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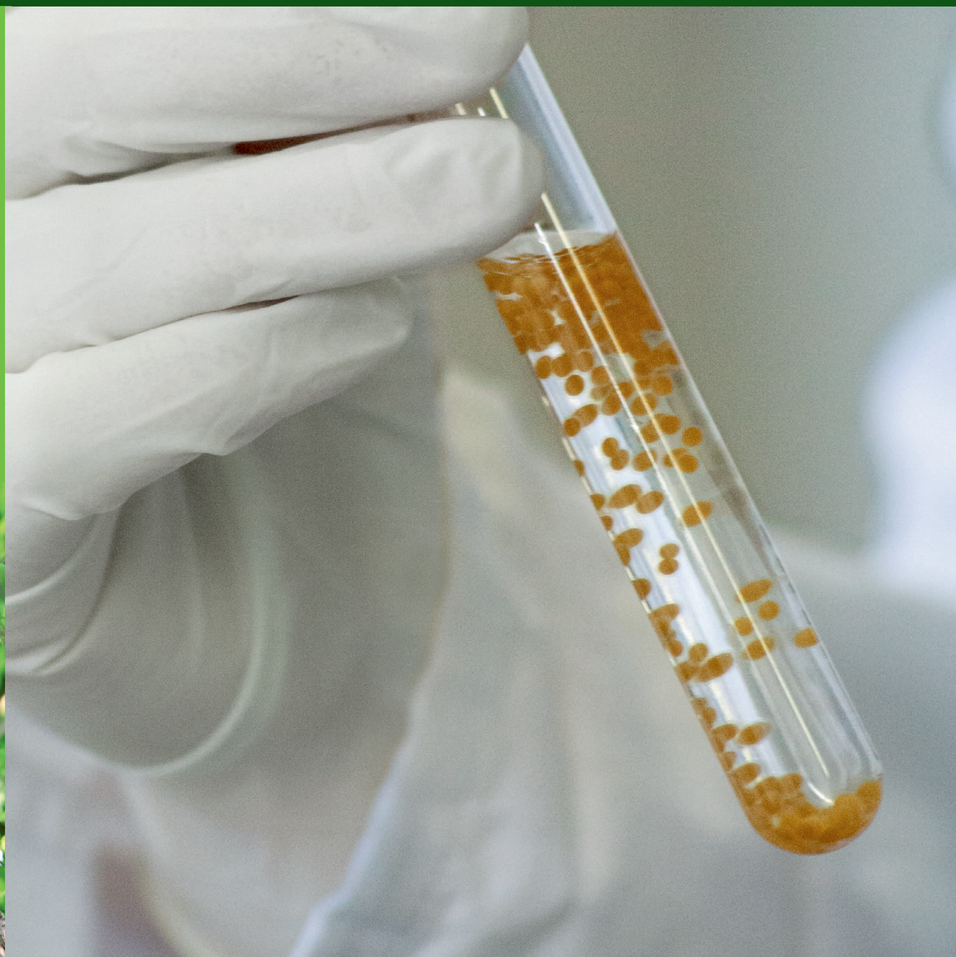

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Evaluation of teat-end vacuum conditions as affected by different pulsation settings in a quarter-individual milking system

Ulrich Ströbel*, Sandra Rose-Meierhöfer*, Hülya Öz**, Christian Ammon*, Toni Luhdo***, and Reiner Brunsch*

Abstract

The objective of this study was to determine the effect of pulsation on the teat-end vacuum behaviour in a quarter-individual milking system (QIMS). To meet this objective, simultaneous (SIM), alternating (ALT) and sequential (SEQ) pulsation were tested in a laboratory milking parlour. In the pulsation system SEQ four pulsators, instead of one (as in SIM) or two (as in ALT), are used. Unlike in SIM and ALT, the pulsation in each quarter is started individually. After pulsation is started in quarter one, pulsation will begin in the following quarters, each with a time delay of 25 % of the pulse duration with respect to the start of the previous quarter. Tests were performed at various flow rates (0.8 to 6.0 l/min) with the help of the wet-test method and the teat-end vacuum behaviour was observed. The lowest vacuum fluctuation of 4.4 kPa was recorded under SIM pulsation as well as the lowest vacuum reduction of 1.3 kPa. Both values were recorded at a flow of 4 l/min during the suction phase (b-phase). For SEQ and ALT pulsation, higher levels of vacuum reduction and fluctuation were measured during the suction phase at a flow rate of 4 l/min (SEQ: 7.6 / 1.8 kPa and ALT: 9.0 / 1.9 kPa). Consequently, it was concluded that SIM pulsation is the most appropriate pulsation setting when optimization for low vacuum reduction and fluctuation during the suction phase is demanded.

Keywords: *Quarter individual milking, Sequential pulsation, vacuum fluctuation, vacuum reduction, wet-test-method*

Zusammenfassung

Bewertung der Vakuumverhältnisse an den Zitzenspitzen bei unterschiedlichen Pulsationseinstellungen in einem viertel-individuellen Melksystem

Ziel dieser Studie war es, mögliche Auswirkungen unterschiedlicher Pulsationssysteme auf das Vakuum an der Zitzenspitze in einem viertelindividuellen Melksystem (VIMS) zu untersuchen. Hierfür wurde im Versuchsmelkstand mit Gleichtakt-, (GT) Wechseltakt-, (WT) sowie sequentieller Pulsation (SP) gemolken. Das Pulsationssystem SP besitzt dabei vier anstelle von einem (GT) oder zwei (WT) Pulsatoren. Im Vergleich zum GT und WT, wird bei SP die Pulsation viertel-individuell gestartet. Nach Beginn der Pulsation in Viertel eins werden die folgenden Viertel nacheinander mit jeweils 25 % zeitlicher Verzögerung der Pulsdauer in Betrieb gesetzt. Die Versuche wurden bei verschiedenen Milchflüssen (0,8 bis 6,0 l/min) mit der Nassmessmethode durchgeführt und dabei das Vakuum an der Zitzenspitze gemessen. Die niedrigste Vakuumschwankung in Bezug auf GT lag bei 4,4 kPa, wobei hier der niedrigste Vakuumabfall 1,3 kPa betrug. Beide Werte wurden bei einem Durchfluss von 4 l/min in der Saugphase (b) aufgezeichnet. Bezüglich SP und WT-Pulsation trat ein höherer Vakuumabfall in der Saugphase bei einem Milchfluss 4 l/min (7,6 / 1,8 kPa SP und 9,0 / 1,9 kPa WT) auf. Folglich ist die Gleichtaktpulsation (GT) die geeignetste Einstellung, wenn eine Optimierung für wenig Vakuumabfall und für kleine Vakuumschwankungen in der Saugphase zugrunde liegt. (VIMS = QIMS, GT = SIM, WT = ALT und SP = SEQ).

