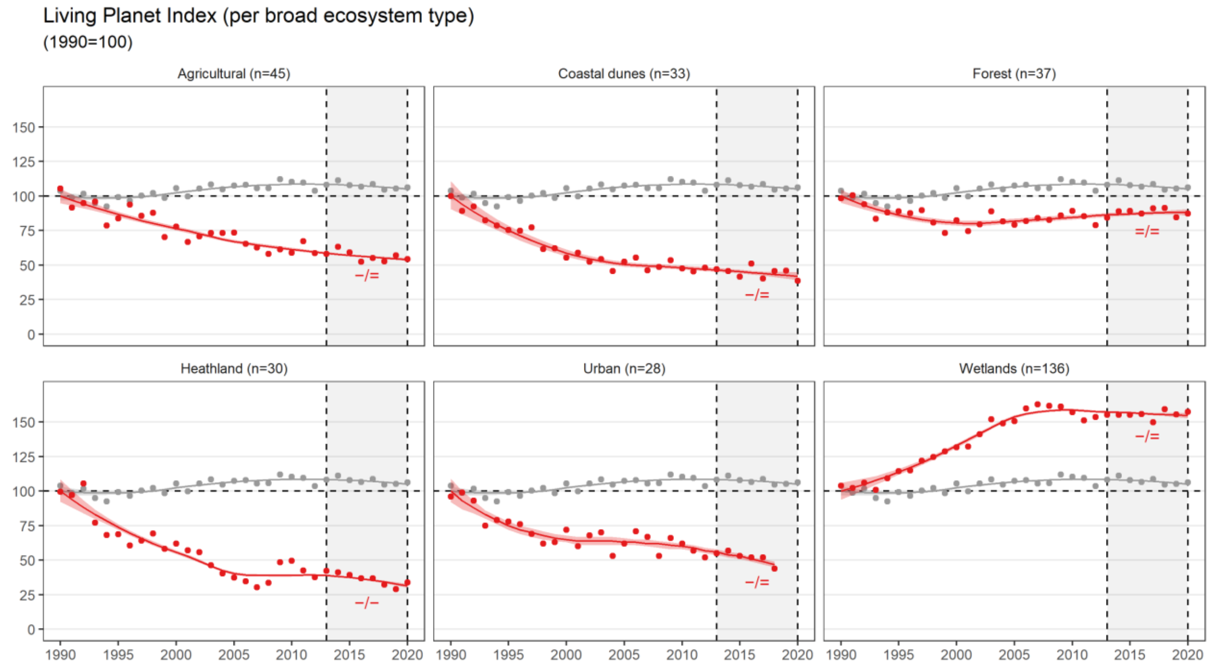

Figure 7. Living Planet Indices for six broad ecosystem types. The overall LPI is plotted in grey for reference purposes. −/=/+ indicate decreasing/stable/increasing trends/changes during the accounting period.

2.4.3 LPI account

An LPI account has been created using a similar approach as the threatened species account. For the identification of the opening and closing stocks the smoothed values were used. The resulting accounting table is presented in Table 5. The LPI for terrestrial nature is declining, even though the LPI for forest shows a small increase. While the decline in the coastal dunes LPI is not significant for both the current and previous accounting period (Bogaart et al. 2020), it is possible a significant decline would be found if a longer period was evaluated.

Table 5. LPI Account for the Netherlands, 2013-2020. LPI values for opening and closing years are smoothed values. The change assessment is taking uncertainty in these smoothed values into account.

Ecosystem (sub)type	CLO	Living Planet index 2013	Living Planet index 2020	Change in LPI Absolute	Change in LPI Relative	Assessment
All Terrestrial and Freshwater	1569	108.4	105.2	-3.3	-3%	Stable
Terrestrial	1579	85.0	81.9	-3.1	-4%	Stable
Terrestrial nature	1581	57.5	54.4	-3.09	-5%	Decreasing
Forest	1162	86.3	88.3	1.98	2%	Stable
Open nature	1586	39.9	35.5	-4.37	-11%	Decreasing
Heathland	1134	39.1	31.4	-7.68	-20%	Decreasing
Coastal Dunes	1123	46.9	41.9	-5.04	-11%	Stable
Freshwater and wetlands	1577	157.3	154.7	-2.64	-2%	Stable
Agricultural	1580	58.7	54.2	-4.48	-8%	Stable
Urban	1585	56.0	47.0*	-9	-16%	Stable

** For the Urban LPI closing stock the year 2018 was used instead of 2020*

2.5 Data sources.

CLO-1052. CBS, PBL, RIVM, WUR (2020). Number of threatened and extinct species in The Netherlands, by 2020 (indicator 1052, version 17, 10 November 2020). https://www.clo.nl/en/indicators/en1052-number-of-threatened-species

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CLO-1134. CBS, PBL, RIVM, WUR (2022). Fauna van de heide, 1990-2020 (indicator 1134, versie 18 , 3 mei 2022). https://www.clo.nl/indicatoren/nl1134-fauna-van-de-heide

CLO-1155. CBS, PBL, RIVM, WUR (2021). Trend broedvogels van moeras en zoet water, 1990-2020 (indicator 1155, versie 16 , 29 oktober 2021). https://www.clo.nl/indicatoren/nl1155-broedvogels-van-moeras-en-zoet-water

CLO-1162. CBS, PBL, RIVM, WUR (2021). Fauna van bos, 1990-2020 (indicator 1162, versie 19 , 21 december 2021). https://www.clo.nl/indicatoren/nl1162-fauna-van-het-bos

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CLO-1386. CBS, PBL, RIVM, WUR (2021). Trend van dagvlinders, 1992-2020 (indicator 1386, versie 18 , 7 juni 2021). https://www.clo.nl/indicatoren/nl1386-dagvlinders

CLO-1387. CBS, PBL, RIVM, WUR (2021). Trend van libellen, 1991-2020 (indicator 1387, versie 16 , 31 mei 2021). https://www.clo.nl/indicatoren/nl1387-libellen

