A guide for using the LUI and the LUI tool

Background

The land use intensity (LUI) index summarizes three land use components which are yearly surveyed by the LMTs for each grassland plot *i*: fertilization (F_i), mowing (M_i) and grazing (G_i). Basically, they are simply added after each of them has been standardized. This approach equally weights each of the three components.
Apart from just using the LUI, we encourage you to look into its individual components for a more in-depth understanding of effects. In turn, analyses of single components alone in isolation from the other two components can also have disadvantages. For instance, most plots are unfertilized, but these can be heavily grazed, and a simple regression with fertilization while ignoring grazing may not be able to detect a combined (overall) land use effect.

There is a lot of temporal and spatial variation in the data. Land use, particularly in grasslands, is not fixed, but may change strongly across years. Moreover, land use is not equal across the three regions either. Therefore you have to make decisions when using the LUI. Here is a guideline:

First of all, and most importantly, you need to identify the desired reference year of land use. Do you want to look at the immediate effect of land use during the same year when your biological data are collected, or the previous year? Do you assume that land use has long-term effects on your target organisms or processes, since communities are likely to respond slowly? You may select LUI for the specific year or use an integrated LUI over several years. This decision is very important, as the land use components and thus the LUI changes between years. Most ecological properties will be affected by long-term management, so the recommendation for a first analysis is to use a LUI consisting of more than one year.

Originally, regional standardization (F_R, M_R, G_R) was implemented in the LUI for the purpose of balancing the contributions of fertilization versus mowing versus grazing in a plot *i* (F_i, M_i, G_i) *within* each of the regions (see Blüthgen et al. 2012). The advantage of a balanced LUI within a region comes at a cost: LUI values *across* regions are not directly comparable. In turn, global standardization (F_G, M_G, G_G) across regions takes care that LUI values are directly comparable, but the regions may then cover different sections of the LUI gradient. After careful examination of the properties, we now recommend global standardization for most analyses, which makes the interpretation of the land use effects easier.

The argument made for space also applies to time: long-term standardization of G_{mean}, M_{mean}, and F_{mean} for a LUI for one specific year removes the equal weight of F_i, M_i, and G_i within that year, but allows for direct comparisons of LUI values across different years. If you compare effects across different years, we recommend that you use the mean in that time span for standardization.

The discrepancy between these approaches is not severe, but should be carefully considered depending on the scope of the analysis.

An example illustrates this issue: You have measured plant diversity in year 2012 in all three regions and are interested in an effect of land use across all regions. As plants do respond relatively slowly, you choose an integrated LUI over the five years until the year of measurement, i.e. 2008–2012 (Fig. 1a). The selection of a single reference year (2012) reveals a slightly different result (Fig. 1b). The default selection is global standardization. The lengths of the land use gradients and their means differ between the regions, e.g. a shorter gradient occurs in the Schorfheide (Fig. 1a,b). If you instead select "regional standardization", means are the same and ranges are more similar across the three regions, but values are no longer directly comparable across regions (Fig. 1c,d).

