SMARTCLIMATE – INTEGRATED ANALYSIS OF AGRICULTURAL PRACTICES IN LUXEMBOURG TO DETERMINE THEIR CLIMATE IMPACT USING THE SMART-FARM TOOL

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Acknowledgement

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Abstract

Luxembourg has joined international and European efforts to tackle the challenge of climate change. Efforts to reduce greenhouse gas emissions are needed in all sectors, thus also in agriculture. The aim of the project is to determine the current sustainability performance of the Luxembourgish agriculture sector in terms of climate change. The climate impact of different farm types (OTE 45 – *Specialist dairying;* OTE 46- *Specialist cattle - rearing and fattening* and OTE 47 - *Cattle - dairying, rearing and fattening combined*) and of different management systems (conventional or organic) was identified. The implemented farming practices were analysed to identify commonalities in terms of climate impact. Furthermore, the relationship between the sustainability performance in terms of climate change and in terms of other areas of sustainability was studied. The Sustainability Monitoring and Assessment RouTine (SMART)-Farm Tool was used to assess on-farm sustainability on 60 farms. An overarching analysis of the four sustainability dimensions of the three farm types and the two management systems was performed, followed by a detailed analysis for the sub-theme *Greenhouse Gases*.

Results show that the overall farms sustainability performances are *moderate* to *good*. The sustainability performance of the three farm types is very close and follow the same trend, whereas for the management system, organic farms had a higher mean goal achievement over all but one of the 21 sustainability themes than conventional farms. Goal achievement for the sub-theme *Greenhouse Gases* was *moderate* and does not differ significantly between the three farm types. Organic farms show a significantly higher mean goal achievement for *Greenhouse Gases* than for conventional farms. For indicators impacting in *Greenhouse Gases,* the organic and the OTE 46 farms have generally higher ratings. Correlation between *Greenhouse gases* and the other sub-themes are mainly in the *Environmental Integrity* dimension, showing that implementing climate positive farming practices can also improve other ecological aspects. The study identified the following linchpins: increase in protein autarky, closing of farming cycles and holistic approach with strategic decision making leading to harmonized actions towards a sustainable and climate positive farming system. Further research is needed taking into account consumer behaviours such as food waste and dietary patterns.

1. Introduction

To tackle the challenge of climate change, Luxembourg has joined international and European efforts to reduce greenhouse gas emissions (GHG)[1]. The Luxembourgish agriculture sector was responsible for the emissions of 711.72 Gg CO_2-equivalents, which corresponds to 6.95% of the total Luxembourgish GHG emissions excluding land-use, land use change and foresting (LULUCF) in 2016 (Bechet et al., 2019). This percentage share is only expected to increase as the emissions of the agriculture sector are predicted to remain the same while the other sectors reduce their emissions (EC, 2011; Wollenberg et al., 2016). However, each sector needs to share in the efforts to tackle climate change, and as such, the agriculture sector also needs to reduce their GHG emissions. Furthermore, the agriculture sector can also play an important role in mitigation GHG emissions by promoting carbon sequestration and increasing carbon sinks.

The aim of this joint project SMARTClimate of the "Institut fir Biologësch Landwirtschaft an Agrarkultur Luxemburg a.s.b.l." (IBLA), "Forschungsinstitut für biologischen Landbau" (FiBL), Luxembourg Institute of Health (LIH), University of Luxembourg (UL) and Sustainable Food Systems GmbH (SFS) is to determine the current sustainability performance of the Luxembourgish agriculture sector in terms of climate change.

The project will analyse

1. the climate impact of different farm types (with focus on dairy and beef production) and of different management systems (conventional or organic).
2. The project will analyse the implemented farming practices and search for commonalities in terms of their climate impact (both positive and negative) in order to discuss linchpins that need changing for a climate positive agriculture landscape.
3. Furthermore, the project will study the relationship between the sustainability performance in terms of climate change and in terms of other areas of sustainability (e.g. liquidity, profitability or quality of life). Thus, trade-offs and synergies between different sustainability topics can be identified, as climate impact and greenhouse gas emissions are not looked upon in isolation.

[1] United Nations Framework Convention on Climate change as well as the follow-up agreements linked to the Convention, the Kyoto Agreement and the Paris Agreement (United Nations (UN), 1992, 1998, 2015a), 2030 Agenda for Sustainable Development of the UN (UN, 2015b), European Climate and Energy package (European Commission (EC), 2011), "Accord de Coalition 2018-2023" (Gouvernement du Grand-Duché de Luxembourg, 2018a), « Plan National du Développement Durable du Luxembourg" (Ministère de l'Environnement, du Climat et du Développement durable (MECDD), 2018; Ministère du Développement durable et des Infrastructures MDDI), 2010), "Nationaler Aktionsplan Klimaschutz" (Ministère de l'Environnement, du Climat et du Développement durable and Ministère de l'Energie et de l'Aménagement du territoire, 2019; Ministère du Développement durable et des Infrastructures, 2013)

2. Materials and methods

2.1 Data collection

2.1.1 Farm-level Sustainability Assessment

The Sustainability Monitoring and Assessment RouTine (SMART)-Farm Tool, developed by FiBL was used for the on-farm sustainability assessment (Schader et al., 2016). This sustainability assessment is based on the sustainability goals set by the Food and Agriculture Organisation (FAO) for the Food and Agriculture Systems and that are outlined in the Guidelines for the Sustainability Assessment of Food and Agriculture Systems (SAFA Guidelines) (FAO, 2014a, 2014b; Schader et al., 2016). SMART-Farm Tool operationalises the SAFA Guidelines in a science-based efficient way (FAO, 2014a; Schader et al., 2016). These guidelines provide a universal framework for such an assessment in an attempt to promote a functional and uniform sustainability assessment approach (FAO, 2014a). The guidelines define four dimensions of sustainability (*Good Governance, Environmental Integrity, Economic Resilience and Social Well-Being*), which are in turn divided into 21 themes and 58 sub-themes (Figure 1), with associated explicit sustainability objectives and targets.

The analysis of the goal achievement in the sub-theme *Greenhouse Gases* in the theme *Atmosphere* within the dimension *Environmental Integrity* will be the focus of the study at hand. The SAFA-Guidelines define the theme goal as "The enterprise's actions contain greenhouse gases to the extent possible and do not release quantities of ozone-depleting substances and air pollutants that would be detrimental to the health of ecosystems, plants, animals or humans." with the sub-theme objective for *Greenhouse Gases* being: "The emission of greenhouse gases is contained" (FAO, 2014a). In the further description of the sub-theme the focus is set on reducing emissions and implementing practices to increase sequestration, respectively. The detailed description as well as the goals and objectives for all the other themes and sub-themes can be looked up in the SAFA Guidelines themselves (FAO, 2014a).

The assessment is based on a farm visit in combination with an interview (approx. 3h) with the farm manager during which the necessary data is collected. The farmers gave their consent to a copy of their "Flächenantrag" being send by the SER directly to IBLA. Relevant data could thus be entered before the farm visit to facilitate the interview. The data from the "Flächenantrag" as well as from the on-farm interview was then used to evaluate the 300+ indicators embedded in the SMART-Farm Tool.

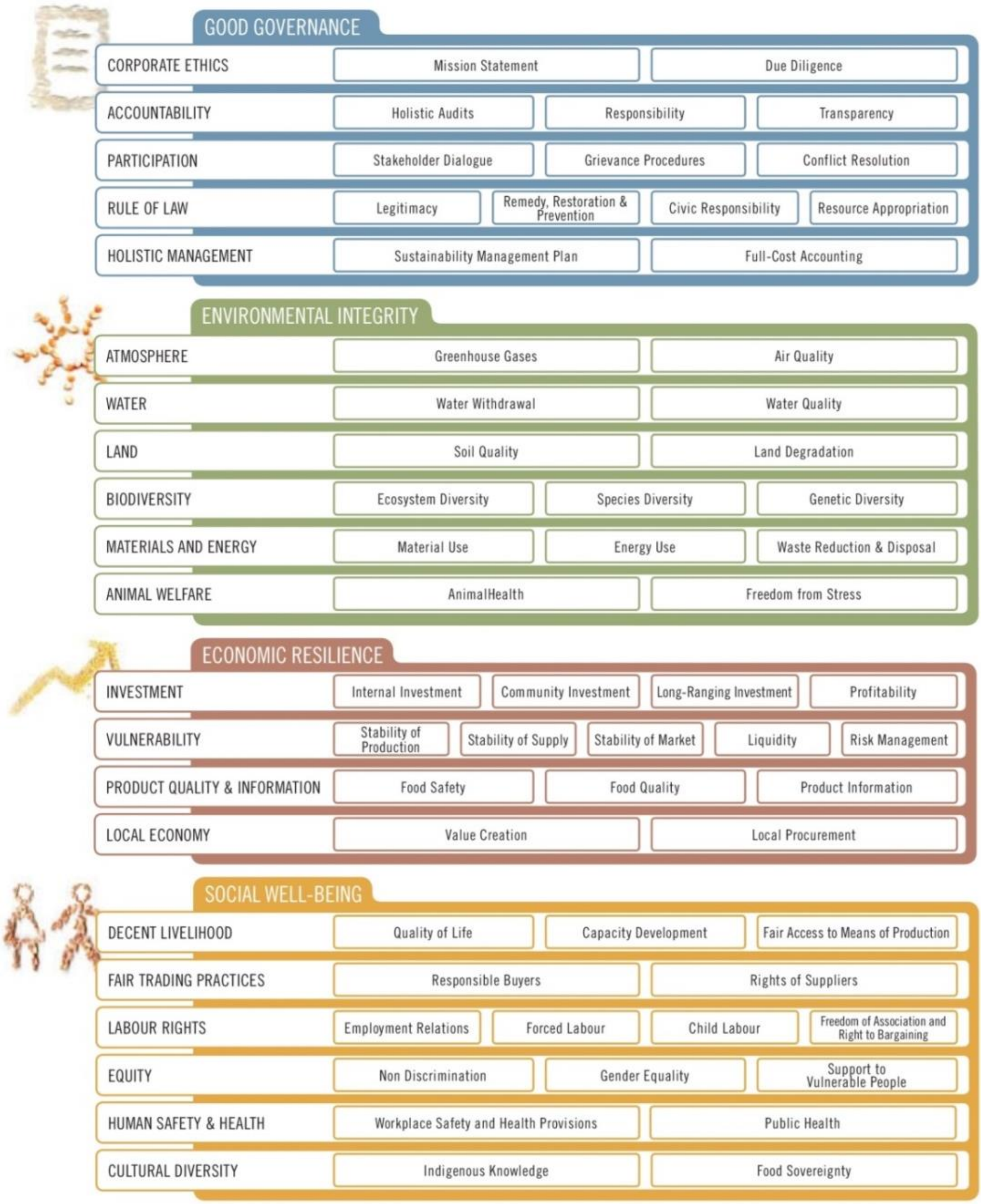

Figure 1: SAFA-Dimensions and themes (FAO, 2014a). The four dimensions of sustainability *Good Governance, Environmental Integrity, Economic Resilience* and *Social Well-Being* are shown, which are in turn divided into 21 themes and 58 sub-themes.

2.1.2 Sampling plan

First, it is important to note that the sampling was designed to fulfil the aims of the project SustEATable and not directly for the aims of SMARTClimate. However, the sampling design proves also adequate for the study at hand.

Luxembourg has an area of 2,586 km^2, of which slightly over half is land used for agricultural production (131,158 ha). Of the area used for agricultural production 47 % are arable land and 51 % are permanent grassland (Service d'Economie Rurale (SER), 2019, 2018). In 2017, there were 1883 agricultural holdings in Luxembourg, (based on data provided by the SER in the summer of 2018). Of these 1883 farms, 73 were organic farms (3.9 % of all farms) and 21 farms were in the process of transitioning to organic production (based on data provided by the SER in the summer of 2018). The average size of agricultural holdings was 69 ha (based on data provided by the SER in the summer of 2018).

The main farm type in Luxembourg is *specialist grazing livestock* comprising OTE (orientation technico-économique) 45 - *Specialist dairying*, OTE 46 - *Specialist cattle - rearing and fattening* and OTE 47 - *Cattle - dairying, rearing and fattening combined*. These three farm types make up over 50 % of the farms in Luxembourg (based on data provided by the SER in the summer of 2018). Of the 94 organic farms and farms transitioning to organic farming, 39 farms were of the farm type OTE 45, 46 or 47. Thus, the *specialist grazing livestock* make up 41 % of the organic farms (based on data provided by the SER in the summer of 2018).

With the global livestock sector representing around 15% of human-induced GHG emissions, of which the beef and cattle milk production account together for over 60% of the sector's global emissions (Gerber and Food and Agriculture Organization of the United Nations (FAO), 2013), the study at hand will focus on the three *specialist grazing livestock* farm types and analyse their climate impact for Luxembourg. Furthermore, the climate impact will also be assessed by management system (organic or conventional).

At the end of September 2018, a call for participation (Annex 1) was sent to 1513 farmers out of the 1883 registered farms in the framework of the project SustEATable. Agricultural holdings that receive their main income from permanent crop productions (e.g. wine production OTE 354), fruit production (OTE 365, 380 and 842)) or that have very specialized production systems (such as mushroom production (OTE 231), tree nurseries (OTE 232), flowers and ornamental plant production (OTE 222)) were excluded. Lastly, beekeepers (OTE 843) were also not considered as they generally do not labour any agricultural land. In order to protect privacy, the call was mailed by the SER.

Furthermore, the call for participation was printed in the IBLA Newsletter N.06 in November 2018 and an advertisement was run in the "Luxemburger Bauer" in December 2018. The different Luxembourgish farmers organizations, many of which are also represented in the SustEATable Advisory Board, were contacted and asked to share the call with their members (e.g. Landwirtschaftlech Kooperatioun Uerwersauer (LAKU), CONVIS, Bio-Lëtzebuerg and Baueren Allianz).

Due to time constraints, no second reminder was sent via mail.

We received 104 answers to our call of which 85 farms were progressively contacted and analysed for their sustainability performances. The sampling run was from January 2019 until August 2019. During this time 60 farms with the OTEs 45, 46 and 47 were assessed, which form the study sample at hand. A more detailed description of the study sample is given in Chapter 3.1.

2.1.3 Auditors

The data collection was performed by a team of four trained SMART-auditors from IBLA, to ensure objective on-farm assessments.

2.1.4 Adaptation of the SMART-Farm Tool

The SMART-Farm Tool (Version 5.0; launched in October 2018) was used for the assessments. Adaptations were made to the tool specifically for Luxembourg: Luxembourg was defined in the tool as its own region with related compliances being implemented in regards to the Luxembourgish laws and regulations (e.g. in regards to waste management and working conditions). Compliances were also introduced for members of Bio-Lëtzebuerg. Pre-defined compliances auto-rate some of the indicators in the SMART-Farm Tool questionnaire helping to reduce the time of the on-farm interview.

