# A new design to assess Land Degradation Neutrality (LDN) in the Netherlands

How can we better report to the UNCCD for SDG 15.3?

Saskia Keesstra, Erik van den Elsen, Tom Harkema

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Nederland is verplicht om aan de UNCCD (United Nations Convention to Combat Desertification) te rapporteren over de voortgang die is gemaakt omtrent de doelstellingen van de conventie. In dit project is onderzocht hoe de standaard UNCCD methodologie kan worden aangepast om rekening te houden met de specifieke omstandigheden in Nederland. Daarbij ging het om de beoordeling van de geschiktheid van de UNCCD SDG 15.3 methode voor monitoring en rapportage voor de Nederlandse context en welke aanvullende tools aan deze methodologie kunnen worden toegevoegd voor een realistische beoordeling van de Land Degradation Neutrality status en ontwikkeling in Nederland.

The Netherlands is party to the UNCCD (United Nations Convention to Combat Desertification) and is, thereby, committed to report about the progress made towards the objectives of this convention. This project explored the shortcomings of the existing UNCCD methodology, and how it could be adapted to take the specific conditions in the Netherlands into account. In this project, we aimed to assess the suitability of the UNCCD SDG 15.3 monitoring and reporting methodology for the Dutch context, and which additional tools could be added to this methodology to enable a more realistic assessment of the actual Land Degradation Neutrality (LDN) status and evolution in the Netherlands.

Keywords: UNCCD, Land Degradation Neutrality, Land Degradation, Sustainable Development Goal 15.3, Land cover, Soil organic carbon, Land Productivity Dynamics

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# Verification

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Approved reviewer who stated the appraisal,

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date: 23-12-2021

Approved team leader responsible for the contents,

name: dr. ir. M.J.D. Hack-ten Broeke

date: 23-12-2021

# Summary

The goal of this project was to design a monitoring and reporting methodology for SDG 15.3 on Land Degradation Neutrality (LDN) that was in line with the UNCCD (United Nations Convention to Combat Desertification) indicators and reporting format, but also considered the specific national context of the Netherlands, and provided a more realistic assessment of the current land degradation status of the soils in the Netherlands.

The current methodology of the UNCCD and the default global Tier 1 data that has been provided by the UNCCD is deemed insufficient for the Dutch context, since more detailed national Tier 2 data is readily available. The current method is also not considered to be transparent, and the results produced differ from current estimations made using national Tier 2 data. Basic practices, such as crop rotation on non-peat soils for arable land and grassland, are not included in the used methodology. It is unclear how greenhouses are incorporated within the standard methodology, and peatland degradation is not sufficiently dealt with.

The new adapted methodology includes the abovementioned factors. As part of the adaptation, grassland and cropland are included separately according to their soil type. Crop rotation, a change of mineral soil grassland to mineral soil cropland, or vice versa, is no-longer considered as degradation. Greenhouses are included in the land cover conversion tables under their own category. Alongside this, peatland under cultivation is assumed to be degradational, even if the land cover does not change.

Additionally, national Tier 2 data was used instead of the global Tier 1 data originally provided. To assess the differences in the methodologies the following methods were used and compared to obtain a land degradation neutrality (LDN) number:

- Original UNCCD methodology with Tier 1 data.
- Original UNCCD methodology with Tier 2 data.
- Newly adapted UNCCD methodology with Tier 2 data.

According to the original UNCCD methodology, around 9.6% of the Netherlands' soils have been degraded. This number rises to 22.6% with the introduction of more detailed, Tier 2 data. This is partly caused by the buffering effect of the coarse resolution of the Tier 1 data. The Tier 1 land cover data shows relatively little grassland to cropland conversion (or *vice versa*). Whereas using the more detailed Tier 2 data with the same method shows that these are the two largest trends in conversion of land cover. The practice of crop rotation between parcels that are within one grid cell of the coarse Tier 1 data was not registerable as a land use change and is thus buffered. However, this became apparent using the Tier 2 data resolution.

With the newly adapted UNCCD methodology, the land degradation number was reduced to 11.7%.
The degradation status of the Netherlands is focused much less on mineral soils than it seemed, based on the original UNCCD methodology. Also, merging cropland and grassland areas as one class affected the result, because crop rotation reduced the degradation to zero in grassland and cropland areas on mineral soils.

Additionally, the introduction of peat soils as a separate class impacted the calculation of degraded land. In the new classification, all peatland under cultivation (grassland and cropland) was classified as under degradation, even if the class did not change for the criterion soil organic carbon. The reason for this choice is that drained peatland oxidises, even when under permanent grassland and, therefore, degrades. Due to this, the degradation neutrality number increased from 9.6% to 11.7%.

# 1 Introduction

## 1.1 Background

The Netherlands is party to the UNCCD (United Nations Convention to Combat Desertification) and is, thereby, obliged to report about the progress made towards the Land Degradation Neutrality (LDN) objectives of the convention. Pre-2018, UNCCD reporting for countries not directly affected by desertification, such as the Netherlands, related mainly to the support provided to developing countries towards combatting desertification and drought occurring there. However, the national reporting of the Convention has evolved considerably over the past two decades. From 2018 onwards, the national reporting process has involved two main types of information:

- Data on progress made in-country towards the five strategic objectives related to the condition of ecosystems and populations, drought, and global environmental benefits.
- The mobilisation of financial and non-financial resources to support implementation of the Convention in-country and in other countries.

For the first type of information, the UNCCD adopted SDG target 15.3: *"By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation neutral world."* and SDG indicator 15.3.1 to lead reporting. Specifically, UNCCD parties are required to report on the proportion of land that is degraded over total land area using, in principle, the following three indicators:

- Trends in land cover (referred to in this report as *"LC change").*
- Trends in land productivity or functioning of the land (land productivity dynamics (referred to in this report as *"LPD"*)).
- Trends in carbon stocks above- and below ground (soil organic carbon stock (referred to in this report as *"SOC")*).

The Netherlands currently does not have a country-specific assessment method for SDG 15.3. In addition, the Dutch Government has not appointed an organisation to perform this task.

The UNCCD has provided a general assessment methodology, that does not consider the specific context of land degradation processes in specific countries that contribute to it as parties. It is important to know how possible adaptations to the general methodology of the UNCCD could change the Land Degradation Neutrality (LDN) assessment for the Netherlands.

For the 2018 reporting process, with a view to reducing the reporting burden, the UNCCD Secretariat and Global Mechanism provided the Convention's Parties with default Tier 1 data on the metrics associated with the three land-based indicators related to SDG 15.3.1. The data presented in the document were based on land use change that was derived from satellite imaging, ISRIC (International Soil Reference and Information Centre) soil grids, and NDVI (Normalized Difference Vegetation Index) data, to assess land productivity.

Wageningen Environmental Research was requested to assess the robustness and accuracy of the LDN assessment provided by the UNCCD. An assessment was undertaken and a resultant internal report was produced from this assessment in March 2019.

In the assessment, the default Tier 1 LDN calculations provided by UNCCD were found to be unsuitable for the Dutch context. The method used was not found to be transparent, and the results produced did not correspond with the information provided. The reported estimated land use change seemed to overestimate the conversion from agriculture into artificial surfaces compared to Tier 2 data available for The Netherlands.

In addition, the rotational use of non-peat soils for arable land and grassland was not taken into account in the method used.

In addition, the second indicator: 'The Land Productivity dynamics' which is based on NDVI data, clearly had little relationship with the actual Net Primary Production (NPP) in The Netherlands, as evidenced by Centraal Bureau voor de Statistiek (CBS – Central Bureau of Statistics). On the issue of data and whether these represent soils in the Netherlands, we conclude that on the Soil Organic Carbon (SOC) stocks, the numbers are high compared to other estimates and measures of SOC in Dutch agricultural and natural soils as provided in the LSK (Dutch Soil Sampling Set). Furthermore, peatlands and the loss of carbon through land subsidence is not taken into account.