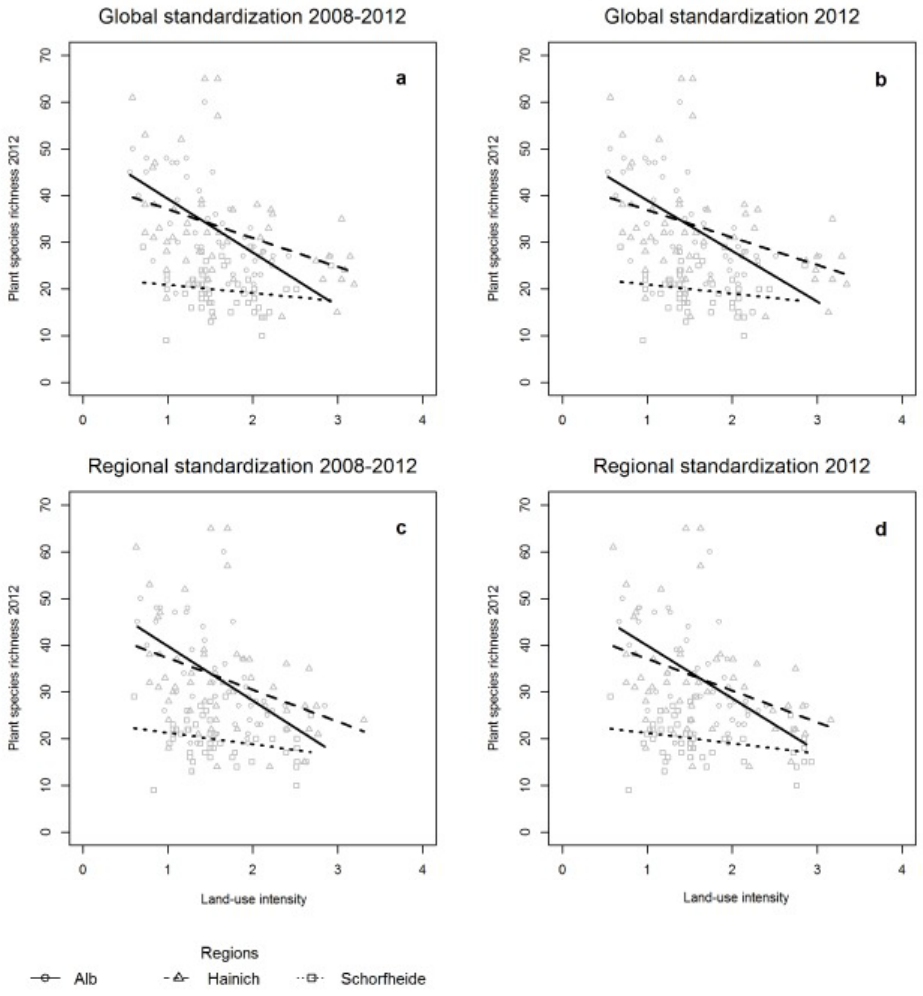


Fig. 1: Comparison of the results of different standardization options for calculating the LUI. a) Plant species richness in 2012 against globally standardized and integrated land use intensity over the five years 2008–2012, b) Plant species richness in 2012 against globally standardized land use intensity in the reference year 2012, c) Plant species richness in 2012 against regionally standardized and integrated land use intensity over the five years 2008–2012, and d) Plant species richness in 2012 against regionally standardized land use intensity in the reference year 2012.

The tool step-by-step

You find the LUI Calculation under the menu “Tools” in BExIS.

1. In the first selection step, you have to choose which component set you want to use.

Since 2024, there have been three sets available. The latest set (default set) is the current up-to-date set and should be used for calculation. The two other sets are available for reasons of reproducibility. The reasons for the changes in the sets and the changes are described in another document. This document is available as a download via the “LUI changes docu”-button on the LUI calculation website.

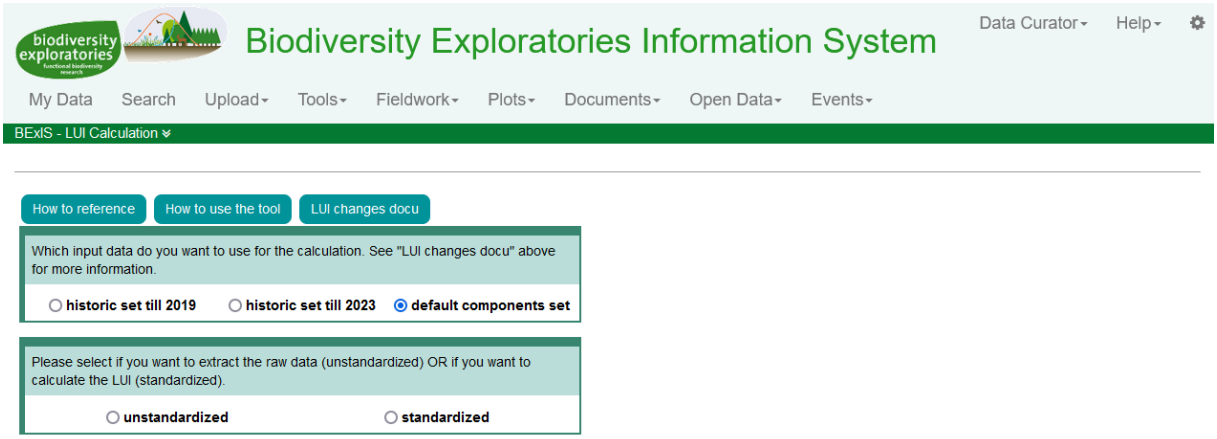


Fig. 2: First selection step within the LUI Tool.