2.1.5 Pre-test

A pre-test was run on five farms between 15th November and 21st December 2018, before the main data collection phase, in order to identify any problems with the implemented changes to the SMART-Farm Tool. Minor issues were discovered, necessary changes were implemented in the tool and the last pre-test interview proved successful. The main data collection phase started in January 2019 until August 2019.

2.1.6 Confidentiality and data protection

The farms were contacted via the from-them-provided phone number in order to set a date for the farm visit and interview. On the day of the interview, a SMART-Farm Assessment Consent Form was signed by both the farmer and the auditor. In this consent form, FiBL, SFS and IBLA commit themselves to treating all data provided from the farmer confidentially, outline how the collected data will be stored and processed and inform the farmer of his rights according to European and national laws and regulations (European Parliament and Council, 2016; Gouvernement du Grand-Duché de Luxembourg, 2018b). The farmers in turn committed themselves to providing complete and truthful information, including their answers during the interview.

Due to confidentiality, no data or results from a single farm will be revealed; only results from overarching assessments of multiple farms will be discussed in the following.

2.2 Data analysis

2.2.1 Individual farm sustainability assessment with the SMART-Farm Tool

As mentioned above, during the on-farm interview, 300+ indicators are being assessed depending on the farm type. These indicator ratings are then used to assess the goal achievement in the 58 sustainability sub-themes. The model is semi-quantitative, meaning that mostly qualitative questions ("Does the farmer take measures to avoid soil compaction?" -Yes/No) are asked and transferred to quantitative ratings. Indicators can impact multiple sub-themes. To reflect the importance of each indicator on a specific sub-theme, the indicators are given different weights (that can be positive or negative). The respective goal achievement corresponds to the weighted average of the indicator ratings of a sustainability sub-theme (Figure 2). The goal achievement, which is given in percentages, is than assessed using a five-level scale from 0 (unacceptable: 0% - 20% of the sustainability objective are achieved) to 4 (best: 81% - 100% of the sustainability objective are achieved; Figure 3). This scale is used for the display of the assessment in the radar charts in Chapter 3.

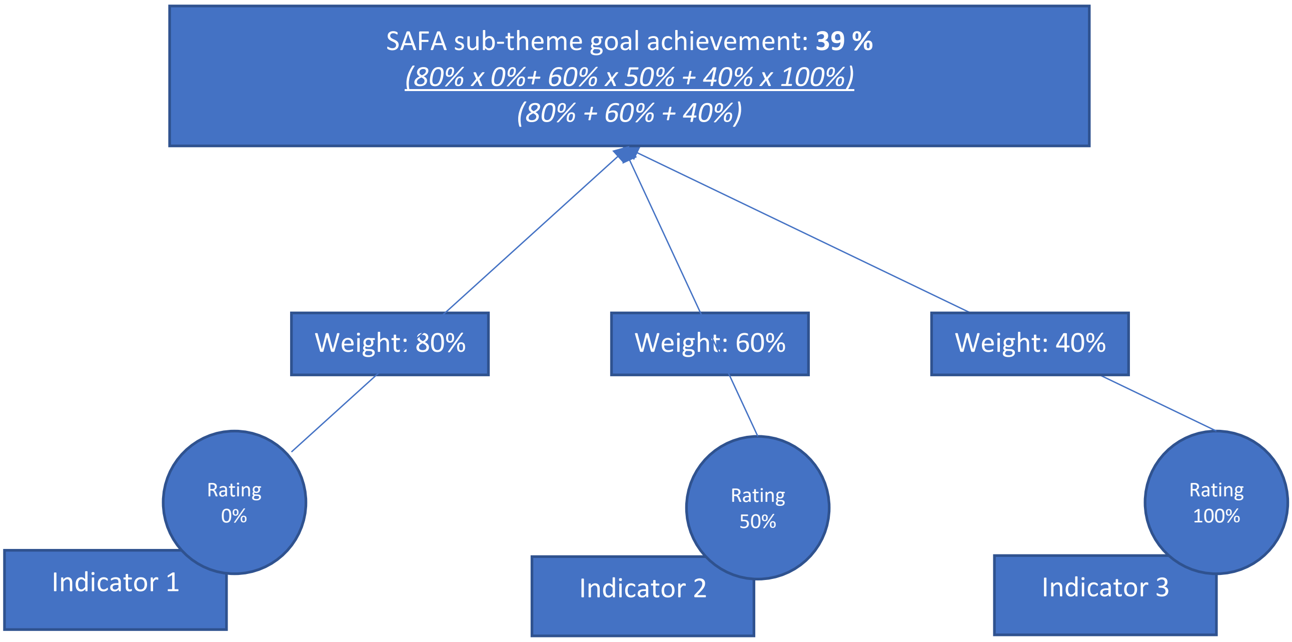

Figure 2: Example of the calculation underlying the goal achievement assessment.

Figure 3: Scheme for the assessment of the sustainability objective achievement.

As the SAFA-Guidelines do not only refer to farms but also to companies, the objectives of some of the themes are only partly achievable or not relevant for farms. This applies mainly to themes from the dimension *Good Governance*, since the management of farms is often organised informally and not structured and systematic as in companies. In the *Social Well-Being* dimension many themes refer to the handling of employees, and therefore have less relevance for small farm holdings, which often operate without employees. But as this theme also refers to the social conditions of primary producers (e.g. when buying-in farm inputs), also small farms can have a certain influence, which is often indirect, e.g. over the selection of suppliers or the demand for socially and/or environmentally certified farm inputs, especially feedstuff. Overall, it should be noted that the SAFA-objectives describe the ideal state of sustainable management. This means that assessments in the red or orange area are quite common and do not necessarily mean that a farm is less sustainable than the average of comparable farms.

2.2.2 Statistical analysis

The individual farm results from the SMART Sustainability assessment and indicator ratings were used to do an overarching analysis of the climate impact of the three farm types and the two management systems.

The statistical analysis was performed in R© (Version 3.6.1) using the integrated development environment RStudio© (Version 1.2.1335). The data was tested for normality using the Shapiro-Wilk test and for equal variance using the Bartlett test.

The impact of farm type (OTE 45, 46, 47) and management system (organic, conventional) on the SAFA-goal achievement in the sub-theme *Greenhouse Gases* was studied.

The statistical tests were chosen depending on the normality and equal variances of the data:

I. Comparison of farm type
    a. One-way ANOVA and Tukey's pairwise comparison in case of normal distribution
    b. Kruskal-Wallis and pairwise comparison with Wilcoxon rank sum test in case of not normal distribution
II. Comparison of management systems
    a. Independent two sample t-test in case of normal distribution
    b. Wilcoxon rank sum test in case of not normal distribution
III. Comparison of indicator results that impact the sub-theme *Greenhouse Gases* responsible for possible differences in I and II.
    a. For farm type
        i. One-way ANOVA and Tukey's pairwise comparison in case of normal distribution
        ii. Kruskal-Wallis and pairwise comparison with Wilcoxon rank sum test in case of not normal distribution
    b. For management systems:
        i. Independent two sample t-test in case of normal distribution
        ii. Wilcoxon rank sum test in case of not normal distribution
IV. Correlation analysis between the sub-theme *Greenhouse Gases* and the other 57 sub-themes for the different farm types and the different management systems
    a. Pearson correlation in case of normal distribution
    b. Spearman rank-correlation in case of not normal distribution

3. Results

3.1 Sample description

A total of 60 farms was analysed using the SMART-Farm Tool, with focus on the OTEs 45, 46 and 47 (Table 1 and Table 2). This represents 3.2 % of all agricultural holdings in 2017, and 6.7 % of all agricultural holdings with the farm types OTE 45, 46 and 47 combined. Of these 60 farms, 16 were managed organically and 44 conventionally. The 16 organic farms represent 17 % of all organic farms and farms transitioning to organic farming in 2017, and 41 % of the farm types OTE 45, 46 and 47 in this management system.

As can be seen in Table 2, the average size of the agricultural holdings in the sample (117 ha) is bigger than the average of all agricultural holdings in Luxembourg (69 ha). Consequently, the average size of arable land and permanent grassland of the sampled farms is higher than the Luxemburgish average. Nevertheless, sampled farms used 45.6 % of their agricultural area as arable land, which is close to the 47.5 % of all farms. Permanent grassland of the sampled farms and of all farms is also close together with 54.3 % respectively 51.3 %.

Table 1: Characteristics of all farms in Luxembourg; farms in sample and the share of farms in sample to all farms (based on data provided by the SER in the summer of 2018).

	All farms in Luxembourg		Farms in sample		Share of farms in sample to all farms
Number of farms	1883	(100 %)	60	(100 %)	(3.2 %)
Agricultural area (ha)	129148	(100 %)	7014	(100 %)	(5.4 %)
Arable land (ha)	61390	(47.5 %)	3201	(45.6 %)	(5.2 %)
Permanent grassland (ha)	66277	(51.3 %)	3806	(54.3 %)	(5.7 %)
OTE 45	531	(28.2 %)	34	(56.7 %)	(6.6 %)
OTE 46	316	(16.8 %)	15	(25.0 %)	(4.4 %)
OTE 47	142	(7.5 %)	11	(18.3 %)	(7.7 %)
Organic	94	(5.0 %)	16	(26.7 %)	(17.0 %)
Conventional	1789	(95.0 %)	44	(73.3 %)	(2.5 %)

Table 2: Characteristics of all farms in Luxembourg and farms in sample in total, for the three farm types (OTE 45, OTE 46 and OTE 47) and the management system (organic, conventional) (based on data provided by the SER in the summer of 2018).

	Number of farms	Agricultural area (ha)	Arable land (ha)	Permanent grassland (ha)
All farms in Luxembourg	1883	68.59	32.60	35.20
Farms in sample	60	116.89	53.34	63.44
OTE 45	35	125.07	62.17	62.82
OTE 46	14	95.40	41.44	53.94
OTE 47	11	120.91	42.28	78.28
Organic	16	89.62	41.29	48.15
Conventional	44	126.81	57.73	69.00

3.2 Overview of the overall performance in the four sustainability dimensions

The overall assessment results are shown in Figure 4 for farm type and in Figure 5 for management system. The figures show the SAFA goal achievement at the theme level. In both figures the overall mean[2] of the sample (n = 60) is shown with the minimum and maximum goal achievement values for each theme. Additionally, the mean goal achievements at theme-levels of the three analysed farm types (OTE 45: n = 35; OTE 46: n = 14; OTE 47: n = 11) are shown in Figure 4 and the mean goal achievements at the theme level of the two analysed management systems (Organic: n = 16; Conventional: n = 44) are shown in Figure 5.

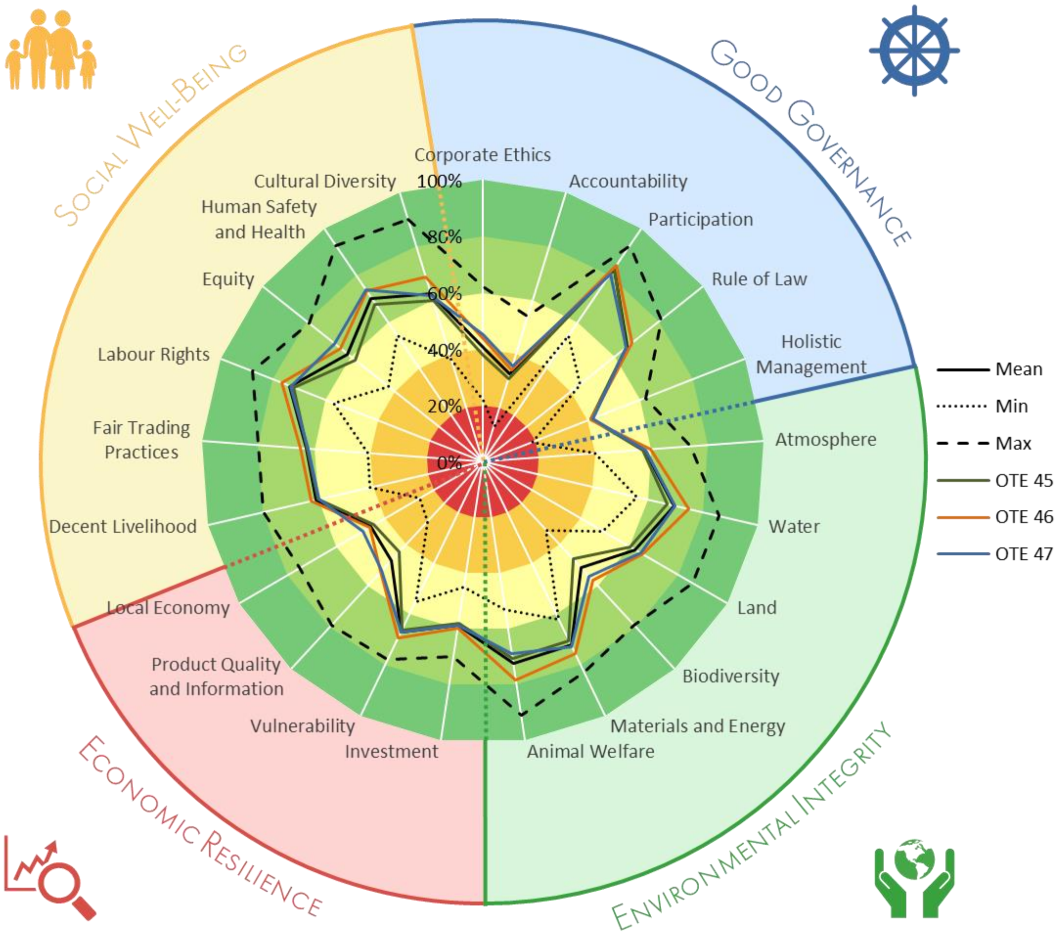

Figure 4: Average overall results of the four sustainability dimensions for the three analysed farm types. Goal achievement at the theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different farm types (OTE 45: n = 35 (olive green line); OTE 46: n = 14 (orange line); OTE 47: n = 11 (blue line)). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.

[2] The mean refers to the arithmetic mean. Mean and average are used as synonyms throughout the report.

