ICAS X
2026
8–10 July 2026 • Kraków, Poland

# Determining managed and non-managed grassland areas and grassland with trees and shrubs cover using registry and earth observation data.

**Authors**
Anika Vaarhorst, Larissa van Vliet, Statistics Netherlands (CBS), The Hague, The Netherlands.
Email: aam.vaarhorst@cbs.nl

This project is part of the MAS2023 project (Modernization of Agricultural Statistics 2023) that is co-funded by Eurostat. The MAS2023 project is a collaboration between the national statistical institutes of France, Germany, and the Netherlands. It comprises of six sub-projects, one of which is the subject of this paper. The project on grassland management is a Dutch project.

**Abstract**
According to new EU regulations (2023/1538) Statistics on Agricultural Input and Output (SAIO) every EU member state has to report the area of managed grassland at national and regional level. In addition, grassland areas with trees and shrubs also need to be reported. This will lead to an increased response burden for farmers. To prevent this increase of burden new approaches to obtain the requested data are needed.
Therefore, we started to investigate if earth observation data can discriminate between managed and non-managed grassland areas. In addition, we would like to investigate if maps containing information on trees and shrubs can be used to determine grassland areas with trees and shrubs cover.

In the Netherlands, farmers have to register their parcels in the Land Parcel Identification System. In this registry the following types of grassland can be registered: a) temporary grassland, b) pasture and meadows, c) rough grazings with agricultural activities and d) rough grazings without agricultural activities (main function nature). Using satellite data, information on these parcels can be obtained. Our goal is to determine if satellite data can be used to discriminate between pasture and meadows (managed permanent grassland) and rough grazings with agricultural activities (non-managed grassland). As a proof of principle, we are currently investigating a set of vegetation indicators based on Sentinel-2 satellite data in a part of the Netherlands (see figure).

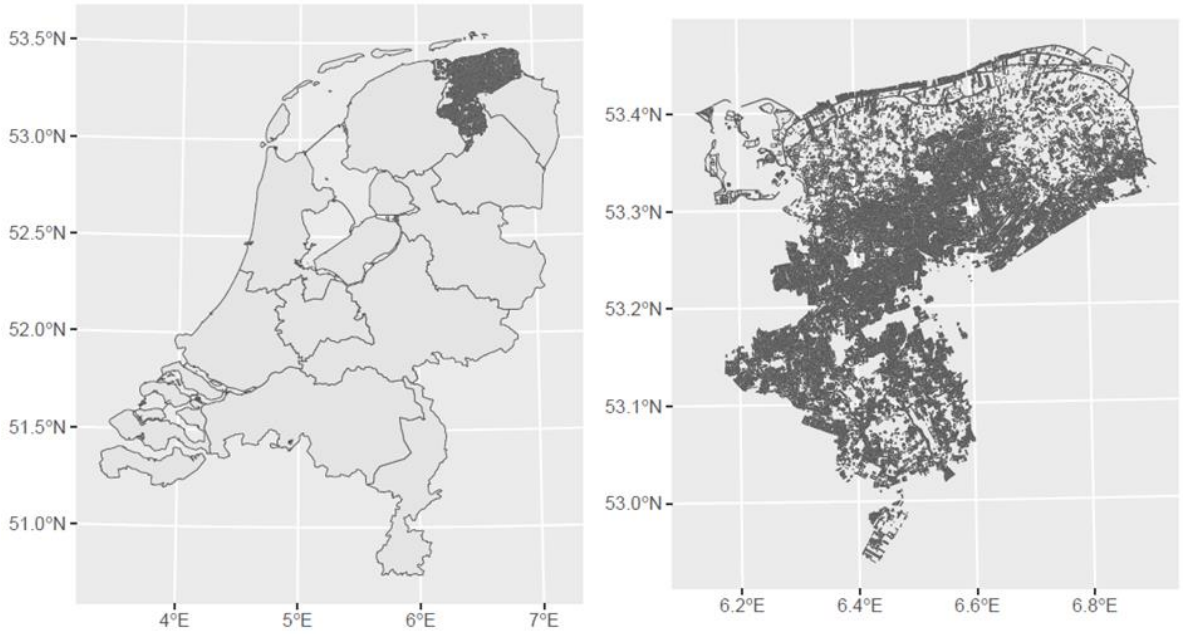


**Figure:** The figure on the left shows the location of the parcels located in the provinces Groningen and Drenthe of which we received information on the ARVI, NDI7, NDII, NDVI, SAVI and NDTI indicators based on Sentinel-2 satellite data from the Netherlands Enterprise Agency. The figure on the right shows the outlines of the parcels.