CLO-1479. CBS, PBL, RIVM, WUR (2022). Trend van boerenlandvogels, 1915-2020 (indicator 1479, versie 13 , 24 maart 2022). https://www.clo.nl/indicatoren/nl1479-boerenlandvogels

CLO-1569. CBS, PBL, RIVM, WUR (2022). Trend fauna - all species monitored - Living Planet Index Netherlands, 1990-2020 (indicator 1569, version 07 , 28 March 2022). https://www.clo.nl/en/indicators/en1569-living-planet-index-for-the-netherlands

CLO-1571. CBS, PBL, RIVM, WUR (2022). Trend van zoogdieren, 1995-2020 (indicator 1571, versie 07 , 22 juni 2022). https://www.clo.nl/indicatoren/nl1571-trend-van-zoogdieren

CLO-1573. CBS, PBL, RIVM, WUR (2021). Rode Lijst Indicator van zoetwater- en landfauna, 1995-2020 (indicator 1573, versie 07 , 18 juni 2021). https://www.clo.nl/indicatoren/nl157307-rode-lijst-land-en-zoetwater

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CLO-1585. CBS, PBL, RIVM, WUR (2020). Fauna van stedelijk gebied, 1990-2018 (indicator 1585, versie 03 , 31 maart 2020.) https://www.clo.nl/indicatoren/nl158503-trend-fauna-stad

CLO-1586. CBS, PBL, RIVM, WUR (2021). Fauna van open natuurgebieden, 1990-2020 (indicator 1586, versie 05 , 21 december 2021). https://www.clo.nl/indicatoren/nl1586-trend-fauna-open-natuurgebieden

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3 Farmland bird statistics

3.1 Introduction

Over the last decades, the population of farmland birds in the Netherlands has significantly declined (Kleyheeg et al., 2020; Statistics Netherlands, 2021). For example, the population of the black-tailed godwit (*Limosa Limosa*), the Netherlands' national bird, has declined from almost 115.000 birds in 1985 to 38.000 birds in 2020. Changing agricultural practices resulting in agricultural intensification are often cited as a significant cause of the decline of Dutch farmland birds (Aanvalsplan Grutto, 2020; Kleyheeg et al., 2020). Land-use changes, accelerated and deeper drainage of agricultural grasslands, mowing management and the application of liquid manure are found to negatively impact the farmland birds' population (Chamberlain *et al.* 2000; Donald et al., 2001). Moreover, intensive dairy farming is associated with large amounts of waste output, manure disposal and (over)grazing of grasslands, degrading the living environment of farmland birds (Söderström et al., 2001). In addition, the growing use of antibiotics and other medicines given to cattle eliminate worms and other organisms in the cattle's faeces, removing vital nutrients for farmland birds (Onrust et al., 2019).

National Statistical Offices (NSOs) could help to understand the pressures of farmland birds by monitoring the farmland birds' population and developing indicators to measure important pressures. Following the SEEA-EA framework, NSOs could systematically quantify the pressures of farmland birds through space and time. A consistent way of measuring could also assist the assessment of policy related to farmland birds and measure its effectiveness. In order to explore the possibilities of using NSO data in the monitoring of such phenomena, two case studies were carried out. In these case studies, two pressure indicators for farmland birds in the Netherlands were created using national NSO data: the level of grazing intensity of dairy cattle, and the application of liquid manure on agricultural grasslands. These two cases are discussed separately. This chapter concludes with a general overview of the limitations and recommendations for using NSO data in developing such indicators.

3.2 Farmland Bird Indicator

The Farmland Bird Indicator (FBI), is the main indicator to assess the state of biodiversity of agricultural landscapes. Birds are high in the food chain and therefore are considered good indicators for the overall state of biodiversity. The FBI is compiled throughout Europe and part of the official EU biodiversity statistics. Data collection and processing methodology are harmonized throughout Europe and quality controlled by both ecological institutions (European Bird Census Council, EBCC; Royal Society for the protection of Birds, BirdLife International), and national statistical offices, of which Statistics Netherlands is the *primus inter pares* regarding methodology.

3.2.1 Data sources

The Farmland Bird Indicator is based on population counts for selected bird species, carried out by a network of volunteer ornithologists coordinated within national monitoring schemes.

Selection of species included in the FBI is based on their specific preference for agricultural habitats. The EU scale species list includes 39 species that are dependent on farmland for feeding and nesting and are not able to thrive in other habitats. The species on the list constitute a maximum, from which the countries select the species relevant to them. However, Member States can select their own species set, ideally following guidelines from the European Bird Census Council (EBCC). No rare species are included in EU species selection. Population trends are derived from the counts of individual bird species at census sites and modeled as such through time.

In the Netherlands, 27 species are included in the national FBI, including 14 from the European list. Monitoring is part of the broader breeding bird monitoring program and the Network Ecological Monitoring. A distinction is made between bird species favouring open landscape (“meadow birds”, 14 species) and bird favouring more dense vegetation, such as farmyards and thicket (13 species).

3.2.2 Methodology

The Farmland Bird Indicator is a multispecies indicator, similar to the Living Planet Index (Section 2.4), and the underlying methodology is extensively described elsewhere (van Strien et al., 2016; Soldaat et al., 2017; Bogaart et al., 2020), and can be summarized as follows:

1. For each species, trends in population sizes are computed from annual counts at specified monitoring locations, using poison regression as part of the imputation method.
2. Trends are normalized with respect to a reference year, usually 1990, the starting year of many nature monitoring programs.
3. Normalized trends for multiple species (‘index values’) are combined into a single composite indicator using a geometric mean of index values.

3.2.3 Regionalization

A recent development (in progress) is the compilation of the Farmland Bird Index to regional scales, i.e. provinces. Two main main challenges have to be met:

First, most of the ecological monitoring schemes have been developed with applications to national scale into mind. The number of sites per province are by definition smaller (on average 1/12 for the Netherlands), resulting in less data and hence potentially larger uncertainties.

