Documentation about changes in the calculation of the LUI

Contents

1) LUI calculation from 2024 onwards

(Status 2024-01-23 by Andreas Ostrowski, Uta Schumacher)

Issue 1:

A problem was discovered towards the end of 2023 with the LUI, or more precisely with the LUI components. By LUI components, we mean the intermediate values for TotalGrazing, TotalMowing, and TotalFertilization, which result from the interview data and serve as the basis for the LUI calculation. The problem concerns the calculation of the component TotalFertilization if manure is included in this calculation.

The calculation of organic nitrogen values for manure has followed the 40-30-30 rule since 2019. That means that only 40% of its organic nitrogen content accounts for the current year when manure is spread. The remaining 60% of nitrogen is distributed equally (30% each) over the consecutive years.

The organic nitrogen value of manure can be given in two different ways:

- as exact value (Norg_exact), if it was determined,
- as calculated value (Norg_eff), where the amount of applied manure is multiplied by a livestock-specific factor (Manure_tha * TypeManure)

When the 40-30-30 rule was introduced in 2019, it was not fully and correctly implemented in the LUI component calculation. The following errors have been made:

- The rule was not applied if a Norg_exact was given. Then, the complete value for the year was always taken.
- The rule was also not correctly applied if there was <u>no</u> Norg_exact value given in the current year. Then also for the 30% values of the previous years, Norg_eff was always used. However, there may be an exact value (Norg_exact) in the previous year(s), which would then have to be used.
- For 2006 and 2007, the proportions for this rule were "simulated" by using the average values of already available measurements. At this point, only the Norg_eff was used, and the Norg_exact was neglected.

Overall 24 Plots were affected:

- ALB: AEG1, AEG13, AEG14, AEG37, AEG39
- HAI: HEG6, HEG34, HEG48, HEG49
- SCH: SEG6, SEG9, SEG13, SEG17, SEG20, SEG21, SEG25, SEG33, SEG34, SEG35, SEG36, SEG42, SEG43, SEG44, SEG48

We have corrected the errors in the calculation of the component and recalculated the values.

The correct values are uploaded to the dataset 31661 "Input data for LUI Calculation Tool of all grassland plots since 2006 - revised 2023".

The old and incorrect values are still available in the dataset 25086 "Input Data for LUI Calculation Tool of all grassland plots since 2006 - revised 2019".

Both sets, together with the very early set, are available as input data for the LUI tool. The current "default components set" is the set with the corrected and recalculated values (dataset 31661). The

set previously offered as standard and now withdrawn is the set "historic set till 2023" (dataset 25086).

You can use the tool to download the components and compare the values by yourself. The good news is that the values for TotalFertilization correlate strongly with each other (r = 0.998).

Please also use the tool for redoing your individual selected LUI calculation.

Issue 2:

In addition to this above-described problem, we found five additional errors in the interview data (26487 - Land use in grasslands: raw data of yearly owner interviews) while revising the LUI calculation. We used the correction for the re-calculation of the components already and will update them in the interview dataset soon. This includes:

- Plot AEG1, year 2017: the exactVal was wrongly set to "yes", we changed it to" no". The organic manure is now calculated from applied manure * a livestock-specific factor (Manure_tha * TypeManure)
- Plot HEG49, year 2020: the value for manure_tha was missing. The correct value is 15.
- Plot SEG25, year 2020: the value for manure_tha was missing. The correct value is 4.
- Plot SEG50, year 2021: the value for DayGrazing1 was wrongly set to 0. The correct value 51 has been used.
- Plot SEG45, year 2022: the value for GrazingArea1 was wrongly set to 43. The correct value of 12.62 has been used.

2) LUI calculation from 2019 onwards

(Stand 23.04. 2019 by Juliane Vogt, Jan Thiele, Andreas Ostrowski and Wolfgang Weisser)

Changes in calculation:

From 2019 onwards, calculations of LUI components will be done directly from the raw land use data, and then the table of the compounds is used directly for the LUI calculations. Thus, the LUI-tool in BExIS has also changed and now it is possible to switch between former LUI calculations (old components set) and the "new calculations" (new components set) from 2019 to be able to trace back the changes.