**Keywords**
Innovative data collection, earth observation data, Sentinel-2, SAIO, grassland management, trees and shrubs on grassland

## 1. Introduction

According to new EU regulation on Statistics on Agricultural Input and Output (SAIO, Regulation (EU) 2022/2379 and the corresponding implementing regulations (EU) 2023/1538, every EU member state has to report statistics on areas of managed permanent grasslands, managed permanent grassland areas that are fertilized, the area of permanent grassland covered with trees and shrubs and permanent grassland areas with managed agro-forestry [1, 2].

If this information is collected by questionnaires, this will lead to an increased response burden for farmers. To prevent this increase of burden, new approaches to obtain the requested data are needed. Therefore, we investigate if earth observation data and/or registries can be used to distinguish between managed and non-managed permanent grasslands and if it can be used to identify permanent grassland covered with trees and shrubs.

According to the implementing regulations (EU) 2023/1538, managed permanent grassland is defined as permanent grassland which is regularly (not necessary annually) managed by reseeding, irrigation, fertilized, or treatment with plant protection products as part of the farm long term management plans [1]. According to the Land Parcel Identification System (LPIS) registry in the Netherlands, permanent grassland is defined as grass that has not been included in crop rotation for at least 5 years [3]. Moreover, permanent grasslands with yields lower than 5 tons dry matter per hectare per year and where the soil quality is not improved by fertilization, cultivation, reseeding, treatment with plant protection products or drainage are registered with a different code than permanent grasslands with yields higher than 5 tons of dry matter per hectare per year [3]. Therefore it is possible to distinguish between managed and non-managed grassland in the Netherlands using the LPIS registry. As a proof of principle, we are currently investigating if several indicators based on Sentinel-2 satellite data differ between permanent grasslands with high yields (managed permanent grassland) and low yields (non-managed permanent grassland) in the northern part of the Netherlands.

Currently, no information on grassland parcels with trees and shrubs cover is available in the LPIS registry in the Netherlands. However, in the Netherlands there are different maps for different kinds of green vegetation available [4]. These maps provide a spatial representation of green space in the Netherlands at a resolution of 5 x 5 meters and 10 x 10 meters [4]. There are separate maps for different types of greenery, including maps on trees, shrubs and grasses. Here we investigated if the map providing a spatial representation of trees at a resolution of 10 x 10 meters can be used in combination with the LPIS registry to identify grassland parcels covered with trees.

## 2. Materials and methods

### 2.1 Materials and methods on managed grassland areas

From the Netherlands Enterprise Agency we received several files we used for our explorative study if and how several indicators based on Sentinal-2 satellite data differ between managed and non-managed grassland parcels. First, we received a file containing information on the type of crop grown, the area and the x-, y-coordinates of that parcel for the Netherlands. Second, we received a file containing information on how many times a parcel was mown. This file also contained a unique identifier and a multi-polygon describing the boundaries of for 25.898 parcels in the North of the Netherlands for the year 2024 (see figure 1).

Both files were joined using a spatial join. Next, the parcels registered as managed permanent grassland parcels (n = 15.933) and non-managed permanent grassland parcels (n = 1.697) were selected.