Second, not all species included in the national indicator are observed in each province. In some cases unobserved bird species have never been present in specific provinces, but in other cases they might have been disappeared in the past, prior to systematic monitoring. This poses a serious challenge to the computation of the multispecies indicator.

The current approach, adopted by Statistics Netherland, is to use province-specific species list, based on the farmland bird species that are observed in sufficient quantities to allow meaningful statistical analysis (Verweij et al., in prep.)

3.2.4 Results

3.2.4.1 National scale

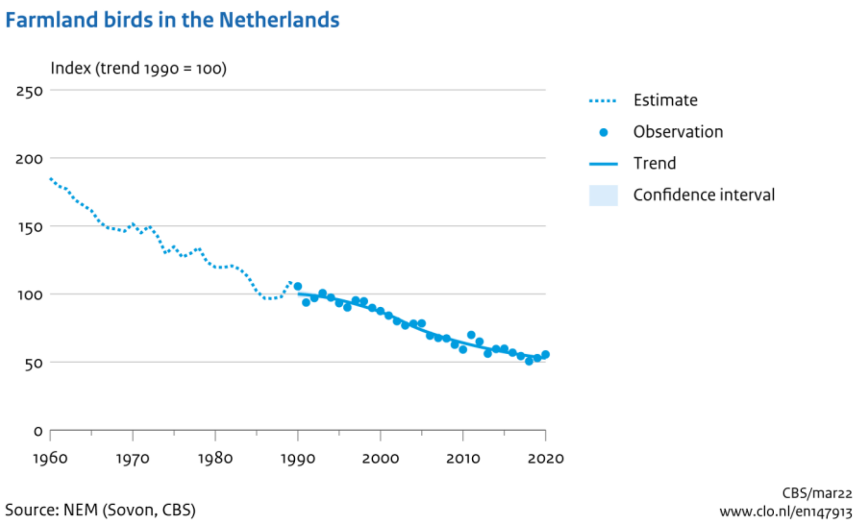


Figure 8. Farmland Bird Indicator on national level. Source: https://www.clo.nl/en/indicators/en1479-farmland-birds

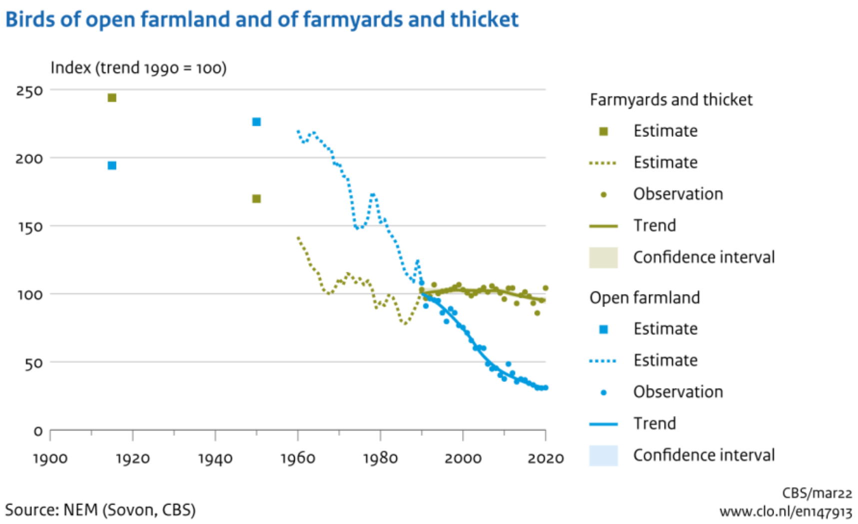


Figure 9. Farmland Bird Indicator per vegetation type. Source: https://www.clo.nl/en/indicators/en1479-farmland-birds

The Farmland Bird Indicator on national scale (Figure 8) clearly shows a declining trend since the start of systematic monitoring (1990), but also in the preceding period (based on estimated population sizes; not further discussed here). There is a marked difference between vegetation type, where birds of open farmland habitats have been declining strongly, while populations of farmyard specific birds have remained stable (Figure 9)