Background explanation from 2019:
From 2019 onwards, calculations of LUI components will be done directly from the raw land use data, and the table of the compounds is used directly for the LUI calculations. A number of adjustments were made on how raw data are assembled. This also included fixing some mistakes, so that new LUI values for 2006-2016 are not exactly the same anymore as before. The calculation of the LUI components i.e. total mowing and total grazing are the same as before. This is applicable as well for the majority of calculations for total fertilization. Only for the manure (Festmist), the algorithm changed in the following way: we now assume that the mineralization process of nitrogen takes place in three years, 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.

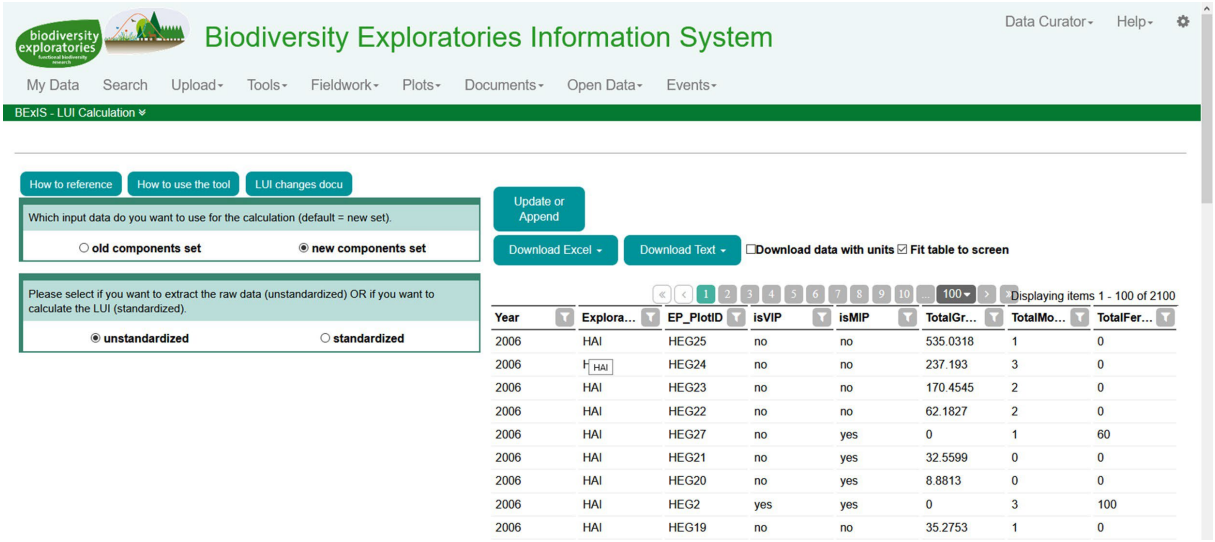
Besides this change, some further corrections were made to derive the new components sets: The conversation factors to convert amounts of manure and slurry to kg N /ha*year have changed. A detailed description of the history of conversion factors used can be found in the last chapter of this document („Important changes in the calculation of the LUI„). Additionally, mulching is considered in the new components set as mowing when area-covering, which was not done 2006-2010. Finally, calculation errors were detected and corrected.

These corrections are included in the new components set for the LUI calculation. For further information, please refer to the document “LuiChangesInfo.pdf” that is available on top of the selection of the components sets.