Schlüsselwörter: *Viertelindividuelles Melken, Sequentielle Pulsation, Vakuumschwankung, Vakuumabfall, Nassmessmethode*

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1 Introduction

The development of an alternating pulsator by Alexander Shields in 1885 was the first milestone in the development of an efficient milking machine. For many years, all milking systems have been equipped with at least one pulsator. The technology of milking machines and even of pulsators has been improved over the years, but the basic principle remains the same. The pulsation behaviour can have a significant influence on the vacuum reduction and fluctuation in a milking system. Unstable vacuum conditions, characterized by high vacuum reductions and fluctuations, were serious problems in the 1930s, when milking machines were first coming into frequent use. Therefore, as stated by O'Shea and O'Callaghan (1980), there was an increasing number of new infections, not only because of cyclic vacuum fluctuations due to vacuum instabilities but also as a result of increases in the "liner-slip rate" (air infiltration between the teat and the milking cluster) and "fall-off rate" (fall-off of the milking cluster from the teat). Furthermore, backwards streaming air during the opening of the teat liner caused accelerated air movement. This strong acceleration of the milk particles and their impact on the teat could damage the udder tissue. If cyclic and acyclic vacuum fluctuations coincide with air infiltration at the milking cluster, then the acceleration of the milk particles may be enhanced (Schlaiß, 1994). Aksen (2008) also reported that the occurrence of cyclic and acyclic vacuum fluctuations can negatively impact udder health. In this regard, Thompson et al. noted as early as 1978 that cyclic vacuum fluctuations alone do not constitute a risk to udder health. Nevertheless, Besier et al. (2016) made the following statement: "In conclusion, irregular vacuum fluctuations during milking combined with cyclic vacuum fluctuations and very high teat-end vacuum levels seem to increase the incidence of udder infection and to reduce milk flow rate. There is an impact on proper liner movement; the degree of massage on the teat end is decreased."

Hamann (1987) concluded that mastitis can be caused by improper milking techniques, such as inappropriate pulsation settings. Furthermore, Spencer et al. (2007) noted that the vacuum level and pulsation ratio are important operating parameters that affect the performance of milking machines. Thus, they tested a liner and the effects of its settings on milking performance by applying three different pulsation ratios, 60:40, 65:35 and 70:30, and found that the interaction between vacuum level and pulsation ratio had a significant effect on milking duration, peak flow rate, and average flow rate but not on milk yield (Spencer et al., 2007). Thus, according to the Agriculture and Horticulture Development Bord (2016), the pulsation ratio between the two phases (b-phase and d-phase), which describes the length of time each phase should last, should be between 50:50 and 70:30, with the ideal ratio being 60:40 in favour of the milking phase. Ratios above 70:30 are a cause for concern because teat damage is more likely to occur; at ratios below 50:50, the cows may be undermilked, and milking times may lengthen. However, there are still controversial debates regarding the optimal teat-end vacuum and pulsation settings (Agriculture and Horticulture Development Bord, 2016). European Patent EP 2 033 511 A2 (Petterson, 2009) describes a device for the measurement of the vacuum near the teat end and the control of that vacuum. In this invention, the vacuum measurement is focused on the head vacuum. The head vacuum is the vacuum state in the mouth piece chamber of the liner, which is responsible for holding the teat cup on the teat, especially at the end of the milking process.

By modifying the head vacuum in combination with the pulsation settings, the milking efficiency of a milking system can be controlled. In this invention, the collapsed state of the liner can be maintained for up to 10 seconds when pulsation is stopped. The objective of the patented device is to shorten the milking duration. Thus, this new invention leverages teat-end vacuum and pulsation control to improve the milking process. In addition, European Patent EP 1 186 229 B1 (Van den Berg and Beije, 2007) describes an individual-animal computer-controlled device. This system is able to control the milking phase, the release phase, and the vacuum level of the pulsator system. These patents demonstrate that there is a strong correlation between control technologies for milking systems and the pulsation settings. Neijenhuis et al. (2000) stated that quarter-individual pulsation systems might prevent overmilking and improve teat-end (tissue) condition. A recent study by Sterrett et al. (2013) was conducted to investigate the effect of a quarter-individual pulsation system on changes in the teat-end (tissue) conditions of cows. The authors compared a standard pulsation system with the Milpro P4C™ quarter-individual pulsation system manufactured by Milkline (Gariga di Podenzano, Italy), which can halt milking by stopping pulsation when there is no longer any milk flow from one of the quarters. Sterrett et al. (2013) came to the conclusion that the use of quarter-individual pulsation gave rise to a positive trend, but the authors did not find a significant effect on the teat-end condition. Reinemann (2010) also commented on the topic of different pulsation settings and suggested that although quarter-based control of pulsation and/or vacuum is possible in quarter-individual milking systems (QIMS), this technology is unlikely to merit commercial development because of its increased cost and complexity.

Some researchers hold the opinion that high teat-end vacuum levels, especially during the release phase of pulsation, lead to damage to the teat tissue. When a higher level of vacuum is applied at the teat, the teat cup liner folds together to a greater extent during the c- and d-phases. Rasmussen and Madsen (2000) reported that on average, milking at low vacuum levels of 26 to 30 kPa at the teat end increases the time-on-machine and the frequency of liner slip compared with milking at higher vacuum levels of 33 to 39 kPa. By contrast, milking at higher vacuum levels slightly decreases the time-on-machine (Reinemann et al., 2001) and increases the number of teat ends that are open after milking. These results were obtained using a constant pulsation setting. In the same study, during milking at a high teat-end vacuum level, the authors found that the amount of time required for the teat ends to close after milking was increased. Generally, the teat takes several hours to recover its full integrity, even following good milking conditions (Neijenhuis et al., 2001). This can cause problems with udder health because the channel inside the teat is much less protected against colonization by bacteria. The practical relevance is that cows are consequently more likely to become ill, which leads to increased costs for the farmer and causes considerable pain for the cows.