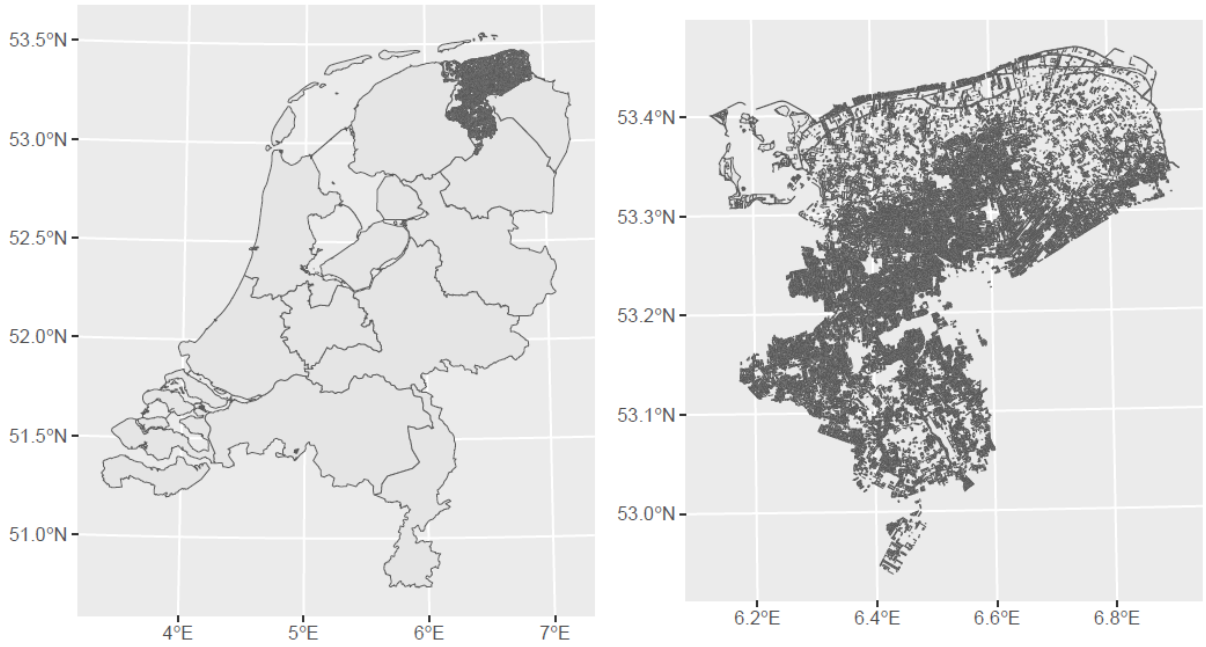


**Figure 1:** The figure on the left shows the location of the parcels located in the provinces Groningen and Drenthe of which we received information on the ARVI, NDI7, NDII, NDVI, SAVI and NDTI indicators based on Sentinel-2 satellite data from the Netherlands Enterprise Agency. The figure on the right shows the outlines of the parcels.

From the Netherlands Enterprise Agency we also received files containing information on the following indicators per parcel: Atmospherically Resistant Vegetation Index (ARVI), Normalized Difference Index 7 (NDI7), Normalized Difference Infrared Index (NDII), Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Normalized Difference Tillage Index (NDTI). Data on these indicators were available from January 2024 until September the first 2024 and obtained using the Sentinel-2 satellite. See table 2 for a short description and the general formula of each indicator. Using the unique identifier, these files can be joined with the file containing information on the type of crop grown and the multi-polygons describing the boundaries of each parcel.

**Table 2:** A description of each signal including the general formulas.

| Full name and abbreviation | General formula |
|---|---|
| Atmospherically Resistant Vegetation Index (ARVI) | (NIR - RED - y*(RED - BLUE)) / (NIR + RED - y*(RED-BLUE)) |
| Normalized Difference Index 7 (NDI7) | (NIR - SWIR2) / (NIR + SWIR2) |
| Normalized Difference Infrared Index (NDII) | (NIR – SWIR1) / (NIR + SWIR1) |
| Normalized Difference Vegetation Index (NDVI) | (NIR - RED) / (NIR + RED) |
| Soil Adjusted Vegetation Index (SAVI) | (NIR - RED) / (NIR + RED + L) * (1 + L) |
| Normalized Difference Tillage Index (NDTI) | (SWIR1 - SWIR2) / (SWIR2 + SWIR2) |

