Environmental indicators for the sustainability assessment of the MilKey project

Description of the selected indicators and methodological choices

for the environmental sustainability assessment of MilKey dairy farm systems

WP4

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Summary

Introduction

This document describes the indicators selected to assess the sustainability of key EU dairy farm systems as part of the MilKey sustainability assessment (i.e., work package (WP) 4). The selection process was based on expert opinion of WP4 partners and followed an interdisciplinary, participatory approach. This assessment covers the three sustainability dimensions, i.e., environmental, social, and economic, and is performed using the "DEX" multi-criteria methodology. This methodology provides the possibility to break down a decisional problem into smaller, less complex sub-problems represented by criteria. All the criteria are arranged hierarchically so those at higher levels depend on those at lower levels (Craheix et al., 2015).

At the lowest level of the arrangement, the last criteria are called "indicators". These indicators can be calculated using the required parameters. Then, they are aggregated to their corresponding levels (criteria). The indicators have different weights on their higher level depending on the importance that is given to the indicator in the criteria definition.

Drawing upon the Dexi method, a model is developed to evaluate sustainability through aggregated and qualitative scores of dairy farms through a Greenhouse Gases (GHG) mitigation perspective. For each sustainability indicator, qualitative scores are assigned on rating scales constructed using reference values. Then, the indicators are aggregated to their corresponding higher levels into another qualitative score by using weight for each indicator.

The current document gathers the list of indicators with their definitions and formulas, as well as reference values of their rating scales. It is normally divided into three sections for each sustainability dimension, but this document only presents the environmental dimension. Some indicators appear twice because they have been selected in two different branches (one branch per sustainability dimension). Please note that this document aims merely at presenting the indicators and does not display detailed calculations nor data requirements.

Environmental Indicators

This section presents the indicators related to the environmental sustainability assessment. These are presented in table 1 and figure 1. The following indicators are calculated through the life cycle assessment method: Eutrophicaption potential, Global warming potential, Air acidification, and Total energy consumption.

Table 1: Environmental indicator list

Indicators	Unit
N efficiency: Feed to animal product	**Percentage**
% of local production	**Percentage**
Concentrate-to-forage ratio	**Percentage**
% of by-products used in diet	**Percentage**
Age at first calving	**Months**
Calving interval	**Days**
Eutrophication potential	**Kg PO43- eq/kg**
Global warming potential	**Kg CO2eq/kg**
Air acidification	**kg SO2 eq/kg**
Erosion risk	**t/ha/year**
Heavy metal balance	**mg/ha**
Water use for animal housing	**L/kg**
% of cultivated area irrigated	**%**
Total energy consumption	**MJ/kg**
% of farm energy production in the total energy use	**Percentage**
Number of different breeds	**Nb breeds/Nb species**
Number of different cultivated species	**Cultivated/farm**
Total treatment frequency index	**Score**
Acute toxicity	**Score (mg/kg)**
Habitat diversity	**Shannon index**
Grassland management	**Percentage**
Participation in agri-environmental scheme	**yes/no**