Gleeson et al. (2004) investigated the topics of machine milking and pulsation settings. They found that the teat tissue changes as a result of machine milking. Upon testing eight treatments, including two pulsator ratios, two pulsation patterns (SIM/ALT) and two cluster types, in a mid-level plant, they found no significant differences between the treatments for any of the teat influence parameters that were measured. By contrast, Hamann (1987) concluded that mastitis could be caused through sub-optimal specification of the milking technique, such as inappropriate pulsation settings. However, the teat-end vacuum can be adjusted indirectly with the aid of different pulsation settings (Ströbel, 2012). This is one advantage of a milking system in which it is possible to switch the pulsation setting between simultaneous (SIM), sequential (SEQ) and alternating (ALT) modes, even when the effect of the pulsation setting on the teat-end vacuum is small. Overall, the literature shows that it is important to consider the type of pulsation used in milking systems because, depending on its interactions with other machine settings, the type of pulsation applied has a relevant effect on the teat conditions of cows.

The QIMS used in this study operates differently from conventional milking clusters. The most important technical innovations of the QIMS are as follows: a quarter-individual tube guidance system; the cleaning and disinfection of the inside and outside of each teat cup in between milking cycles with an automatic washing unit; the possibility for sequential pulsation; and four vacuum cut-off valves, one for each udder quarter. As the name implies, this valve is able to automatically shut off the vacuum supply when one or more teat cups are kicked off by the cow (Rose and Brunsch, 2007). Another characteristic of the used QIMS is the integration of Biomilker® technology (Hoefelmayr and Maier, 1979) into the milking system. Biomilker® technology, with its periodic inlet of air during the release phase of pulsation, produces a low teat-end vacuum level during the release phase (d-phase) but also a very low vacuum reduction during the suction phase (b-phase). The purpose of the b-phase is to open the liner to receive milk from the udder. During this phase, the pulsation chamber of the teat cup is connected to the machine vacuum system. The purpose of the d-phase is to close the liner to use it as a massage tool. During the d-phase, the liner is closed and applies pressure to the teat end. Thus, blood coagulations are massaged to higher regions of the teat to ensure that they will have no negative impact on the teat health condition. Furthermore, each pulsation mode also includes a- and c-phases. In a plot of vacuum vs. time, these two phases simply represent the times when the liner is folded over the teat or is pulled away from the teat. Both phases consist only of the time delay between the triggering of the (often) electric pulsator and the mechanical impact on the liner and teat. The time required for the evacuation and filling of the pulsation chamber is included in a- and c-phases. More detailed information is given in the book by Tröger (2003).

In some QIMSs, it is possible to operate the system with either simultaneous, alternating or sequential pulsation. The system software enables the selection of one of these three alternative pulsation settings. SEQ is a pulsation system with four pulsators, instead of one (as in SIM) or two (as in ALT); one pulsator is used for each teat cup. Unlike in SIM and ALT, the pulsation cycle of each udder quarter starts later than that of the previous pulsator by 25 % of the pulsation period. Currently, SEQ is not often an available setting in the milking systems that are officially offered on the market. The scientific relevance of this study lies in improving the knowledge of these different machine settings and their effects on the vacuum during the b- and d-phases. In earlier studies, only the mean for each pulsation cycle was calculated. Knowledge about the effects of milking machine settings on teat-end vacuum is of practical relevance because this knowledge helps to guide the optimization of machine settings in a milking system.

Based on these considerations, the objective of this study was to compare the vacuum conditions at the teat end during milking under simultaneous (SIM), alternating (ALT) and sequential (SEQ) pulsation during the suction and release phases of the pulsation cycle. The teat-end vacuum is of critical importance for the health of the teat tissue. The hypothesis of this paper is that the chosen pulsation pattern exerts a strong effect on the teat-end vacuum conditions in the tested milking system.

2 Materials and Methods

2.1 Test set-up

In the test set-up, vacuum measurements were conducted using the wet-test method (ISO 6690, 2007) to evaluate the teat-end vacuum under different settings at various flow rates (ISO 5707, 2007). In total, 336 individual milking processes of approximately 10 s in duration were completed under SEQ pulsation, and 332 milking processes with the same milking duration were completed under the ALT and SIM pulsation settings. In all experiments, ISO artificial teats were used in the wet-test method for simulated milking in a laboratory milking parlour (ISO 6690, 2007) (Figure 1). The test liquid was water, which was used as a substitute for milk to simulate the effects on the milk flow. The flow rate was varied between 0.8 and 6.0 l/min during the experiments. As a flow simulator, four flow metres (Parker Hannifin Corporation, Cleveland, USA) installed on a board were used. Each flow metre allowed the flow rate, which ranged between 0.0 and 2.0 l/min, to be measured with an accuracy of ± 2 %. The liquid tank, the flow simulator and the artificial teats were connected with tubes. The four teat cups of the milking system were attached to a holder and connected to the artificial teats. The artificial teats were manufactured strictly in accordance with the specifications of ISO 6690 (2007). The