2. Decide if you want to download raw data, including values for mowing, grazing, and fertilization (unstandardized), or if you want to calculate the LUI (standardized).

a. Choosing “unstandardized”

will give you a downloadable output table including all raw values for every land use component on each plot, in each Exploratory for each year, based on the yearly grassland surveys. According to Blüthgen et al. (2012), fertilization is given as kg nitrogen in fertilizer/dung per ha per year, mowing is given as cuts per year, and grazing is given as livestock units*days the grassland was grazed and per ha and year:



Year	Explora...	EP_PlotID	isVIP	isMIP	TotalGr...	TotalMo...	TotalFer...
2006	HAI	HEG25	no	no	535.0318	1	0
2006	HAI	HEG24	no	no	237.193	3	0
2006	HAI	HEG23	no	no	170.4545	2	0
2006	HAI	HEG22	no	no	62.1827	2	0
2006	HAI	HEG27	no	yes	0	1	60
2006	HAI	HEG21	no	yes	32.5599	0	0
2006	HAI	HEG20	no	yes	8.8813	0	0
2006	HAI	HEG2	yes	yes	0	3	100
2006	HAI	HEG19	no	no	35.2753	1	0

Fig. 3: Output of raw data after selecting “unstandardized”.

b. Choosing “standardized”

gives you different options to calculate the LUI and to obtain standardized values for fertilization, grazing, and mowing.

First you have to select if you want to standardize over each region separately or globally over all or at least two regions, which just makes sense if you want to compare Exploratories.

In both cases, you then have to choose which Exploratories you want to include in your calculation.

Next, you can select the years you want to include. You can choose just one year or several years that do not have to be in a gapless order, such as 2006, 2007, and 2009,

in case you collected samples only in these three years and just want to include your sampling years in the calculation.

Afterwards, you will be asked, if you want to calculate the LUI for each of these years separately or if want to make a 3-year-index e.g., over all selected years.

The last question addresses the plot type you want to include. You can either choose all grassland VIPs, MIPs or all EPs.