NIR = near infrared band (B08), RED = red band (B04), BLUE = blue band (B02), SWIR1 = Short-Wave Infrared band 1 (B11), SWIR2 = Short-Wave Infrared band 2 (B12), 'L' is added to the formula accounting for soil reflectance, usually with a value around '0.5' (can be between 0 and 1), y = quotient derived from the components of atmospheric reflectance in the blue and red channel

The Sentinal-2 satellite revisit time is every 10 days at the equator, and 5 days with 2 satellites, which results in a revisit time every 2 to 3 days at mid-latitudes [5]. However, due to cloud cover, data from the Sentinal-2 satellite is not always available. Therefore, we investigated for how many parcels and on which dates the data was available to see how this impacts the quality of the data.
Next, as an explorative analysis, we studied how and if the signals differ for managed and non-managed grassland by calculating for every date the median and interquartile ranges aggregated by managed and non-managed grassland. These results were visualized to show the differences.

## 2.2 Materials and Methods to determine permanent grassland covered with trees and shrubs

On August 2025 we have downloaded the map giving a spatial representation on trees from the Groenkaart van Nederland. This map was created by the Dutch National Institute for Public Health and the Environment and shows the location of trees in the Netherlands [4]. All trees taller than 2.5 meters are displayed on this raster map with a resolution of 10x10 meters [4]. The tree cover per grid cell is also expressed in the map (as a percentage of tree cover per grid cell) [4]. The map is derived from the Current Elevations Model Netherlands AHN4 file at a resolution of 0.5 meters [6] from 2022, the BAG (Netherlands Buildings Act) buildings from 2022, and the infrared aerial photograph (CIR file) of the Netherlands from 2022 (at a resolution of 0.25 meters) [4]. Similar maps are available for shrubs and grass [4]. For a detailed description on how these maps were created see this link: https://github.com/rivm-syso/GroeneBatenPlannerPublic/blob/main/Handleiding%20Groene%20Baten%20Planner%202024.18.12.pdf (only available in Dutch).

We visually compared small parts of this map with aerial photos taken in the same year to see if trees were correctly identified. The aerial images were derived from here: https://www.beeldmateriaal.nl/bekijk-luchtfotos.

Next the raster map containing information on trees was combined with data available from the LPIS registry from the Netherlands [3]. The LPIS registry contains data on the location of parcels (as polygons) and the type of crop grown. Annually every farmer has to register their parcels in the LPIS registry and indicate which type of crop is grown on the parcel in question on the reference date of May the 15th. The LPIS is maintained by the Dutch Enterprise Agency and available for everyone. Here we used the LPIS version from 2022.

According to the Crop Production Statistics Handbook, which was compiled by Eurostat on the basis of Council Regulation (EU) 2022/2379 and Implementing Regulation (EU) 2023/1538, a grassland parcel is covered with trees and shrubs if at least 5% of the total area is covered with trees and shrubs. Since the polygons of the parcels are known, the area of the parcel can be calculated based on these polygons. Also, the area of the grid cell and the percentage of tree cover per grid cell is known. Suppose you have a parcel of 10.000 $m^2$, this parcel will be categorized as covered with trees when it contains five grid cells of 10 x 10 meters containing trees with a 100% tree cover. The parcel will also be classified as covered with trees when the parcel contains ten grid cells of 10 x 10 meter with a 50% tree cover.

## 3. Results

### 3.1 Results on managed and non-managed permanent grassland areas

In 2024, between January first until September first, there were Sentinel-2 indicators available on 51 days. If there would have been no clouds for this time period, than we would have had Sentinel-2 indicators available on 97 days. As shown in table 3, due to cloudy conditions in January, February and March, there were only 6 days with Sentinel-2 indicators available for these three months. In April, Sentinel-2 indicators were available on 9 days and in May indicators were available on 12 days. In June, July and August there where in total 22 days with Sentinel-2 indicators available.