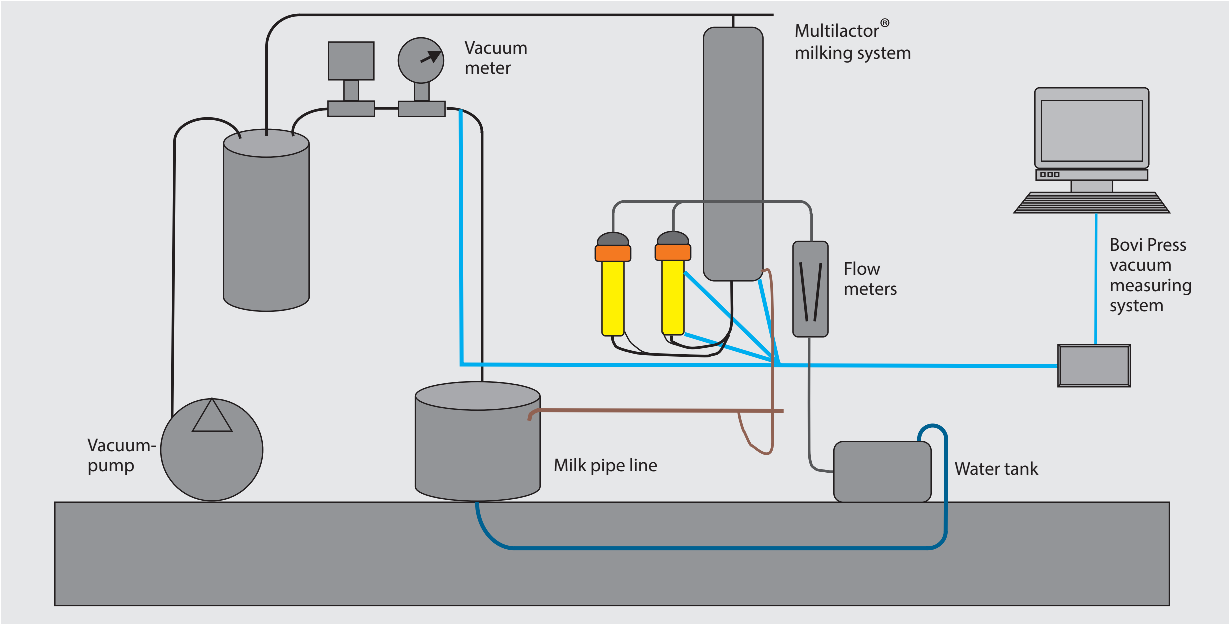

Figure 1
A schematic drawing of the QIMS used in this study, with the equipment for the wet-test method (modified according to Rose, 2006). The artificial teats were connected to the teat cups as shown in the middle of this figure. The pulse tube of the rightmost teat cup was connected to a vacuum sensor by 16-gauge injection needles, which are represented by blue lines. At each of the four points in the figure where a blue line meets a vacuum line, a pressure sensor was connected to the vacuum line at a distance of less than 10 cm. Point 1 was at the machine vacuum, point 2 was at the pulse tube of the teat cup pictured on the right and point 3 was at the teat end of the artificial teat to which the rightmost teat cup was attached.

test set-up, including the artificial teats, is depicted in Figure 1. A QIMS was used as the milking system in each test performed in this study. SIM, ALT and SEQ pulsation was applied using the QIMS in all tests. All tests were performed in a laboratory milking parlour – none of them was performed under farm conditions or with real cows.

Table 1
Technical details of the QIMS used in the laboratory milking parlour

Data	Value
Year of production	2008
Machine vacuum	35 kPa
Pulsation ratio	60/40
Pulsation rate	60/min
Construction of milking unit	quarter-individual
Milk tube length from teat cup to the Y-piece	3.095 mm
Inner diameter of the milk tube at the connection to the teat cup	10 mm
Style of air inlet	periodic air inlet via Biomilker® valve

The QIMS used in this study was developed in Germany. Other than the settings being tested, all other settings of the QIMS that were used during the tests, such as the pulsation rate, pulsation ratio and machine vacuum, were set to the levels recommended by the manufacturer (Table 1). All settings of the QIMS other than the tested parameters, namely, the pulsation setting and the flow rate, remained constant during the experiments. During each of the tests, the QIMS was operated in milking mode, and the four vacuum-cut-off-valves were deactivated. The different pulsation settings and the overall settings can be controlled using the control unit of the milking system (Table 1).

The vacuum was measured using a Bovi Press measuring system (A & R Trading GmbH Echem, Germany), which acquired samples at a rate of greater than 300 Hz and with an accuracy of ± 0.1 kPa. The measuring system stored the vacuum samples as DAT files (*.dat), which were renamed for each individual test by the laboratory staff and which could be opened for further statistical processing using MS Excel, MS Word and SAS (SAS Institute, Cary, USA). A measurement accuracy of ± 0.6 kPa is required by ISO 6690 (2007). Vacuum measurements were recorded over five pulsation cycles for each measurement at the end of the ISO teat (ISO 6690, 2007) in the pulsation chamber and in the machine vacuum line, simultaneously. The sensors were directly connected to the machine vacuum line and to the vacuum measurement point of each artificial teat (ISO 6690, 2007) to measure the teat-end vacuum. Furthermore, one sensor was connected with 16-gauge injection needles (BD Nokor Admix Kanüle 16G) to the pulse tube of one teat cup (Figure 1). The opening of each needle was oriented in the downstream direction. From the recorded data, the vacuum reductions during the b- and d-phases and the vacuum fluctuations during these phases were calculated for each of the five pulsation cycles in accordance with ISO 6690 (2007). Experiments were performed at various flow rates of 0.8, 2.0, 2.8, 4.0, 4.8, 5.6, and 6.0 l/min, where these flow rates are the sum of the flow rates for all four udder quarters. For each quarter, the flow was exactly 25 % of the total flow rate, and the flow rates for the four quarters were at the same level in each of the performed experiments. Each of the seven flow rates was tested in combination with each of the three pulsation settings, SIM, ALT and SEQ.

2.2 Statistical analysis

The recorded data were used to calculate the mean vacuum levels during the b- and d-phases of the pulsation cycle. For each repetition at each flow rate, the data from five selected contiguous pulsation cycles were considered, and the vacuum fluctuation (vf) in each phase was calculated as follows (ISO 6690, 1996):

$$vf_{phase} = \frac{1}{n} \cdot \sum_{i=1}^{n} \left(p\max_i - p\min_i \right)$$

where

i pulsation cycle,

$p\max$ maximum vacuum per pulsation cycle,

pmin minimum vacuum per pulsation cycle, and

n number of contiguous pulsation cycles ($n = 5$).

Furthermore, the vacuum reduction (vr) was calculated for each phase as follows (ISO 6690, 2007): Each measured vacuum value per pulse cycle was recorded, and the mean for each pulsation cycle was calculated. The difference was calculated between the mean sensor reading at the "machine vacuum" measurement point during each cycle and the mean value at the "teat-end vacuum" measurement point for that cycle.

The pulsation phases were identified using a SAS macro based on the formulae presented in ISO 5707 and ISO 6690 (2007). The effects on the vacuum reduction at the teat end were evaluated through parametric tests based on a linear model using the Proc MIXED procedure of SAS (SAS Institute, Cary, USA). To adjust for multiple comparison tests between factor levels, the SIMULATE option was used.