In the wake of this process, a number of adjustments were made on how raw data are assembled (see section "*Changes in data*". This also included fixing some mistakes, so that new LUI values for 2006-2016 are not exactly the same anymore as before. In this document you will find as well a list for all plots and years changes in the LUI and its components.

Here the important points for LUI calculation that changed, did not change:

- The calculation of the LUI components i.e. total mowing and total grazing is the same as before. This is applicable as well for the majority of calculations for total fertilization.
- Only the manure (Festmist) the algorithm changed in the following way: we now assume that the mineralization process of nitrogen takes place of three years (Grünlandsignale Klein Swormink et al 2013)., i.e. the total N amount distributed over time in the following way:

Year 1 (year of application): 40%, Year 2: 30%, Year 3: 30% (3rd year) of the nitrogen. Thus, for all plots where manure is applied, the amount of fertilization is now much lower than before (60%), but the fertilization in the two subsequent years is increased.

- Further changes in the LUI calculation occurred due:
    - **Conversation factors**, to convert amounts of manure and slurry to kg N /ha*year have changed. This is the largest change in the calculation of LUI (many plots with manure/slurry fertilisation now have a higher fertilisation component and hence higher LUI)
    - **Mulching** is considered as mowing when area-covering, which was not done **2006-2010** (now some plots have one cut more)
    - **Calculation errors** were detected and corrected

Comparison of LUI calculations:

The comparison is made for LUI calculations which are standardized, global and separated for years (Fig 1). Both LUI calculations (old and new) are found in BExIS and can be analyzed more in detail if necessary.
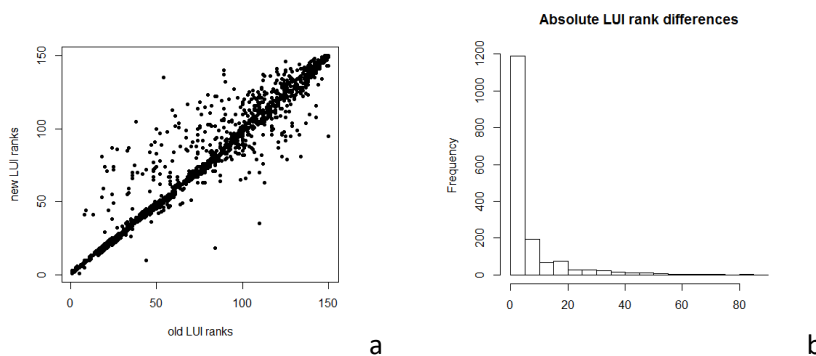

Fig 1: a) Comparison of the ranks of the old and the new LUI calculation. Small ranks correspond to small absolute LUI values b) histogram of the absolute rank differences of old and new LUI calculations

Changes in data:

Documentation of changes in the land use data table

(state 23.4.2019, Juliane Vogt, Wolfgang Weisser)

ID in Bexis 23746 Grassland survey … since 2006

A) General changes in data table:

- Replacement and standardization of missing values:
  "**NA**" - if not known,
  "**0**" if something was counted but was zero (e.g. no mowing or no cows or no maintenance)
  "**-1**" if not possible, e.g. if no mowing a "-1" has been given for the question about mowing machine
- Columns with dates were changed to the ISO-format: yyyy-mm-dd
- Names of the table columns were translated into English and Metadata containing the variable name, data type, units and description were updated for the dataset, the table itself is in German due to the questionnaires which are in German in the uploaded BExIS version

- The column of irrigation of grassland (Bewässerung) was deleted, currently no grassland is irrigated

B) Changes in the variables obtained in land-use questionnaire, starting from 2017

For new variables not obtained before 2017 we tried to fill them in as far as possible, details see below.