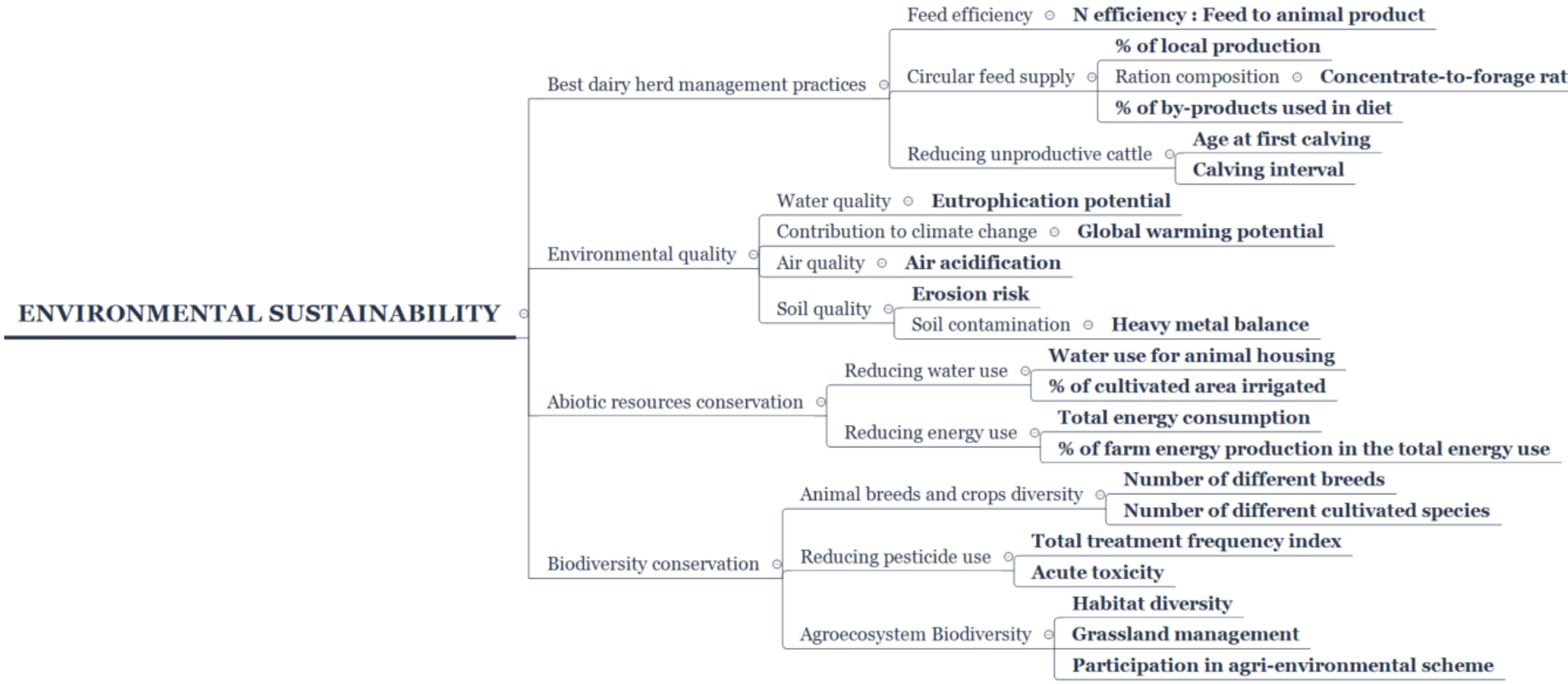


Figure 1 : Environmental branch of the sustainability assessment

N efficiency: Feed to animal product

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Herd management practices: feed efficiency

Description:

This indicator calculates the percentage of total nitrogen inputs recovered in the biomass of the cattle. It evaluates an aspect of the environmental impacts of feed management, as the type of diet highly influences nitrogen emissions of dairy production.

Indicator calculation:

$$\frac{\frac{DP * 1{,}033 * \frac{CP_{milk}}{(0{,}9 * 6{,}38)}}{1000} + (0{,}024 * 50)}{((\sum i\,(DM_{F,i} * CP_{F,i}) + \sum j(DM_{C,j} * CP_{C,j}))/1000)/6{,}25} * 100$$

Unit: Percentage

Where:

$DM_{F,i}$ = Dry matter in forage i, expressed in t of DM per head per year
$CP_{F,i}$ = Crude protein content in forage i, expressed in g of N per kg of DM
$DM_{C,j}$ = Dry matter in concentrate j, expressed in kg per head per year
$CP_{C,j}$ = Crude protein content in concentrate j, expressed in g of N per kg of DM

N inputs

DP = Dairy production per cow over 2020 expressed in L of milk per head per year
CP_{milk} = Protein content in milk expressed in g per kg of milk
1.033 is the conversion factor to express L of milk in kg
0.9*6.38 is the factor to express milk protein content in total nitrogen content
0.024 is the factor of N content in dairy cow meat
50 is the average of body weight calf expressed in kg

N outputs

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values (%)	Scalings	Dexi interpretations		References
20 min	>35	High	+	(Aguirre-Villegas et al., 2017). Scale built in a participative approach by scientists and experts
45 theoretical max	[30; 35]	Medium to high		
	[25; 30[	Medium to low		
	[20; 25[	Low	-	

References:

(Dulphy and Grenet, 2001), (INRA, 2007)

% of local production

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Dairy herd management practices: Circular feed supply

Description:

The percentage of local production refers to the dependency on external feed supply. We consider a production local when it is located within a limited perimeter around the farm. This indicator is important to measure the contribution of the local territory (an area of land under the jurisdiction of a ruler or state) to the local dairy enterprise. The limit of local has been defined within a 100 km radius around the farm location. For the concentrate production, only the place where it is produced is taken into account. The origin of feedstuffs composing concentrates is not considered in this indicator. The on-farm production is considered as local.

Indicator calculation:

$$\frac{Total\ local\ feed\ use\ (concentrates\ and\ forages)}{Total\ feed\ use} * 100$$

Unit:

Percentage

Where:

The total local feed use and the total feed use are expressed in dry matters (DM).

Indicators interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Reference values (%)	**Scale**	**Dexi interpretation**		**References**
55	>80	High	+	Adapted on the concentrate-forage ratio from (Machado et al., 2014). Scale built in a participative approach by scientists and experts
45	[60;80]	Medium to high		
	[40;60[	Medium to low		
35	<40	Low	-	

References:

Based on the recommendations to reduce the carbon footprint of dairy production, transport plays an important role and should be strongly reduced (Üçtuğ, 2019).

Concentrate-to-forage ratio

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Herd management practices: Circular feed supply: Ration composition

Description:

This indicator refers to the forage-to-concentrate ratio in the dairy cattle diet. It allows for the comparison of concentrate and forage consumptions. It is an indirect measure of the industrial feed production dependency.

Indicator calculation:

$$\frac{Total\ concentrate\ use}{Total\ forage\ use} * 100$$

Unit:

Percentage

Where:

Total concentrate use = Total amount of concentrates fed, expressed in t DM per year or in kg per L of milk
Total forage use = Total amount of forage fed, expressed in t DM per year or in kg per L of milk

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values (%)		**Scale**	**Dexi interpretation**		**References**
35		< 20	Low	+	Adapted from (Machado et al., 2014). Scale built in a participative approach by scientists and experts
45		[20; 35[	Medium to low		
55		[35; 50]	Medium to high		
		>50	High	-	

References:

Expert opinion based on technical information Based on Pellerin et al. (2013) technical report on reducing protein intake in animal feed to limit nitrogen content in effluents and associated N2O emissions (i.e, action #8).

% of by-products used in diet

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Herd management practices: Circular feed supply

Description:

This measure refers to the amount of by-products in the diets to feed the cattle. It gives an indication of the recycling of by-products in the feed, which is recommended to save primary resources. The byproduct content in concentrates bought is not included in this indicator.