In our 2019 assessment, we concluded the following:

- The methodology used by the UNCCD is currently not transparent. Therefore, we recommended asking the UNCCD to provide the data-sources and a description of the methodologies used. It is currently not clear how the UNCCD calculated that an area of 3,313 $km^2$ of land is degraded in the Netherlands.
- The data provided by UNCCD for the most recent UNCCD reporting in 2018 does not, or at least insufficiently, reflect the condition and situation in the Netherlands. The Netherland has available and can provide better and more detailed information on the status of its soils.
- We recommended collecting better quantitative data than currently used, based on at least Tier 2 type of data. However, it is important to realise that every dataset that would be used as the basis of a land use change assessment would give different results because of difference in definition of the land use classes, differences in resolution and differences in the characterisation of the classes.
- The data provided by UNCCD currently do not reflect the situation of land degradation in the Netherlands. The parameters evaluated were overestimated by as much as 50% according to our assessment.
- There are other land degradation processes that were not taken into account that are very relevant for The Netherlands to monitor, such as soil compaction, land subsidence, soil salinisation and soil pollution.

Therefore, the Dutch Government's Ministries of Agriculture, Nature and Food Quality (Ministeries of Landbouw, Natuur en Voedselkwaliteit (LNV)) and Foreign Affairs (Buitenlandse Zaken (BuZa)) requested an evaluation of what would be required to adapt the UNCCD methodology to the Dutch situation, without changing the actual methodology; by using higher resolution data and including specific degradation processes and land use changes.

## 1.2 Objectives

The assignment request can be summarised as follows: Perform the original UNCCD monitoring and reporting methodology for SDG 15.3, and develop a subsequent methodology that takes into account relevant, context-specific processes that are currently not considered in the original methodology, including:

i. Crop rotation of grassland and arable land;
ii. Conversion of land into greenhouses; and
iii. Peatland degradation;

to be able to realistically assess the current land degradation status of the soils in the Netherlands.

Sub-objectives:

- Evaluate the existing UNCCD methodology in more detail and identify its suitability for the Netherlands.
- Perform the existing UNCCD methodology for the Netherlands to verify the methodology.
- Design a merged methodology in a single assessment method that is in line with the existing UNCCD standard, but is more specifically suitable for use in the Netherlands' context and that takes the three identified differences compared to the UNCCD methodology into account, namely: i) crop rotation of grassland and arable land; ii) how to deal with new greenhouses; and iii) includes peatland degradation.
- Perform the adapted UNCCD methodology, including the three additional processes.
- Compare with existing UNCCD methodology.

## 1.3 Study Design

A more detailed study of the current status of soil degradation in the Netherlands is needed, together with an assessment of relevant land degradation processes and their indicators linked to soil threats as they have been described by the European Commission.

WENR has worked on a number of European soil degradation related projects in the last few years (DESIRE, RECARE, SoilCare). The experience and information collected in these projects was leveraged in this project to design of a new assessment methodology that complements existing Land Degradation Neutrality initiatives in the Netherlands and SDG 15 reporting by the Netherlands.

The following steps were followed:

Step 1: An assessment methodology was proposed for the three identified degradation processes, including suitable indicators.
Step 2: The existing UNCCD / SDG 15.3 methodology was evaluated and compared in detail to identify its suitability for the Netherlands.
Step 3: A methodology was designed that merged all information and methods. The developed method will be submitted to the UNCCD for approval (by BuZa) and adjusted if necessary.

In a second phase, the designed methodology was tested and built using the data of the previous reporting period for the Netherlands. The output of Step 2 (as above) was compared to the UNCCD datasets.

# 2 Methodologies for map production

A detailed plan for assessing LDN in the Netherlands, including an assessment and evaluation of the methodology was made and reported. Assessment methods used and databases that were consulted were also reported.

## 2.1 Methodology using recommended datasets

In this section, we will briefly explain the methodology developed by the UNCCD. For further details we refer to the UNCCD guidelines for Land Degradation Neutrality assessment (Cowie, 2020). The method as described by the UNCCD centres around three criteria that are evaluated on Tier 1 data. The three criteria were: i) land cover change; ii) land productivity change and iii) soil carbon content change.

**Land cover change**
In the guidelines of the UNCCD for the country assessment of LDN, Table 1 was used to assess the land cover change. For six land use classes, an evaluation as to whether conversion causes degradation, restoration, or remains stable was made.

***Table 1*** *UNCCD table of land use types and how they are used to assess the Land Cover changes. Major Land Cover processes are identified and boxes are colour-coded as improvement (green), stable (blue) or degradation (red). Table adapted from UNCCD report: Default data: methods and interpretation (UNCCD, 2018).*

| | | **Final Class** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Tree-covered area | Grassland | Cropland | Wetland | Artificial Surfaces | Other land |
| **Original Class** | Tree-covered area | Stable | Vegetation loss | Deforestation | Inundation | Deforestation | Vegetation loss |
| | Grassland | Afforestation | Stable | Agricultural expansion | Inundation | Urban expansion | Vegetation loss |
| | Cropland | Afforestation | Withdrawal of agriculture | Stable | Inundation | Urban expansion | Vegetation loss |
| | Wetland | Woody Encroachment | Wetland drainage | Wetland drainage | Stable | Wetland drainage | Wetland drainage |
| | Artificial Surfaces | Afforestation | Vegetation establishment | Agricultural expansion | Wetland establishment | Stable | Withdrawal of settlements |
| | Other land | Afforestation | Vegetation establishment | Agricultural expansion | Wetland establishment | Urban expansion | Stable |

**Land productivity: Identification of "degradation processes" at national level – land productivity dynamics (LPD)**
When calculating the proportion of degraded land for SDG indicator 15.3.1 at national level, the LPD default dataset was aggregated into two classes as *"degraded"* and *"non-degraded",* as indicated in Table 2. Table 2 shows the aggregation of land productivity dynamics default data for the calculation of Sustainable Development Goal indicator 15.3.1.

***Table 2*** *Aggregation of land productivity dynamics default data for the calculation of Sustainable Development Goal indicator 15.3.1. Table adapted from UNCCD report: Default data: methods and interpretation (UNCCD, 2018).*

| Land productivity dynamics (LPD) values | LPD classes | Degradation status for the calculation of Sustainable Development Goal 15.3.1 |
|---|---|---|
| 1 | Decline | Degraded |
| 2 | Moderate Decline | |
| 3 | Stressed | |
| 4 | Stable | Non-degraded |
| 5 | Increasing | |

**Soil organic carbon and determining degradation**

In general, any loss in soil organic carbon (SOC) stocks is considered as degradation (see Table 3). However, as the magnitude of SOC loss is important in differentiating significant from non-significant losses, a general default rule of 10 percent loss over 20 years (the duration period of a change factor) was used. This threshold loss represents a loss of 0.05 per cent per annum as compared to a reference year, and indicates sustained low-level degradation.

If countries decide to populate management factors ($F_{MG}$) and input factors ($F_I$) for use in land changing classes and/or remaining in the same LC class, then the sensitivity of the default threshold level for SOC stock degradation may be reconsidered to detect areas only impacted by management and/or input differences. In practice, FMG and/or FI have smaller impacts on the total SOC stocks that can be less than 10 percent in 20 years.