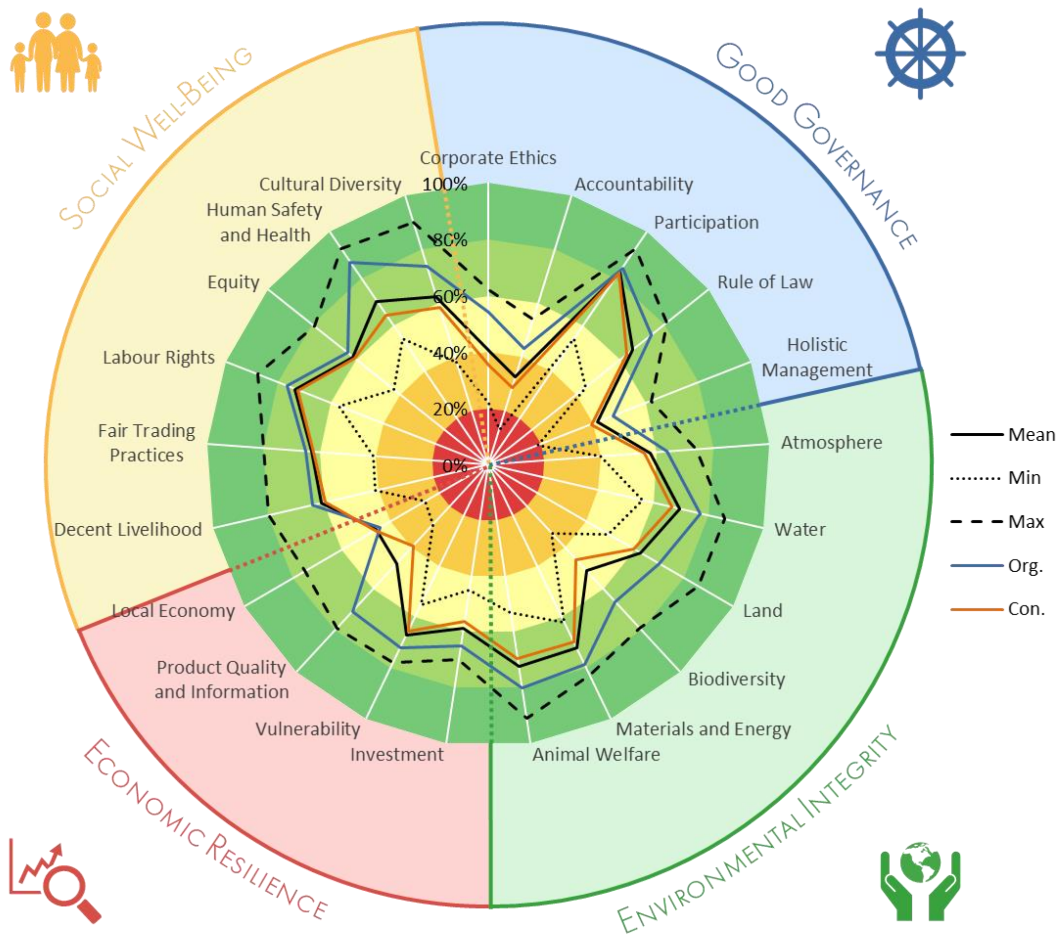

Figure 5: Average overall results of the four sustainability dimensions for the two analysed management systems. Goal achievement at the theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different management systems (Org. (Organic): n = 16 (blue line); Con. (Conventional): n = 44 (orange line)). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.

3.2.1 Goal achievement of the total sample

The overall mean of the partaking farms shows that the farms attained over 50 % goal achievement in most of the sustainability themes. Only in 5 of the 21 themes, the goal achievement was below 50 % (*Accountability*: 32.7 %; *Corporate Ethics*: 40.5 %; *Holistic Management*: 41.4 %; *Local Economy:* 45.9 %; and *Product Quality and Information*: 47.7 %). The highest mean goal achievement was attained in the sustainability theme *Participation* (82.9 %), with goal achievements *Human Safety and Health* (70.3 %), *Materials and Energy* (72.1 %), *Animal Welfare* (72.2 %) and *Labour Rights* (73.6 %) all also reaching goal achievements over 70 %. Averaging the goal achievement in all themes, a mean of 60 % is attained. Thus, it can be said that the farms sustainability performances are *moderate* to *good*.

The minimum and the maximum goal achievement in each sustainability theme show that wide differences exist in the sustainability performances at the individual farm level. Stark differences can especially be seen in *Participation* (min: 54 %; max: 93 %), *Corporate Ethics* (min: 22 %; max: 62 %), *Accountability* (min: 13 %; max: 54 %), *Holistic Management* (min: 19 %; max: 62 %), Biodiversity (min: 33 %; max: 79 %), *Local Economy* (min: 26 %; max: 75 %), *Product Quality and Information* (min: 29 %; max: 79 %), *Cultural Diversity* (min: 38 %; max: 90 %).

Looking more closely at the theme *Atmosphere*, of which the sub-theme *Greenhouse Gases* is a part of, it can be seen, that the mean goal achievement over all 60 partaking farms was 57.8 %, with the minimum of 40 % and the maximum of 74 %. Thus, the overall sustainability performance in the theme can be classified as *moderate*.

3.2.2 Goal achievement by farm type

Looking at the mean of the three different farm types (OTE 45: *Specialist dairying*; OTE 46: *Specialist cattle - rearing and fattening*; and OTE 47: *Cattle - dairying, rearing and fattening combined*) (Figure 4), it can be seen that their sustainability performances in the 21 themes are very close together and follow the same trend. Small differences can be seen in *Biodiversity* (OTE 45: 47.1 %; OTE 46: 57.3 %; OTE 47: 55.3 %), *Product Quality and Information* (OTE 45: 43.7 %; OTE 46: 53.2 %; OTE 47: 52.6 %), *Human Safety and Health* (OTE 45: 67.9 %; OTE 46: 73.3 %; OTE 47: 73.9 %), and *Cultural Diversity* (OTE 45: 60.1 %; OTE 46: 68.6 %; OTE 47: 61.8 %). Overall, the *specialist dairying farms* (OTE 45) have lowest goal achievement scores in all the sustainability themes, whereas the *Specialist cattle - rearing and fattening farms* (OTE 46) tend to have the highest scores, with a few exceptions (e.g. *Accountability* and *Equity*), out of the three analysed farm types.

Looking again more closely at *Atmosphere*, it can be seen that all 3 farm types have attained very similar goal achievement in this theme, with OTE 46 performing best out of the three (OTE 45: 56.9 %; OTE 46: 59.6 %; OTE 47: 57.9 %). Their sustainability performance can be classified as *moderate*.

3.2.3 Goal achievement by management system

Larger differences in goal achievement can be seen when looking at the mean results per management system (Figure 5). The organic farms have a higher mean goal achievement in all but one sustainability theme (*Local Economy:* Org. = 44.3 %; Con. = 46.4 %) and their sustainability performances are overall in the *good* to *best* categories (67.7 % mean goal achievement over the 21 sustainability themes), except in 4 out of the 21 sustainability themes (*Accountability*: 43.1 %; *Local Economy*: 44.3 %; *Holistic Management*: 47.7 %; *Corporate Ethics*: 54.3 %). The conventional farms' sustainability performances are on average in the *moderate* category (57.1 % mean goal achievement over the 21 sustainability themes) with lowest goal achievement in *Accountability* (28.8 %) and highest in *Participation* (82.3 %).

In *Corporate Ethics* (Org.: 54.3 %; Con.: 35.5 %), *Biodiversity* (Org.: 66.1 %; Con.: 45.7 %), *Human Safety and Health* (Org.: 87.1 %; Con.: 64.2 %), and *Product Quality and Information* (Org.: 70.9 %; Con.: 39.3 %) the mean goal achievement for organic and conventional show the highest differences.

In *Atmosphere,* the trend is continued with organic farms attaining a higher goal achievement then organic farms (Org.: 63.6 %; Con.: 55.7 %). Organic management system shows on average a *good* sustainability performance, whereas conventional management system can be classified on average as *moderate*.

3.3 Overview of the overall performance in the sub-theme *Greenhouse Gases*

The goal achievements at the sub-theme level in the dimension *Environmental Integrity* are shown in Figure 6 for farm type and in Figure 7 for management system. As in the previous figures, the mean of the sample (n = 60) is shown with the minimum and maximum goal achievement value for each sub-theme of the *Environmental Integrity* sustainability dimension. Additionally, the mean goal achievements at the sub-theme level of the three analysed farm types (OTE 45: n = 35; OTE 46: n = 14; OTE 47: n = 11) are shown in Figure 6 and the mean goal achievements at the sub-theme level of the two analysed management systems (Organic: n = 16; Conventional: n = 44) are shown in Figure 7.

As the focus of the project at hand is the sustainability performance of the farming sector in terms of GHG emissions and climate change, only the *Environmental Integrity* dimension with the sub-theme *Greenhouse Gases* is shown and discussed in more detail. However, the detailed figures of the other three sustainability dimensions are shown in the Annexes 2-7.

3.3.1 Goal achievement of the total sample of the overall performance in the sub-theme *Greenhouse Gases*

On average, the sustainability performance of the 60 participating farms in this sub-theme *Greenhouse Gases* can be classified as *moderate* with a mean of 54.1 % goal achievement. The lowest goal achievement was 40 % and the highest 73. The sustainability performance spans two categories, from *limited* to *good* sustainability performance.

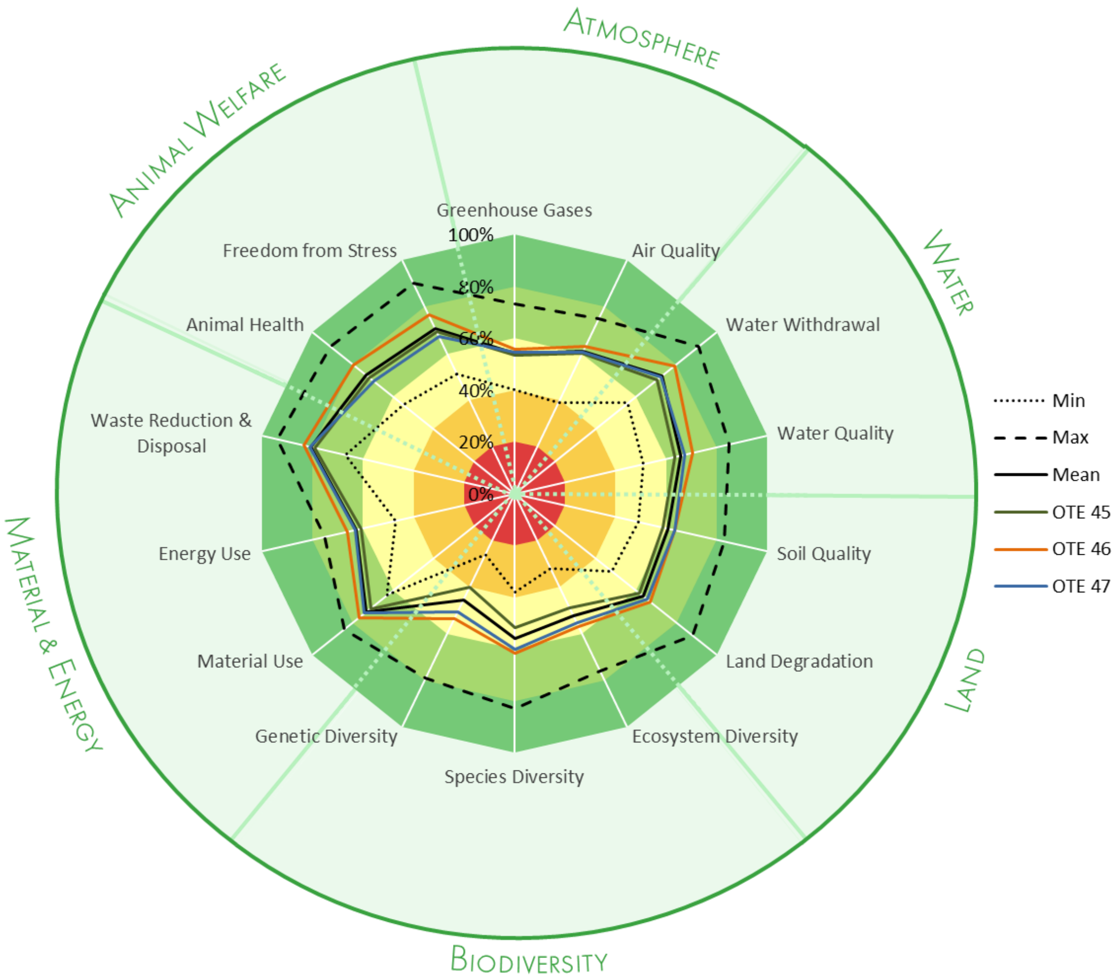

Figure 6: Results for the sustainability dimension *Environmental Integrity* with the sub-theme *Greenhouse Gases*. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different farm types (OTE 45: n =35 (olive green line); OTE 46: n = 14 (orange line); OTE 47: n = 11 (blue line)). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.

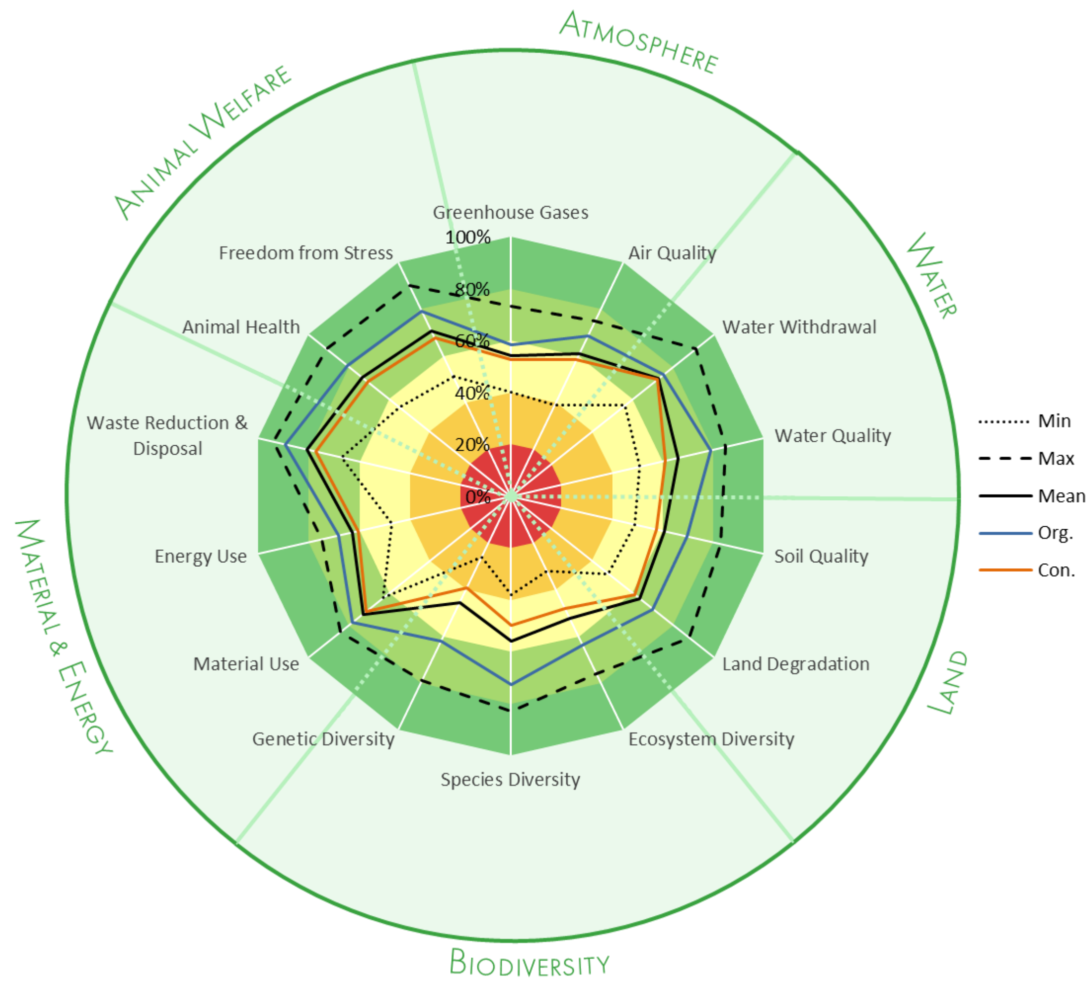

Figure 7: Results for the sustainability dimension *Environmental Integrity* with the sub-theme *Greenhouse Gases*. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different management systems (Org. (Organic): n = 16; Con. (Conventional): n = 44). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.