**Table 3**: The number of days per month were Sentinel-2 indicators were available for grassland parcels in the North of the Netherlands.

| | Number of days with data available | | |
|---|---|---|---|
| **Month** | **Potential days** | **In practice** | **Percentage** |
| January | 11 | 3 | 27% |
| February | 12 | 1 | 8% |
| March | 12 | 2 | 17% |
| April | 12 | 9 | 75% |
| May | 13 | 12 | 92% |
| June | 12 | 5 | 42% |
| July | 12 | 8 | 67% |
| August | 12 | 9 | 75% |

From the 17.630 grassland parcels, there were 17.136 parcels with indicators available for at least one date between January 2024 until the first of September 2024. Depending on the date, the number of parcels with the indicators available ranged between 17 (0,1%) and 17.134 (97,2%). For example, in January data on the indicators were available on three days. On January the 22$^{nd}$, for 15.501 parcels (87,9%) indicators were obtained. For the other 2 days, indicators for 56 and 6.176 parcels were obtained. In the next month, indicators were available on the first of February, with 13.692 parcels covered (77,7%). In March, indicators were available on 2 days, with 2363 (13,4%) and 179 (2,4%) parcels. In April the number of parcels with indicators ranged between 28 (0,2%) and 10.326 (58,5%). On 5 days for less than 10% of the parcels indicators were obtained. In May the number of parcels with indicators ranged between 86 (0,5%) and 17.122 (97,1%) parcels. On three days for more than 90% of the parcels indicators were obtained. In June, July and August the coverage ranged between 0,1% and 97%. In this period, on five dates, for more than 90% of the parcels indicators were obtained. For the results on all dates see figure 2.

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Percentage of parcels with a signal | | | | | | | | | | 0% | | | | | | | | | | | | 88% | | | | | 35% | | | | |
| February | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | | |
| Percentage of parcels with a signal | 78% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| March | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Percentage of parcels with a signal | | 13% | | | | | | | | | | | | | | | | | | | | | | | 2% | | | | | | |
| April | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| Percentage of parcels with a signal | | | | | | 36% | | | 1% | | | | | 35% | | 4% | | | 0% | | 3% | | | 20% | | 7% | | | 59% | | |
| May | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Percentage of parcels with a signal | 96% | | | 14% | | 54% | | | 5% | | 97% | | | 97% | | 40% | | | 85% | | 49% | | | 25% | | 58% | | | 0% | | |
| June | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| Percentage of parcels with a signal | | | | | 2% | | | | | | | | | | 1% | | | | | | | | 19% | | 92% | | | 18% | | 20% | |
| July | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Percentage of parcels with a signal | | | | | | | | 11% | | 12% | | | 0% | | 50% | | | | | 97% | | | 23% | | | | | 70% | | 95% | |
| August | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | |
| Percentage of parcels with a signal | | 26% | | | | | 0% | | | | | 97% | | 9% | | | 97% | | 25% | | | | | 10% | | | 84% | | 5% | | |
| September | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percentage of parcels with a signal | 97% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Images created by the sentinel-2 satellites from the North of Netherlands

**Figure 2**: This figure shows in grey the dates when images from the North of the Netherlands were taken by the Sentinel-2 satellites. For the dates where indicators per parcels could be obtained, the percentage of parcels with a indicators is showed. For the other dates, cloudy conditions prevented that the Sentinal-2 satellites could takes images from the area of interest and indicators per parcel could not be obtained.

Next to see if the indicators differ between managed and non-managed grassland parcels, the median and the interquartile ranges for every indicator per date for managed and non-managed grassland was calculated. Indicators created on dates with less than 1% of the parcels covered were excluded. The results are visualized as showed in figure 3.

For all indicators we found that for most dates the median value was lower for non-managed grassland than for managed grasslands. Only between May the 11$^{th}$ and May the 24$^{th}$ higher median values were found for non-managed grasslands than for managed grasslands. Between February the 22$^{nd}$ and May the 9$^{th}$ the differences between the two types of grassland for the indicators were larger than on the remaining dates.