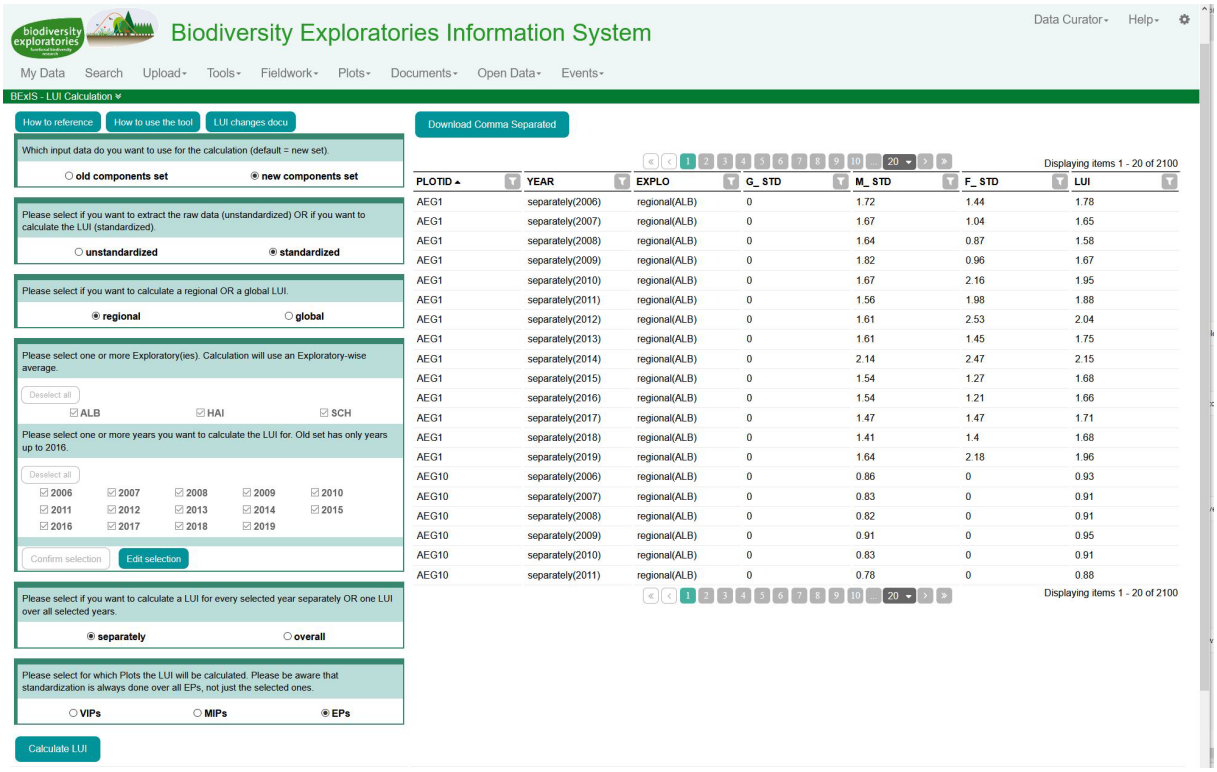


Fig. 4: Selection and output for regional standardization for each Exploratory and year separately.

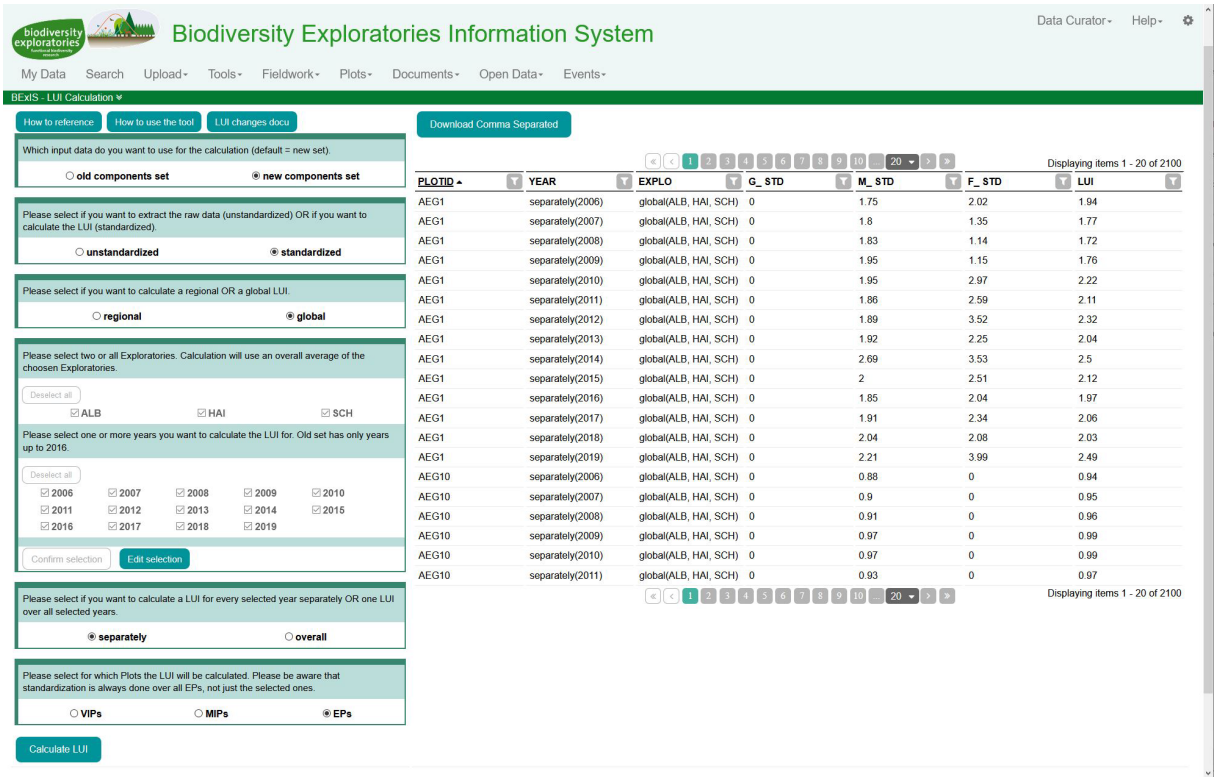


Fig. 5: Selection and output for global standardization for each Exploratory and year separately.

The output table always shows your selections (procedure, Exploratory, and year), the standardized values for each land use component (grazing, mowing, and fertilization) and the calculated LUI for each plot. Comparing figures 4 and 5, you can easily recognize the different results for the LUI depending on regional or global standardization.