***Table 3*** *UNCCD table of land use classes used for assessment of soil organic carbon stock changes, where default land use factors (FLU) lead to losses (red), gains (green) or no change (blue). Table adapted from UNCCD report: Default data: methods and interpretation (UNCCD, 2018).*

| | | Final Class | | | | | |
|---|---|---|---|---|---|---|---|
| Original Class | | Tree-covered area | Grassland | Cropland | Wetland | Artificial Surfaces | Other land |
| | Tree-covered area | Stable | Stable | Degradation | Restoration | Degradation | Degradation |
| | Grassland | Stable | Stable | Degradation | Restoration | Degradation | Degradation |
| | Cropland | Restoration | Restoration | Stable | Restoration | Degradation | Degradation |
| | Wetland | Degradation | Degradation | Degradation | Stable | Degradation | Degradation |
| | Artificial Surfaces | Restoration | Restoration | Restoration | Restoration | Stable | Degradation |
| | Other land | Restoration | Restoration | Restoration | Restoration | Stable | Stable |

## 2.2 Improved LDN data for the Netherlands

In this section, we briefly describe the data used in the methodology developed by the UNCCD. For further details, we refer to the UNCCD guidelines for Land Degradation Neutrality assessment (Cowie, 2020). Furthermore, we also describe the data that we have selected to be used in the assessment for the Netherlands.

**Land cover change**
For the assessment of trends in land cover change, the default Tier 1 data recommended for use by the UNCCD is the ESA CCI-LC dataset (ESA, 2017). This is a dataset of consistent global LC maps at 300m spatial resolution on an annual basis for the years 1992 to 2015 (Mattina et al., 2018). The dataset is based on moderate resolution satellite data and produces high-quality and reliable land cover data. For the default methodology, the land cover trend was calculated from this dataset between the years 2000 and 2015.

For the assessment of the LDN methodology in the Netherlands, a Tier 2 dataset was selected with a high spatial resolution and a temporal frequency that was similar to the default UNCCD data. The Landelijk Grondgebruik Nederland (LGN – National Landuse Netherlands; http://lgn.nu) datasets were selected for this assessment. The LGN datasets are nationwide land use/ cover datasets based on satellite data for the Netherlands with a spatial resolution of 25m. Since 1986, they have been updated with a frequency of about three- to six years. Since the 2018 version of the LGN dataset, an annual update of the data has been made. The LGN datasets that were used to determine the land cover trend were LGN4 (1999-2000) and LGN7 (2012).

**Soil organic carbon**
For the assessment of trends in soil organic carbon stocks, the default Tier 1 data recommended for use by the UNCCD is the ISRIC SoilGrids250m (https://soilgrids.org/). This was, however, only used as a baseline, as consistent data on multiple years within the trend was unavailable. The change in carbon stock was, therefore, derived from a land cover conversion table provided by the UNCCD (Table 3), in which each conversion type was classified as decreased, stable, or increased carbon stock.

A direct dataset on soil organic carbon trends in the required years for the assessment (2000-2015) is also not available for the Netherlands. Therefore, it was determined that the same land cover conversion table used in the UNCCD would be used in the assessment. The available land cover data (the LGN datasets) would, however, be of higher quality than the datasets that were used in the default method for soil organic carbon trends.

**Land productivity dynamics**
For the assessment of land productivity dynamics (LPD), the default Tier 1 data recommended for used by the UNCCD are the Joint Research Centre (JRC) LPD datasets (Ivits & Cherlet, 2013). These are 1km resolution datasets that are based on daily updated SPOT VGT normalised difference vegetation index (NDVI) images. The data is available for between the years 1999 and 2013. Based on the data, each pixel is classified as declining, moderately declining, stressed, stable, or increasing, regarding land productivity dynamics.

Several drawbacks regarding the use of this dataset as a proxy for the LPD for The Netherlands were already mentioned in the Assessment of the UNCCD report for The Netherlands (internal report). Variation in weather conditions on the NPP trend analysis in the default dataset were, for instance, not taken into account. However, there is currently no nationwide dataset available for the Netherlands with similar data on LPD that could have been used in the UNCCD methodology. It was, therefore, deemed necessary to use the JRC dataset in the assessment for the methodology of the Netherlands.

## 2.3 Designed LDN methodology for use in the Dutch context

The designed merged methodology considers the three identified difference compared to the UNCCD methodology:

i. Crop rotation of grassland and arable land;
ii. How to deal with new greenhouses;
iii. Inclusion of peatland degradation.

In the section below, the implemented changes are explained.

**Adapted methodology for land cover change**
For land cover change, the LGN dataset was used that has a resolution of 25m. Each pixel was evaluated for the changes to land cover for 2000 to 2012, as per the methodology of the UNCCD.

***Table 4*** *Conversion table for land cover change, adapted to Dutch context; instead of 'grassland' and 'cropland', a subdivision was made between these forms of land use on mineral soils and on peatland. Vertically, all 'source' land cover forms are listed, horizontally all 'destination' land cover forms are listed. Colour-codes for land cover change: red: decline, green: increase, blue: stable. 'X' designates an impossible conversion; in this case peat soil cannot be converted to mineral soil and vice versa.*

| | | **Final Class** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Original Class** | **Land Cover** | Tree-covered area | Mineral soil grassland | Mineral soil cropland | Peat soil grassland | Peat soil cropland | Wetland | Artificial Surfaces | Green-houses | Other land |
| | Tree-covered area | | | | | | | | | |
| | Mineral soil grassland | | | | X | X | | | | |
| | Mineral soil cropland | | | | X | X | | | | |
| | Peat soil grassland | | X | X | | | | | | |
| | Peat soil cropland | | X | X | | | | | | |
| | Wetland | | | | | | | | | |
| | Artificial Surfaces | | | | | | | | | |
| | Greenhouses | | | | | | | | | |
| | Other land | | | | | | | | | |

**Implemented changes:**

1. For grassland and cropland, a distinction was made between mineral and peat soils.
2. Grassland and cropland in mineral soils were merged into one category.
3. Greenhouses were added as a category.

**Justification of changes:**

**Addition 1)** For the categories 'grassland' and 'cropland', we distinguished between two soil categories: mineral soils and peatland.

**Addition 2)** We merged the land use types 'grassland' and 'cropland'. This was carried out, as in the Netherlands, most grassland is cultivated in rotation with crops, such as maize and wheat. Therefore, the conversion from grassland to cropland, and *vice versa,* has no meaning, and, therefore, should be considered as one category, as long as it does not change into another land use type. On peat soils, the original classification was retained, as there is no crop rotation on peatland in this way. If such a conversion is implemented, it is generally a permanent change and can, therefore, be considered as restoration from crop to grassland, and as degrading when the conversion is in the other direction.

**Addition 3)** We added the category 'greenhouses' to the table; as it does not fit in artificial surfaces or cropland, Although, on average, a relatively small amount of the total agricultural land surface in the Netherlands is used for greenhouses (0.51%), the area in some provinces can constitute up to 3.7% (Zuid-Holland, 2018 – source: https://www.clo.nl/indicatoren/nl211908-agrarisch-grondgebruik-).The conversion from cropland to greenhouses is considered as a decline in land cover (thus: 'degradation'); according to the Guidance document for 2018 UNCCD reporting, conversion from 'Any other class' to 'Artificial surfaces' yields a Change factor for land-use change (FLU) of 0.32 (Mattina et al., 2018: Table 9, page 22). Factors smaller than one are considered degradation. This can be explained by the fact that the effective area covered with crops is reduced with the construction of Greenhouses, although the efficiency of the actual land surface that is in use might be greater. There is one exception with the conversion to greenhouses: the conversion from

Artificial surface into Greenhouses is considered 'restoration', as agricultural production moves from zero to a positive value.

**Adapted methodology for Net Primary Productivity (NPP)**

Land productivity estimates the overall above-ground vegetation biomass productivity resulting from all land components and their interactions. It reflects long-term changes in the health and productive capacity of the land and reflects the effects of changes in ecosystem functions for plant and biomass growth (Cowie, 2020).