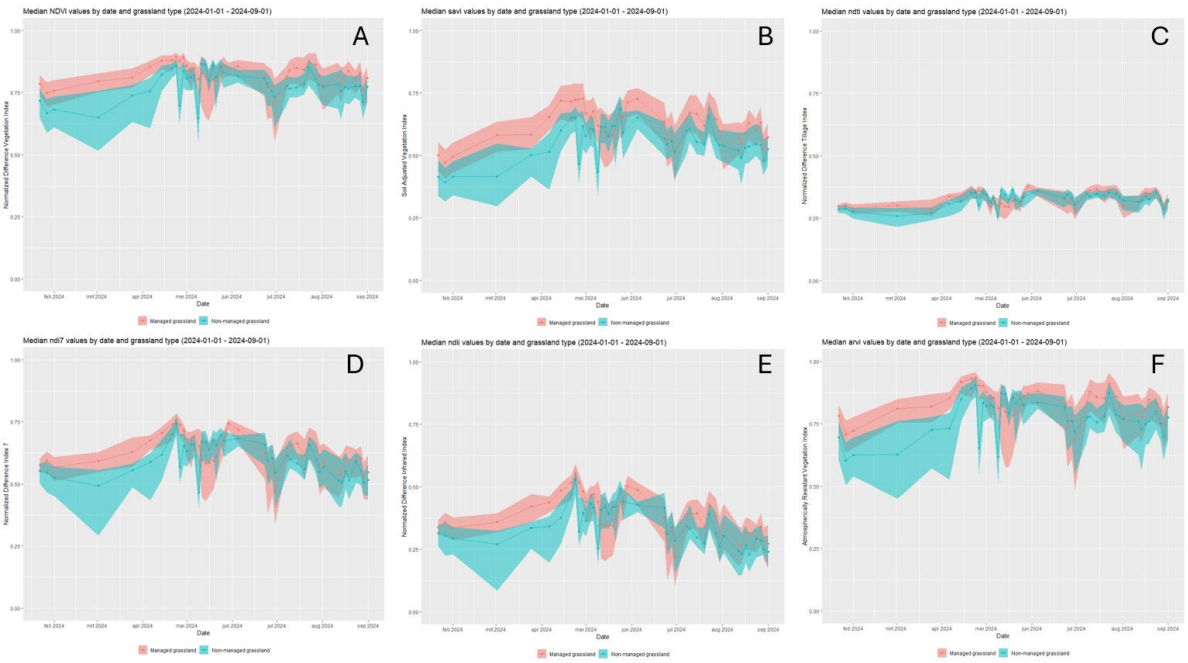


**Figure 3:** These figures show the median values and the interquartile ranges for the different indicators by date and by managed and non-managed grassland. (A: NDVI, B: SAVI, C: NDTI, D: NDI7, E: NDII and F: ARVI).

When looking at the different indicators we found that the differences between managed and non-managed grasslands was smaller for the NDTI indicator than for the other indicators. The remaining indicators showed similar results between managed and non-managed grasslands.
It is noticed that the interquartile ranges for managed grassland are smaller than for non-managed grassland, except for the NDTI indicator.

### 3.2 Results on permanent grassland covered with trees and shrubs

Figure 4 shows the locations of trees taller than 2.5 meters in a part of the municipality of Lisse, the Netherlands according to the Groenkaart van Nederland. When comparing the locations of trees with an aerial photo with a resolution of 27 cm taken in the same year, as showed in figure 4 we observed that locations with trees were correctly identified.


**Figure 4.** The figure on the left shows locations of trees taller than 2.5 meters in a part of the municipality of Lisse in 2022. The figure on the right shows an aerial photo at a resolution of 27 cm of the same location in the same year.

Next the raster map containing information on areas with trees was combined with data from the LPIS registry (see figure 5). As shown in figure 5, some of these parcels contain grid cells indicating trees. In all cases these trees were located on the edges of the fields, which is in agreement with the aerial photo shown in figure 4.


**Figure 5**: In this figure the plots coloured blue were registered as grassland, on the red plots other crops were registered. The grid cells indicate trees.