Indicator calculation:

$$\frac{\sum i(Byproduct\ content_i)}{Total\ feed\ consumption} * 100$$

Unit:

Percentage

Where:

Byproduct content $_i$ = By-product content in the diet i, expressed in kg of DM
Total = Total of feed consumed (concentrates + forages + byproducts) in all diet, expressed in kg of DM

Indicators interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Reference values (%)	**Scale**	**Dexi interpretation**		**References**
95	>60	High	+	Adapted from (Condren et al., 2019; Whelan et al., 2017). Scale built in a participative approach by scientists and experts
75	[40; 60]	Medium to high		
55	[20; 40[	Medium to low		
35	<20	Low	-	

References:

Expert opinion based on technical information Based on Pellerin et al. (2013) technical report on reducing protein intake in animal feed to limit nitrogen content in effluents and associated N2O emissions (i.e, action #8).

Age at first calving

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Herd management practices: Unproductive cattle

Description:

This indicator refers to the average age of dairy heifers at first calving. Delays in age at first calving lengthen the unproductive period of dairy cows. They increase avoidable environmental costs associated with maintaining and feeding unproductive animals. This measure is estimated by farmers directly.

Unit:

Months

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values (months)	**Scale**	**Dexi interpretation**		**References**
28	<24	Low	+	The reference values are based on the tool "Reproscope" created by IDELE, data based on the French cattle distribution in dairy farm (2018-2019). Quantile method based on 53953 cattle and all French breeds. Scale built in a participative approach by scientists and experts
31	[24; 27[	Medium to low		
35	[27; 30]	Medium to high		
	>30	High	-	

Note: It is likely that the scale changes after collecting data for a better distribution of our results

References:

Expert opinion based on technical information from (Pellerin et al., 2013) and (Hevari Moussavi and Danesh Mesgaran, 2008).

Calving interval

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Herd management practices: Unproductive cattle

Description:

This indicator refers to the average period between two calvings of the dairy herd. Longer calving intervals increase the unproductive period of dairy cows, which is associated with avoidable environmental costs of feeding and maintaining unproductive animals.

Unit: Days

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values (days)	**Scales**	**Dexi interpretation**		**References**
397	<390	Low	+	The reference values are based on the tool "Reproscope" created by IDELE, data based on the French cattle distribution in dairy farm (2018-2019). Quantile method based on 53953 cattle and all French breeds. Scale built in a participative approach by scientists and experts
414	[390; 415[	Medium to low		
437	[415; 440]	Medium to high		
	>440	High	-	

Note: It is likely that the scale changes after collecting data for a better distribution of our results

References:

Expert opinion based on technical information from (Pellerin et al., 2013).

Eutrophication potential

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Environmental quality: Water quality

Description:

This indicator refers to a life cycle assessment (LCA) midpoint impact category. The LCA midpoint methods looks at environmental impact at an early stage in the cause-effect chain to calculate impacts. In this case, It evaluates the direct impact of excess nitrogen and phosphorus inputs on water quality.It is given in kg PO_4^{3-} equivalent per Functional Unit (i.e. quantitative amount that represents the function delivered by the system, for example, the production of 1kg of milk during 2020 production).

Indicator calculation:

$$EP = \sum e_i * CF_i$$

Where:

e_i= the emission of substance i and

CF_i = associated characterization factor

Unit:

kg PO_4^{3-} equivalent per kg of milk

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values	Reference values	Scales	Dexi interpretation		References
0.00269 kg PO_4^{3-} /kg (New Zealand) Average of 3 scenarios	25.5 kg PO_4^{3-} /ha	< 0.003	Low	+	(Basset-Mens et al., 2009)
0.00605 kg PO_4^{3-} /kg in conventional (Sweden)	31.4 kg PO_4^{3-} /ha	[0.003; 0.005]	Medium to low		(Cederberg and Mattsson, 2000)

Reference values	Reference values	Scales	Dexi interpretation		References
0.0066 kg PO_4^{3-} /kg in organic (Sweden)	19.1 kg PO_4^{3-} /ha	]0.005; 0.007]	Medium to High		
0.011 kg PO_4^{3-} /kg in conventional (Netherlands)	85.9 kg PO_4^{3-} /ha	> 0.007	High	-	(Thomassen et al., 2008b)
0.007 kg PO_4^{3-} /kg in organic (Netherlands)	39.6 kg PO_4^{3-} /ha				

Check with other LCA studies covering a good diversity of system:

(Brizga et al., 2021) : from 0.0019-0.0039 kg PO_4^{3-} /kg

From 0.0029-0.0075 kg P eq/kg (CML eutrophication) in dairy system (De Vries and de Boer, 2010)

References:

Emission calculation: (Koch and Salou, 2016)

Characterization factor: CML-IA characterization method (CML, 2001)

Global warming potential

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Environmental quality

Description:

This indicator is based on the Global Warming Potential (GWP) measure developed by the United Nations Intergovernmental Panel on Climate Change (IPCC). It refers to a LCA midpoint impact category and quantifies the GHG emitted by the dairy system. It is given in kg CO_2 equivalent per Functional Unit (i.e. quantitative amount that represents the function delivered by the system, as the production of 1kg of milk during 2020 production).

Indicator calculation:

$$GWP = \sum e_i * CF_i$$

Where:

e_i = GHG emission $_i$

CF_i = associated characterization factor $_i$

Unit:

kg CO_2 equivalent per kg of milk

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values	Reference values	Scales	Dexi interpretation		References
0.856 kg CO_2 /kg (New Zealand) Average of 3 scenarios	8136 kg CO_2 /ha	< 0.7	Low	+	(Basset-Mens et al., 2009)
1.1 kg CO_2 /kg in conventional (Sweden)	5714 kg CO_2 /ha	[0.7; 1[	Medium to low		(Cederberg and Mattsson, 2000)
0.950 kg CO_2 /kg in organic (Sweden)	2742 kg CO_2 /ha	[1; 1.3]	Medium to High		
1.410 kg CO_2 /kg in conventional (Netherlands)	11016 kg CO_2 /ha	>1.3	High	-	(Thomassen et al., 2008b)

Reference values	Reference values	Scales	Dexi interpretation		References
1.480 kg CO_2 /kg in organic (Netherlands)	8362 kg CO_2 /ha				

Based on three LCA studies "cradle to farm-gate" of dairy farm using IPCC method and mostly eco-invent database.