For the purposes of reporting on SDG indicator 15.3.1 ('the proportion of land that is degraded over total land area'), it is not necessary to quantify the magnitude of change in productivity in biomass units of net primary productivity (NPP); rather, it is important to determine whether productivity is increasing (positive), decreasing (negative), or stable for the land unit over time (Sims et al., 2019).

In this regard, the land productivity dynamics (LPD) dataset provides five qualitative classes of land productivity trends over the time period 1999−2013. These qualitative classes do not directly correspond to a quantitative measure (e.g., tonne/ha of NPP or gross primary production (GPP)) of lost or gained biomass productivity, nevertheless there is an indirect relationship. The five classes are a qualitative combined measure of the intensity and persistence of negative or positive trends and changes of the photosynthetically active vegetation cover over the observed period. While not an absolute measure of land productivity, it depicts trajectories of long-term seasonal dynamics and departures from it that are typically related to overall land productivity change. For a detailed explanation of the classification of the NPP trends using the JRC's dataset, we refer to the UNCCD Good Practice Guidance Report (Sims et al., 2017). The five qualitative JRC classes are subdivided into three classes (decline, stable and increase) according to instructions of the UNCCD Guidance report (Mattina et al., 2018).

***Table 5*** *Net Primary Production change when changing land use class, adapted to Dutch context; instead of 'grassland' and 'cropland' a subdivision was made between these forms of land use on mineral soils and on peatland. Vertically, all 'source' land cover forms are listed, horizontally all 'destination' land cover forms are listed. Colour-codes indicate changes: red: NPP decline, green: NPP increase, blue: stable, or no significant change, 'X' Designates an impossible conversion; in this case peat soil cannot be converted to mineral soil and vice versa.*

| | | **Final Class** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Original Class** | **NPP** | Tree-covered area | Mineral soil grassland | Mineral soil cropland | Peat soil grassland | Peat soil cropland | Wetland | Artificial Surfaces | Green-houses | Other land |
| | Tree-covered area | | | | | | | | | |
| | Mineral soil grassland | | | | X | X | | | | |
| | Mineral soil cropland | | | | X | X | | | | |
| | Peat soil grassland | | X | X | | | | | | |
| | Peat soil cropland | | X | X | | | | | | |
| | Wetland | | | | | | | | | |
| | Artificial Surfaces | | | | | | | | | |
| | Greenhouses | | | | | | | | | |
| | Other land | | | | | | | | | |

**Implemented changes:**

1. We used the land use categories for the assessment instead of the JRC's land productivity dynamics dataset.
2. Land use categories were the same as in the other two sections.

**Justification of changes:**

**Addition 1)** As stated previously, there is currently no nationwide dataset available for the Netherlands that contains similar data on LPD compared to the JRC's dataset. The 1km resolution of the dataset was, however, deemed insufficient for use in a densely populated country, such as the Netherlands. Especially compared to the 25m resolution of the LGN dataset that is used for land cover change and SOC trend. A different approach was considered after additional concerns that weather conditions were not considered, and the fact that this methodology is best suited for water-limited, temperate regions (Sims et al., 2017).

In the UNCCD Good Practice Guidance report, it is stated that changes in land cover type or land use usually result in changed land productivity levels and dynamics (Sims et al., 2017). A logical alternative to the use of the JRC dataset as a proxy for NPP trends is, therefore, the use of the LGN dataset. It is readily available, it has a better resolution, and it is largely unaffected by weather conditions. Considering these upsides, the LGN land use dataset is deemed sufficient as a proxy for trends in NPP, as it is not necessary to quantify the magnitude of changes in NPP. Using expert knowledge, we determined the trend in NPP associated with a certain land use change (Table 5). For the assessment of the conversion of newly introduced classes, we consulted experts in crop production to judge whether NPP would increase or decrease, and to what extent.

**Addition 2)** See section 'Adapted methodology for Land Cover change', implemented changes 1, 2 and 3. For 'grassland and cropland', we sub-divided this into two categories: mineral soils and peatland. This was done, as in the Netherlands all grassland cultivated is rotated with crops, such as maize and wheat. Therefore, the conversion from grassland to cropland and *vice versa* has no meaning, and, therefore, should be seen as one category, as long as it does not change into another land use type.

Table 5 converts the separate LPD classes into two degradation statuses: 'Degraded' and 'Non-degraded'. Using the addition of soil types; mineral soils and peat soils, a more accurate degradation status for the Dutch context was achieved. Although some land use changes are very unlikely, this is not indicated in Table 5, as these changes will not occur in practice and, therefore, will not be taken along in the calculation of the total amount of degraded land surface.

**Adapted methodology for Soil Organic Carbon (SOC)**

The original methodology was based on the data from ISRIC with a 250m grid, which is relatively inaccurate. The original methodology uses actual SOC values as a baseline and changes in these SOC values to assess the trend in SOC. As no periodic SOC values are available on a European scale to monitor SOC dynamics, land use changes were taken as a proxy for SOC dynamics. This methodology was adapted by UNCCD by the use of the combination of land use/land cover maps to make the assessment more precise and of higher resolution. Land use/land cover changes are combined with the SoilGrids estimate, the general bioclimatic zone and the ESA annual assessment of LC in order to make coarse estimates of SOC stock change using change factors (e.g., see Table 3.3.4 in IPCC (2006) for Cropland change factors). Such changes were averaged over 20 years and then applied on an annual basis for the duration of the change within the 2000−2015 period. To allow for a more accurate assessment SOC dynamics for the Netherlands, available land use (change) information from the Landelijk Grondgebruik Nederland (LGN – National soil use Netherlands)-dataset was used to construct the assessment table instead of the coarser UNCCD method (Table 6).

***Table 6*** *Summary of the Soil Organic Matter content (SOC) change matrix for the six UNCCD classes enriched with several new classes relevant for the Netherlands. Red boxes indicate degradation, green indicate land cover improvement and blue indicate stable conditions. The x-es indicate impossible changes (related to soil type).*

| | | **Final Class** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Original Class** | **SOC** | Tree-covered area | Mineral soil grassland | Mineral soil cropland | Peat soil grassland | Peat soil cropland | Wetland | Artificial Surfaces | Green-houses | Other land |
| | Tree-covered area | | | | | | | | | |
| | Mineral soil grassland | | | | X | X | | | | |
| | Mineral soil cropland | | | | X | X | | | | |
| | Peat soil grassland | | X | X | | | | | | |
| | Peat soil cropland | | X | X | | | | | | |
| | Wetland | | | | | | | | | |
| | Artificial Surfaces | | | | | | | | | |
| | Greenhouses | | | | | | | | | |
| | Other land | | | | | | | | | |

**Implemented changes:**

1. The use of the actual land use (change) information as the leading characteristic to assess SOC changes, instead of land cover (LC) changes averaged over 20 years.
2. The use of two soil type categories (mineral and peat soil).
3. The merging of crop and grassland as one.
4. Addition of greenhouses as an extra category.

**Justification of changes:**

**Addition 1)** As described in the introduction above, the UNCCD method comprises averaging land use changes over 20 years and then applied on an annual basis. In the method we propose, we used LGN data to reflect the actual land use changes as a basis to construct Table 6. Cells for the newly introduced classes were filled according to expert judgement.

**Additions 2 and 3)** For grassland and cropland we sub-divided the category into two: mineral soils and peatland. This was carried out as the process of the degradation of SOC is different for the two soil types. In peat soils, both grassland and cropland on peat soils (also when there is no change) are considered as degradation; as peat soils oxidises under these land use types. In mineral soil, crop and grassland are in rotation and, therefore, the conversion from grassland to cropland and *vice versa* has no meaning, and therefore, should be considered as one category, as long as it does not change into another land use type. In the table (Table 6), these blocks show up as stable.