3.3.2 Goal achievement by farm type of the overall performance in the sub-theme *Greenhouse Gases*

In the sub-theme *Greenhouse Gases*, the goal achievement of the three analysed farm types lie very close together in the *moderate* sustainability performance category. Tests for normality and equal variance showed that the data was not normally distributed and that equal variance was not given. The data was therefore analysed using the non-parametric Kruskal-Wallis test and no significant difference between the three farm types was detected (p-value = 0.3749) for the goal achievement in the sub-theme *Greenhouse Gases*. On average the farms with OTE 45 had 53.3 % ±3.9 standard deviation (SD) goal achievement (n= 35), the farms with OTE 46 had 55.6 % ±7.3 SD goal achievement (n= 14) and the farms with OTE 47 had 54.6 % ±6.9 SD goal achievement (n= 11).

3.3.3 Goal achievement by management systems of the overall performance in the sub-theme *Greenhouse Gases*

A small difference can be visually discerned in the goal achievement for the sub-theme *Greenhouse Gases* of the two management systems. Tests for normality and equal variance showed that normal distribution and equal variance were given. The data was thus analysed using the parametric two sample t-test. The organically managed farms showed a significantly higher goal achievement in the sub-theme *Greenhouse Gases* compared to the conventionally managed farms (df = 58, p-value < 0.001). On average the organic farms had 58.3 % ±6.0 SD goal achievement (n= 16), and the conventional farms had 52.6 % ±4.4 SD goal achievement (n= 44). Both these results still fall in the moderate sustainability performance category.

3.4 Analysis of the sub-theme *Greenhouse Gases* at the indicator level

In order to look at the underlying cause for the before described goal achievements in *Greenhouse Gases*, differences in the ratings of indicators relevant to the sub-theme were analysed. Depending on the different production sectors on the farm, a maximum of 74 indicators can influence the goal achievement in *Greenhouse Gases*. The full list of these indicators is given in Annex 8. In the following only the results of relevant indicators are shown and discussed. It is important to note, that a high indicator rating reflects a positive impact with regard to the different sustainability goals. However, it does not mean that the answer to the indicator question is high as well. As an example, for the indicator ID00323_1_NFromFertilizers_Calc, the amount of nitrogen which is spread on the farm as mineral or organic fertilizer is calculated per ha. The high rating, however, does not mean a high quantity of nitrogen spread per ha, but rather a low amount, which is positive in terms of various environmental sustainability issues, notably GHG emissions (e.g. from mineral fertilizer production) and eutrophication potential (e.g. lower N-surplus). Ratings can range from 0 to 1.

3.4.1 Impact of farm type on indicators relevant to the sub-theme *Greenhouse Gases*

In the Table 3 only the indicators that showed significant differences depending on the farm type as well as indicators that are relevant to the further discussion are presented. None of the indicators showed normal distribution, thus the non-parametric Kruskal-Wallis test was used and the subsequent pairwise comparison was done using the Wilcoxon rank sum test.

Significant differences between the different farm types were observed for feeding practices. *Specialist cattle - rearing and fattening farms* (OTE 46) showed significantly higher fodder autarky in regard to concentrated feedstuff compared to specialist dairying farms (OTE 45) (ID00199_BoughtConcentratedFeed: OTE 45: 0.35 ± 0.32a; OTE 46: 0.68 ± 0.40b; OTE 47: 0.40 ± 0.27ab; p = 0.020). Similarly, there is also a significant difference in the practice of feeding feedstuff that could be used for human consumption. Here, OTE 46 and 47 feed significantly lower amounts of such feed compared to OTE 45 (ID00517_FeedNoFoodGrazingLivestock: OTE 45: 0.00 ± 0.00a; OTE 46: 0.15 ± 0.32b; OTE 47: 0.18 ± 0.36b; p = 0.012).

Table 3: Mean ratings, standard deviation and p-values for Kruskal-Wallis test of the indicators relevant to the sub-theme *Greenhouse Gases* depending on farm type (OTE 45, OTE 46, OTE 47).

Indicators	Mean rating*			
	OTE 45	OTE 46	OTE 47	p – value**
ID00182_1_PloughLessSoilManagement	0.17 ± 0.24	0.09 ± 0.18	0.09 ± 0.12	0.455
ID00186_RenewableEnergyProductionOnFarm_Calculated	0.54 ± 0.40	0.55 ± 0.45	0.47 ± 0.46	0.848
ID00192_PlantsForEnergyInsteadFood	0.99 ± 0.03	0.97 ± 0.08	1.00 ± 0.00	0.767
ID00196_InsulationHeatedFarmBuildings	0.95 ± 0.21	0.93 ± 0.26	0.91 ± 0.30	0.924
ID00199_BoughtConcentratedFeed	**0.35 ± 0.32a**	**0.68 ± 0.40b**	**0.40 ± 0.27ab**	**0.020**
ID00201_SlurryApplicationDragHoseInjection	0.48 ± 0.46	0.43 ± 0.49	0.35 ± 0.49	0.816
ID00206_ShareLegumesArableLand	0.38 ± 0.38	0.39 ± 0.31	0.43 ± 0.41	0.925
ID00207_ArableLandShareDirectSeeding	0.04 ± 0.12	0.00 ± 0.01	0.11 ± 0.29	0.552
ID00215_ArableLandShareTemporaryGrassland_Calculated	0.50 ± 0.42	0.43 ± 0.33	0.50 ± 0.33	0.819
ID00219_ArableLandUnderSownCrops	0.13 ± 0.28	0.09 ± 0.19	0.13 ± 0.27	0.991
ID00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	**0.50 ± 0.19a**	**0.63 ± 0.21ab**	**0.68 ± 0.20b**	**0.017**
ID00225_ArableLandShareGreenCoverOutsideGrowingPeriod	**0.89 ± 0.17a**	**0.99 ± 0.02b**	**0.96 ± 0.06ab**	**0.038**
ID00229_1_BiodivAreaShareOfFarmLand_Calc	0.51 ± 0.34	0.60 ± 0.37	0.57 ± 0.34	0.630
ID00237_1_AgriculturalLandShareMulching	0.01 ± 0.03	0.00 ± 0.01	0.00 ± 0.00	0.610
ID00253_PermanentGrasslandsExtensivelyManaged	**0.08 ± 0.11a**	**0.21 ± 0.26b**	**0.26 ± 0.38ab**	**0.033**
ID00285_HumusFormationCatchCrops	0.23 ± 0.19	0.27 ± 0.21	0.34 ± 0.18	0.133
ID00289_1_HumusFormationCropResidues	0.01 ± 0.03	0.01 ± 0.03	0.08 ± 0.24	0.8144
ID00290_1_SoilAnalysisFertilizerRequirements	0.42 ± 0.16	0.43 ± 0.11	0.34 ± 0.17	0.296
ID00323_1_NFromFertilizers_Calc	**0.25 ± 0.32a**	**0.45 ± 0.38a**	**0.20 ± 0.35a**	**0.033**
ID00332_ElectricityConsumption	**0.41 ± 0.16a**	**0.65 ± 0.21b**	**0.55 ± 0.25ab**	**<0.001**
ID00368_StockingDensity	0.91 ± 0.29	0.80 ± 0.41	0.82 ± 0.40	0.503
ID00371_AccessToPasture	0.40 ± 0.38	0.48 ± 0.48	0.23 ± 0.39	0.236
ID00517_FeedNoFoodGrazingLivestock	**0.00 ± 0.00a**	**0.15 ± 0.32b**	**0.18 ± 0.36b**	**0.012**
ID00620_PermanentGrasslandMowingFrequency	**0.40 ± 0.24a**	**0.10 ± 0.21b**	**0.23 ± 0.26ab**	**<0.001**
ID00700_MesuresPreventErosion	0.29 ± 0.46	0.36 ± 0.50	0.50 ± 0.53	0.488
ID00748_HumusFormationHumusBalance	0.29 ± 0.45	0.43 ± 0.51	0.60 ± 0.52	0.208

* rating scale from 0 -1; 0 being the lowest rating and 1 the highest rating. Values are given ± standard deviation. Values followed with different letter(s), within each row, are significantly different at p ≤ 0.05. Significant differences determined by pairwise comparison with the Wilcoxon rank sum test.
** p-value based on Kruskal-Wallis test

The proportion of grassland on the farm as well as its management also significantly differed between the farm types. Farms with focus on cattle - dairying, rearing and fattening combined (OTE 47) had a significantly higher proportion of permanent grassland compared to the other analysed farm types (ID00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated: OTE 45: 0.50 ± 0.19a; OTE 46: 0.63 ± 0.21ab; OTE 47: 0.68 ± 0.20b; p = 0.017). OTE 46 showed significantly higher proportion of extensively managed permanent grassland compared to OTE 45; while there was no significant difference between OTE 46 and OTE 47, nor between OTE 45 and OTE 47 (ID00253_PermanentGrasslandsExtensivelyManaged: OTE 45: 0.08 ± 0.11a; OTE 46: 0.21 ± 0.26b; OTE 47: 0.26 ± 0.38ab; p = 0.033). Conversely, OTE 45 showed a significantly higher mowing frequency of their permanent grassland compared to OTE 46, while there was no significant difference between OTE 45 and OTE 47, nor between OTE 46 and OTE 47

(ID00620_PermanentGrasslandMowingFrequency: OTE 45: 0.40 ± 0.24a; OTE 46: 0.10 ± 0.21b; OTE 47: 0.23 ± 0.26ab; $p < 0.001$).

Crop production practices also play an important factor in identifying a farms climate impact. While several indicators were assessed to this regard (e.g. ID00182_1_PloughLessSoilManagement, ID00201_SlurryApplicationDragHoseInjection, and ID00206_ShareLegumesArableLand), significant differences between farm types were only observed for two. While all farm types had a high proportion of their arable land under a green cover outside the growing period, a significantly higher proportion was observed for OTE 46 compared to OTE 45 (ID00225_ArableLandShareGreenCoverOutsideGrowingPeriod: OTE 45: 0.89 ± 0.17a; OTE 46: 0.99 ± 0.02b; OTE 47: 0.96 ± 0.06ab; $p = 0.038$). A significant difference was also indicated for the amount of nitrogen used from fertilizers (both mineral and organic) (Kruskal Wallis test: $p = 0.033$); however, the pairwise comparison using the Wilcoxon rank sum test did not give significant differences between the analysed farm types (ID00323_1_NFromFertilizers_Calc: OTE 45: 0.25 ± 0.32a; OTE 46: 0.45 ± 0.38a; OTE 47: 0.20 ± 0.35a; $p = 0.033$).

3.4.2 Impact of management system on indicators relevant to the sub-theme *Greenhouse Gases*

In Table 4 only the indicators that showed significant differences depending on the management system as well as indicators that are relevant to the further discussion are presented. None of the indicators showed normal distribution, thus the non-parametric the Wilcoxon rank sum test was used.

Similar to the results for farm type, significant differences were also observed between the different management systems for feeding practices. Organic farms show significantly higher fodder autarky in regard to concentrated feedstuff (ID00199_BoughtConcentratedFeed: Org.: 0.68; Con.: 0.36; $p = 0.004$). Furthermore, the partaking organic farms feed significantly less feedstuff, that could be used for human consumption than the participating conventional farms (ID00517_FeedNoFoodGrazingLivestock: Org.: 0.27; Con.: 0.00; $p < 0.001$).

Unlike with farm type, there are more significant differences in indicators that relate to arable land and crop production methods. The organic farms show a significantly higher share of legumes in their crop rotation (ID00206_ShareLegumesArableLand: Org. 0.70; Con. 0.28; $p < 0.001$) as well a significantly higher share of temporary grassland, i.e. field fodder such as clover-grass leys (ID00215_ArableLandShareTemporaryGrassland_Calculated: Org.:0.65; Con.: 0.42; p =

0.049). Moreover, organic farms show a significantly lower N input from fertilizers (in regards to both mineral and organic) (ID00323_1_NFromFertilizers_Calc: Org.: 0.64; Con.: 0.16; p < 0.001). Likewise, organic farms have significantly more measures implemented to prevent erosion (ID00700_MesuresPreventErosion: Org.: 0.60; Con.: 0.26; p = 0.017) which is also mirrored in the significantly higher share of arable land under green cover outside of the growing period that can be observed for organic farms. Although, as was seen for farm types, the ratings for both management systems are high for this indicator (ID00225_ArableLandShareGreenCoverOutsideGrowingPeriod: Org.: 1.00; Con.: 0.90; p = 0.001).

Table 4: Mean ratings, standard deviation and p-values for Kruskal-Wallis test of the indicators relevant to the sub-theme *Greenhouse Gases* depending on management system (organic, conventional).