Check with other LCA studies covering a good diversity of system:

"The results show that the gross greenhouse gas emissions differ by 29%: from 1.09 kg CO2 equivalents (CO2e) per kg of raw milk for the farms with 51-100 cows, down to 0.84 kg CO2e/kg milk for farms with more than 200 cows." (Brizga et al., 2021)

In other studies : from 0.9 to 2.4 kg CO2 eq / per kg of milk (Thomassen et al., 2008b)

From 1.26 to 1.56 kg CO2 eq/kg milk (Drews et al., 2020)

From 0.87 to 1.4 kg CO2 eq/kg milk (De Vries and de Boer, 2010)

References:

Emission calculation: (Koch and Salou, 2016)

Characterization factor: CML-IA characterization method (CML, 2001)

Air acidification

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Environmental quality: Air quality

Description:

This indicator measures the potential impact of acidifying pollutants through the LCA method. Acidifying pollutants have a wide variety of impacts on soil, groundwater, surface water, biological organisms, ecosystem, and materials.

The major acidifying pollutants considered are SO_{2}-, NO_x, and NH_3.

Indicator calculation:

$$AP = \sum e_i * CF_i$$

Where:

e_i = emission of substance i

CF_i = associated characterization factor i

Unit:

kg SO_2 equivalent per kg of milk

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

New Zealand study: average of three scenarios at dairy farm scale (scenario 1 = low input, scenario 2 = N fertilizer and scenario 3 = N fertilizer + maize silage) using "CML method" to calculate the impacts and eco-invent mostly for the Life Cycle Inventory (LCI) (calculating the emissions) (Claudine et al., 2009) or 0.00745 kg SO2-eq/kg of milk

Reference values	**Reference values**	**Scales**	**Dexi interpretation**		**References**
0.00745 kg SO_{2}-/kg (New Zealand) Average of 3 scenarios	70.8 kg SO_{2}-/ha	< 0.009	Very low	+	(Basset-Mens et al., 2009)
0.0180 kg SO_{2}-/kg in conventional (Sweden	93.5 kg SO_{2}-/ha	[0.009; 0.01[	Low		(Cederberg and Mattsson, 2000)
0.0158 kg SO_{2}-/kg in conventional (Sweden	45.6 kg SO_{2}-/ha	[0.01; 0.015[	Medium		

Reference values	Reference values	Scales	Dexi interpretation		References
0.0095 kg SO_2-/kg in conventional (Netherlands)	74.2 kg SO_2-/ha	[0.015; 0.02]	High		(Thomassen et al., 2008b)
0.0108 kg SO_2-/kg in organic (Netherlands)	61.0 kg SO_2-/ha	> 0.02	Very high	-	

Based on three LCA studies "cradle to farm-gate" of dairy farm using CML method and mostly eco-invent database.

Check with other LCA studies covering a good diversity of system:

Terrestrial acidification: from 0.0240 to 0.0298 kg SO_2-/kg of milk (Drews et al., 2020)

Terrestrial acidification: from 0.0081 to 0.019 kg SO_2-/kg of milk (De Vries and de Boer, 2010)

References:

Emission calculation : (Koch and Salou, 2016)

Characterization factor: CML-IA characterization method (CML, 2001)

Erosion risk

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Environmental quality: Soil quality

Description:

Erosion risk refers to the potential average of eroded soil for one hectare of the assessed farm over a year of production. Erosion is taken into account in the LCA due to its influence on pollutants washing. Moreover, erosion affects the productivity of crops due to soil damage. It is affected by the precipitation, type of soil, and topography.

Indicator calculation:

$$R * K * L * S * C * P * f$$

Unit:

t of eroded soil/ha/year

Where:

E = Erosion risk, R = Run-off factor, K = Soil factor, L = Slope length factor
S = Slope factor, C = Land cover, P = Cultural practice and f = Acre factor (2,47)

Indicator interpretation:

Higher values have larger negative impacts on the environment.

Scale definition:

Reference values (t of eroded soil/ha/year)	**Scales**	**Dexi interpretation**		**References**
0.2	< 0.5	Very low	+	Adapted from (Gassman et al., 2006; Vadas and Powell, 2013)
1.5	[0.5; 1.5[	Low		
2.2	[1.5; 2.5[	Medium		
5	[2.5; 4.5]	High		
	>4.5	Very high	-	

References:

(Koch and Salou, 2016) (Renard et al., 1991)

Heavy metal balance

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Environmental quality: Soil quality

Description:

This indicator calculates the difference between of heavy metal inputs and outputs. It takes into account the atmospheric feedback of heavy metal components from fertilizers, seeds, and phytosanitary products. It represents the remaining heavy metals (HM) in the soil and is thus an indirect indicator of soil toxicity. In high concentrations, heavy metals are toxic for the biodiversity in aquatic and terrestrial biospheres and affect crop fertility.