**Addition 4)** We made an exception for the conversion from cropland to greenhouses. This is considered as a decline in land cover (thus: 'degradation'); according to the Guidance document for 2018 UNCCD reporting, conversion from 'Any other class' to 'Artificial surfaces' yields a Change factor for land-use change (FLU) of 0.32 (Table 10, page 24). Factors smaller than one are considered degradation. This can be explained by the fact that the effective area covered with crops becomes smaller with the construction of Greenhouses, although the efficiency might be greater. There is one exception: We describe 'restoration' when an artificial

surface is converted into greenhouses, as it can be argued that more carbon is stored within greenhouses than in artificial (or sealed) surfaces).

Conversion of 'greenhouse to grassland on mineral soil' and 'greenhouse to grassland on peatland soil': this is considered as restoration, as grass roots add more organic material to the soil.
Conversion of 'greenhouse to cropland on mineral soil' and 'greenhouse to cropland on peatland soil': this is considered as stable, as the amount of organic material stored in the soil will be comparable and not change considerably with these conversions.

# 3 Resultant LDN maps

## 3.1 Results using the UNCCD methodology with recommended datasets

The spatial distribution of degraded land between 2000 and 2015 according to the standard UNCCD methodology and the recommended datasets is shown in Figure 1. Degraded areas are scattered throughout the Netherlands, and about 9.6% of the Dutch land area, or about 3,258 km$^2$, was degraded in this time period according to the standard methodology.

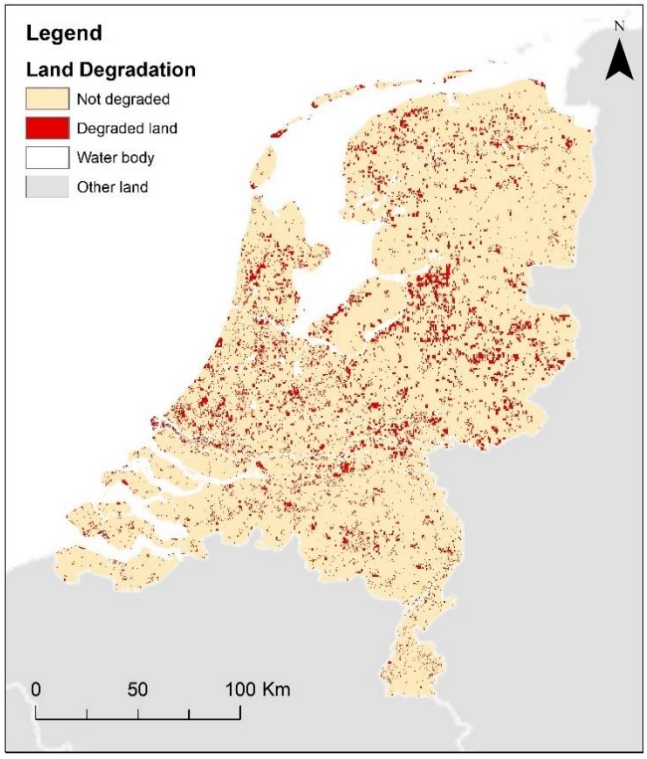


***Figure 1*** *Map of the Netherlands showing the LDN assessment with UNCCD methodology and standard data.*

Looking at the land cover trend data in Table 7, it can be seen that there is a general decrease in area for most classes, apart from artificial surfaces. This can be expected as a result of urbanisation. The data also shows that most land remained within the same class over time. The total area for each class in 2015 is comprised for more than 97% of unchanged land, apart for artificial surfaces, where only 64% of the total area was already an artificial surface in 2000. The rather stable land use change over time can be expected, as the resolution of the data is rather coarse, thus, it has a buffering effect for smaller changes. The data also shows that some water bodies were turned into artificial surface and wetland, but also that some land was being turned into water bodies. The water bodies that remain are left out of Table 7, as these do not affect the land cover change and can cause confusion when compared to data from other datasets.

***Table 7*** *Land cover trends between 2000 – 2015 according to UNCCD methodology and standard data.*

| | | Final Class | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Land Cover Area (km²)** | Tree-covered area | Grassland | Cropland | Wetland | Artificial Surfaces | Other land | Water bodies |
| **Original Class** | Tree-covered area | 3505 | 27 | 30 | 12 | 115 | 0 | 20 |
| | Grassland | 7 | 11850 | 10 | 0 | 268 | 0 | 1 |
| | Cropland | 83 | 58 | 13831 | 0 | 980 | 0 | 4 |
| | Wetland | 13 | 0 | 0 | 608 | 15 | 0 | 2 |
| | Artificial Surfaces | 0 | 0 | 0 | 0 | 2514 | 0 | 0 |
| | Other land | 0 | 0 | 0 | 0 | 1 | 44 | 0 |
| | Water bodies | 0 | 0 | 0 | 2 | 29 | 0 | X |

## 3.2 Results using the UNCCD methodology with improved data from Dutch sources

The spatial distribution of degraded land between 2000 and 2012 according to the standard UNCCD methodology and improved datasets is shown in Figure 2. Degraded areas are abundant throughout the Netherlands and about 22.6% of the Dutch land area, or about 7,478 km$^2$, was degraded in this time period according to this methodology.

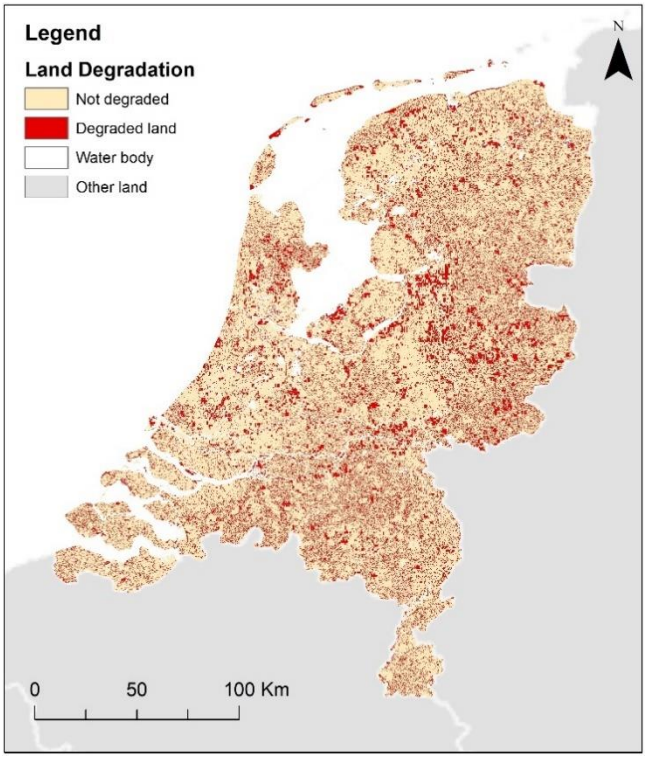


***Figure 2*** *Map of the Netherlands showing the LDN assessment with UNCCD methodology and more detailed data.*

Looking at the land cover trend data in Table 8, it is apparent that the total areas of most land cover classes differ from the standard UNCCD data. According to the LGN dataset, there is significantly more grassland and artificial surface in the Netherlands than the UNCCD dataset suggests. On the other hand, the LGN dataset shows a significantly lower amount of cropland compared to the UNCCD dataset.

Furthermore, when compared to the standard UNCCD methodology, the data shows more change throughout the classes. Where at least 97% of the total area for each class, apart from the artificial surface, remained unchanged in the standard UNCCD methodology, the amount of unchanged area is lower than 80% in all cases for this methodology. This can be explained by the fact that the LGN dataset used in this methodology has a higher resolution. Smaller changes to land cover were considered, compared to the relatively coarse UNCCD land cover data.

One final remark on the results shown in Table 8 is that about 22% of all cropland in 2000 was turned into grassland by 2013. While 14% of all grassland in 2000 was turned into cropland by 2013. These are two of the most significant changes in land cover that Table 8 shows. This can possibly be explained by the crop rotation cycle that will be addressed in the following methodology.