3.2.4.2 Regional scale (by province)

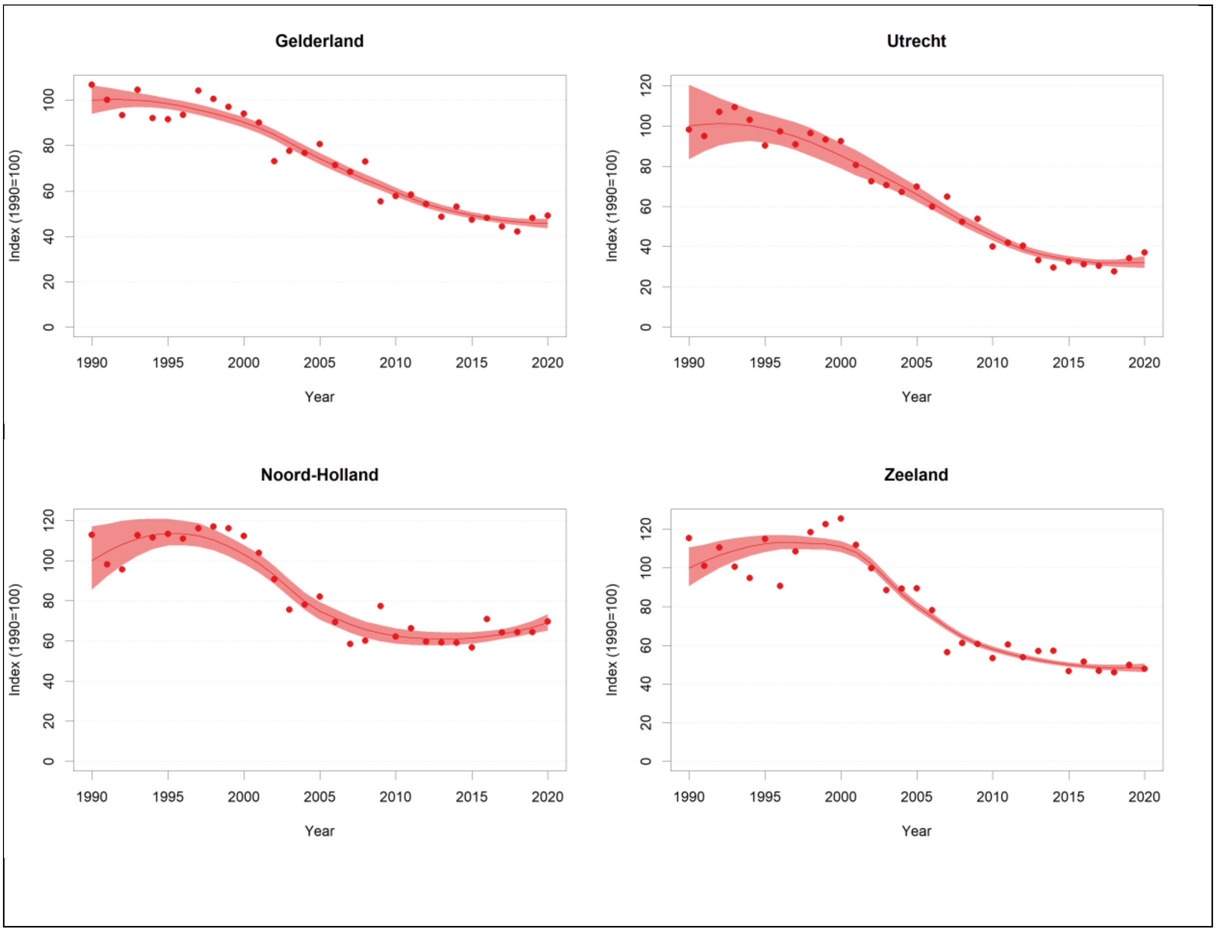


Figure 10. Example Farmland Bird Indicators on province level (Based on Verweij et al., in prep)

Farmland Bird indicators on province level have not been systematically published yet, but for some provinces they are disseminated to the province boards (Figure 10). Although it is difficult, if not impossible to compare across provinces, due to different species analyses in each province see Section 3.2.2, they all share a common declining trend.

3.2.4.3 Regional scale (by soil type)

A second type of regionalization is not by administrative unit, but by landscapes characterized by distinct physiographic properties. In the Netherlands, three major soil types are being found: sand (Pleistocene), clay and peat (Holocene). The floodplains of the major rivers (Rhine, Meuse, IJssel) form a fourth ("fluvial") landscape. Farmland bird indicators can be computer for each of these regions. Results suggest that the strongest decline of farmland bird is in the fluvial district (Figure 11).

Figure 11. Farmland bird index per physiographic region

3.3 Level of grazing intensity by dairy cattle

A possible indicator to quantify the pressures of agricultural practices on the living environment of the farmland birds in the Netherlands is the level of grazing intensity by livestock on agricultural grasslands. Excessive grazing of (dairy) cattle is suggested as a possible cause for the widespread reduction of farmland birds, either directly through the tramping of nests – and therefore increasing exposure to nest predation – or indirectly through other forms of environmental degradation (Barzan et al., 2021; Söderström *et al.* 2001). In *Aanvalsplan Grutto* (2020), a Dutch initiative of nature conservation organisations and scientists to protect the black-tailed godwit, one of the key recommendations is to reduce the cattle intensity from the current Dutch average of 2.5 cows to a maximum of 1 cow per hectare. Here, the first attempts were undertaken to quantify the grazing intensity in the Netherlands using NSO data.

3.3.1 Methodology

Here, grazing intensity is conceptualised as the number of livestock per area of agricultural grassland per farm. In this case study, livestock was limited to dairy cattle, as these animals are the Netherlands' most prominent grazers of agricultural grasslands. For this reason, other domesticated ungulates, including horses, sheep and goats, were excluded from this analysis. To measure the grazing intensity of dairy cattle in the Netherlands, data from the recent 2021 agricultural census of Statistics Netherlands, was used. Here, the data of 17.032 agricultural holdings that own at least one dairy cow were selected for analysis. This data was transformed for this case study. These steps are described below.

For each agricultural holding, the following variables from the agricultural census were used:

- Geographic coordinates of the location of the agricultural holding, enabling spatial analysis of the data;
- The total number of dairy cattle per agricultural holding, divided into age categories;
- The number of grazing dairy cattle per agricultural holding;
- The average number of days and daily hours of grazing per age category;
- The area of agricultural grassland per agricultural holding.

To accurately compare the grazing intensity of dairy cattle per agricultural holding, the number of dairy cattle was standardised as merely the total number of dairy cattle is not an accurate description of the resource use of a farm’s livestock. Since mature cows are larger than calves, they require more food and, therefore, have a larger grazing footprint than younger, smaller calves. Therefore, to account for the age distribution of cattle within agricultural holdings, the number of dairy cattle was measured in livestock units (or GVEs (Dutch: *Grootvee-eenheden*). A GVE is a unit that standardises the amount of livestock based on resource use intensity. Therefore, GVEs are better quantifiers for grazing intensity than merely the number of animals. Following the operationalisation of Statistic Netherlands (2022), GVEs are calculated as follows:

- For each example of a cow aged 0–1 year (calves): 0.25 GVE;
- For each example of a cow aged 1 year and older (*pinken and vaarzen*): 0.5 GVE;
- For each example of cow calved at least once (cows): 1 GVE.

Based on the available data, three different approaches in calculating the level of grazing intensity of dairy cattle in the Netherlands were undertaken:

1. By dividing the total number of dairy cattle to the total area of agricultural grassland. This approach is the most straightforward, applying two general agricultural statistics. It assumes

that per farm, each cow grazes on the entirety of the agricultural grasslands of that particular farm.