The linear model used was

$$\underline{y}_i = \mu + \alpha_i + \beta x + (\alpha\beta)_i\, x + \underline{e}_i$$

where

y_i vacuum reduction or vacuum fluctuation,

μ general mean,

α_i (fixed) effect of the i^{th} pulsation setting ($i = 1,...,3$),

β (fixed) effect of the covariate x (flow rate),

$(\alpha\beta)_i$ (fixed) effect of the interaction between the i^{th} pulsation setting and the covariate x (flow rate),

e_i independent normally distributed residual.

Pulsation settings 1 through 3 denote the alternating (ALT), sequential (SEQ) and simultaneous (SIM) pulsation settings, respectively. Three replications per quarter were performed for all pulsation settings at all seven flow rates ranging from 0.8 to 6.0 l/min, resulting in 336 observations for the SEQ setting and 332 observations each for the ALT and SIM settings.

3 Results

3.1 Vacuum reduction

From the calculated vacuum reductions during the b-phase (suction phase), it was found that at a flow rate of 4.8 l/min, the three pulsation settings (ALT, SEQ and SIM) exert a comparable effect on the teat-end vacuum reduction (Figure 2). However, at a flow rate of 4 l/min, the observations for SIM differ significant from those for the other two pulsation settings during both the b- and d-phases (suction and release phases). For this flow rate, the vacuum reductions observed during the b-phase for the ALT and SEQ pulsation settings are significantly higher than those for SIM (Figure 2), whereas the values observed during the d-phase are significantly lower for ALT and SEQ than for SIM (Figure 3).

It was found that in all cases for ALT and SEQ, the vacuum reductions are nearly identical, although in many cases, they differ considerably from those observed under the SIM pulsation setting (Figures 2 and 3). This is true for a flow rate of 2.0 l/min or lower, but it is not valid for flow rates higher than 4.8 l/min during both the b- and d-phases of the pulsation cycle (Figures 2 and 3).

In total, the values recorded during the b-phase indicate a maximum vacuum reduction of approximately 6.0 kPa (SIM) and a minimum reduction of -3.0 kPa (SIM), as seen from Figure 2. For the d-phase, the values indicate a higher maximum vacuum reduction of approximately 28 kPa (SEQ) and a minimum reduction of approximately 7.0 kPa (SEQ), as seen from Figure 3. Thus, during the d-phase (release phase), much higher vacuum reductions were observed at all flow rates and for all three pulsation regimes in comparison with the vacuum reductions during the b-phase (suction phase). This is expected because during the b-phase, a higher vacuum is required for milking the cow and for transporting the milk.

3.2 Vacuum fluctuation

The following wet-test results presented in Figure 4 and 5 for the three different pulsation settings during the b- and d-phase show that each of the three pulsation settings has a significant effect on the vacuum fluctuations in the milking system.

At a low flow rate of 0.8 l/min, the fluctuations during the d-phase were approximately three times higher than those during the b-phase. By comparison, at a higher flow rate of 6.0 l/min, the teat-end vacuum fluctuations showed values of between 4 and 10 kPa in both the b-phase and the d-phase (Figures 4 and 5).

The fluctuations observed under SEQ and SIM pulsation during the b-phase (Figure 4) show an approximately

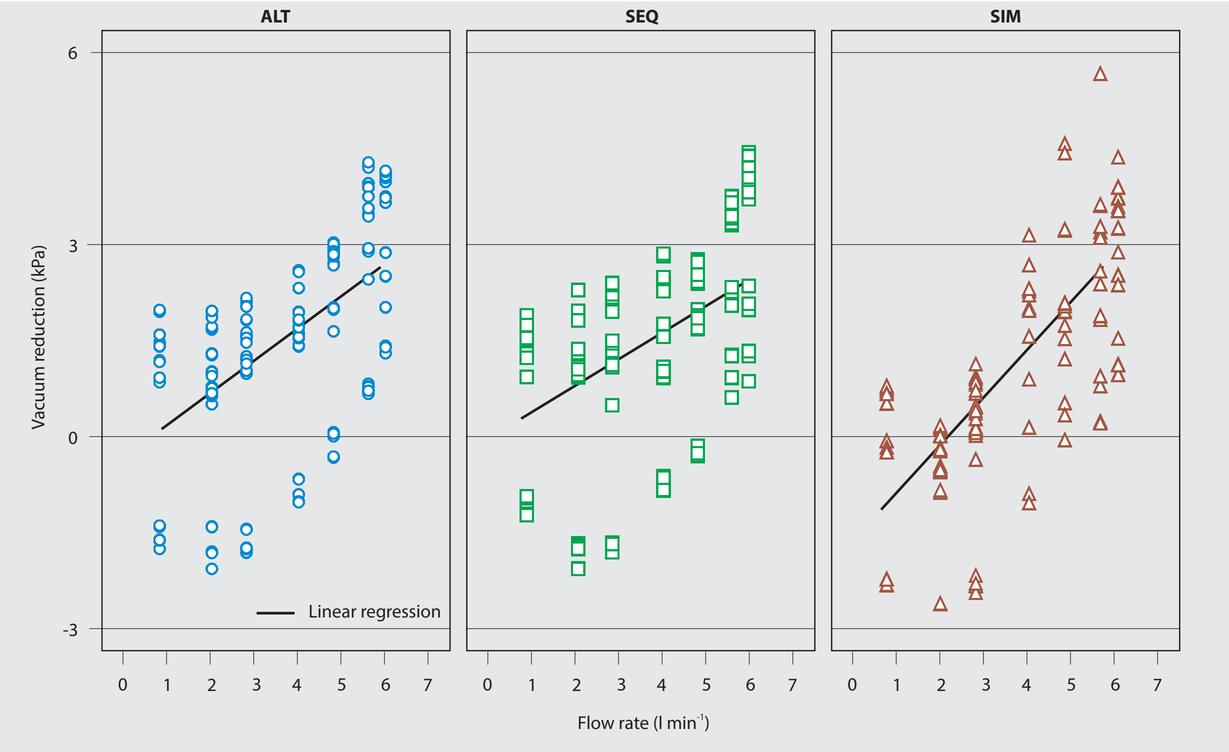

Figure 2
Vacuum reductions at the teat end during the b-phase of the pulsation cycle under the ALT, SEQ and SIM pulsation settings at various flow rates.