***Table 8*** *Land cover trends between 2000 – 2013 according to UNCCD methodology and more detailed data.*

| | **Final Class** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Original Class** | **Land Cover Area (km²)** | Tree-covered area | Grassland | Cropland | Wetland | Artificial Surfaces | Other land | Water bodies |
| | Tree-covered area | 2863 | 325 | 37 | 31 | 241 | 6 | 51 |
| | Grassland | 507 | 10164 | 1975 | 182 | 595 | 16 | 253 |
| | Cropland | 157 | 2168 | 7054 | 21 | 359 | 1 | 98 |
| | Wetland | 5 | 69 | 1 | 316 | 2 | 1 | 34 |
| | Artificial Surfaces | 261 | 526 | 117 | 11 | 5007 | 2 | 143 |
| | Other land | 6 | 29 | 2 | 3 | 7 | 66 | 41 |
| | Water bodies | 33 | 103 | 14 | 53 | 80 | 28 | X |

## 3.3 Results using the newly adapted methodology and detailed Dutch data sources

The spatial distribution of degraded land between 2000 and 2012 according to the newly adapted methodology and improved datasets is shown in Figure 3. Degraded areas are centralised in certain areas of the Netherlands, and about 11.7% of the Dutch land area, or about 3865 km$^2$, was degraded in this time period according to this methodology.

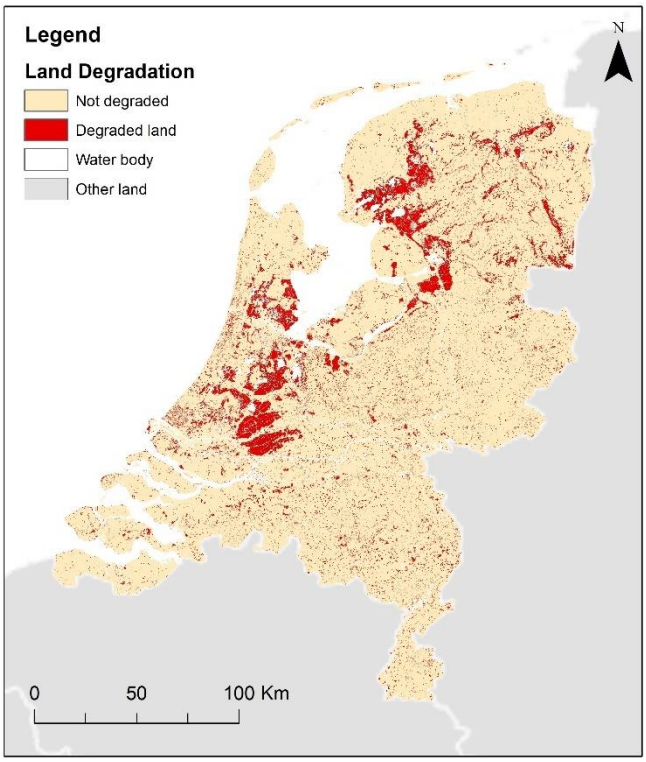


***Figure 3*** *Map of the Netherlands showing the LDN assessment with newly adapted methodology and more detailed data.*

Table 9 shows similar trends compared to Table 8, as it is based on the same data. Slight differentiations occur due to differences in rounding after combining the data with the soil data. Using this methodology, a lot of change in land cover can be seen between 2000 and 2013, a large part of this change in land cover is still the change from grassland into cropland and *vice versa*.

It is noteworthy that the increase of artificial surfaces in the period 2000 to 2013 is only 3.6% (6,064km$^2$ to 6,283km$^2$) according to the improved methodology. The increase of artificial surfaces according to the standard UNCCD method was 56% (2,514km$^2$ to 3,923km$^2$).

***Table 9*** *Land cover trends between 2000 – 2013 according to the newly adapted methodology and more detailed data.*

| | | Final Class | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Original Class | **SOC** | Tree-covered area | Mineral soil grassland | Mineral soil cropland | Peat soil grassland | Peat soil cropland | Wetland | Artificial Surfaces | Green-houses | Other land | Water bodies |
| | Tree-covered area | 2862 | 311 | 35 | 14 | 2 | 31 | 241 | 0 | 6 | 51 |
| | Mineral soil grassland | 481 | 8427 | 1870 | x | x | 134 | 551 | 15 | 16 | 180 |
| | Mineral soil cropland | 152 | 2045 | 6768 | x | x | 20 | 326 | 31 | 1 | 86 |
| | Peat soil grassland | 26 | X | x | 1735 | 88 | 48 | 44 | 2 | 0 | 73 |
| | Peat soil cropland | 4 | X | x | 99 | 171 | 1 | 6 | 1 | 0 | 9 |
| | Wetland | 5 | 39 | 1 | 31 | 0 | 316 | 2 | 0 | 1 | 34 |
| | Artificial Surfaces | 261 | 493 | 111 | 33 | 2 | 11 | 5006 | 3 | 2 | 142 |
| | Greenhouses | 0 | 21 | 4 | 2 | 0 | 0 | 28 | 77 | 0 | 3 |
| | Other land | 6 | 29 | 2 | 0 | 0 | 3 | 7 | 0 | 62 | 34 |
| | Water bodies | 33 | 84 | 13 | 18 | 1 | 53 | 74 | 0 | 19 | X |

# 4 Discussion: Comparison of the results of proposed and current UNCCD methodologies

## 4.1 Effect of better data

When we compare the outcomes of the standard UNCCD methodology to assess LDN with the two different datasets (original and more detailed data) we found that the assessed area of degraded land increased (Figure 4). This was mainly due to the fact that there is more information about the mosaic landscape of the Netherlands on which mineral soils grassland and cropland are cultivated in rotation. In the UNCCD methodology for the assessment of SOC stock, a conversion from grassland to cropland is considered as degradation; and a conversion from cropland to grassland is considered as restoration. On the other hand, the assessment of land use/cover a conversion from cropland to grassland is considered as degradation, and a conversion from cropland to grassland, as restoration. By applying a "one out, all out" rule, a negative change in any of the three indicators results in overall degradation. Therefore, any change related to cropland and grassland resulted in degradation according to the UNCCD methodology. The effect of using smaller scaled pixels for land cover classes caused more pixels to have changed class, which increased the number of pixels that converted into a degrading state. As this is not compensated by a similar increase in restored pixels in the methodology, the total degraded area seems higher.

Figure 4 shows the total LDN assessment of 'het Groene Hart' - an area in the West of the Netherlands - for both the standard methodology and the same methodology with better data. The level of added detail to the assessment is instantly apparent. The assessment with better data shows the detail of the data. Water bodies, new roads and individual plots of land were clearly distinguishable in the assessment. The large squares that occur in both assessments are the pieces of land that are degraded according to the land productivity dynamics assessment. The data used for this assessment remains the same, as more detailed data was unavailable.