Indicator calculation:

$$HM\ i, input\ flow - HM\ i, output\ flow * HM\ i, allocation\ factor$$

Unit:

DBeq/kg of soil

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

HM	Reference values(concentration mg/kg)	CML Characterization Factor (CF)	Threshold CML (TV*CF)	Lower guideline CML (LG*CF)	References
Cd	Threshold value (**TV**) = 1 mg/kg of soil Lower guideline value (**LG**) = 10 mg/kg of soil	170 kg DBeq/kg	0.00017	0.0017	Adapted from (Guinée and Lindeijer, 2002; Toth et al., 2016)
Cu	Threshold value (**TV**) = 100 mg/kg of soil Lower guideline value (**LG**) = 150 mg/kg of soil	14 kg DBeq/kg	0.017	0.0255	
Zn	Threshold value (**TV**) = 200 mg/kg of soil Lower guideline value (**LG**) = 250 mg/kg of soil	25 kg DBeq/kg	0.034	0.0425	

HM	Reference values(concentration mg/kg)	CML Characterization Factor (CF)	Threshold CML (TV*CF)	Lower guideline CML (LG*CF)	References
Pb	Threshold value (**TV**) = 60 mg/kg of soil Lower guideline value (**LG**) = 200 mg/kg of soil	33 kg DBeq/kg	0.0102	0.034	
Ni	Threshold value (**TV**) = 50 mg/kg of soil Lower guideline value (**LG**) = 100 mg/kg of soil	240 kg DBeq/kg	0.0085	0.017	
Cr	Threshold value (**TV**) = 100 mg/kg of soil Lower guideline value (**LG**) = 200 mg/kg of soil	6300 kg DBeq/kg	0.017	0.034	
Hg	Threshold value (**TV**) = 0.5 mg/kg of soil Lower guideline value (**LG**) = 2 mg/kg of soil	56000 kg DBeq/kg	0.000085	0.00034	

Ranking of the HM soil contamination potential based on CML characterization factor (Guinée and Lindeijer, 2002) TETP (agricultural soil compartment):

Scale per aggregation of threshold and guideline values using CML CF:

Scale for the DEXI model	Dexi interpretation	
< 0.086955 ($\sum$ (**TV** $_i$***CF** $_i$))	Low	+
[0.086955; 0.15504]	Medium	
> 0.15504 ($\sum$(**LG** $_i$***CF** $_i$))	High	-

References:

(Koch and Salou, 2016)

Water use for animal housing

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Abiotic resources conservation: Water use

Description:

This indicator estimates water consumption for the dairy herd. It includes drinking and cleaning water during the housing and grazing periods. As water is a limited resource, it is an important parameter to take into account when evaluating abiotic resources conservation efforts. This indicator can be directly obtained during the survey. Alternatively, it can be estimated with the LCA method for the housing period (assuming that water consumption is null during grazing).

Unit:

L/kg of milk

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values (L/kg of milk)	**Scales**	**Dexi interpretation**		**References**
3.65	<3.5	Low	+	Based on (Krauß et al., 2016)
3.94	[3.5; 3.9[	Low to medium		
4.23	[3.9; 4.4]	Medium to high		
	> 4.4	High	-	

The Mean blue water consumption for the production of 1kg of milk between 1999 to 2008 for Holstein Friesian cow in Brandenburg (Germany) was 3.94 +-0.29 L. (Krauß et al., 2016)

The blue water consumption used mostly as drinking water accounts for 1.7% to 6.3 % of the water footprint (Brizga et al., 2021) => variation of 4.6%

Mean of water for drinking: 77.5L/cow/d (3.32L/kg milk) and for cleaning: 15,610 L/cow/y.

References:

Adapted from (Van Calker et al., 2004)

% of cultivated area irrigated

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Abiotic resources conservation: Water use

Description:

This indicator is an indirect measure of the water consumption at farm scale. Due to a lack of data and to the complexity to collect the water consumption at crop level. This indicator has been built to take into consideration the management of water consumption. This indicator measure the % of cultivated area irrigated at farm scale. The permanent grassland area is not taken into account.

Unit:

m^3/ha of crops (including grassland)

Indicator calculation:

$$\frac{Total\ area\ of\ crop\ irrigated}{Total\ crop\ area\ of\ the\ farm}$$

Where:

Total area of crop irrigated and total crop area of the farm are expressed in ha.

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Scales	Dexi interpretation		References
0	none	+	Scale built in a participative approach by scientists and experts
]0; 25]	Low		
]25; 50]	Medium		
50	High	-	

Not enough data has been found to build a scale. This indicator depends strongly on the 2020 climate. Thus, it is difficult to find data for this particular year.

Is there a possibility to build a scale after recovering all the data based on the quantile method?

References:

Adapted from (Van Calker et al., 2004)

Total energy consumption

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Abiotic resources conservation: Energy use

Description:

This indicator includes direct and indirect energy consumption. Direct energy consumption is recorded during data collection, while indirect energy consumption is obtained through the LCA methodology from the indirect data. The indirect data are from the background system, that consists of processes on which no or, at best, indirect influence may be exercised by the decision maker for which LCA is carried out (i.e., from machinery, tool production, feed production, phytosanitary production, transport).

Indicator calculation:

$$\frac{direct\ energy\ consumption + indirect\ energy\ consumption}{Total\ milk\ production}$$

Where:

Direct energy consumption and indirect energy consumption is expressed in Mj/year, and the total milk production is expressed in kg of milk/year.

Unit:

MJ/kg of milk

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values (MJ/kg of milk)	**Scales**	**Dexi interpretation**		**References**
1.39 MJ/kg of milk 13,186 MJ/ha	< 2	Very low	+	(Claudine et al., 2009)
3.55 MJ/kg of milk 18,442 MJ/ha	[2; 3.5[	Low		(Christel and Berit, 2000)
2.51 MJ/kg of milk 7246 MJ/ha	[3.5; 4[	Medium		
5 MJ/kg of milk 39,063 MJ/ha	[4; 5]	High		(Thomassen et al., 2008a)
3.10 MJ/kg of milk 17,514 MJ/ha	>5	Very high	-	

Based on three LCA studies "cradle to farm-gate" of dairy farm using mostly Ecoinvent.