- **Mowing** is now assessed in the following way:
    - for every single cut we now distinguish between: *product* (e.g. hay), *mowing machinery* (which could as well be reconstructed for former years), *cutting width* of mower, *cutting height*, *cutting speed* and the use of a *mowing conditioner*
    - for the *product* of mowing we also added two new levels: Mulch_Nachmahd (Mulch_after_Grazing) and Mulch_komplett (EntireMulch)
    - *Yield* [dt*dry mass per ha] (not calculated for Mulch): we previously only had the yield per year, now we obtain yield for every year. This cannot be reconstructed for former years, hence "NA", only the overall yield remains for years before 2017. As a general remark, we would like to point out that the yield estimated by the farmer during the interview is only a rough estimation
    - Extra column for the 5th cut was inserted
    - Mulch was counted 2006-2010 as a maintenance measure, not as a cut, this has now been reconstructed as cuts – hence the number of cuts is generally higher than before. For the reconstruction of mulching as cuts, we proceeded as follows
        - if only a small part of the plot is mulched, it remained as maintenance
        - if entire plot is mulched, it is counted as cut with two options: if the vegetation of the entire year is cut and left on the plot, the product is "entire mulch, and mulching of the entire plot after grazing (product: "mulch_after_grazing")
        - Following plots are affected declaring mulching as cut, generally one time, or two times marked as (2x):
            - 2006: AEG8, HEG4, HEG5, HEG6, HEG17, HEG19, HEG22, HEG23, HEG24 (2x), HEG25, HEG38 (2x), HEG39(2x), HEG42, SEG9, SEG20, SEG21, SEG33, SEG34, SEG35, SEG36, SEG39, SEG46, SEG47, SEG49 SEG50
            - 2007: HEG5, HEG17, HEG22, HEG24, HEG25, HEG30, HEG38 (2x), SEG9, SEG20, SEG21, SEG36 (2x), SEG39 (2x), SEG46 (2x), SEG47 (2x), SEG48, SEG49 (2x), SEG50
            - 2008: HEG4, HEG5, HEG7, HEG8, HEG10, HEG11, HEG17, HEG25 (2x), HEG38, SEG46 (2x)
            - 2009: HEG4, HEG5, HEG7, HEG8, HEG24, HEG35, SEG17, SEG36
            - 2015: SEG7
- **Fertilization** is now assessed in the following way:
    - columns were inserted to consider seven fertilization dates (previously only max. 4)
    - a new variable of extra (not together with other fertilizer) Sulphur fertilization introduced as an extra column. Sulphur fertilization before 2017 was reconstructed by checking the column DescFert (DescDuengung)
    - new variables were introduced about the way fertilizer (manure and slurry) was applied:
      drag hose (Schleppschlauch), slut cutter or slurry injector (Schlitzgerät), gooseneck

distributor (Schwanenhalsverteilung), baffle plate (Prallteller)
For dates before 2017, the way fertilizer (manure and slurry) was applied could be reconstructed

- o mineral/organic fertilizer: a special case is Mash (Schlempe) applied in SCH SEG 13 (2006-2008): although the nitrogen content of mash has an organic origin, the mineral nutrient contents (NPK) is known (in contrast to e.g. slurry), thus values can be directly used for calculation, hence it is listed under mineral

- **Grazing**: no changes were implemented
- **Maintenance** (Pflegemaßnahmen)
  - o Levelling (Schleppen) and harrowing (Striegeln bzw. Eggen) were combined into one variable (*levelling*), as farmers do not distinguish clearly between these two measures
  - o a new variable *Scrub clearance* was introduced, as scrub clearance is done either by sawing or by using a mulcher

C) Changes in entries of grazing:

Grazing information were sometimes estimated by the observation of the LMT and were described as texts in the column e.g. "DescLSU1" as "estimation < 1.4LSU/ha". This information was transmitted as values in column "LSU1" (1.4 LSU *management unit), which changed the grazing component for SEG4, SEG5, SEG8, SEG15, SEG16, SEG19 in 2006 and 2007.

Furthermore, during the calculation of the grazing compounds within the additional table led to typos e.g. by omitting all grazing periods as an error source for the following plots: 2007: SEG 37, 2011: SEG8, 2012: AEG3, HEG16, 2013: HEG5, HEG42, SEG8, SEG43, 2015: AEG4, SEG39

D) Changes in entries of organic nitrogen

A major uncertainty concerned the conversion of amounts of manure and slurry into appropriate amounts of nitrogen. Here, conversion factors were updated and calculation errors were corrected.