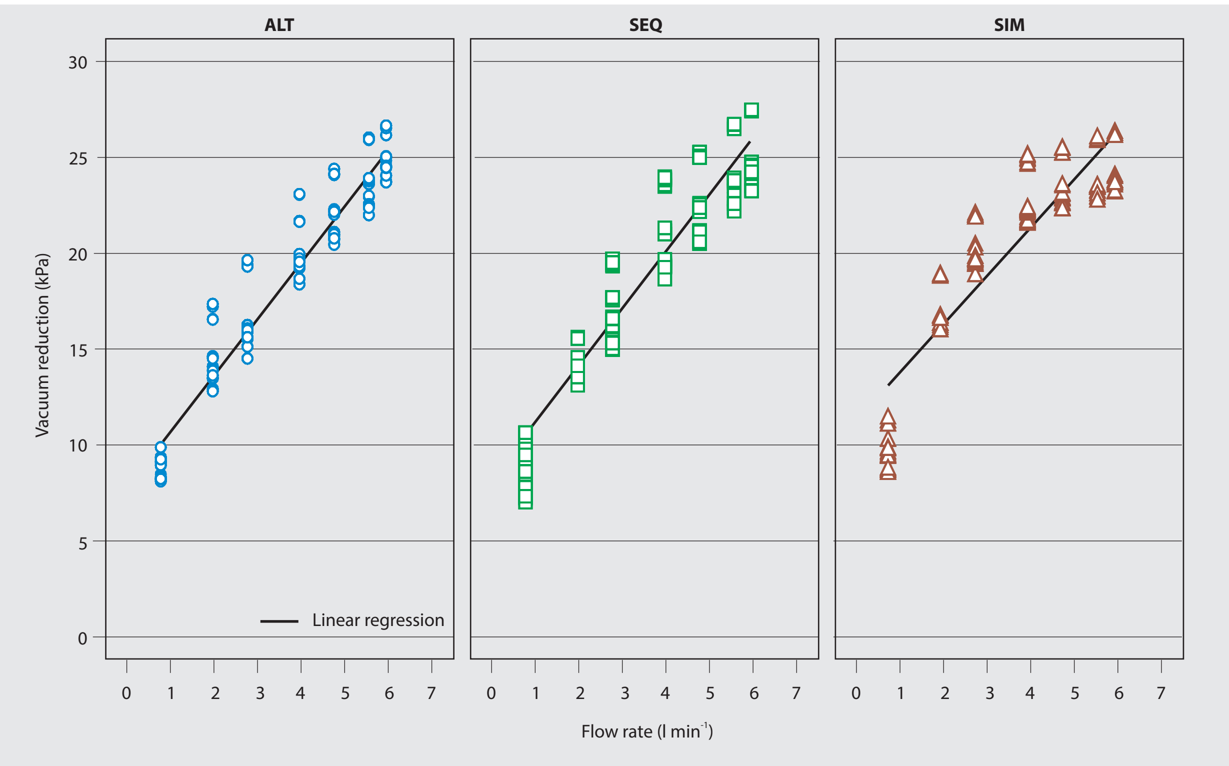

Figure 3
Vacuum reductions at the teat end during the d-phase of the pulsation cycle under the ALT, SEQ and SIM pulsation settings at various flow rates.

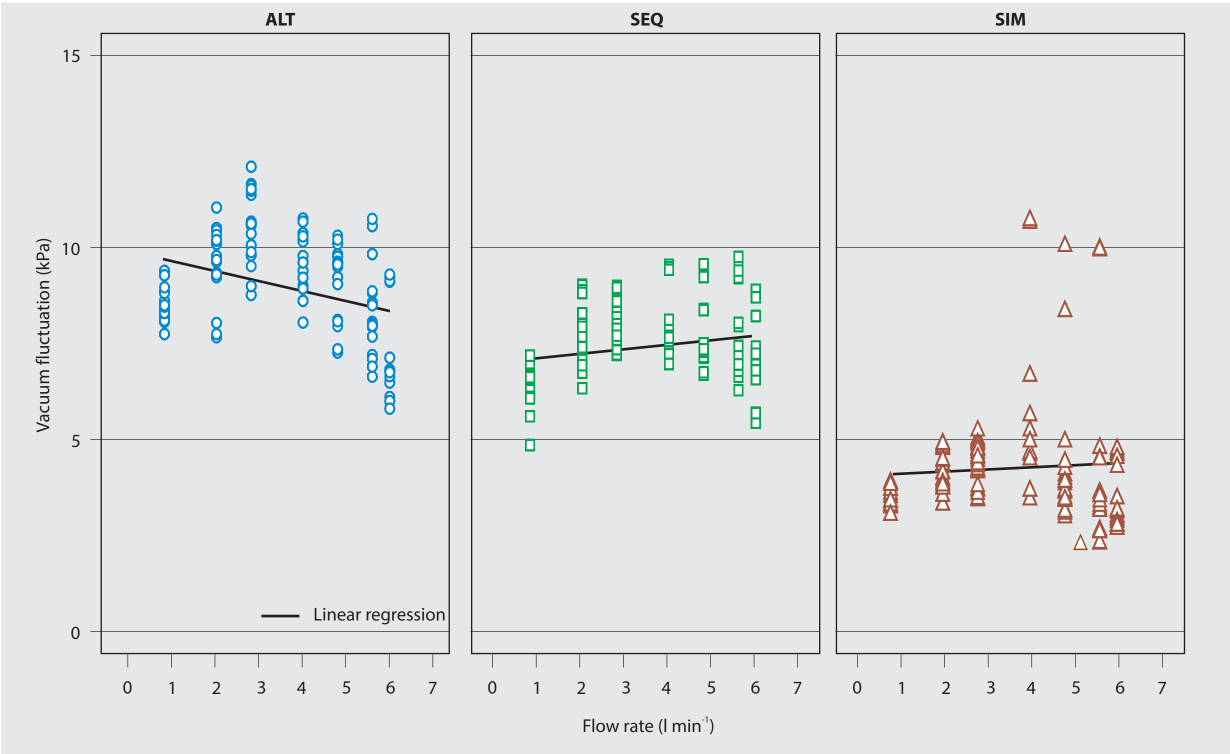

Figure 4
Vacuum fluctuations at the teat end during the b-phase of the pulsation cycle under the ALT, SEQ and SIM pulsation settings at various flow rates.