2. By calculating the number of grazing cattle to the amount of agricultural grassland. Here, rather than using the total GVEs of each farm, the average number of grazing GVEs are used. For this, the total number of grazing dairy cattle per agricultural holding is used as collected by Statistics Netherlands.
3. By calculating the daily average of grazing cattle to the amount of agricultural grassland. In this approach, the amount of time that cattle is grazing is incorporated into the calculation to account for temporal differences in grazing patterns among agricultural holdings. This method represents the average grazing intensity standardised over 365 days: assuming when a grassland plot is grazed upon 300 days, the grazing intensity is assumed to be higher that when a grassland plot is grazed upon 100 days by the similar number of GVEs. This methodology requires the most detailed amount of data, as not only the amount of grazing dairy cattle and amount of agricultural grassland is necessarily, but also the amount of days and daily hours the cattle is grazing.

The data from individual agricultural holdings were aggregated into larger groups to analyse the spatial pattern of grazing intensity in the Netherlands. Moreover, individual data from the agricultural census of Statistics Netherlands contains confidential information and, therefore, cannot be published with any possible identifiers, including the location of each agricultural holding. Consequently, several steps were undertaken to adhere to the data confidentiality and statistical security principles of Statistics Netherlands. First, the data were aggregated into larger groups to prevent the disclosure of confidential information from individual agricultural holdings. In this case study, the data were aggregated into spatial units based on the location of each agricultural holding to enable spatial analysis. Spatial units can be existing political units (e.g., municipalities or provinces) or any manually created spatial entity. In this case study, the individual data points were aggregated into a grid consisting of rectangular cells, with each cell representing the average level of grazing intensity by dairy cattle for that particular grid cell. The publishability of the aggregated grid cells depends on two legal guidelines of Statistics Netherlands to ensure data confidentiality and privacy. Firstly, a group's information cannot be published if this group consists of less than three individual cases. Secondly, it should not be possible to predict the value of the largest contribution to the group (A) from the value of the second largest contribution (B). The difference between the actual value of A and the value of A estimated from B must not be less than the critical threshold value of 0.15 (15%).

In determining the optimal resolution of geographic aggregation (i.e., the size of the grid cells), there exists a trade-off between the legal requirement of data confidentiality and privacy and the desired level of spatial analysis. Smaller spatial units enable, for example, a more detailed analysis of spatial patterns. However, more spatial units may be omitted due to the inability to fulfil the legal guidelines of data privacy. In contrast, using larger spatial units may lead to a significantly smaller portion of omitted grid cells based on the data privacy requirements, yet may lead to a more granular spatial analysis in which insightful spatial patterns may get lost. Four different fishnet grid resolutions were tested to approximate the most useful grid resolution for the Netherlands: 1x1, 2.5x2.5, 5x5 and 10x10 kilometres.

Figure 12 illustrates the relationship between the grid resolution and the amount of omitted cells based on the legal guidelines. In Annex 1, the grazing intensity of dairy cattle is mapped at the four different grid resolutions to further illustrate these differences.Figure 12 shows an evident exponential decay of the percentage of non-publishable cells towards larger grid cell resolutions. In particular, between the grid resolution of 1x1 km (88.5%) and 5x5 km (39.5%), a significant decrease in the percentage of non-publishable cells is found. However, the decline in the percentage of non-publishable cells slows towards lower resolutions. This pattern suggests that from a certain point, the increase in grid cell size does not significantly reduce the number of omitted cells and, therefore, does not provide any benefit related to the level of spatial detail. Naturally, the 'optimum' grid cell size differs per research objective, scale of analysis, data availability and the spatial distribution of data, among others. Therefore, by no means the found results regarding grid resolutions should be regarded as standard, even for the Netherlands. Still, for this case study, the normative decision has been made to use the 5x5 km grid resolution.

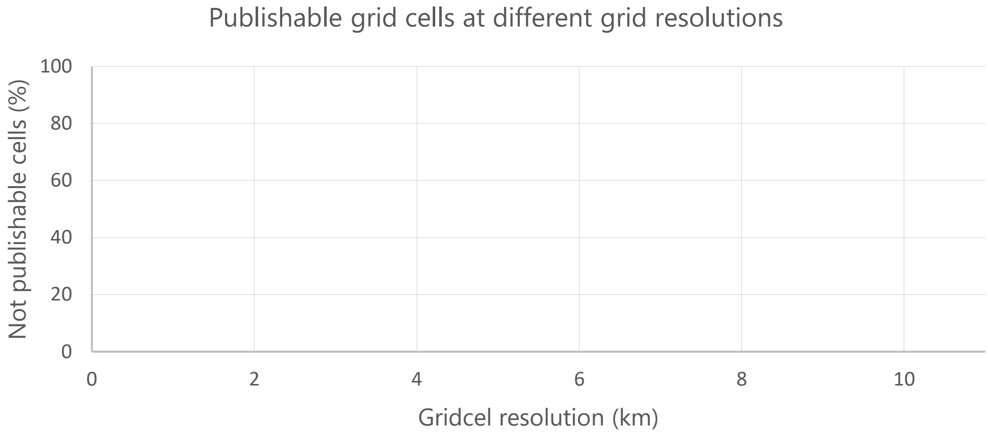


Figure 12. Trade off between grid resolution and the number of publishable grid cells

3.3.2 Results

Figure 13–Figure 16 show the spatial distribution of grazing intensity in the Netherlands for the three different approaches at a grid resolution of 5 kilometres. In these figures, the publishable cells are illustrated in a sequential colour scheme, depicting the level of grazing intensity of dairy cattle measured in GVEs per hectare of agricultural grassland. The unpublishable cells, based on the legal requirements, are shown in grey. The three figures illustrate that the different approaches have resulted in different spatial patterns.