Correction of errors in fertilization (values too high, affects LUI values before 2017)

Because in some plots very high values were detected (60 – 80 t manure per ha), the source of error was searched for and it was found that it was very likely that the farmer forgot to mention that this amount of manure was not put per hectare, but on the entire management unit. Thus, the total amount of manure applied was divided by the size unit of the management unit.

- AEG 21 (2006-2008): manure 80 t/ha (error: division by the management unit was forgotten): solution: 80 t/2.93 ha = 27 t/ha; (2009) 60 t /2.93 ha = 20 t/ha
- AEG 24 (2016) 30 t/ha: in previous years only 10 – 15 t/ha input (error: division by the management unit was forgotten): solution: 30t /1.88ha = ca. 15.96 t/ha
- AEG 50 (2006-2009) 60 t/ha in previous years only 10 – 15 t/ha input (error: division by the management unit was forgotten): solution: 60t /6.56 ha = 9.15 t/ha
- SEG42 (2008) 80 t/ha (error: division by the management unit was forgotten): solution: 80 t /10.93 ha = 7.32 t/ha
- SEG42 (2013) 70 t/ 10.93 ha = 6.4 t/ha
- SEG43 (2013) 40 t/ 9.722 = 4.11 t/ha

Changes in the source of manure and slurry (different livestocks, affects LUI values before 2017)

The N content in manure and slurry (Gülle) varies with the type of livestock from which it originates. This was noted down in the variable *DescFertilization* (DescDuengung). Now there are separate columns for manure and slurry where the origin (livestock) is recorded. A special case is the slurry originating from a biogas plant. In general, biogas slurry is quite heterogenic according to the compositions of the origin (type livestock) and dwelling time within the system. The origin "biogas" was added where appropriate.

For all entries of manure and slurry the origin of manure and slurry was checked and where necessary corrected:

- ALB: AEG1-> horse, 2 -> cattle, 2 -> cattle, 11 -> horse, 12 -> horse, 13 -> horse, 14 -> cattle, 15 -> biogas, 16 -> horse (and cattle) 17 -> cattle, 18 -> cattle,21 -> cattle, 23 -> cattle, 24 -> sheep, 37 -> horse, 39 -> horse, 40 -> cattle, 41 -> cattle, 42 -> cattle, 50 -> horse
  Further errors corrected for AEG 16: in 2006, 2011 values for organic nitrogen slurry were available but not shown the LUI table (now inserted)
- HAI: from 2007 biogas at HEG 6, HEG 34, HEG 35, no changes in livestock
  SCH: no changes were necessary

Exact nutrient values of organic fertilizer:

Normally, the nutrient (NPK) content is calculated by conversions factors (see Table 2). In case of specific manure or slurry analyses either collected by the LMTs and analyzed by the LUFA, or directly obtained from land owners the exact values are filled in additional columns namely "NorgExact", "PorgExact", "KorgExact". For the fertilization compound of the LUI these specific data are directly accessed by checking the column "ExactVal" for own analyses (Table 1) and from information of the land owners (2006: SEG 13, SEG33, SEG34, SEG35; 2007: SEG 13, SEG33, SEG34, SEG35, SEG 39, 2008: SEG 13, SEG33, SEG34, 2013: HEG35, SEG8, SEG23, SEG26, 2014: SEG8, SEG23, SEG26, 2015: HEG6, HEG 34, HEG35). These calculations are also applied to LUI before 2017.