Next the percentage of trees per grassland parcel was calculated using the method described in the method section. Here we used a slightly different outtake to include more complete grassland parcels as shown in figure 6. We found one grassland parcel covered with more than 5% trees. The grassland parcel itself had an area of 34.204 $m^2$, of which 3.711 $m^2$ was covered by trees. The trees are located on the edge of the field, but within the parcel boundaries, as is shown in figure 6. The results for the other grassland parcels are shown in table 4.

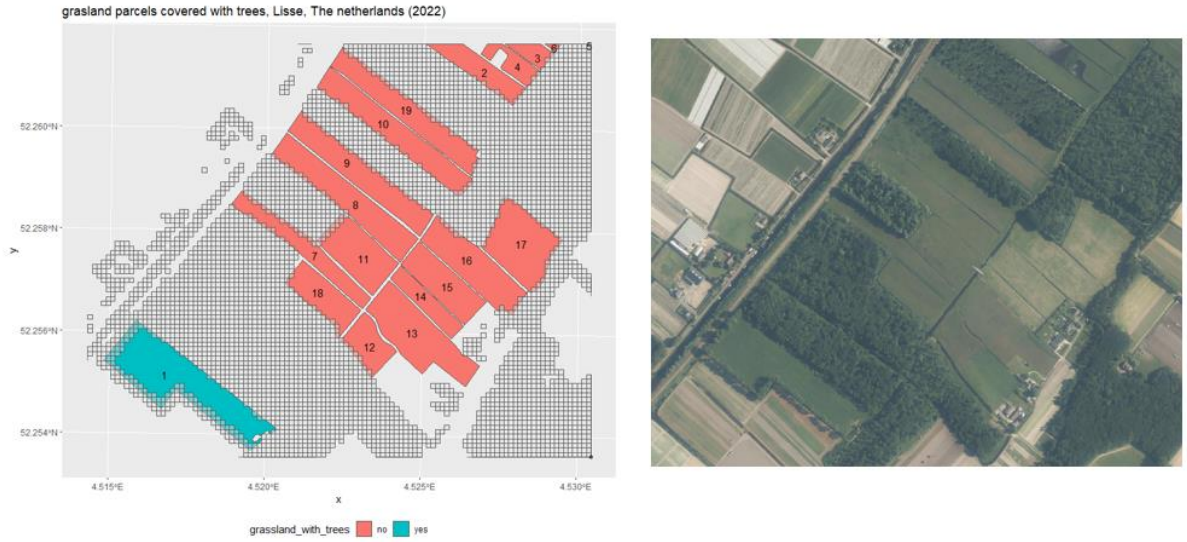


**Figure 6**: In the figure on the left grassland parcels are shown in the municipality of Lisse in 2022. We found one grassland parcel (in blue) covered with trees, which was confirmed by the aerial photo taken in the same year.

**Table 4:** This table shows the area of the grassland parcels shown in figure 6. The field ID's correspond with the ID's shown in figure 6. Note that the parcels with the ID's 2, 3, 4, 5 and 6 are not included in this table. As shown in figure 4, these parcels were not complete, as a result the calculated areas do not correspond with the areas according to the LPIS registry.

| Field ID | Area ($m^2$) | Trees ($m^2$) | Percentage of trees |
|---|---|---|---|
| 1 | 34 204 | 3 712 | 10,9 |
| 7 | 13 522 | 316 | 2,3 |
| 8 | 21 211 | 124 | 0,6 |
| 9 | 19 817 | 287 | 1,5 |
| 10 | 20 488 | 185 | 0,9 |
| 11 | 14 964 | 396 | 2,7 |
| 12 | 8 278 | 142 | 1,7 |
| 13 | 22 025 | 1 | 0,0 |
| 14 | 7 014 | 0 | 0,0 |
| 15 | 12 924 | 0 | 0,0 |
| 16 | 18 277 | 174 | 1,0 |
| 17 | 19 708 | 231 | 1,1 |
| 18 | 11 012 | 204 | 1,9 |
| 19 | 19 482 | 456 | 2,3 |