Indicators	Mean rating*		
	organic	**conventional**	**p - value****
ID00182_1_PloughLessSoilManagement	0.10 ± 0.17	0.14 ± 0.22	0.478
ID00186_RenewableEnergyProductionOnFarm_Calculated	**0.35 ± 0.40**	**0.60 ± 0.41**	**0.037**
ID00192_PlantsForEnergyInsteadFood	1.00 ± 0.00	0.98 ± 0.05	0.305
ID00196_InsulationHeatedFarmBuildings	0.88 ± 0.34	0.96 ± 0.18	0.131
ID00199_BoughtConcentratedFeed	**0.68 ± 0.34**	**0.36 ± 0.33**	**0.004**
ID00201_SlurryApplicationDragHoseInjection	0.60 ± 0.48	0.39 ± 0.45	0.119
ID00206_ShareLegumesArableLand	**0.70 ± 0.24**	**0.28 ± 0.33**	**< 0.001**
ID00207_ArableLandShareDirectSeeding	0.02 ± 0.06	0.05 ± 0.18	0.940
ID00215_ArableLandShareTemporaryGrassland_Calculated	**0.65 ± 0.28**	**0.42 ± 0.40**	**0.049**
ID00219_ArableLandUnderSownCrops	0.18 ± 0.26	0.10 ± 0.26	0.071
ID00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated	0.61 ± 0.24	0.55 ± 0.20	0.400
ID00225_ArableLandShareGreenCoverOutsideGrowingPeriod	**1.00 ± 0.01**	**0.90 ± 0.16**	**0.001**
ID00229_1_BiodivAreaShareOfFarmLand_Calc	**0.72 ± 0.27**	**0.48 ± 0.34**	**0.013**
ID00237_1_AgriculturalLandShareMulching	0.01 ± 0.04	0.00 ± 0.01	1.000
ID00253_PermanentGrasslandsExtensivelyManaged	**0.32 ± 0.36**	**0.09 ± 0.10**	**0.004**
ID00285_HumusFormationCatchCrops	0.26 ± 0.15	0.26 ± 0.21	0.922
ID00289_1_HumusFormationCropResidues	0.00 ± 0.01	0.03 ± 0.12	0.467
ID00290_1_SoilAnalysisFertilizerRequirements	0.41 ± 0.15	0.41 ± 0.15	0.711
ID00323_1_NFromFertilizers_Calc	**0.64 ± 0.32**	**0.16 ± 0.26**	**< 0.001**
ID00332_ElectricityConsumption	**0.63 ± 0.16**	**0.45 ± 0.22**	**0.004**
ID00368_StockingDensity	1.00 ± 0.00	0.82 ± 0.39	0.071
ID00371_AccessToPasture	**0.63 ± 0.39**	**0.30 ± 0.39**	**0.005**
ID00517_FeedNoFoodGrazingLivestock	**0.27 ± 0.39**	**0.00 ± 0.00**	**< 0.001**
ID00620_PermanentGrasslandMowingFrequency	0.19 ± 0.25	0.33 ± 0.26	0.069
ID00700_MesuresPreventErosion	**0.60 ± 0.51**	**0.26 ± 0.44**	**0.017**
ID00748_HumusFormationHumusBalance	0.23 ± 0.42	0.43 ± 0.49	0.495

* rating scale from 0 -1; 0 being the lowest rating and 1 the highest rating. Values are given ± standard deviation.
** p-value based on Wilcoxon rank sum test

Energy use and energy production also impact the goal achievement in the sub-theme *Greenhouse Gases* and significant differences were observed between the management types. The conventional farms show a significantly higher on-farm renewable energy production

(ID00186_RenewableEnergyProductionOnFarm_Calculated: Org.: 0.35; Con.: 0.60; p = 0.037). Organic farms, on the other hand, have a significantly lower electricity consumption (ID00332_ElectricityConsumption: Org.: 0.63; Con.: 0.45; p = 0.004).

Finally, significant differences were also seen in terms of access to pasture (ID00371_AccessToPasture: Org.: 0.63; Con.: 0.30; p = 0.005), management of permanent grasslands (ID00253_PermanentGrasslandsExtensivelyManaged: Org.: 0.32; Con.: 0.09; p = 0.004) and promotion of biodiversity on farmland (ID00229_1_BiodivAreaShareOfFarmLand_Calc: Org.: 0.72; Con.: 0.48; p = 0.013), where the organic management system shows significantly higher ratings in all three.

3.5 Correlation between the sub-theme *Greenhouse Gases* and other sub-themes

3.5.1 Correlation between the sub-theme *Greenhouse Gases* and other sub-themes for the different farm types

Correlations between the goal achievement in the sub-theme *Greenhouse Gases* and the other 57 sub-themes were calculated separately for each analysed farm type. Depending on the normality tests, either the Pearson or the Spearman-rank correlation was performed. In Table 5 only the results are presented that show a significant correlation with *Greenhouse Gases* for at least one of the three analysed farm types.

For the farm type OTE 45, positive correlations were detected between *Greenhouse Gases* and 16 of the other 57 sub-themes. The highest number of significant correlations are between the sub-theme *Greenhouse Gases* and the other sub-themes of the *Environmental Integrity* dimension, although the strength of these correlations is between weak and moderate (with the exception of the correlation with *Air quality* (R^2 = 0.584)).

The highest number of correlations between sub-themes were found for the Specialist cattle - rearing and fattening farms (OTE 46), where the goal achievement for the sub-theme *Greenhouse Gases* were significantly and positively correlated with 32 of the remaining 57 sub-themes. Especially in the dimension *Environmental Integrity*, significant correlations were observed with 11 of the 13 remaining sub-themes in this dimension (14 sub-themes minus the sub-theme *Greenhouse Gases*), with the strongest correlation being found with the sub-theme Air quality (R^2 = 0.721). For the farm type OTE 46, the goal achievement of the sub-theme *Greenhouse Gases* also significantly correlates positively with 10 of the 14 sub-themes in the *Economic Resilience* dimension. In this dimension, the sub-theme *Greenhouse Gases* correlates strongest with *Risk Management* (R^2 = 0.640). In the dimension Social Well-Being, the strongest positive correlation was identified between *Greenhouse Gases* and *Quality of Life* (R^2 = 0.766) and in the dimension *Good Governance* between *Greenhouse Gases* and *Holistic Audits* (R^2 = 0.548).

For the farm type OTE 47, *Greenhouse Gases* goal achievement correlates significantly with two other sub-themes: *Full Cost-Accounting* and *Liquidity*. In both cases the sub-themes have a strong negative correlation (R^2 = 0.546 and R^2 = 0.506, respectively).

Please refer to Table 5 for further details on all the significant correlations between the sub-theme *Greenhouse Gases* and the other sub-themes for the different farm types.

Table 5: Correlations between the sub-theme *Greenhouse Gases* and the other sub-themes for the different farm types (OTE 45, OTE 46 and OTE 47). Coefficient of determination and p-values are shown. Depending on the normality tests, either the Pearson or the Spearman-rank correlation was performed.

Dimension	Sub-theme	Farm Type					
		OTE 45		OTE 46		OTE 47	
		p-value	R^2	p-value	R^2	p-value	R^2
Good Governance	Due Diligence	0.933	0.000	**0.006**	**0.458**	0.400	0.080
	Holistic Audits	0.536	0.012	**0.002**	**0.548**	0.287	0.125
	Transparency	0.816	0.002	**0.005**	**0.464**	0.995	0.000
	Sustainability Management Plan	0.693	0.005	**0.029**	**0.315**	0.710	0.016
	Full-Cost Accounting	0.681	0.005	**0.030**	**0.314**	**0.009**	**0.546**
Environmental Integrity	Air Quality	**<0.001**	**0.584**	**<0.001**	**0.721**	0.061	0.336
	Water Quality	**<0.001**	**0.305**	**0.011**	**0.402**	0.204	0.173
	Soil Quality	**0.001**	**0.285**	**0.002**	**0.545**	0.138	0.228
	Land Degradation	**<0.001**	**0.329**	**<0.001**	**0.584**	0.092	0.283
	Ecosystem Diversity	**<0.001**	**0.346**	**0.004**	**0.493**	0.112	0.256
	Genetic Diversity	**0.004**	**0.230**	**0.002**	**0.543**	0.461	0.062
	Species Diversity	**0.020**	**0.158**	**0.006**	**0.456**	0.292	0.123
	Material Use	0.247	0.042	**<0.001**	**0.694**	0.117	0.250
	Waste Reduction & Disposal	0.575	0.010	**0.008**	**0.434**	0.550	0.041
	Energy Use	**0.001**	**0.276**	0.230	0.109	0.591	0.033
	Animal Health	**<0.001**	**0.375**	**0.015**	**0.379**	0.531	0.045
	Freedom from Stress	**<0.001**	**0.355**	**0.015**	**0.379**	0.626	0.028
Economic Resilience	Internal Investment	0.098	0.084	**0.014**	**0.379**	0.583	0.035
	Long-Ranging Investment	0.065	0.103	**0.022**	**0.342**	0.446	0.066
	Community Investment	**0.003**	**0.240**	**0.048**	**0.267**	0.346	0.099
	Stability of Production	**<0.001**	**0.310**	**0.018**	**0.359**	0.377	0.088
	Risk Management	**0.024**	**0.149**	**<0.001**	**0.640**	0.766	0.010
	Stability of Supply	0.071	0.099	**0.007**	**0.446**	0.442	0.067
	Liquidity	0.935	0.000	0.426	0.049	**0.014**	**0.506**
	Food Quality	**<0.001**	**0.403**	**0.013**	**0.387**	0.343	0.100
	Product Information	0.440	0.019	**0.046**	**0.271**	0.443	0.067
	Food Safety	0.398	0.023	**0.004**	**0.475**	0.554	0.040
	Value Creation	0.180	0.055	**0.047**	**0.269**	0.615	0.029
Social Well-Being	Quality of Life	0.138	0.068	**<0.001**	**0.766**	0.904	0.002
	Employment Relations	0.331	0.030	**<0.001**	**0.659**	0.855	0.004
	Freedom of Association and Right to Bargaining	0.780	0.003	**0.033**	**0.305**	1.000	0.000
	Workplace Safety and Health Provisions	**0.006**	**0.212**	**0.008**	**0.429**	0.765	0.010
	Public Health	**0.027**	**0.143**	**0.011**	**0.401**	0.590	0.033
	Food Sovereignty	0.099	0.083	**0.002**	**0.537**	0.432	0.070

3.5.2 Correlation between the sub-theme *Greenhouse Gases* and other sub-themes for the different management systems

Correlations between the goal achievement in the sub-theme *Greenhouse Gases* and the other 57 sub-themes were also calculated separately for each analysed management system. Depending on the normality tests, either the Pearson or the Spearman-rank correlation was performed. As before, only the results that show a significant correlation with *Greenhouse Gases* for at least one of the two analysed management systems are presented in Table 6.

For the organic management system, significant correlations were observed between *Greenhouse Gases* and 8 out of the other 57 sub-themes. A moderate significant negative correlation was found between *Greenhouse Gases* and *Full-Cost Accounting* (R^2 = 0.319). All the other correlations are positive with a moderate to strong strength, the strongest correlation being found again with the sub-themes *Greenhouse Gases* and *Air Quality* (R^2 = 0.733) followed by *Land Degradation* (R^2 = 0.677).

Table 6: Correlations between the sub-theme *Greenhouse Gases* and the other sub-themes for the different management system (Org. (organic) and Con. (conventional)). Coefficient of determination and p-values are shown. Depending on the normality tests, either the Pearson or the Spearman-rank correlation was performed.

Dimension	Sub-theme	Management System			
		Org.		Con.	
		p-value	R^2	p-value	R^2
Good Governance	**Full-Cost Accounting**	**0.023**	**0.319**	0.791	0.002
Environmental Integrity	**Air Quality**	**<0.001**	**0.733**	**<0.001**	**0.472**
	Water Quality	**0.002**	**0.498**	**0.003**	**0.196**
	Soil Quality	0.074	0.210	**0.003**	**0.194**
	Land Degradation	**<0.001**	**0.677**	**<0.001**	**0.245**
	Ecosystem Diversity	0.268	0.087	**<0.001**	**0.248**
	Genetic Diversity	**0.043**	**0.260**	**0.031**	**0.106**
	Species Diversity	0.394	0.052	**0.042**	**0.095**
	Material Use	**0.023**	**0.318**	**0.032**	**0.104**
	Animal Health	**0.042**	**0.264**	**<0.001**	**0.238**
	Freedom from Stress	0.161	0.135	**0.001**	**0.222**
Economic Resilience	**Long-Ranging Investment**	0.564	0.024	**0.023**	**0.116**
	Stability of Production	0.076	0.207	**<0.001**	**0.243**
	Stability of Supply	0.688	0.012	**0.009**	**0.151**
	Food Quality	0.660	0.014	**<0.001**	**0.308**
Social Well-Being	**Quality of Life**	0.118	0.166	**0.033**	**0.104**
	Responsible Buyers	**0.019**	**0.336**	0.575	0.008
	Food Sovereignty	**0.024**	**0.314**	0.072	0.075

For the conventional management system, significant correlations were detected for 15 of the 57 sub-themes, most of which with only a weak strength. Only the correlations with *Air Quality* and

Food Quality show moderate strength (R^2 = 0.308). 10 of the 15 significant correlations are with other sub-themes of the *Environmental Integrity* dimension. Please refer to Table 6 for further details on all the significant correlations between *Greenhouse Gases* and the other sub-themes for the different management systems.

4. Discussion

The study of the sustainability performance in terms of climate impact of the Luxembourgish farming sector lead to interesting results and new insights into the issue. In the following, the main findings are discussed and possible solutions for the development of a climate positive agricultural landscape proposed.

The project sample with its 60 farms is representative for all agricultural holdings in Luxembourg in regard to their share of arable land and permanent grassland. As the focus in the present study was on the three farm types OTE 45, 46 and 47, these farm types are overrepresented in the sample. For management system, organic farms are highly overrepresented with 26.7 % in the sample compared to 5 % of all Luxembourgish farms. In the sample, 17 % of the existing organic farms are represented, while only 2.5 % of the conventional farms are represented. This overrepresentation of organic farms is justified as a critical number of organic farms is needed to perform a statistical analysis. Nonetheless, the results have to be interpreted against this background. A reason for this overrepresentation could be that the Institute for Organic Agriculture Luxembourg is responsible for the study and most of the organic farmers are in close contact with the institute, and therefore might feel more obligated to participate in the study. Furthermore, it must be said, that farmers with a higher interest and maybe also awareness of sustainability topics and climate change might be overrepresented. However, this does not conclude that the farms in the sample are per se the more sustainable farms.

The overall results from the sustainability assessment indicate on average a *moderate* to *good* sustainability performance from the participating farms in most of the 21 sustainability themes. The high average goal achievements in the themes *Materials and Energy* and *Labour Rights* can be attributed in large parts to the existing legislation in place in regards to these methods (e.g. recycling opportunities for paper, old oil, plastics, collection of silage foil and pesticide canisters, proper disposal of waste and animal cadavers, minimum wages, possibility to join labour unions, social security for workers, etc.). The high average goal achievement in the theme *Animal Health* is a result of Luxembourgish legislation in place to prevent animal cruelty (Loi du 27 juin 2018 sur la protection des animaux) and of the importance the farmers generally place on animal care: mostly no tethering of the animals, areas for lying that are big enough for the cattle, clean drinking throughs with fresh water, shelters from cold or heat exposure, etc.