Table 1: List of own analyses for the exact nutrient contents

Own analyses	Norg	Porg	Korg	EPs
Marbach 2014 (Alb- Unterer Hof)	3.5	1.3	4.9	AEG 13
Marbach 2014 (Alb- Feldscheune)	7.3	6.0	18.0	AEG 35, AEG 36
Marbach 2017 (*horse manure-old*) N1	5.67	1.55	9.27	AEG1
Marbach 2017 (*horse manure-old*) N2	4.36	2.84	11.32	AEG13
Marbach 2017 (*horse manure-recent*) N1	4.32	2.05	7.07	AEG37
Marbach 2017 (*horse manure-recent*) N2	3.13	1.51	6.38	AEG39
Sambach 2017 (cattle manure) N1	*5.33*	*3.04*	*7.85*	
Sambach 2017 (cattle manure) N2	*6.73*	*6.73*	*4.64*	
Sambach 2017(Mean from N1 and N2)	6.03	4.885	5.51	HEG 6, 34
SCH Liepe 2018 (*feed remains*)	3.03	1.52	1.9	SEG42

<u>Other typos:</u>

- AEG 20 (2006-2008): never fertilized
- AEG23 (2009): additional information 2x mowing with information about the yield (date and amount), no fertilization
- HEG 16 (2009) the column DescZufütterung (DescSupplementaryFeeding, DescGVE (DescLSU) was shifted in the rows, corrected
- AEG 14 (2013) - mistake no mash (Schlempe) was inserted – (30 m³/ha)– number was deleted
- HEG 37 (2015) slurry value was not inserted, despite it was described in the DescDuengung (DescFert) column. The amount of slurry is unfortunately unknown

<u>Changes in conversion factor into nitrogen for manure and slurry (affects LUI values before 2017)</u>

The factors to convert amounts of slurry and manure into values of nitrogen fertilization vary in the literature. Until 2016 values from the Landwirtschaftsamt (Agriculture Office) of Baden Württemberg were used (Table 1, "old values"). These were found to be quite low compared to other sources. We analysed some samples of manure heaps ourselves (analysis done by Landwirtschaftliche Untersuchungs- und Forschungsanstalt Nordrhein Westfalen, Table 1 („own LUFA…").

In the future, we will use the "new factors" from the literature combining available factors of different Agriculture offices of (Baden Württemberg and North Rhine-Westphalia) that were closer to our own values. These factors will also be applied to LUI calculations before 2017.

Table 1: Comparison of the formerly used and the newly adapted conversion factor for calculating the nitrogen content from manure and slurry. Additional analyzes were conducted from manure heaps within the exploratories used to fertilize several plots.

Origin	Old factor * (until 2016)	Source	New factor	Source	Own LUFA analyses (benchmark)	Comments
Manure kg N/t					Mean (Min-Max)	
Cattle	4.73	BW[2] LWA[1]	**5.6**	NRW[3] LWA[1]	6.0 (5.3-6.7)	Manure samples in Hainich
Horse	1.65	BW[2] LWA[1]	**4.9**	NRW[3] LWA[1]	4.4 (3.1-5.7)	Manure samples at the Alb. The old conversion factor was assumed quite low
Sheep	8.13	BW[2] LWA[1]	**8.13**	BW[2] LWA[1]	7.3 (6.6-7.9)	Manure samples of farmer in Hainich contained additional plant residues (not only manure) Conversion factor remained
Slurry Kg N/ m³			Mean (Min-Max)			
Cattle	3.23	BW[2] LWA[1]	**3.85** (3.2-4.5)	NRW[3] LWA[1]	-	
Mixed	3.07	BW[2] LWA[1]	**4.45** (4.0-4.9)	NRW[3] LWA[1]	-	
Digestate /Biogas	5.2 /4.4		**4.4**	BW[2] LWA[1]	-	Digestate and Biogas are now treated in the same way due to similarity of composition

* Old conversion factor was used for LUI calculation until 2017, from now we introduced other conversion factors.

[1] LWA -Landwirtschaftsamt (Agriculture Office), [2] BW – Baden Württemberg, [3] NRW – Nordrhein-Westfalen (North Rhine-Westphalia)

E) Reconstruction of missing values grazing, mowing, fertilization for plots in the Schorfheide

Plot information in SCH: **SEG 4,5, 8, 15,16,19, 23,26** were missing due to communication difficulties with the farmer in 2011 and 2013. It was possible to reconstruct the components of the LUI mowing, grazing and fertilization. Missing values were filled with "NA". This was already done in 2012/2014 hence there is no change in LUI for these plots and 2011 and 2013.