Calculating grazing intensity by total GVEs and total grazing GVEs (Figure 13 and Figure 15) resulted in highly similar spatial patterns. With these approaches, the most significant grazing intensity by dairy cattle is found in the southern regions of the Netherlands, most noticeably in the provinces of Noord-Brabant and Limburg. On the other hand, the regions known for their large amounts of dairy farms, grasslands and farming birds – the *Groene Hart* region and the provinces of Noord-Holland and Friesland – are found to have a relatively small to moderate grazing intensity. Compared to these regions, Noord-Brabant and Limburg contain relatively little grassland (Figure 16). Nevertheless, dairy farming is found to be more intensive here (i.e. more cattle on a smaller plot of grassland), hence a higher grazing intensity. One of the limitations of approaching the grazing intensity by the total number of GVEs is that the indicator assumes that all cattle of each agricultural holding are grazing. However, grazing management differs between farms. Therefore, the average grazing intensity using the total number of grazing GVEs was used. Using this approach, the grazing intensity of dairy cattle in the Netherlands was in terms of GVEs per hectare of grassland lower compared to the first approach. Still, no significant spatial differences between these two approaches are found.

On the other hand, approaching grazing intensity of dairy cattle by the daily average GVEs per area of grassland shows a different spatial pattern than the previous discussed approaches. Here, the number of days and average daily hours that cattle are grazing was incorporated into the quantification of grazing intensity to better account for the differences in grazing management among agricultural holdings. The spatial analysis of the daily grazing intensity shows that the highest levels of grazing intensity by dairy cattle are found in the provinces South- and North-Holland (Figure 14).

3.3.3 Discussion

The different spatial patterns found among the different approaches to grazing intensity of dairy cattle underline the importance of accurately conceptualizing what precisely the aim of the indicator should be. Neither approach is wrong, yet they do depict different spatial patterns and could therefore lead to different policy recommendations, for example. As mentioned before, *Aanvalsplan Grutto* (2020) recommends reducing the cattle density per hectare of grassland to a maximum of 1 cow (or: 1 GVE) to protect the farmland birds in the Netherlands. When looking at the first two approaches, defining the density of grazing cattle by the total number of GVEs or the total grazing number of GVEs, respectively 0 out of 1121 and 1 out of 1114 grid cells meet this criteria. When defining the grazing intensity by the daily average, all grid cells (1027 out of 1027) meet this criterion. This example therefore illustrates the importance of both the precise formulation of policy aims as well as a clear definition of the object of monitoring to be helpful in the analysis of policy to biodiversity issues such as the decline of farmland birds in the Netherlands.

Figure 13 – Grazing intensity of dairy cattle by total GVEs (2021)

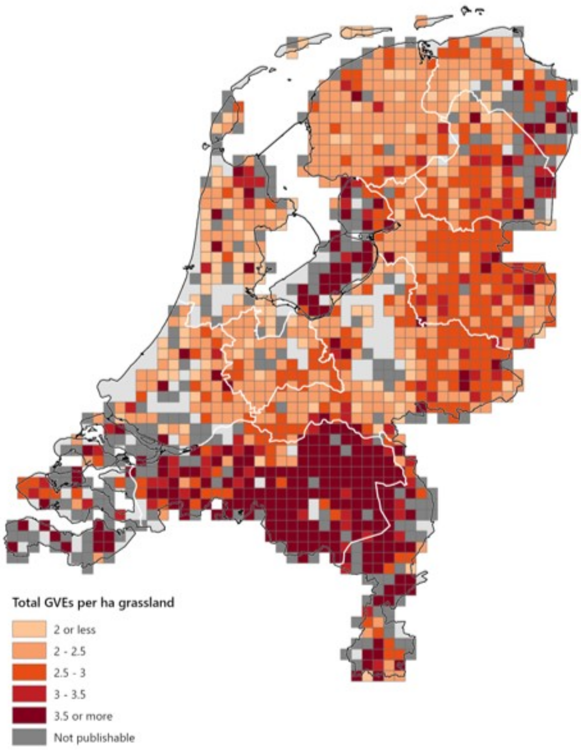


Figure 15 – Grazing intensity of dairy cattle by total grazing GVEs (2021)

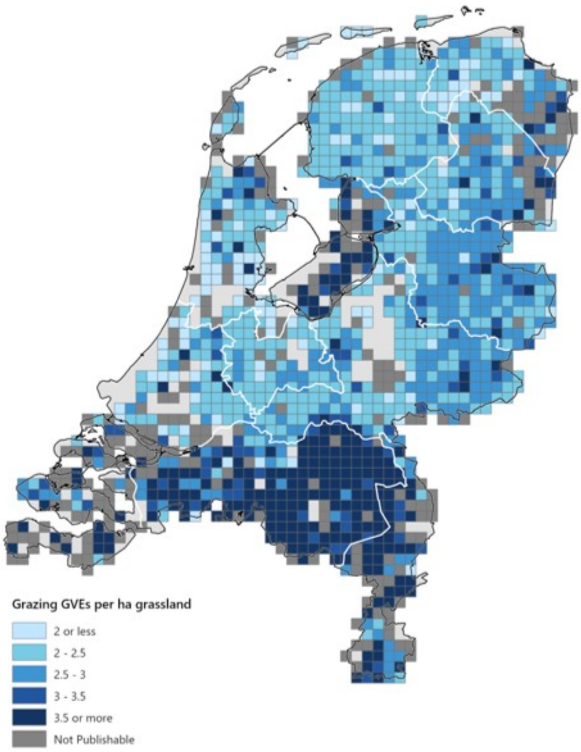


Figure 14 – Grazing intensity of dairy cattle by daily grazing GVEs (2021)