Energy consumption through LCA studies varies from 1.5 to 6.2 MJ/kg of milk (De Vries and de Boer, 2010) (Eide, 2002).

References:

Expert opinion adapted from the technical report (Arvalis et al., 2020) and the action 10 : reducing the energy consumption from building and equipment to limit direct CO2 emission (Pellerin et al., 2013)

Expert opinion based on technical report of Arvalis et al., (2020) and Pellerin et al. (2013) (i.e, action #10).

CED method (Frischknecht et al., 2015)

% of farm energy production in the total energy use

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Abiotic resources conservation: Energy use

Description:

This indicator includes the direct energy consumption (direct data collected during the survey) and the indirect energy consumption through the life cycle assessment methodology. The indirect energy consumption is the background processes energy consumption (from machinery, tool, feed, and phytosanitary production, transport …).

Indicator calculation:

$$\frac{farm\ energy\ production}{total\ energy\ use} * 100$$

Unit:

Percentage

Indicator interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Reference values (%)	**Scales**	**Dexi interpretation**		**References**
32% share for renewable energy	>32	Very high	+	Based on the reference values of the European target: 20% of energy consumption from renewable energy (Energy-climate, 2006) and more than 27% in 2030 (Energy-climate, 2009)
	[27; 32]	High		
27% share for renewable energy	[20;27[	Medium		
20% share for renewable energy	[10;20[	Low		
10% share for renewable energy	<10	Very low	-	Based on the key 2030 targets in the EU climate and energy framework. (European Commission, 2014)

References:

Expert opinion adapted from the technical report (Arvalis et al., 2020) and the action 10 entitled: Reducing the energy consumption from building and equipment to limit direct CO2 emission (Pellerin et al., 2013)

Number of different breeds

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Biodiversity conservation: Animal breeds and crops diversity

Description:

It indicates the number of different breeds per species occupying the dairy farm. It represents the genetic diversity of the herd. Only the dairy herd is taken into account. This indicator is positively associated with herd resilience. More specifically, the herd genetic diversity is an important aspect to improve herd resilience against disease and parasitism. However, it adds difficulty to herd management as different breeds may vary in terms of dietary requirements.

Indicator calculation:

$$\frac{Total\ number\ of breeds\ in\ the\ livestock}{1}$$

Unit:

Number of breeds

Indicator interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Based on Phocas et al. (2017), increasing the diversity of breeds in the dairy herd is hard to implement. The reference values suggested below are based on this fact and on the observed data of reproscope (distribution of breeds through French dairy farm).

Reference values (breed)	**Scales**	**Dexi interpretation**		**References**
Minimum = 1	>=4	High	+	Based on the information from (Phocas et al., 2017) applied to a Swedish case study in (Rodríguez-Bermúdez et al., 2019). Scale built in a participative approach by scientists and experts
	3	Medium to high		
	2	Medium to low		
	1	Low	-	

References:

Adapted from (Last et al., 2014; Phocas et al., 2017)

Number of different cultivated species (Crop species richness)

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Biodiversity conservation: Animal breeds and crops diversity

Description:

This indicator quantifies the total amount of different cultivated species at farm level, thus displaying on-farm crop diversity. We assume that farm biodiversity is enhanced by greater diversity of cultivated species per ha as it results in higher potential of species shelter.

Unit: Number of crop species per farm

Indicator interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Reference values (sp)	**Scales**	**Dexi interpretation**		**References**
Minimum = 1sp at farm scale	> 6	High	+	Adapted from the results on the whole case study region (13 regions, covering 203 farms) (Last et al., 2014) Scale built in a participative approach by scientists and experts
Maximum value = 16 sp at farm scale	[5; 6]	Medium to high		
	[3; 5[	Medium to low		
	< 3	Low	-	

References:

Adapted from (Last et al., 2014)

Treatment frequency Index

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Potential loss of biodiversity

Description:

The treatment frequency index is an indicator of phytosanitary treatment intensity and product management. It represents the number of treatments with a certified dose being applied during a technical management route over a year of production. The size of treated area is taken into account in the calculation as well. This index is calculated for each type of crops.

Indicator calculation:

$$\frac{\sum j(\sum i(\frac{Amount\ applied\ of\ PPi}{Certified\ dose\ of\ PPi} * \frac{treated\ area}{total\ area}))}{number\ of\ crops\ j}$$

Where:

PP = Phytosanitary Product

Indicator interpretation:

Higher values indicate larger negative impacts on the environment.

Scale definition:

Reference values	Scales	Dexi interpretation		References
	0	None	+	(Pelzer et al., 2012) based on European and French data collected from several arable crops Scale built in a participative approach by scientists and experts
	]0; 2]	Low		
	]2; 4.5]	Medium		
	>4.5	High	-	

References:

Adapted from (Aouadi, 2011)

Acute toxicity

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Potential loss of biodiversity

Description:

This indicator refers to pesticide toxicity based on the Pesticide Properties Database (PPDB) and the World Health Organization (WHO). It takes into account the acute toxicity of the most widely used active substances in agriculture. The Lethal Dose median (LD50) is used to classify substances (where most LD50 comes from rat experiments). Some data is available for insects and fish (PPDB).