Three of the themes where goal achievement was on average below 50 % are in the dimension of *Good Governance* (*Accountability*, *Corporate Ethics* and *Holistic Management*). As was mentioned in Chapter 2.2.1, the SAFA-Guidelines also refer to companies in the food and agriculture sector, and the objectives of some of the themes are therefore only partly achievable or relevant to farms.

This applies especially to themes of the dimension *Good Governance*. Due to the informal, family run farming structures predominant in Luxembourg, the holdings often do not have an explicit sustainability plan, do not make any documentation, sustainability reports or written commitments to sustainability publicly available, and external environmental costs are not considered in the accounting of the farms.

The below 50 % goal achievement in the theme *Local Economy* can be explained by a generally low number of jobs created, high weekly working hours and low number of apprenticeships offered. The theme *Product Quality and Information* is heavily impacted by the use of pesticides, the use of antibiotics in animal husbandry, procurement of farm inputs from countries with known problematic social conditions (e.g. soybean from South America) and the transparent communication of production system to the consumer (e.g. through websites or certifications). Understandably, a large difference in the goal achievement of this theme is also observed between the two management systems as the organic farms forego the use of chemical synthetic pesticides and undergo the certification process for organic farming. Other themes that are heavily impacted by the use of chemical pesticides, among other practices, are the themes *Biodiversity* and *Human Safety and Health*, which explains the similarly high differences in the average goal achievement per theme for the two management systems.

Looking at the theme *Atmosphere* and its sub-theme *Greenhouse Gases*, the mean goal achievement at the sub-theme level is in the *moderate* sustainability performance category. Furthermore, a significant, albeit not stark, difference was observed in this sub-theme in regard to management system. These results are comparable to results from other holistic sustainability assessment studies using the SMART-Farm Tool. A *moderate* goal achievement in the sub-theme *Greenhouse Gases* was observed in Hungary, where 25 organic and 25 conventional farms (with both animal husbandry and crop production) were analysed with the SMART-Farm Tool (Mészaros, 2017). The organic farms had a significantly higher goal achievement in this sub-theme than the conventional farms. In a study comparing organic and conventional wheat producers in France, the goal achievement for *Greenhouse Gases* was also in the *moderate* category, with a mean goal achievement of 50.4 % for the organic farms and 46.5 % for the conventional farms. These observed differences, however, were not significant (Epple, 2018).

In terms of impact of farm type on climate change and GHG emissions, no significant difference was detected in the study at hand. However, the farm type OTE 46 (*Specialist cattle - rearing and fattening*) shows, the same as for the other sustainability themes, a slightly better sustainability performance in both the theme *Atmosphere* as in its related sub-theme *Greenhouse Gases*, compared to the other two analysed farm types. While the impact of farm type has not been as extensively studied in terms of their SAFA-goal achievements, early studies show similar results, with suckler cow holdings (similar to OTE 46) having higher goal achievements in this sub-theme compared to dairy production (similar to OTE 45) and combined dairy / suckler cow holdings (similar to OTE 47) (FIBL, unpublished data).

The overall results at theme and sub-theme level show that the farm type OTE 46 and the organic management system present the highest sustainability performance over all sustainability themes and specifically in *Atmosphere* and the sub-theme *Greenhouse Gases*. On the whole, independent of farm type or management system, the general *moderate* goal achievement in this sub-theme shows that there is still a large improvement potential in terms of reducing the climate impact of the agriculture sector in Luxembourg. In order to identify the linchpins to affect this positive change, a closer look was taken at the indicators influencing the sub-theme. Looking at the commonalities in farming practices, it can be discerned that OTE 46 and the organic farms share a higher resource efficiency and a focus on closed farming cycles (lower nitrogen input from fertilizer, lower electricity consumption, lower share of bought in concentrate feedstuff, higher adherence to the feed no human-edible feedstuff concept for ruminants, etc.). These results re-confirm the results from the öko-öko study where Luxembourgish organic and conventional dairy and suckler cow holdings were compared in terms of, among others, their ecological performances (Schader et al., 2011). Here both the suckler cow holdings as well as the organic farms showed higher nitrogen and phosphorous nutrient efficiency, lower energy use and higher fodder, energy and protein autarky.

From these commonalities, already two strategies for a more climate positive farming landscape can be identified: increase in concentrate feed autarky (i.e. energy and protein feedstuff), and closed farming cycles. In terms of feeding practices especially the buying in of concentrated feed (e.g. cereals, soybean meal, etc.) and the overall practice of feeding such feedstuff as well as maize silage to ruminants has a high impact on the goal achievement in the *Greenhouse Gases* sub-theme and significant differences are both seen for farm type as well as for management system. Thus, increasing the fodder autarky, in addition to encouraging larger changes in the feeding practices of the ruminants could meaningfully improve the climate impact at the farm level. A large issue hidden within these indicators is the feeding of sources of concentrated energy (e.g. cereals and maize silage) which then need to be balanced out by concentrated protein sources (e.g. soybean meal from overseas) (Zimmer, 2019). A better valorisation of the permanent grasslands, which is approx. 50 % of the agricultural area in Luxembourg, could already decrease the need for concentrate feedstuff in ruminant feeding rations. Additionally, soybean could be reduced for cattle fattening if in parallel maize silage would be reduced in the ration and focus would be laid on grass silage instead. Nevertheless, this might lead to a slower fattening rate and would entail that changes would also have to be made in established marketing chains (Zimmer, 2019). The largest reduction potential lies in the dairy sector and in the feeding of dairy cows, as they are by far the most prevalent in Luxembourg. A part from an optimization of the permanent grasslands, a rethinking in the feeding calculations is needed, away from the protein surplus towards a higher percentage of milk yield from forage. This could possibly mean a reduction of the current milk yield, with the offset of an increased protein autarky and a reduction of feed costs (Zimmer, 2019).

Additionally, improved pasture management can also increase carbon sequestration potential of these (Beukes et al., 2010; Soussana et al., 2010). However, research results on the effect of grazing on pasture carbon sequestration potential and whether it offsets the emissions from the cattle themselves are not as clear (Garnett, T. et al., 2017). Keeping ruminants on the land has the potential to achieve greater carbon sequestration than removing them and promoting a reforestation with woody vegetation (Garnett, T. et al., 2017). The sequestration potential, however, may not be enough to offset all the emissions from a grazing system (between 20 - 60 % offset potential) (Garnett, T. et al., 2017). An increase in roughage in the rations results in an increase in the enteric fermentation of the ruminants resulting in higher methane emissions (Gerber and FAO, 2013). Gerber and FAO (2013) talk about a "better" feeding and nutrition reducing methane emissions from ruminant livestock. Better feeding is seen here as a shift away from roughage and towards a higher share of concentrates in the rations.

Yet, from a global perspective, the opposite is the case; reducing concentrated feedstuffs can reduce the environmental impacts of the total sector, while still producing the same amount of human-edible food (Schader et al., 2014). For example, it is calculated that ca. 21'000 t of soybean were imported to Luxembourg in 2018 alone for the feeding of ruminants (Zimmer, 2019). Reducing these imports will not only reduce GHG emissions from transport, but will also reduce the complicity of the Luxembourgish agriculture sector in the social and environmental problems associated with soybean cultivation in South America. Of course, it requires a strong rethinking in the feeding practices and a holistic protein strategy for Luxembourg is needed to boost such a change. However, a rethinking would not only be needed in the terms of farming practices but in terms of changes in dietary habits and a reduction in food waste at the consumer end of the food system (Muller et al., 2017; Röös et al., 2017; Schader et al., 2015, 2014).

The second strategy "closing of the farming cycles" goes hand in hand with the first. One of the cycles that needs closing is the nutrient cycle on the farm, with focus on nitrogen and phosphorous. The farms have many options to influence and close especially the N-cycle on farm. Organic farms make already increasing use of this strategy, since they forego the use of mineral nitrogen fertilizer. The organic farms have a higher share of legumes (grain legumes, clover-grass leys, clover share in permanent grassland communities) and a higher share of temporary grassland (mainly leguminous mixtures such as clover-grass leys) in their crop rotations. These practices on one hand help increase their overall fodder autarky (also in terms of energy and protein), but on the other hand, these practices also introduce atmospheric nitrogen through biotic nitrogen fixation into the farming system, increasing soil fertility and reducing the need for other N-fertilizer sources. Closing the nutrient cycle from converting grass leys to for example grass-legume mixtures can also reduce carbon losses and increase carbon sequestration in the farming system (Soussana et al., 2010).

Closing the nutrient cycle, needs, on the one hand, a reduced nutrient input or a more efficient use of the nutrient input, and, on the other hand, a prevention of nutrient losses from the system. The former involves a reduction in the nutrient surpluses and improving the fertilization plans on each farm. From the indicator analysis, it could be seen that the farms only rely in part on soil analysis information for their fertilization plans. Most only take soil samples every 5 years per plot of arable land. However, most of the sampled farms receive help in constructing their fertilization plan and the extension services need to consistently advice and educate farmers in regard to proper fertilizer requirements and correctly estimating the yield potential in their location. One of the interview questions in the SMART-Farm Tool asks about yield potential in the farmers region and it was of utmost interest to see how difficult it was for many farmers to estimate this for their farm.

In terms of reducing nutrient losses from the system, it is important to understand, when these losses can occur: during storage, during fertilizer application and after the application. The first two are mainly important for organic fertilizers. These three possible stages for losses were also assessed in this study and a large improvement potential can be observed. Slurry, for example, is often still spread using the traditional baffle plate or swivel distributor techniques. Lioy (2018) also sees a strong reduction potential of the N-surplus in Luxembourgish farms and identifies the same linchpins as above plus the following two: introduction of flexible application periods for organic fertilizers to allow application in favorable weather conditions or to prevent them in adverse weather conditions, both in winter and in summer; and increase in storage capacity for liquid manure. Especially the first condition is crucial in decreasing the potential losses during and right after organic fertilizer application. A similar system than developed for the application of pesticides in the SENTINELLE project could be envisioned for the application of organic fertilizers.

From the discussion so far, it becomes apparent that changing one thing in the complex farm system, will have repercussions and ripple effects (either good or bad) in other areas of the system. For example, area for the promotion of biodiversity or agri-environmental measures such as hedges and rows of tree, implemented on the agricultural area with the main focus on habitat creation and species protection, have been shown to also have positive impacts in regard to climate protection, as they increase carbon sequestration (Aertsens et al., 2013). It is therefore important to consider the whole farm system and take a holistic approach – in terms of creating a climate positive agricultural landscape, but also in creating an overall environmentally friendly farming system. The organic management system showed a higher mean goal achievement in all but one sustainability theme and their sustainability performances are overall in the good to best categories in 17 out of the 21 themes. This shows that the organic management approach can simultaneously have a positive impact in multiple aspects of sustainability. This corresponds with other scientific findings, at least for the sustainability performance in the *Environmental Integrity* dimension. Sanders and Heß (2019) looked at the societal performance of organic agriculture the terms of water protection, soil fertility, biodiversity, climate protection, climate adaptation, resource efficiency and animal welfare based on a comprehensive analysis of scientific publications. The organic management system showed benefits for all the environmental protection and resource efficiency parameters compared to the conventional management system in 58 % of the analysed comparisons. Similar results were seen for the farm type 46 in the study at hand, where moderate to strong correlations were observed between their goal achievement in *Greenhouse Gases* and other sub-themes in the *Environmental Integrity* dimension. This indicates that farms implementing climate positive farming practices are also implementing practices that are positive for other environmental sustainability issues. This is also reflected in the SMART-Farm Tool, where some of the *Greenhouse Gases* indicators have also an impact (with different positive or negative weights) on other sub-themes. While the focus of this study was the climate impact of the agriculture sector, taking on a holistic approach with strategic decision making could lead to harmonized actions towards a sustainable farming system. The need for a holistic approach is also highlighted when considering that due to the complex nature of GHG fluxes in agricultural systems, a practice will often affect more than one GHG, by more than one mechanism, sometimes in opposite ways. Thus, the net benefit depends on the combined effects on all gases (Smith et al., 2008). GHG fluxes from agricultural systems are complex and heterogeneous, nevertheless, mitigation possibilities exist through active management of the system, as was highlighted above.

What is important to keep in mind, when talking about all the different possibilities of mitigating GHG emissions, is that the farming practices need to be practical for the farmer to implement. Some of the farming practices that show good mitigation potential are reduced tillage and leaving of crop residues on field, however, these were only implemented by a very low number of sampled farmers. Reduced tillage, which is difficult to establish well, especially when foregoing the use of herbicides, was only implemented on a very small share of the arable land. Leaving crop residues on field was also not often practiced as the straw is needed for bedding. This shows that while some practices are beneficial in terms of climate mitigation, they also need to be feasible and practical for the farmer in order for them be practiced and become part of the routine. This needs vulgarisation of the benefits of these methods as well as further research to enhance their practicality. The farmers need support and results from sustainability assessments, such as those from this study, should be used as basis for further discussions, reflections and learning (de Olde et al., 2016). Especially as these decisions can also influence the economic aspects of the farm and further add to the farmers already high work load. 61 % of the farmers in Luxembourg work over 50 hours per week and still 27 % work more than 70 hours per week (SER, 2016). With such a high workload per week, one can argue that no time is left to seriously think about the environmental impact of their farming practices or even plan and implement any changes. For OTE 46 a strong correlation was found between the goal achievement in *Greenhouse Gases* and *Quality of Life*. Although this correlation was not mirrored for the other farm types or all management systems (a weak correlation was seen in conventional farms), it hints at an underlying problem.