Important: Please keep in mind that the latest LUI may change within the year, since sometimes one or two Exploratories already uploaded their land use data from the survey of the last year, but maybe one Exploratory has to upload this information later because of some troubles reaching all land users in time. The program will only consider the Exploratories that uploaded their data, so please check the output table with the unstandardized raw data first to get an overview, which Exploratories are already included!

Important changes in the calculation of the LUI

The three components of LUI calculation include cuts per year ("mowing", cuts/year), livestock units per hectare and days of grazing ("grazing", GVE*d/ha) and nitrogen content in kilogram nitrogen per cubic meter ("fertilization", kg(N)/m^3). For the nitrogen content in organic fertilizers, such as dung and slurry, tables with reference values are available. For solid fertilizers, these values are given in kg(N)/t or kg(N)/dt, and for liquid fertilizers in kg(N)/m^3.
For the calculation of the LUI, we always used the same table, which was also used in the article "A quantitative index of land-use intensity in grasslands: Integrating mowing, grazing and fertilization" (Blüthgen et al., Basic App Ecol 13, 2012, 207-220):

Tab. 1: Mean nutrient content in kg/m^3 (FS) in organic fertilizer from October 1997 till May 1998

	Schweinegülle	Rindergülle	Mischgülle	Festmist
Probenzahl	28	80	46	16
Nährstoff				
CaO	2.57	2.15	2.38	1.83
MgO	0.88	0.83	1.25	0.23
K 2 O	2.62	4.2	4.85	1.12
P 2 O 5	2.93	1.55	1.28	0.94
Ges. N	5.69	3.23	3.07	0.60
NH 4 -N	2.95	1.31	1.34	0.27

https://www.landwirtschaft-bw.info/pb/,Lde/644543

Comparing these values to newer reference values for N content in kg/m^3 we noted, that the originally used values are much lower than the new ones. We assume that there is a mistake in our table regarding the units for the nitrogen content. Dung seems to be quoted in kg(N)/dt and not kg(N)/m^3, which means, that its total N must be corrected to 4.98 kg(N)/m^3. Thus, for calculating the nitrogen content of dung for the LUI Tool we used another table from the ministry of Thuringia from 2001, which seems to be a more reliable reference (Tab.2).

Tab. 2: Nutrient content in organic fertilizers.

Nährstoffgehalte in Wirtschaftsdüngern und anderen organischen Düngestoffen

Tabelle 2: Trockensubstanz- und Nährstoffgehalte in der Frischmasse organischer Düngestoffe für Stickstoff, Phosphor, Kalium und Magnesium (Element- und Oxidwert)

Art organischer Düngestoff	Tierart	Trocken-substanz %	Menge n-einheit	Nährstoffgehalt je Mengeneinheit in der Frischmasse							
				N [1]	N [2]	P	P_2O_5	K	K_2O	Mg	MgO
Rindermist	Milchkuh	25	kg/dt	0,71	0,57	0,18	0,41	1,07	1,29	0,13	0,21
	übrige Rinder	25	kg/dt	0,72	0,58	0,19	0,44	0,93	1,12	0,14	0,24
	Mittelwert	25	kg/dt	0,71	0,57	0,19	0,43	0,96	1,16	0,14	0,23
Schweinemist	Standardfütterung	25	kg/dt	0,74	0,59	0,27	0,62	0,54	0,65	0,22	0,36
	N/P-reduzierte Fütterung	25	kg/dt	0,59	0,47	0,21	0,48	0,49	0,59	0,21	0,35
	Mittelwert	25	kg/dt	0,67	0,53	0,24	0,56	0,51	0,62	0,21	0,35
Mischmist	Rind und Schwein	25	kg/dt	0,69	0,55	0,22	0,50	0,74	0,89	0,17	0,29
Geflügelmist mit Einstreu	Standardfütterung	45	kg/dt	1,55	1,24	0,48	1,11	1,15	1,39	0,24	0,39
	N/P-reduzierte Fütterung	45	kg/dt	1,48	1,19	0,37	0,84	1,00	1,20	0,23	0,38
	Mittelwert	45	kg/dt	1,53	1,23	0,46	1,05	1,12	1,35	0,24	0,39
Geflügelmist ohne Einstreu	Standardfütterung	45	kg/dt	1,90	1,52	0,59	1,35	1,23	1,48	0,28	0,46
	N/P-reduzierte Fütterung	45	kg/dt	1,81	1,45	0,44	1,02	1,04	1,25	0,27	0,44
	Mittelwert	45	kg/dt	1,88	1,50	0,55	1,27	1,18	1,42	0,27	0,45
Pferdemist	Mittelwert	25	kg/dt	0,41	0,33	0,17	0,38	0,43	0,52	0,13	0,21
Schafmist	Mittelwert	25	kg/dt	1,56	1,25	0,34	0,78	2,28	2,75	0,27	0,44
Rindergülle	Milchkuh	10	kg/m³	4,38	3,50	0,74	1,70	5,31	6,40	0,50	0,83
	übrige Rinder	10	kg/m³	5,54	4,43	0,97	2,22	5,86	7,06	0,71	1,18
	Mittelwert	10	kg/m³	5,28	4,22	0,92	2,10	5,74	6,91	0,67	1,11
Schweinegülle	Standardfütterung	10	kg/m³	6,78	5,42	1,65	3,79	2,95	3,55	1,18	1,95
	N/P-reduzierte Fütterung	10	kg/m³	4,35	3,48	1,29	2,97	2,53	3,05	1,21	2,00
	Mittelwert	10	kg/m³	6,21	4,97	1,50	3,44	2,77	3,34	1,19	1,97
Mischgülle	Rind und Schwein	10	kg/m³	5,75	4,60	1,21	2,77	4,26	5,13	0,93	1,54