## 4. Conclusions

### 4.1 Conclusions on managed grasslands

In this explorative analysis, differences between managed and non-managed grassland were observed for all six indicators. We found that for all indicators the values were lower for non-managed grassland than for managed grasslands, except between May 11$^{th}$ and May 24$^{th}$. A possible reason for this observation is that the first mowing events, normally takes place in May for managed grassland [7, 8]. For non-managed grassland the first mowing event usually takes place after June 15$^{th}$ [8].
The largest differences between managed and non-managed grasslands were found in February, March and April. This is in line according to the results described by Bekkema and Eleveld where they describe that visible differences in grassland management intensity are most noticeable in the second half of April [8]. It should be noticed that for the dates with the largest differences observed (i.e. 2-3-2024, 26-4-2024), only a few parcels with data were available. Based on our explorative results and results from literature it seems that indicators based on images taken by Sentinel-2 satellites in April are the most useful to discriminate between managed and non-managed grasslands. Unfortunately, due to cloudy weather, indicators for relatively few parcels were available in April, which makes it difficult to draw conclusions. At this point it is to early to determine which of the indicators is the most promising candidate to distinguish between managed and non-managed grasslands.

### 4.2 Conclusions on trees and shrubs on permanent grassland

At the moment, we think that the method we described in section 2.2 to determine grassland areas with trees and shrubs cover is working well. To test if this method is also useful in regions with different characteristics (for example hilly areas), we are planning to show more examples in different regions of the Netherlands.

So far, we only have studied the map from Groenkaart van Nederland containing information on trees taller than 2.5 meters [6]. We are also planning to study if the map containing information on shrubs is useful to identify grassland parcels with shrub cover.
At this point we have not investigated if the method described in this paper can distinguish between grassland covered with trees and shrubs and agroforestry on grassland. Therefore, we have asked the Netherlands Enterprise Agency if they can provide us information on which grassland parcels agroforestry is practiced. Using this additional information we are planning to study if it is possible to distinguish between grassland parcels covered with trees and shrubs and agroforestry on grassland.

## References


[1] COMMISSION IMPLEMENTING REGULATION (EU) 2023/1538 of 25 July 2023 laying down rules for the application of Regulation (EU) 2022/2379 of the European Parliament and of the Council as reagards crop production statistics. *Official Journal of the European Union,* 2023:187;40-73.

[2] REGULATION (EU) 2022/2379 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 November 2022 on statistics on agricultural input and output, amending Commision Regulation (EC) No 617/2008 and repealing Regulations (EC) No 1165/2008, (EC) No 543/2009 and (EC) No 1185/2009 of the European Parliament and of the Council and Council Directive 96/16/EC. *Official Journal of the European Union,* 2022:315:1-29.

[3] Dataset: Basisregistratie Gewaspercelen (BRP) [Internet]. Rijksdienst voor Ondernemend Nederland, 2022 [Cited 6-2-2026] Available from: https://www.pdok.nl/introductie/-/article/basisregistratie-gewaspercelen-brp-.

[4] Atlas Natuurlijk Kapitaal (ANK) [Internet]. 2024. [Cited 2026 feb 24]. Available from: https://www.atlasnatuurlijkkapitaal.nl/nieuws/bekijk-nieuwe-en-geactualiseerde-groen-kaarten.

[5] Data & Information > Copernicus Sentinel Missions > Sentinel-2 [Internet]. [Cited 2026 feb 24]. Available from: https://documentation.dataspace.copernicus.eu/Data/SentinelMissions/Sentinel2.html.

[6] Dataset: Actueel Hoogtebestand Nederland (AHN) DSM [Internet]. Rijkswaterstaat (Rijk) 2025 [Cited 2026 feb 23] Available from: https://data.overheid.nl/dataset/36461-actueel-hoogtebestand-nederland-dsm--ahn4-.

[7] J. Visscher. Verlenging groeiseizoen grasland. Wageningen UR Livestock Research, Lelystad, 2010. Available from: https://edepot.wur.nl/50627

[8] Bekkema ME, Eleveld M. Mapping Grassland Management Intensity Using Sentinel-2 Satellite Data. *GI_Forum.* 2018; issue 1:194-213.