It is important to remember in all the discussions around a sustainable food production and the benefits of one farm type or one management system to the other, that, in order to truly make a step towards a climate friendly or overall sustainable food system, all stakeholders need to be included in the efforts and that changes need to be considered along the whole supply chain. This includes advisory services, agrarian organizations, interest groups, research institutes, policy makers and the consumers (Bachev, 2017). This is of the utmost importance when the actual amount and the quality of food produced by one system or another is factored in. Smith et al. (2019), for example, come to the conclusion that a transition to 100 % organic farming in England and Wales would lead to drastic shortfalls in most agricultural products compared to the conventional baseline, which would then have to be compensated by products from overseas, the transportation of which would reduce the GHG emission offsets from an organic production system. In view of Luxembourg's own goal of transitioning to 100 % organic agriculture by 2050 (Gouvernement du Grand-Duché de Luxembourg, 2018a), such results are especially of interest. However, Muller et al. (2017) put forward that feeding the world organically is possible, when a few changes are taken into account. In their holistic study, they identify a reduction in food waste and a change in dietary patterns through a reduction in animal protein sources as necessary conditions to achieve this. In the Luxembourgish context, first efforts are already made on the level of food waste with the awareness campagne *AntiGaspi* of the Ministère de l'Agriculture, de la Viticulture et du Développement Rurale. This is an important starting point, knowing that of the overall 30 % food waste created worldwide, at least 40 % are generated by the end consumer (FAO, 2013). Finally, the issue of necessary dietary changes for a sustainable food system in Luxembourg is one of the foci of the project SustEATable. The global approach from the study by Muller et al. (2017) will be translated to the national context of Luxembourg.

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Annex

Annex 1: Call of participation

Munsbach, den 28. September 2018

Sehr geehrte(r) Landwirt/-in

Im luxemburgischen Projekt SustEATable werden wir landwirtschaftliche Betriebe für wissenschaftliche Zwecke auf ihre ganzheitliche Nachhaltigkeit analysieren und auch Sie können mit dabei sein. Fragen um die es geht:

- Wie nachhaltig wirtschaften Sie bereits?
- Wie schneidet Ihr Betrieb in den Bereichen Ökonomie, Soziales und Ökologie ab?
- Welche Verbesserungsmöglichkeiten gibt es?
- Wo stehen Sie im Vergleich zu Ihren Berufskollegen?

Sie erhalten im Anschluss an das Projekt einen Bericht mit den detaillierten Ergebnissen der Nachhaltigkeitsanalyse Ihres Betriebes. Der Bericht kann beispielsweise als Anregung für die zukünftige Betriebsführung genutzt werden oder an Ihre Kunden/-innen kommuniziert werden.

Die Analyse beruht auf einer Betriebsbesichtigung und einem etwa dreistündigen Interview zu verschiedenen Themenbereichen.

Der Bericht sowie alle Betriebsdaten, die vorab, während oder bei der Nachbereitung einer Analyse erhoben wurden, sind vertraulich und werden nur dem Betriebsleiter/-in direkt zugänglich gemacht. Ansonsten werden diese Daten ausschließlich anonymisiert verwendet. Um den Schutz ihrer Daten zu gewährleisten, wurde auch dieser Brief über das Service d'Economie Rurale (SER) verschickt. Jeder Austausch von Daten zwischen SER und IBLA im Rahmen dieses Projektes wird gemäß den nationalen Datenschutzgesetzen vom 27. Juli 2007 und 1. August 2018 und der Europäischen Verordnung (EU) 2016/679 vom 27. April 2016 verrichtet werden.

Das Projekt wird vom Institut fir Biologësch Landwirtschaft an Agrarkultur Luxemburg a.s.b.l. (IBLA) in Zusammenarbeit mit dem Forschungsinstitut für Biologischen Landbau (FiBL), Sustainable Food Systems GmbH (SFS), Luxembourg Institute of Health (LIH) und der University of Luxembourg (UL) durchgeführt und über das Ministère du Développement Durable et des Infrastructures und der Oeuvre Nationale de Secours Grande-Duchesse Charlotte finanziell unterstützt.

Mehr Informationen zu diesem Forschungsprojekt finden Sie auch auf www.ibla.lu/susteatable.

Wir bedanken uns jetzt schon ganz herzlich für ihre Teilnahme und Zusammenarbeit im Projekt.

Mit freundlichen Grüßen, im Namen aller Projektpartner,

Dr. Stéphanie Zimmer
Direktorin IBLA

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Sie sind daran interessiert am Projekt SustEATable teilzunehmen?

Dann schicken Sie uns diese ausgefüllte Einverständniserklärung zurück. So können wir Sie im Rahmen des Projektes kontaktieren.

Einverständniserklärung
Ich, die/der Unterzeichnete,

(Name und Vorname) ____

(Betriebsnummer) ____

(Adresse und Ort) ____

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gebe hiermit dem „Service d'Economie Rurale" die Vollmacht, die Antragsdaten des Jahres 2017, sowie meine OTE-Kategorie an das IBLA zwecks der Studie SustEATable zu übermitteln.

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Datum und Unterschrift

Der Zugriff auf Ihren Flächenantrag ermöglicht es uns bei der ganzheitlichen Nachhaltigkeitsanalyse bereits vor dem Betriebsbesuch einige Eckdaten über Ihren Betrieb auszufüllen, was die Interview-Zeit um einiges verkürzt.

Selbstverständlich werden Ihre Daten dabei **absolut vertraulich** behandelt. Wir verpflichten uns, Ihre betriebsindividuellen Daten keinesfalls an Drittpersonen weiterzuleiten und nur im Rahmen dieser Studie zu verwenden.

Für weiterführende Informationen können Sie uns auch gerne direkt kontaktieren:

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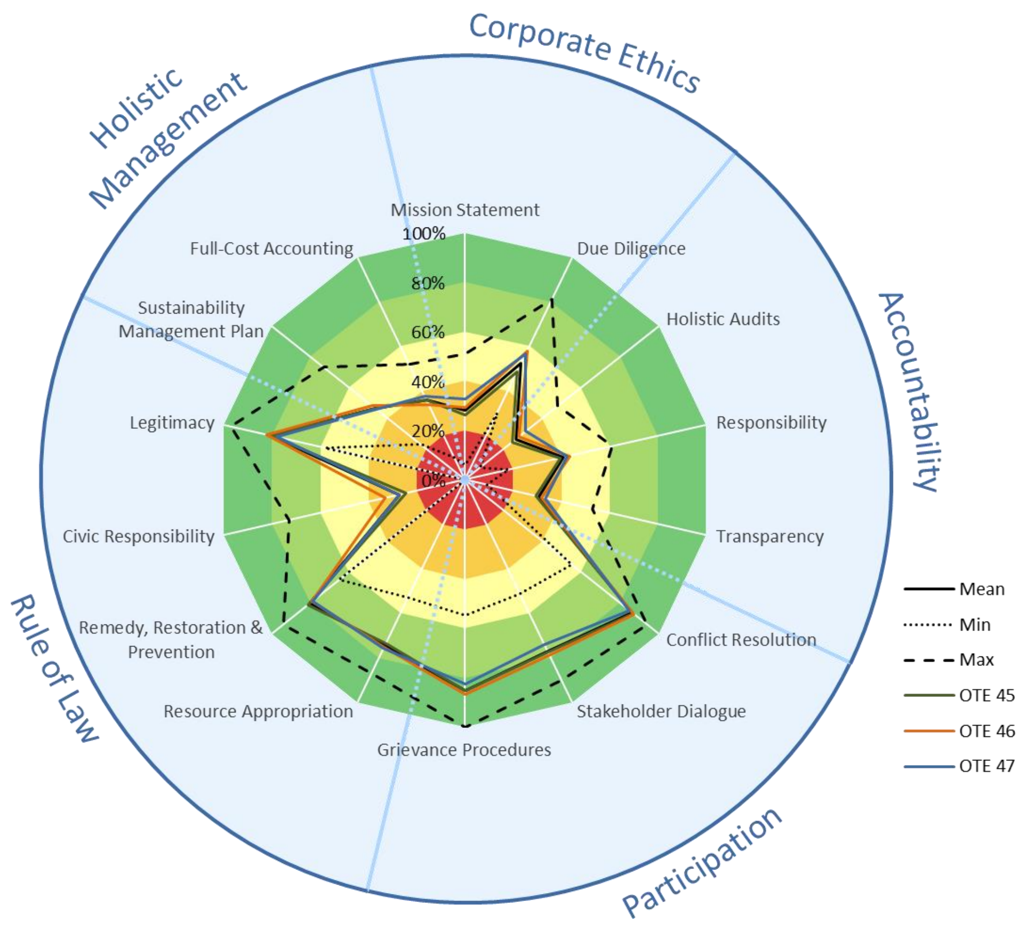
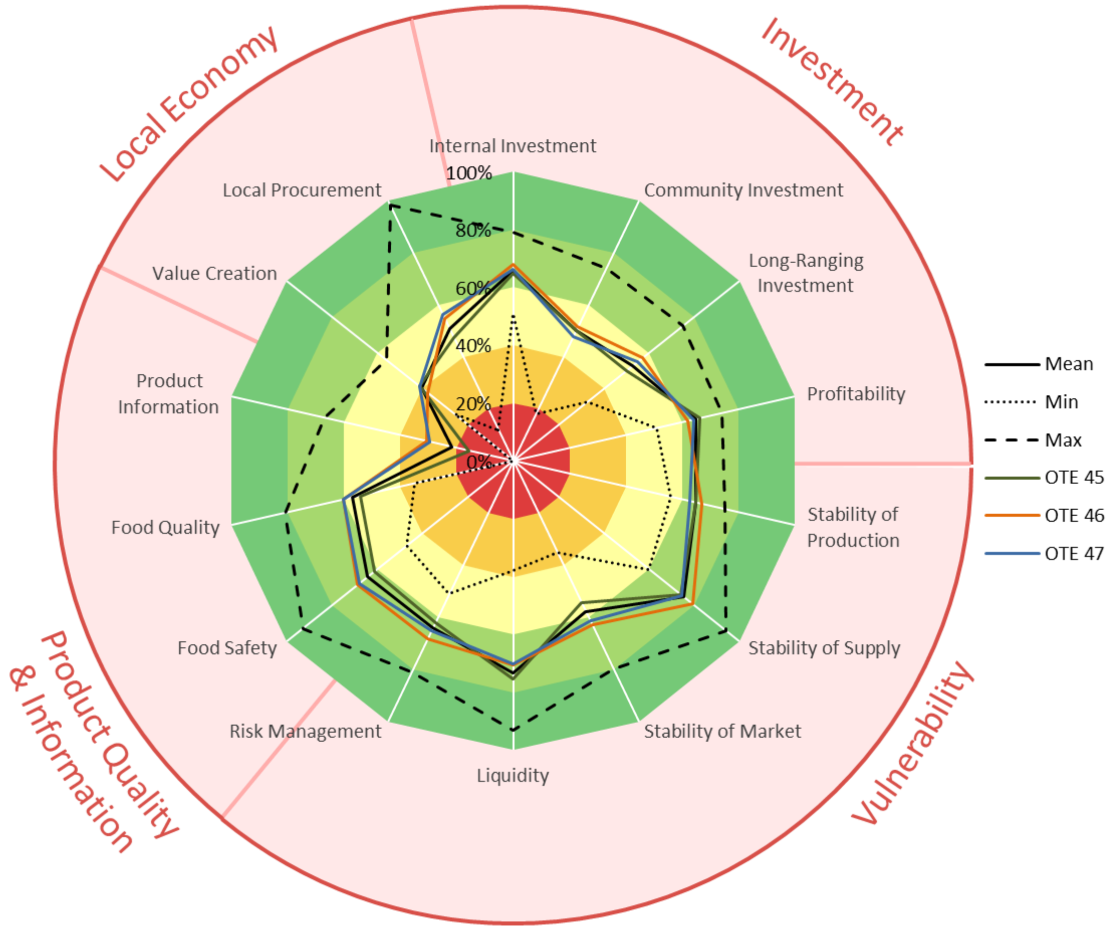
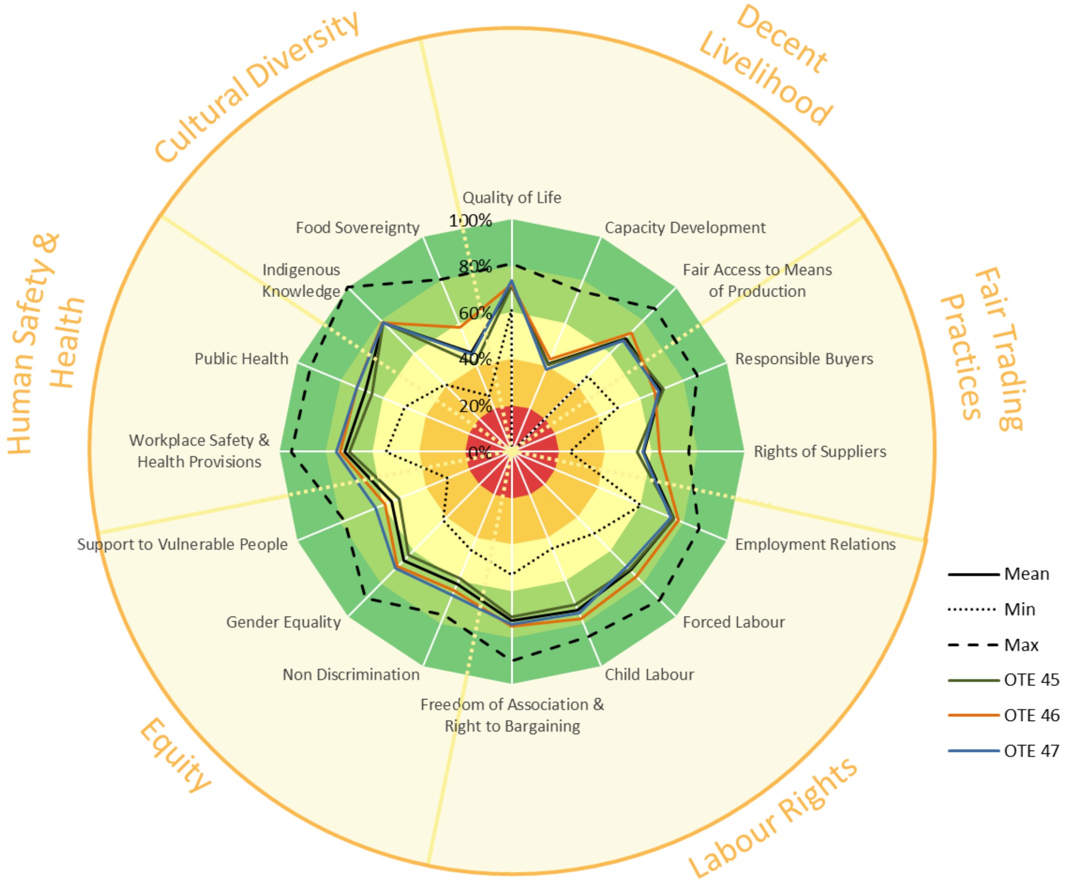
Annex 2: Results for the sustainability dimension *Good Governance* for farm type. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different farm types (OTE 45: n =35 (olive green line); OTE 46: n = 14 (orange line); OTE 47: n = 11 (blue line)). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.