Indicator calculation:

$$average\ of\ the\ LD50 = \frac{\sum i\ (LD50\ of\ active\ substance\ i)}{Total\ number\ of\ active\ substance}$$

Unit:

mg/kg

Indicator interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Reference values (mg/kg)	**Scales**	**Dexi interpretation**		**References**
5000	>=5000	Very low	+	(World Health and International Programme on Chemical, 2010)
2000	[2000; 5000[	Low		
200	[200; 2000[	Medium		
50	[50; 200[	High		
	< 50	Very high	-	

References:

Adapted from (Aouadi, 2011)

(World Health and International Programme on Chemical, 2010)

Habitat diversity

Type of indicator:

Quantitative

Relative dimension and aggregated criteria:

Environmental sustainability: Agroecosystem biodiversity

Description:

This indicator represents the diversity in habitat types at farm level. The method used is the Shannon Index, which takes the value of zero if there is only one habitat on the farm (i.e., no diversity). The value increases as habitat richness increases.

The term habitat is defined as categories of habitats in a general way (e.g., forest, crop, wetland). Similarly to the indicator "number of different cultivated species", we assume that greater diversity in habitats is strongly linked to a greater biodiversity . This indicator covers also the unproductive area (see below the different categories).

Indicator calculation:

$$\sum i \left(\left(\frac{habitat\ area\ i}{total\ habitat\ area} \right) * \left(\frac{Ln\left(\frac{habitat\ area\ i}{total\ habitat\ area} \right)}{Ln(2)} \right) \right)$$

No.	Land Cover Class	Land Cover Subclass	Examples in this subclass
1	Cultivated and Managed Terrestrial Areas (A11)	Trees	Orchards, other tree plantations
2.	Cultivated and Managed Terrestrial Areas (A11)	Shrubs	Plantations of dwarf trees, shrubs (also vineyard)
3	Cultivated and Managed Terrestrial Areas (A11)	Graminoids	Any grain grasses, maize, and cereal grasses
4.	Cultivated and Managed Terrestrial Areas (A11)	Non-graminoids	Others (e.g. sunflowers, raps, any vegetables, herbs)
5.	Natural and Semi-Natural Terrestrial Vegetation (A12)	Woody	Forests (managed and not managed)
6.	Natural and Semi-Natural Terrestrial Vegetation (A12)	Herbaceous	Grassland, meadow
7.	Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation (A24)	Woody	Swamps = forested wetland area along stream, river or lake), bogs, flats
8.	Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation (A24)	Herbaceous	Marshes= wetland at the edges of lakes, streams, rivers dominated by grasses, rushes or reeds

No.	Land Cover Class	Land Cover Subclass	Examples in this subclass
			here also wet meadows! mires, bogs, fens
9.	Artificial Waterbodies, Snow and Ice (B27)	-	ponds, small water bodies, channels

Where:

The unit of each land cover class is ha

Indicator interpretation:

Lower index indicates a lower biodiversity and a higher index indicates a higher biodiversity

Scale definition:

The table below display the calculation for the maximum value of the Shannon index in our study The data column to survey is in yellow (the area). The maximum value of the Shannon index is reached when all the LCCS subclasses are all equally distributed through the farm area. In the blue cell, the maximum of the Shannon index is displayed, i.e. 2.197.

LCCS subclass	area (ha)	p_i	$\ln p_i$	$p_i * \ln p_i$	H
1	10	0,11	-2,20	-0,24	2,197
2	10	0,11	-2,20	-0,24	
3	10	0,11	-2,20	-0,24	
4	10	0,11	-2,20	-0,24	
5	10	0,11	-2,20	-0,24	
6	10	0,11	-2,20	-0,24	
7	10	0,11	-2,20	-0,24	
8	10	0,11	-2,20	-0,24	
9	10	0,11	-2,20	-0,24	
Sum	90	1,000			

Reference values	Scales	Dexi interpretation		References
Minimum Shannon index (0)	[1.4; 2.2]	High	+	Expert opinion
Maximum Shannon index = 2,2	[0.7; 1.4[	Medium		
	<0.7	Low	-	

References:

Adapted from (Di Gregorio and Jansen, 2000; Herzog et al., 2013; Walz, 2011)

Grassland management

Type of indicator:

Qualitative

Relative dimension and aggregated criteria:

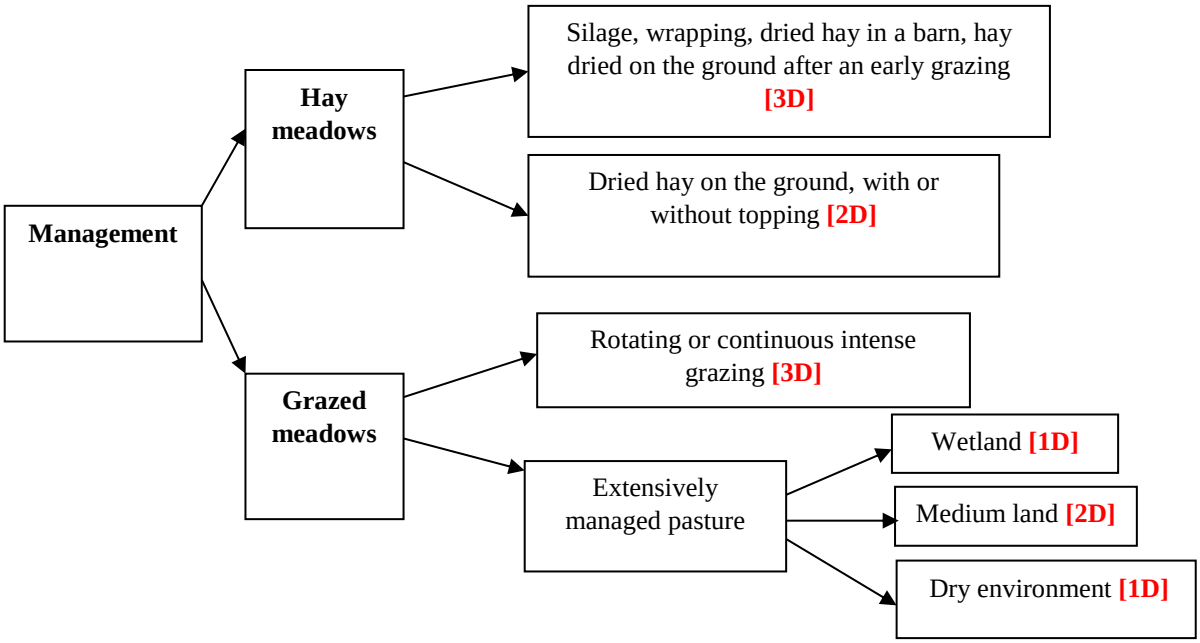
Environmental sustainability: Agroecosystem biodiversity