[1] Bei Gülle und Jauche 10 % Lagerungsverluste, bei Stallmist 25 % Lagerungsverluste (Rotte) berücksichtigt. Übrige organische Düngestoffe nach Lagerung.
[2] Bei Gülle und Jauche 10 % Lager- und 20 % Ausbringungsverluste, bei Stallmist 25 % Lager- (Rotte) und 20 % Ausbringungsverluste berücksichtigt.

http://www.tll.de/ainfo/archiv/rwnv0101.pdf

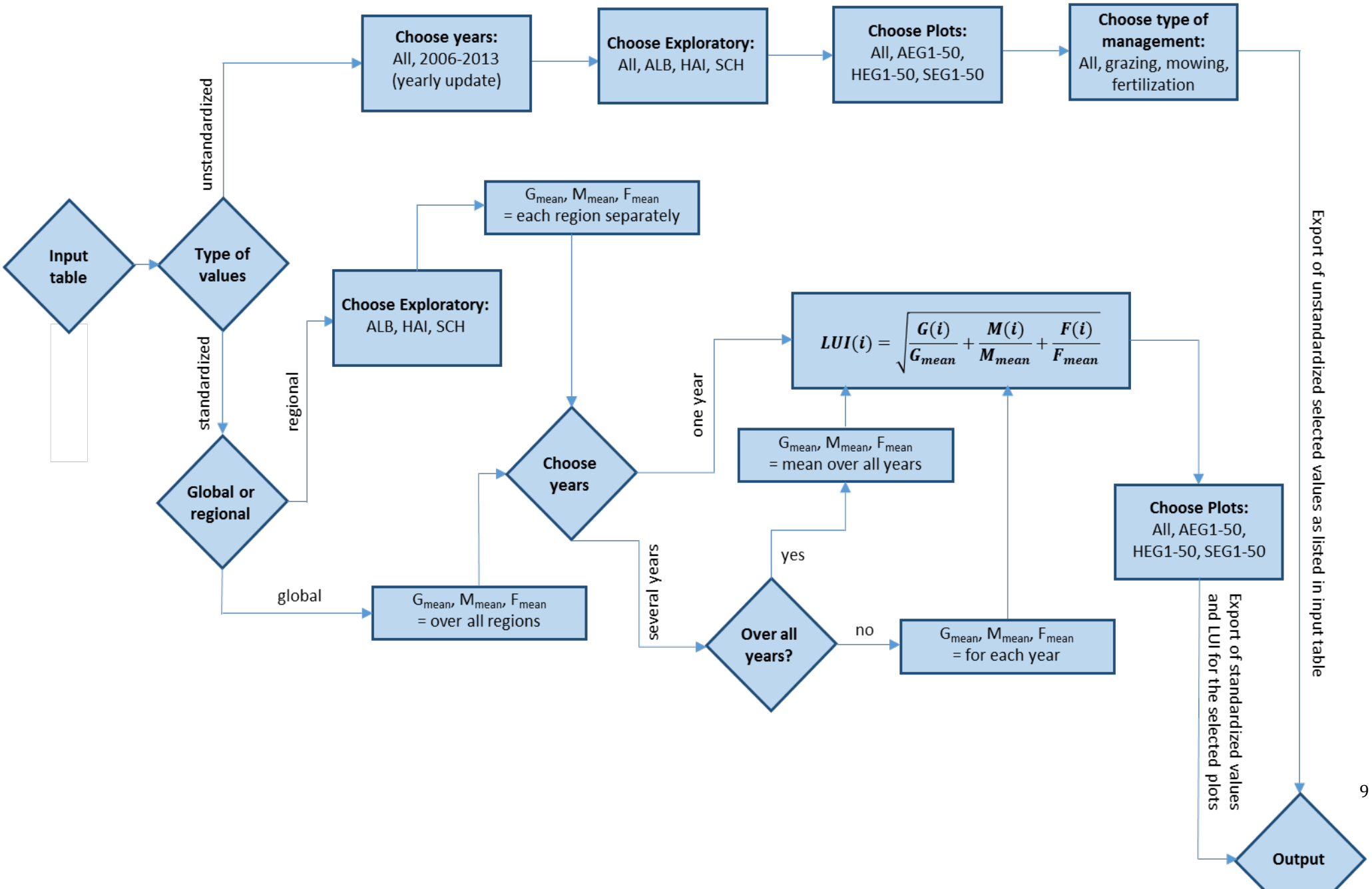
From these information, we derived a table that is currently in use for the LUI-computation (Tab.3):