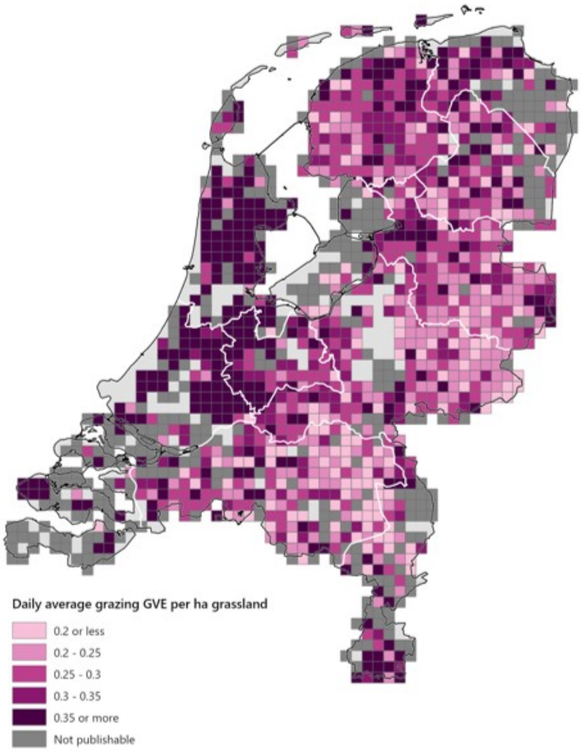


Figure 16 – Distribution of agricultural grassland in the Netherlands (2020)

3.4 Liquid manure use on agricultural grasslands

The level of liquid manure used on agricultural grasslands is also suggested as a possible pressure indicator to measure and monitor the condition of the living environment of farmlands birds. Liquid manure is a mixture of animal waste and organic matter and is often injected into the ground as a fertiliser. The Dutch government encouraged the use of liquid manure in the last decades to reduce the emission of ammonia (NH_3) in the agricultural sector. However, liquid manure, compared to traditionally used fermented manure, contains fewer (micro)organisms that could serve as nutrition for farmland birds. In addition, for earthworms, liquid manure is a food source of lower quality than fermented manure. Further, the injection of liquid manure is found to harden the grasslands' soils, making it difficult for worms and other organisms to reside in the top soils. Due to these effects of liquid manure use, a reduction of important nutrients in the soils is cited as damaging for farmland birds (Onrust *et al.*, 2019). Consequently, quantifying liquid manure use on agricultural grasslands could serve as an indicator to monitor the condition of farmland birds' living environment.

3.4.1 Methodology

To develop an indicator to quantify and analyse the use of liquid manure on agricultural grasslands in the Netherlands in a spatially explicit way, a similar methodology was followed as applied in the construction of the indicator related to the grazing intensity of dairy cattle. Again, data was used from the 2021 agricultural census of Statistics Netherlands. For each agricultural holding in this census, the amount of grassland and the relative distribution of liquid and fermented manure for different types of agricultural land is known. Based on this information, the amount of grassland under liquid manure was calculated both absolutely (measured in ha grassland under liquid manure use) and relatively (measured in the percentage of agricultural grassland under liquid manure use). However, the absolute quantity of used manure per agricultural holding is unknown. Therefore, the calculation of this indicator was done under the assumptions that: a) each plot of agricultural grassland is similarly covered in manure; b) at each areal unit of agricultural grassland per holding, a similar amount of manure is applied by farmers. This approach does not account for any disparities in the quantity of used manure among agricultural holdings due to data availability.

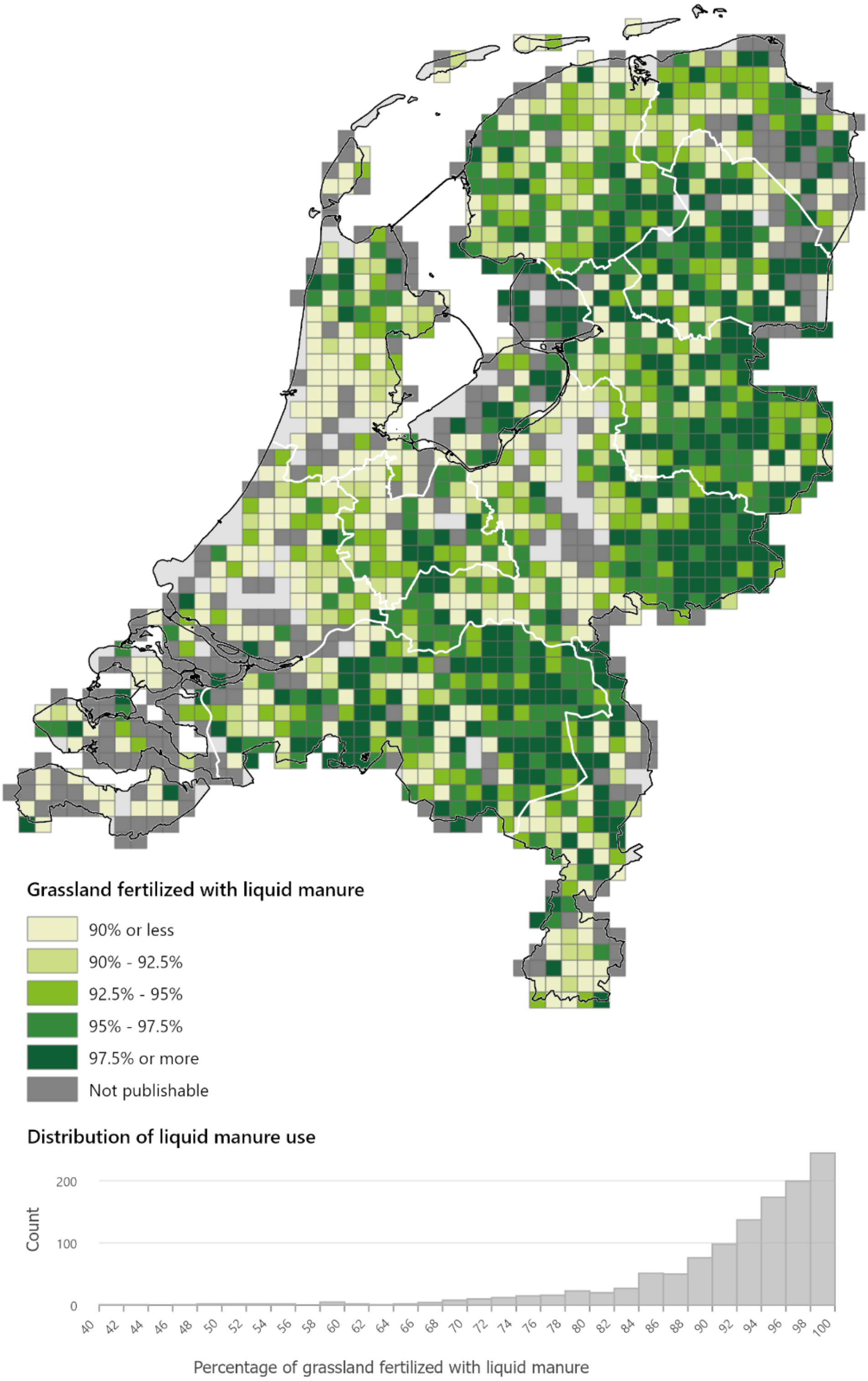
The same approach is followed for spatial aggregation as for the previous indicator. For each agricultural holding, the absolute amount of agricultural grassland under liquid manure and the total agricultural grassland were aggregated into spatial grid cells of 5 by 5 kilometres. Using the aggregated sums of both these variables for each grid cell, the relative liquid manure use was then calculated by dividing the area of agricultural grassland under liquid manure by the total amount of agricultural grassland. This approach was chosen to ensure that agricultural holdings with larger grassland areas had a higher weight in the final calculation of the relative liquid manure use. Given the subject, it is relevant to measure the mean condition of the grassland area per grid cell, rather than the average use per agricultural holding.. Finally, the grid cells were subjected to the legal guidelines of Statistics Netherlands to determine their publishability (elaborated in 3.3.1).