Description:

This indicator evaluates the ecological value of grasslands. It takes into account the management of these meadows and their surface areas. Depending on their degree and way of management, grasslands can be important shelters for biodiversity. The selected fertilization classes are the following:

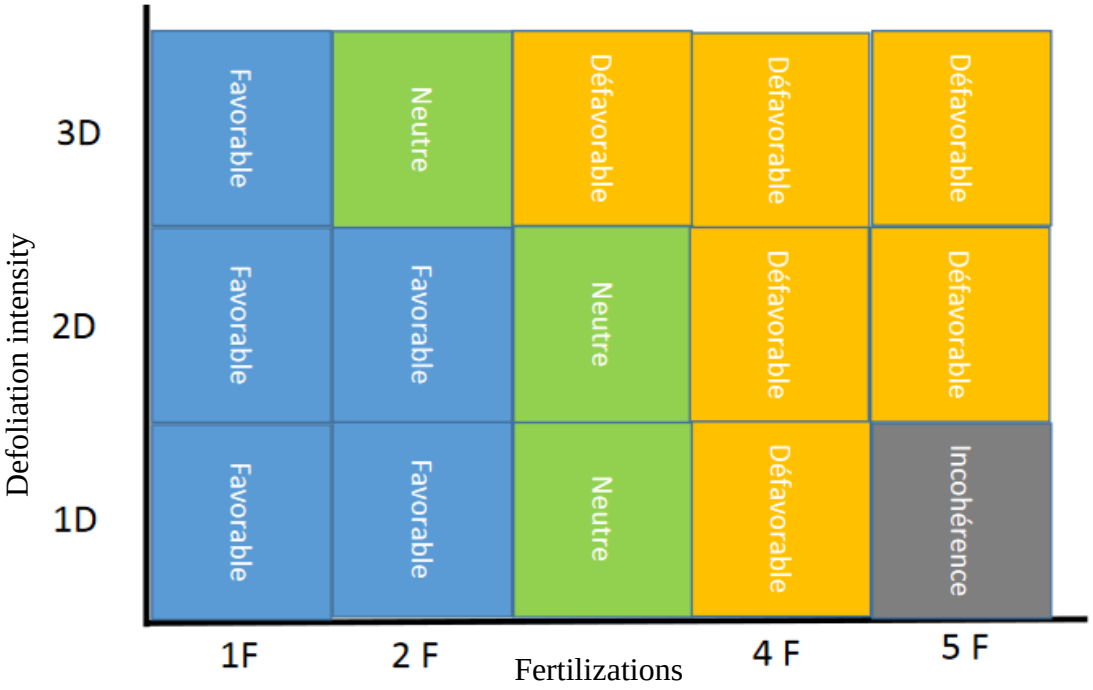
Fertilization code	Mineral fertilizer	Organic fertilizer
1F	0	Very occasional
2F	0	Regular
3F	< 80 N units /ha/year (mowing) < 40 N units /ha/year (grazing)	Occasional
4F	< 80 N units /ha/year (mowing) < 40 N units /ha/year (grazing)	Regular
5F	> 80 N units /ha/year (mowing) > 40 N units /ha/year (grazing)	With or without intake

Grassland management types under consideration are the following:



Indicator calculation:

The scoring matrix is built in function of the grassland management types (Y-axis) and its fertilization (X-axis).



Blue = favorable (Bdv2), Green = neutral (Bdv1), Yellow = unfavorable (Bdv0)

Aggregation of the scores: $\frac{Bdv1 + Bdv2}{Bdv0 + Bdv1 + Bdv2} * 100$

Unit:

Percentage

Indicator interpretation:

Lower values indicate larger negative impacts on the environment.

Scale definition:

Scale	**Dexi interpretation**		**References**
>45	High	+	Adapted from (Manneville et al., 2014)
]25; 45]	Medium		
[0; 25]	Low	-	

References:

Adapted from (Manneville et al., 2014)

Participation in agri-environmental scheme

Type of indicator:

Qualitative

Relative dimension and aggregated criteria:

Environmental sustainability: Agroecosystem biodiversity

Description:

This indicator permits us to know if a specific management plan dedicated to the protection of biodiversity is set up. This pillar includes specific agricultural practices supporting biodiversity in its broad sense. For instance, this scheme could include the implementation of hedgerows, management system of wetlands or other semi-natural habitats.

Unit:

Yes/No

Indicator interpretation:

Yes = positive impact on the environment

No = negative impact on the environment

Scale definition:

Scale	Dexi interpretation		References
Yes	Positive impact	+	Adapted from (Manneville et al., 2014)
No	Negative impact	-	

References:

Adapted from (Manneville et al., 2014)

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