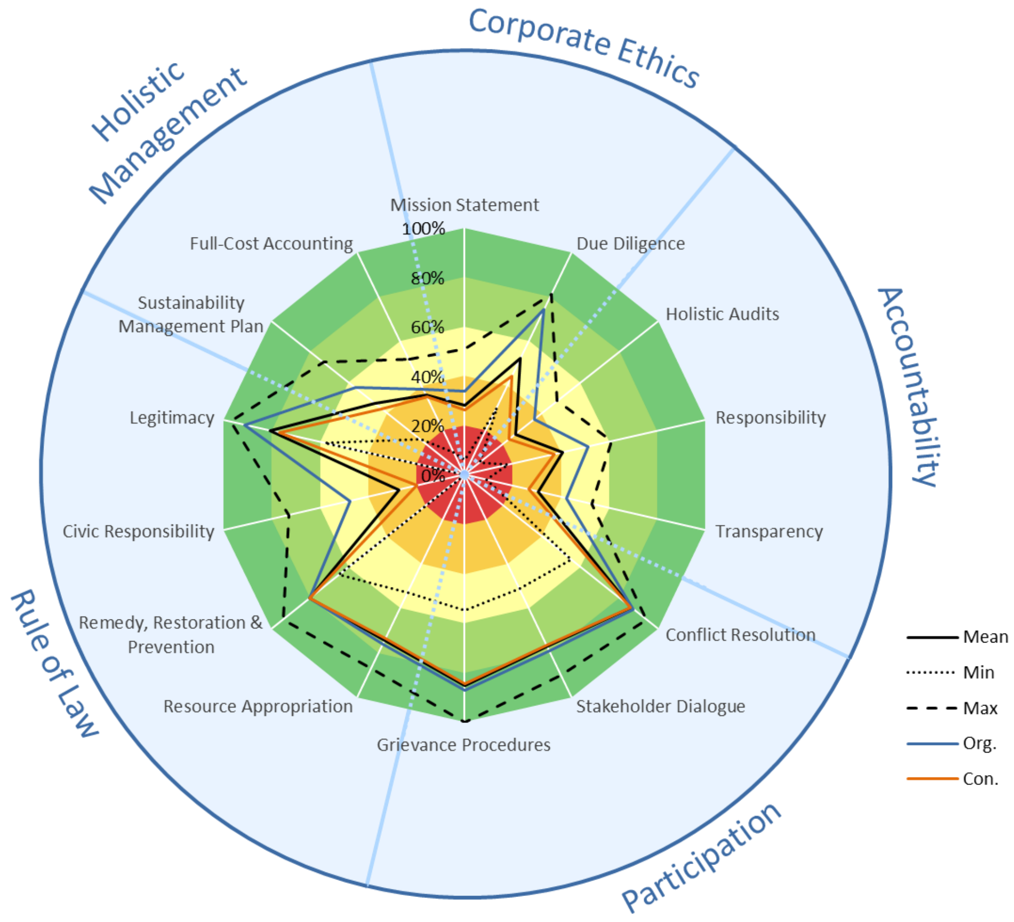
Annex 3: Results for the sustainability dimension *Economic Resilience* for farm type. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different farm types (OTE 45: n =35 (olive green line); OTE 46: n = 14 (orange line); OTE 47: n = 11 (blue line)). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.



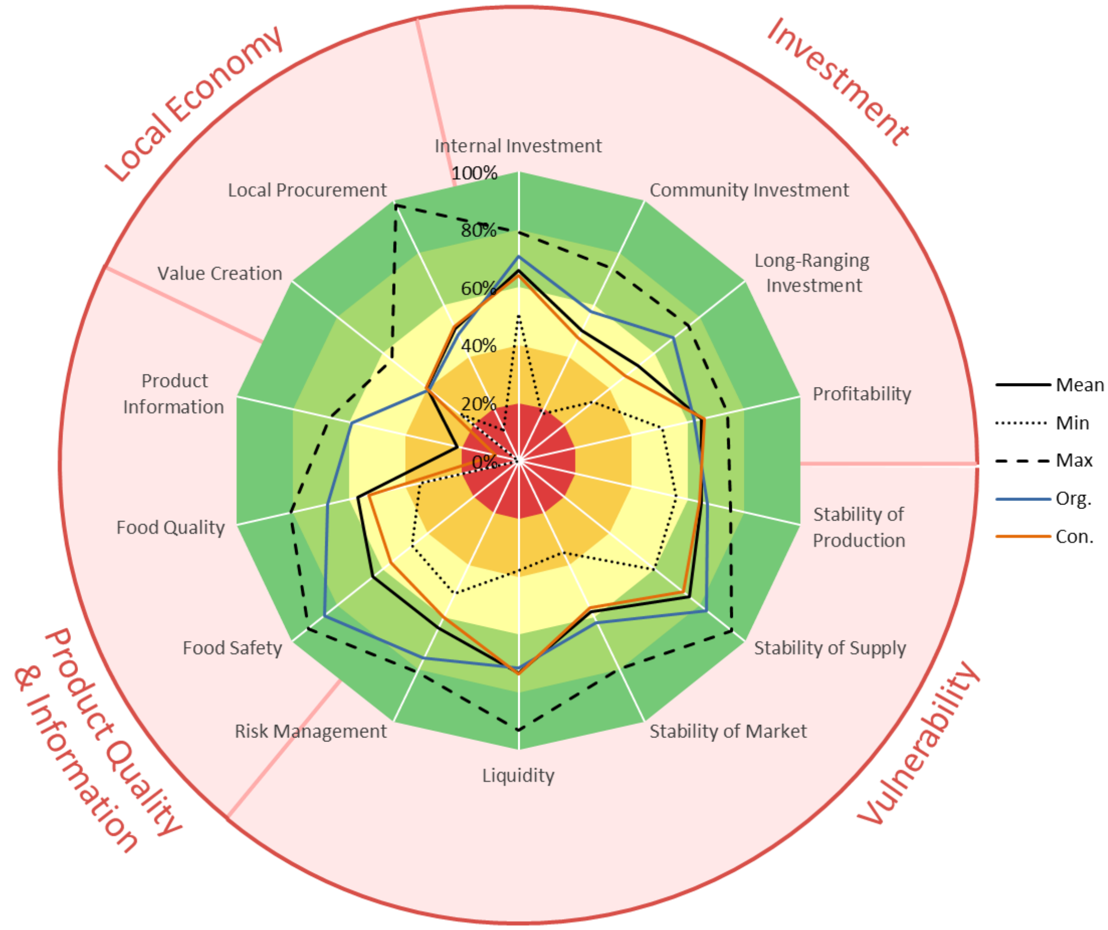
Annex 4: Results for the sustainability dimension *Social Well-Being* for farm type. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different farm types (OTE 45: n =35 (olive green line); OTE 46: n = 14 (orange line); OTE 47: n = 11 (blue line)). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.



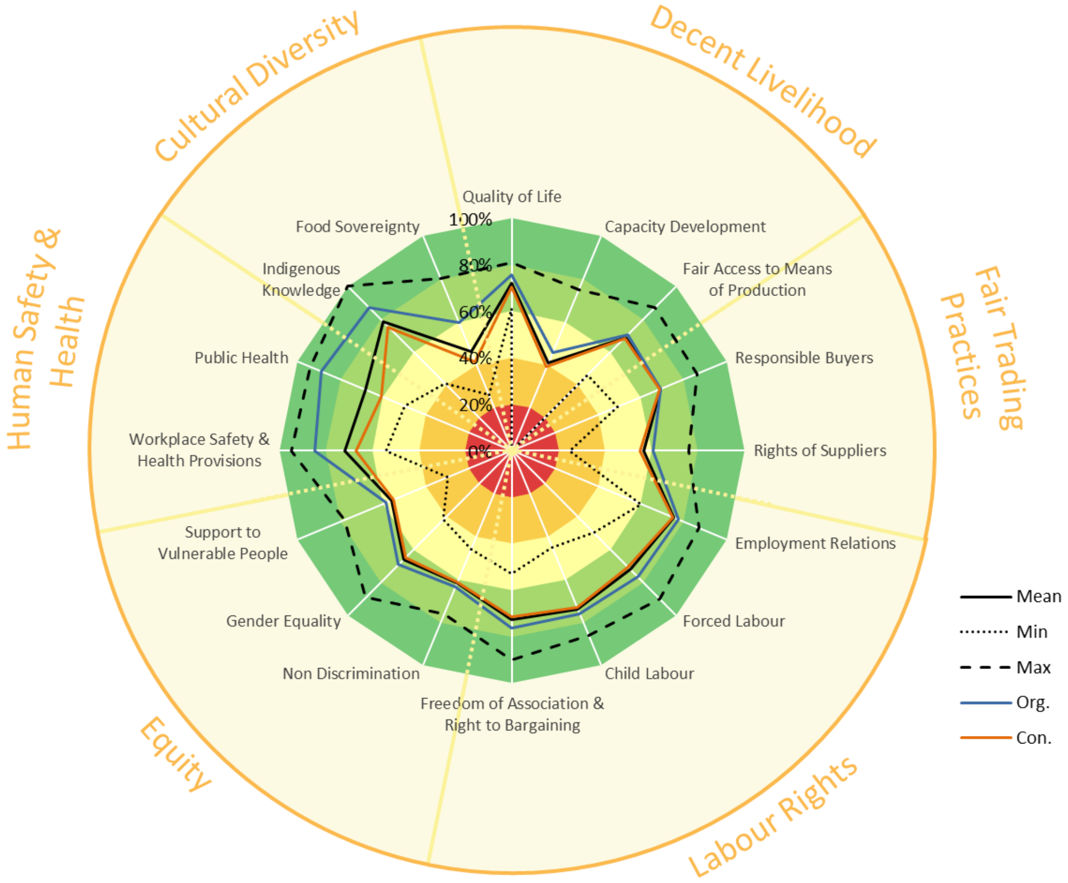
Annex 5: Results for the sustainability dimension *Good Governance* for management system. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different management systems (Org. (Organic): n = 16; Con. (Conventional): n = 44). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.



Annex 6: Results for the sustainability dimension *Economic Resilience* for management system. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different management systems (Org. (Organic): n = 16; Con. (Conventional): n = 44). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.



Annex 7: Results for the sustainability dimension *Social Well-Being* for management system. Goal achievement at the sub-theme-level shown for the mean of the study sample (n = 60) (full black line) and of the different management systems (Org. (Organic): n = 16; Con. (Conventional): n = 44). The minimum (dotted black line) and maximum (dashed black line) goal achievement values in each theme are also shown.



Annex 8: List of Indicators influencing *Greenhouse Gases* goal achievement.

Indicators impacting the sub-theme *Greenhouse Gases*	
1	ID00159_5_AverageLactations
2	ID00182_1_PloughLessSoilManagement
3	ID00185_RenewableElectricity
4	ID00186_RenewableEnergyProductionOnFarm_Calculated
5	ID00187_RenewableHeatingHotWater
6	ID00188_FuelFromOwnProduction
7	ID00190_BiogasPlantShareOrganicResidues
8	ID00192_PlantsForEnergyInsteadFood
9	ID00195_EcoDrive
10	ID00196_InsulationHeatedFarmBuildings
11	ID00198_1_DualPurposeBreedsPoultry
12	ID00198_DualPurposeBreedsRuminants
13	ID00199_BoughtConcentratedFeed
14	ID00200_SlurryStoresCovered
15	ID00201_SlurryApplicationDragHoseInjection
16	ID00202_AgroForestrySystems_Calculated
17	ID00203_OnFarmRenewableHeatingProduction
18	ID00204_WoodlandsDeforestation
19	ID00205_UtilizationPeat
20	ID00206_ShareLegumesArableLand
21	ID00207_ArableLandShareDirectSeeding
22	ID00208_WoodlandsShareAgriculturalLand_Calculated
23	ID00215_ArableLandShareTemporaryGrassland_Calculated
24	ID00219_ArableLandUnderSownCrops
25	ID00222_PermanentGrasslandsShareOfAgriculturalArea_Calculated
26	ID00225_ArableLandShareGreenCoverOutsideGrowingPeriod
27	ID00229_1_BiodivAreaShareOfFarmLand_Calc
28	ID00237_1_AgriculturalLandShareMulching
29	ID00249_HybridLivestock
30	ID00253_PermanentGrasslandsExtensivelyManaged
31	ID00285_HumusFormationCatchCrops
32	ID00288_ArableLandErosionControlGreater15Percent
33	ID00289_1_HumusFormationCropResidues
34	ID00290_1_SoilAnalysisFertilizerRequirements
35	ID00299_ArableLandGreenCoverGreater30Percent
36	ID00323_1_NFromFertilizers_Calc
37	ID00332_ElectricityConsumption
38	ID00335_1_RecyclingPaper
39	ID00341_CombustionMotors
40	ID00345_IrrigationLowEnergyTechnologyPumps
41	ID00348_FuelFromRenewableSources
42	ID00368_StockingDensity
43	ID00370_5_DailyOutdoorAccess
44	ID00371_AccessToPasture
45	ID00372_OutdoorAccesPigs
46	ID00373_OutdoorAccesPoultry
47	ID00374_TransportDurationAbattoir

Annex 8: List of Indicators influencing *Greenhouse Gases* goal achievement (continued).

Indicators impacting the sub-theme *Greenhouse Gases*	
48	ID00380_NutrientsPollutantsSourcesOnFarm
49	ID00517_FeedNoFoodGrazingLivestock
50	ID00518_FeedNoFoodNonGrazingAnimals
51	ID00521_ProductionBioenergyCrops
52	ID00601_PermanentGrasslandConversion
53	ID00602_PermanentGrasslandRenewal
54	ID00618_2_ProportionUndrainedPermanentGrasslandOnPeatland_Calc
55	ID00618_3_ProportionWaterloggedPermanentGrassland_Calc
56	ID00619_2_DrainedArableLandOnPeatland
57	ID00619_3_ProportionWaterloggedAgriculturalAreaWithoutPermGrassland_Calc
58	ID00620_PermanentGrasslandMowingFrequency
59	ID00626_BoughtInRoughage
60	ID00700_MesuresPreventErosion
61	ID00708_PreciseFertilisation
62	ID00712_1_ImportedOrgFert_Calc
63	ID00720_SilageStorage
64	ID00737_UseSyntheticAggregatesForSoilSubstrate
65	ID00739_ReusablePackagingMaterials
66	ID00741_SteamingOpenGround
67	ID00742_SteamingGreenhouse
68	ID00748_HumusFormationHumusBalance
69	ID00757_ShareGreenCoverPerennialCropLand
70	ID00763_ErosionPreventionPerennialCrops
71	ID00764_ShareLegumesOnPerennialCropArea
72	ID00788_OpenBurning
73	ID00800_LandClearingMethod
74	ID00802_AgroforestryLayers

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