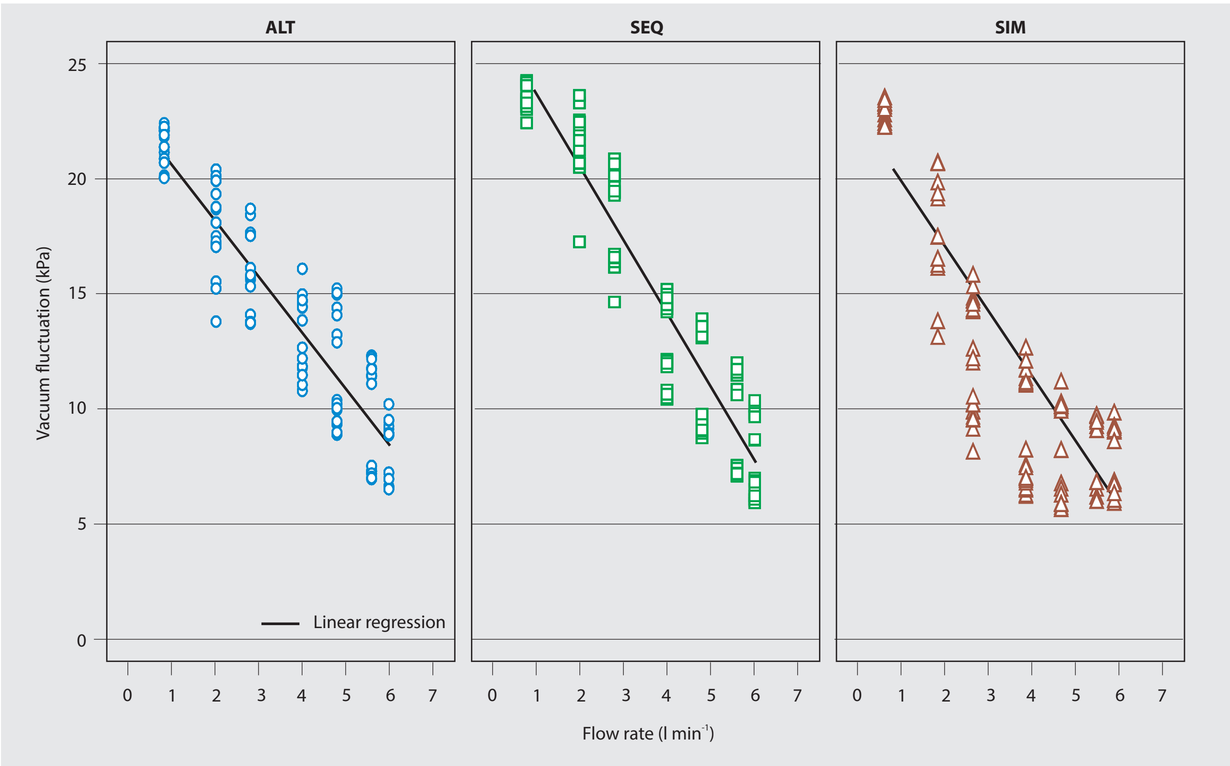

Figure 5
Vacuum fluctuations at the teat end during the d-phase of the pulsation cycle under the ALT, SEQ and SIM pulsation settings at various flow rates.

constant trend with an increasing flow rate. By contrast, for ALT pulsation, a moderately decreasing trend with an increase in the flow rate was found. For the b-phase, the ALT setting yielded the highest fluctuations at almost all flow rates, whereas the SIM setting yielded the lowest (Figure 4). The calculated regression line for the vacuum fluctuations during the b-phase under SEQ pulsation was found to lie between the other two regression lines (Figure 4).

For ALT, SEQ and SIM during the d-phase (Figure 5), a decreasing trend was observed with an increasing flow rate. This was true for the d-phase at all measured flow rates. The lower vacuum fluctuations during the d-phase at high flow rates (6.0 l/min) and the higher vacuum fluctuations at low flow rates (1.0 l/min) can be explained based on the development of the teat-end vacuum over the duration of the pulsation cycle. At low flow rates, the vacuum reductions during the d-phase that are induced by the pulsator arrive at the teat end very late in comparison to the case at high flow rates under otherwise identical conditions. Therefore, the range between the minimum and maximum vacuum values during the d-phase is much larger at low flow rates. During the c-phase, there is almost no vacuum reduction (Figures 4 and 5).

During the d-phase, the SIM setting yielded the lowest overall vacuum fluctuations at all flow rates, according to the regression lines. The SEQ setting yielded the highest d-phase fluctuations for liquid flow rates between 0.8 and 5.0 l/min (Figure 5). The results for ALT pulsation lie between those for SEQ and SIM, according to the regression lines, for flow rates of 0.8 to 5.0 l/min. At flow rates between 5.5 and 6.0 l/min, ALT and SEQ again yielded similar values for the teat-end vacuum fluctuations during the d-phase, whereas the SIM setting yielded moderately lower fluctuations.

3.3 *Statistical analysis*

The results of the wet tests regarding the effects of the pulsation setting, the flow rate, and the interaction between these factors on the vacuum reductions and fluctuations during the b- and d-phases are given in Table 2. The F test for heterogeneity revealed that both the flow rate and the interaction between the flow rate and the pulsation setting have significant effects on both the vacuum reductions and the vacuum fluctuations ($P < 0.0001$) in both phases (Table 2). A significant effect of the pulsation setting on the teat-end vacuum was found for almost all cases; the only exception was that the SEQ pulsation setting was not found to significantly affect the vacuum fluctuation in the d-phase. Furthermore, a significant effect of the interaction between the pulsation setting and the flow rate was also found for almost all cases, with the exception of the effects on the b-phase vacuum fluctuation of the interactions of the ALT and SIM pulsation settings with the flow rate.