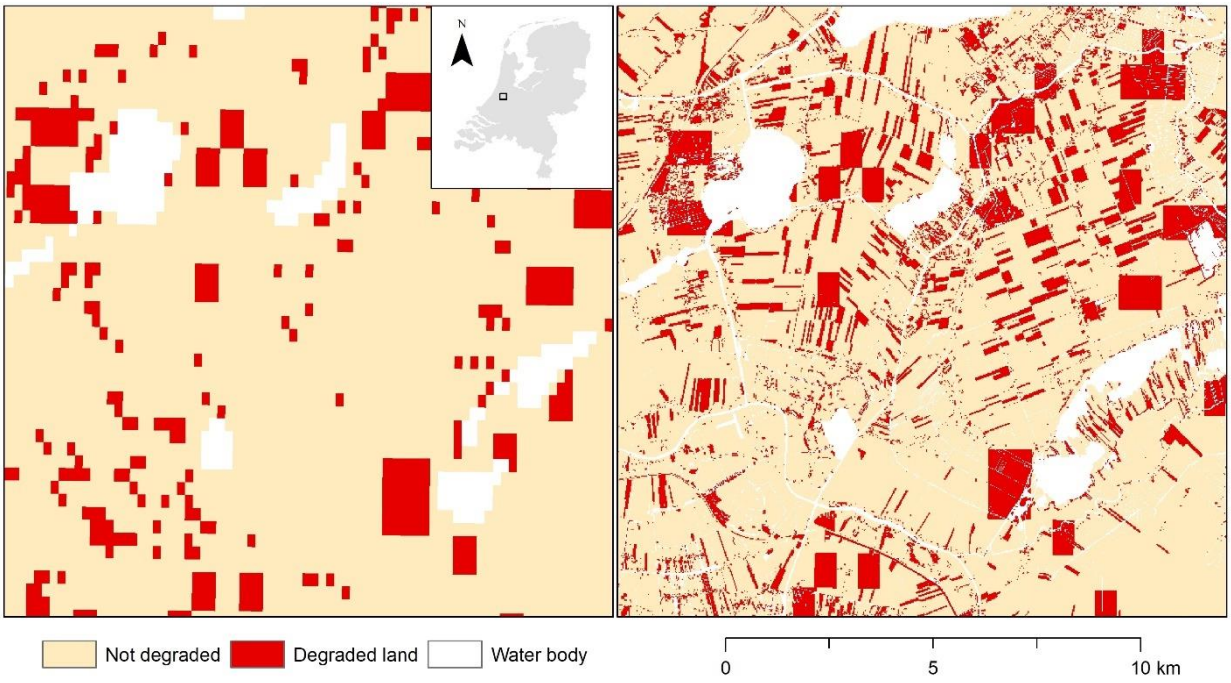


***Figure 4*** *Detail of the Groene Hart area in the West of the Netherlands showing the effect of the more detailed data use. left: LDN assessment with UNCCD methodology original data; right: LDN assessment with UNCCD methodology with more detailed data.*

The degraded area in the more detailed method seems to double in Figure 4. In this agricultural area, crop rotation is a standard practice. By removing the buffering effect of large pixels, any change to a plot of land from grassland to cropland or *vice versa* was considered to be degradational.

## 4.2 Effect of adapted assessment methodology

The assessment of the adapted methodology shows a large drop in degraded land on mineral soils. Three reasons can be found for this:

**Related to land cover criteria:**

1. Crop rotation was not considered as degradational when grassland was turned into cropland. Therefore, all pixels that convert from grassland to cropland were considered as stable on mineral soils. Figure 5 shows an area in the East of the Netherlands (Achterhoek), where this change is clearly depicted.
2. Smaller effects were found related to other changes to the table are found due to the addition of the class 'greenhouses'. In the original methodology, greenhouses were considered as artificial surfaces. The conversion to greenhouses is not always a negative, as is now indicated. This lead to a reduction of the pixels considered as degradation.

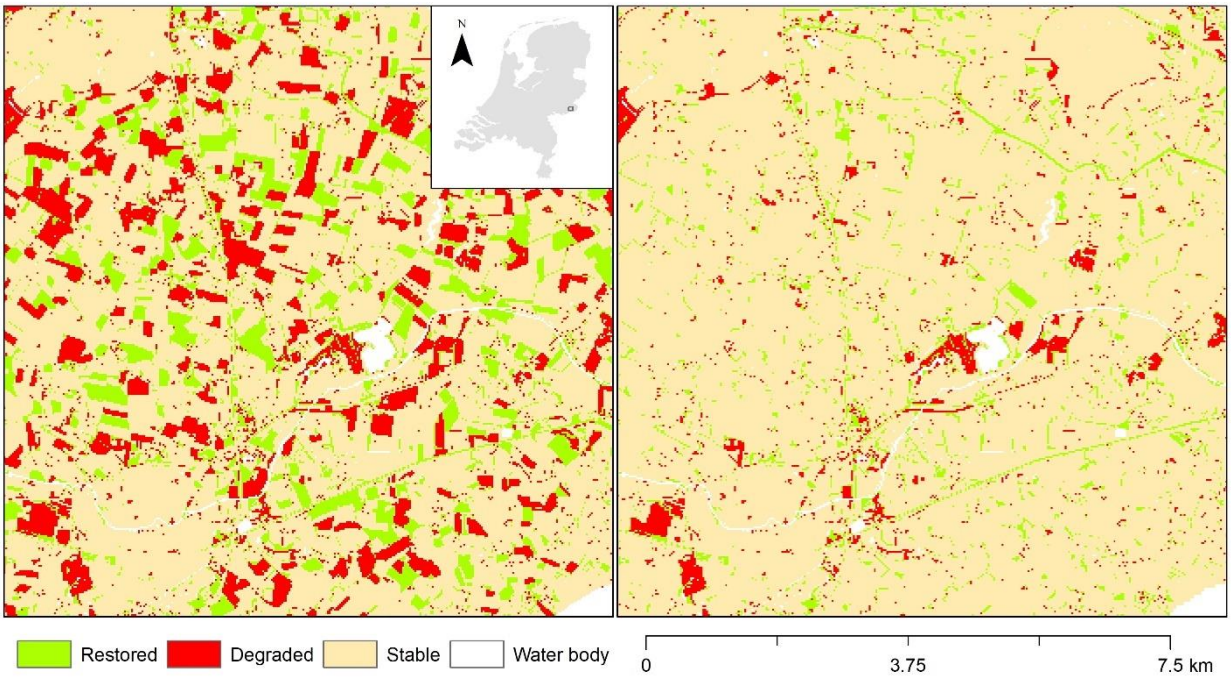


***Figure 5*** *Detail of mineral soil area in the East of the Netherlands (Achterhoek) showing the effect of using more detailed data: left: LDN assessment for land cover with UNCCD methodology with more detailed data; right: LDN assessment with the new, adapted methodology.*

**Related to the land productivity criteria:**

The UNCCD dataset used for land productivity was based on the JRC LPD dataset (Ivits & Cherlet, 2013). This data was based on NDVI data that basically is a proxy for the amount of biomass that is produced. The issue with this type of data is that any data series of National Primary Production (NPP) has a large annual variation, because of meteorological differences over the years. This causes large differences in productivity without the changes that are caused by land degradation. In addition, the independent data of CBS does not show large changes in NPP for the Netherlands. However, as this data is not spatially explicit, it cannot be used for this LDN assessment. The observation that this methodology is not suitable for the Netherlands is further strengthened by the fact that the patches of land that are now classified as degrading do not correspond with landscape elements that could be related to this classification (Figure 6). Therefore, we

decided to use the land use LGN dataset instead to evaluate the change in land productivity based on the changes that can be expected from a specific land use/land cover.

1. Conversion of cropland into greenhouses was not considered as degradation; while this was the case in the original version, as this was seen as a loss of NDVI.
2. The added detail of the LGN dataset compared to the JRC's NDVI based dataset is quite clear in Figure 6. As shown before in Figure 5, crop rotation is a widely used agricultural practice in this area. To assess this mosaic-like agricultural landscape the resolution of the used data should be small enough to distinguish individual plots of land. The rather large, degraded pixels do not match the spatial resolution that is required to assess this type of landscape.
3. We could not find a clear spatial relationship between the large, degraded pixels of the original assessment and the landscape (Figure 6). The main land use type in these pixels seems to be agriculture. The practice of crop rotation in these areas would explain to some extend the location of these pixels, but the pattern does not seem to match the landscape pattern, as can be seen in Figure 5. The rather non-transparent methodology of the use of JRC's dataset does not allow for easy access to answers as to why these large pixels are degraded.