Tab. 3: Nitrogen input conversion factor of manure and slurry.

Type of manure (t/ha)	**Conversion Factor for total Nitrogen [kg/t]**	**Literature and Notes**
Cattle Horse Sheep	5.6 4.9 8.13	LWK (Chamber of Agriculture) Nordrhein-Westfalen (2014), own measurements analyzed by LUFA Nord-West (Agricultural Investigation and Research Institute - accredited laboratory of the Chamber of Agriculture in Niedersachen) (2017)
Type of slurry (m^3/ha)	**Total Nitrogen [kg/m^3]**	
Cattle Pig Mixed	3.85 (3.2-4.5) 5.4 (4.3-6.5) 4.45 (4.0-4.9)	Mean values of slurry ranges were used. (LWK Nordrhein-Westfalen(2014))
Biogas / Digestate	4.4	LWK Baden-Württemberg (2012)

So please keep in mind that the LUI calculated by the LUI Tool may be different to the one that is uploaded in BExIS in the data sets 16026-16028 and 17286 and also different from the values reported in Blüthgen et al. (2012)!

For further questions regarding the LUI Tool please do not hesitate to ask Anna Franke (LMT Hainich) or Andreas Ostrowski (BExIS).


Input table
Type of values
unstandardized
standardized
Choose years:
All, 2006-2013
(yearly update)
Choose Exploratory:
All, ALB, HAI, SCH
Choose Plots:
All, AEG1-50,
HEG1-50, SEG1-50
Choose type of management:
All, grazing, mowing, fertilization
Export of unstandardized selected values as listed in input table
Global or regional
regional
Choose Exploratory:
ALB, HAI, SCH
Gmean, Mmean, Fmean
= each region separately
global
Gmean, Mmean, Fmean
= over all regions
Choose years
one year
several years
LUI(i) = √(G(i)/Gmean + M(i)/Mmean + F(i)/Fmean)
Gmean, Mmean, Fmean
= mean over all years
Over all years?
yes
no
Gmean, Mmean, Fmean
= for each year
Choose Plots:
All, AEG1-50,
HEG1-50, SEG1-50
Export of standardized values and LUI for the selected plots
Output