3.4.2 Results

Figure 17 shows the spatial distribution of the application of liquid manure on agricultural grasslands in the Netherlands. The map shows that the highest levels of liquid manure use are primarily found in Noord-Brabant and the eastern regions of Gelderland and Overijssel. These regions are known for high concentrations of pig farming, associated with large outputs of liquid manure (Statistics Netherlands, 2022). Conversely, lower levels of liquid manure use are found in the West Netherlands, such as parts of Noord- and Zuid-Holland. These areas are known peat areas where the Dutch government highly regulates the application of liquid manure.

However, the distribution of the data (Figure 17) is highly negatively skewed: most of the data is concentrated towards the right tail of the distribution. This means that for most of the grid cells, the share of agricultural grassland under liquid manure use is more than 90% mean = 91.9%, standard deviation = 8.5%).

Figure 17 – Use of liquid manure on agricultural grasslands (2021)



3.5 Conclusion

In this chapter, the possibilities were explored for National Statistical Offices (NSOs) to monitor relevant biodiversity (-pressure) indicators. Here, two pressures on the living environment of the declining farmland birds' populations in the Netherlands were analysed. The first attempt was undertaken to construct two indicators based on scientific literature: the grazing intensity of dairy cattle and the use of liquid manure on agricultural grasslands. For these two indicators, geocoded data from the 2021 agricultural census of Statistics Netherlands was used. For more than 17.000 individual agricultural holdings, multiple variables were used related to their concerning agricultural practices to construct the indicators.

During the research, it became apparent that there exists a clear trade-off between the detail of (spatial) analysis and the obligation to conform to legal guidelines related to statistical privacy. As a NSO, Statistics Netherlands is legally obliged to ensure that privacy sensitive information cannot be disclosed to the public in a way that can be traced back to a particular entity, such as an individual agricultural holding. In order to ensure this statistical privacy, data should be aggregated. In this research, data was aggregated into spatial units (rectangular grid cells of 5 by 5 kilometres) in order to analyse the spatial patterns of the two indicators. However, the size of the grid cells determines how much agricultural holdings are captured by a particular grid cell and, therefore, whether the aggregated data of this cell can be published or not. Here, the trade-off originates: larger grid cells are more likely to fulfil all legal requirements related to publishability, however are less likely to sufficiently show spatial differences. To find the right grid resolution depends on several factors, such as data distribution, research objective and subject, and requires a trail-and-error based testing (as also shown in this research). Another possibility is to aggregate data into administrative units, such as provinces, municipalities or other NUTS regions. The added benefit of this can be the combined use of other statistics that are collected at this spatial level. Again, this choice depends on the research objective.

Furthermore, in developing an indicator for the grazing intensity of dairy cattle in the Netherlands, several approaches were used using different variables from the agricultural census. The different approaches, based on data needs, resulted in different results. The level of data availability and detail of data determines the potential accuracy of an indicator, and should therefore be considered during the creation of such indicators. For example, in the case of the grazing intensity indicator, the different spatial patterns found among the different ways of calculating grazing intensity could potentially result into different policy recommendations. While the different approaches cannot be characterised as 'good' or 'bad', it should be noted that they measure a different phenomenon. Exploring these differences is recommended during the process of designing such indicators.

When designing indicators to measure complex phenomena, it is inevitable to make certain assumptions. For example, for the indicator concerning the use of liquid manure on agricultural grasslands, the assumptions were made that each plot of agricultural grassland is similarly covered in manure, and that for each areal unit of agricultural grassland, a similar amount of manure is applied by the farmers. However, it is likely that in the 'real world', this is not the case. For instance, farmers may apply less manure on grassland plots that are managed following ecologically sustainable practices, or fertilize only a part of their grassland area. Additional data, such as data on land management practices or manure quantities, may improve the indicator to capture these differences. Now, these data sources were not sufficiently explored, and further research is needed to explore these possibilities.

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