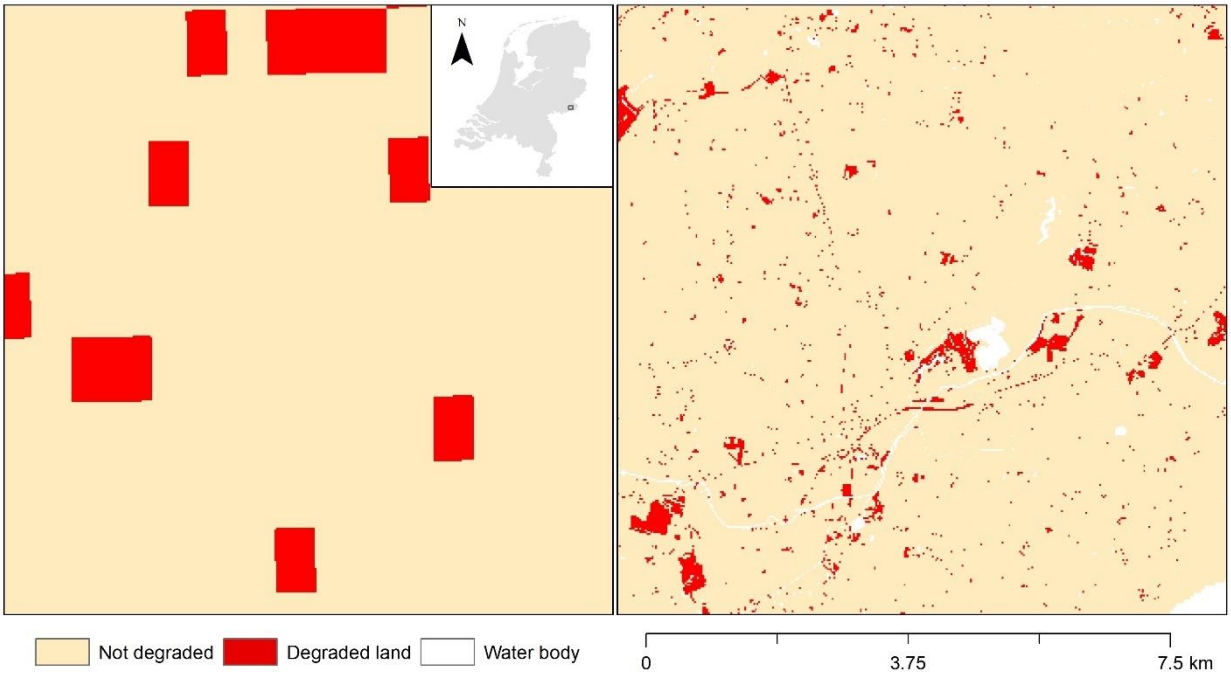


***Figure 6*** *Detail of land productivity assessment in East Gelderland. left: using the UNCCD methodology with the NVDI data; right: using the newly developed methodology using the LGN data.*

**Related to the soil organic matter criteria:**

The newly introduced peatland class makes the area of degrading land much larger. This is due to the decision to classify all peatland under grassland or cropland as degrading for the parameter Soil Organic Carbon. This, in combination with the 'one out-all out' method of the UNCCD, makes the majority of peat soil areas in the Netherlands classifiable as under degradation. This is also according to the reality, as peat soils with a lowered water table continuously lose soil carbon to the atmosphere through oxidation. This is especially true for cropland, where the water table is typically higher and ploughing worsens the situation by facilitating the oxidation process (Couwenberg, 2011; Maljanen et al., 2007). However, there is also a continuous loss of SOM in grassland (Görres, Kutzbach, & Elsgaard, 2014; Tiemeyer et al., 2016). Figure 7 shows an area in the Groene Hart, where the impact of the changed assessment methodology is evident.

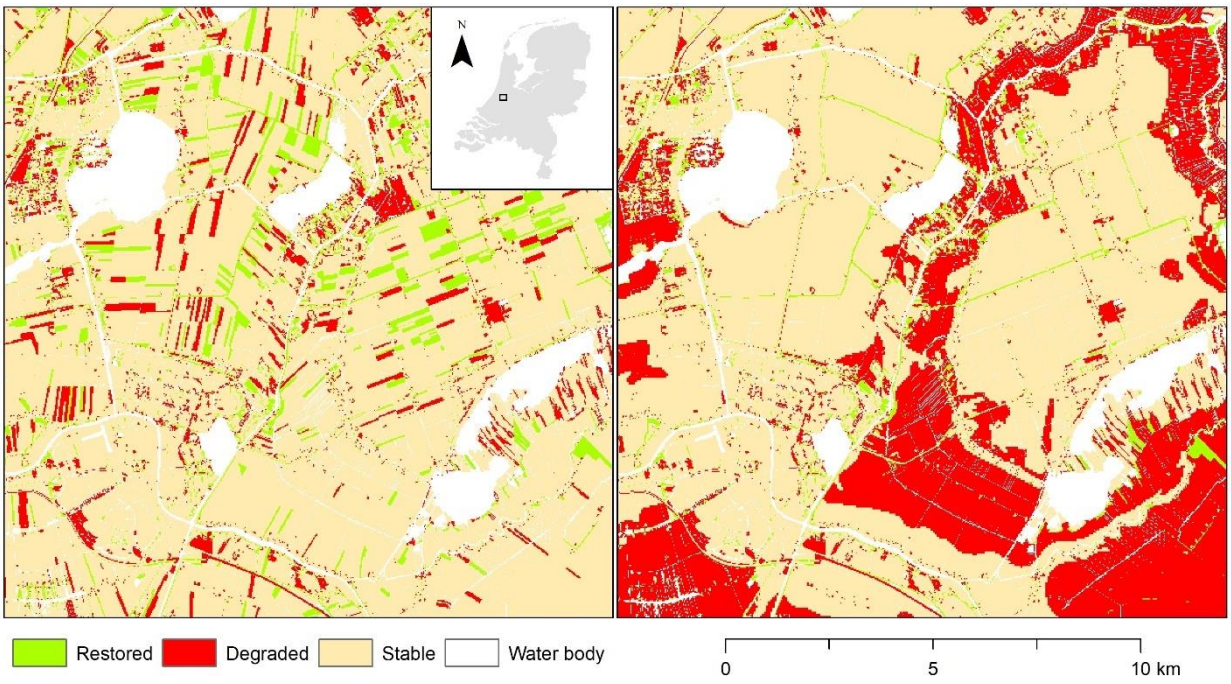


***Figure 7*** *Detail of peat soil area in the West of the Netherlands (Groene Hart) showing the effect of the implemented changes. left: LDN assessment for SOC with UNCCD methodology with more detailed data; right: LDN assessment with newly adapted methodology.*

# 5 Conclusions and Recommendations

From this study, we concluded the following:

- The degradation status of the Netherlands is much less focused on mineral soils than it seemed with the UNCCD methodology. The merging of the arable crop and grassland areas as one class due to the existing crop rotation that is realistic in most areas, reduced the degradation to zero in grassland and cropland areas on mineral soils.
- The introduction of peat soils as a separate class affected the calculation of degraded land. In the new classification, all peatland under cultivation (grassland and cropland) is classified as under degradation, even if its class is not changing for the criterion soil organic carbon. The reason for this choice is that drained peatland oxidises, even when used as permanent grassland and, therefore, degrades. Due to this, the degradation neutrality number increased from 9.6% to 11.7%.

We recommend using the newly developed methodology instead of the one developed by the UNCCD to achieve a more realistic estimation of the land degradation status of the Netherlands. However, we also recommend that the addition of peat soils is promoted also for other countries, where peat soils are abundant. When this is only implemented in the Netherlands, the estimation of LDN of the Netherlands is not comparable to neighbouring countries.

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