The significant effects of the flow rate and pulsation setting show that increasing the flow rate will cause an increase in the vacuum reductions but not the vacuum fluctuations. Furthermore, for the significant interactions between the flow rate and pulsation setting, the slopes are similar for the effects of ALT and SEQ pulsation on the vacuum reductions in both phases, but both are different to the slope for the SIM pulsation setting. By contrast, a different picture was found for the vacuum fluctuations. During the b-phase, for SEQ and SIM, no increase in the slopes of the two regression lines was observed with an increasing flow rate. These two regression lines are nearly horizontal. For ALT pulsation, however, the slope of the regression line shows a decrease in the vacuum fluctuation with an increasing flow rate. By contrast, in the d-phase, all three pulsation settings led to a decrease in the fluctuations with an increasing flow rate.

4 Discussion

The hypothesis of this study was that each pulsation setting would produce significant differences in the teat-end vacuum conditions in the tested milking system. This hypothesis was found not to be true for all three pulsation settings. As

Table 2

Estimates (± s.e.) of the least-squares means † and the coefficients of regression on the flow rate for the vacuum reductions and vacuum fluctuations during the b- and d-phases of the pulsation cycle for three pulsation settings (ALT, SEQ and SIM) in a QIMS.

Effect	Vacuum reduction (kPa) in		Vacuum fluctuation (kPa) in	
	b-phase	d-phase	b-phase	d-phase
Pulsation setting				
ALT	2.10 ± 0.088	21.89 ± 0.117	8.72 ± 0.087	11.36 ± 0.142
SEQ	1.94 ± 0.086	22.16 ± 0.116	7.62 ± 0.086	11.55 ± 0.140
SIM	1.82 ± 0.086	22.94 ± 0.116	4.40 ± 0.086	9.27 ± 0.141
Regression on flow rate for				
Setting ALT	0.50 ± 0.042	2.95 ± 0.056	-0.25 ± 0.041	-2.44 ± 0.068
Setting SEQ	0.41 ± 0.041	3.02 ± 0.055	0.12 ± 0.041	-3.15 ± 0.067
Setting SIM	0.73 ± 0.041	2.51 ± 0.055	0.06 ± 0.041	-2.83 ± 0.067
F test for heterogeneity	<0.0001	<0.0001	<0.0001	<0.0001

† At a flow rate of 4.8 l/min

shown by the vacuum reduction results, the hypothesis is not true for the ALT and SEQ pulsation settings. The ALT and SEQ settings result in very similar teat-end vacuum reductions. However, significant differences were observed between the effects of both the ALT and SIM settings and the SEQ and SIM settings on the measured vacuum reductions, indicating that the hypothesis does hold for this subset of the results. Overall, the hypothesis was also confirmed regarding the effect of the pulsation setting on the vacuum fluctuations. Only the findings for SEQ pulsation during the d-phase did not differ from those for the other two settings in terms of the observed teat-end vacuum fluctuations. In the literature, several studies and arguments have been put forward to demonstrate that pulsation settings can affect the teat-end vacuum conditions in a milking system. For example, a milking system was developed in the 1990s that allowed the pulsation to be controlled throughout the entire milking process, with frequent alterations in the pulsation rate and ratio that depended on the measured milk flow data.

During the development and testing of that pulsator system, Ordolff (1991) found that varying the pulsation rate exerted effects on the liner movement, teat-end vacuum and strippings compared with earlier measurements in uncontrolled milking systems. However, it could not be ensured that the liner would completely collapse in that pulsator-controlled milking system. It permitted a pulsation ratio of up to 85 % in favour of the suction phase at the highest possible milk flow rates (Schlaiß, 1994). However, the teat-end vacuum was affected by different pulsation settings, as observed in the current study, in many cases. Those observations support the results of the current study. Concerning the suction phase (Figure 2), it can be postulated that ALT or SEQ pulsation is moderately superior to SIM pulsation for achieving effective and udder-tissue-preserving vacuum conditions at the teat end. Udder-tissue-preserving vacuum conditions are conditions in which the teat-end vacuum during the b-phase shows almost no vacuum reduction and the d-phase vacuum is as low as possible while still achieving sufficient massaging of the teat ends. In addition to the vacuum conditions at the teat end, many other parameters also influence the health of teat tissue, such as liner type and dimensions, milking duration, feeding, and seasonal effects. Moreover, one technical reason for Figure 4 and 5 is that the range of the different possible vacuum conditions at all possible flow rates is smaller under ALT and SEQ pulsation than it is under SIM pulsation. Thus, under the application of SIM pulsation, teat-end vacuum values could be measured that are much higher than the machine vacuum. However, this depends on the correct selection of the machine vacuum setting. If the machine vacuum is low, then SIM pulsation will be the better alternative; if it is high, then SIM pulsation will be a poor option because the overall vacuum applied at the teat ends of the cows will be too high.

If the release phase (Figure 3) is the focus of analysis, then SIM pulsation seems to be the better alternative because it was found that under SIM, especially at low flow rates, a moderately higher vacuum reduction is produced compared with the other two alternatives (ALT and SEQ). However, the difference in the vacuum reduction in the d-phase is relatively marginal. Thus, the effect in the b-phase is more important. Moreover, during the time interval of one pulsation cycle, it is not possible to make any adjustment to the pulsation settings. Therefore, the use of ALT or SEQ pulsation in the QIMS seems to be more appropriate than adjusting to the SIM pulsation regime. For this reason, it would be useful to develop a technical system that is capable of switching between pulsation settings at a high speed. Furthermore, the results of this study show that for all cases, the difference in the teat-end vacuum conditions produced by the ALT and SEQ pulsation settings is not large. Therefore, the QIMS can be operated under either ALT or SEQ pulsation almost equivalently. In a study by Gleeson et al. (2004), a slight (but not significant) difference was found in the teat tissue conditions measured via ultrasonography before and after the milking process under either ALT or SIM pulsation. Thus, there is no difference in the effect on the teat tissue between the two pulsation regimes.

It is also necessary to compare the teat-end vacuum conditions in the tested QIMS under ALT, SEQ and SIM pulsation with the corresponding conditions in other milking systems. O'Callaghan and Berry (2008) investigated a conventional cluster (CON) and a self-developed quarter-individual milking system (SD-QIMS) in a parlour with high-line installations. In this earlier study, the machine vacuum was 50 kPa for both the CON and SD-QIMS configurations. The vacuum reductions observed in the CON and QIMS cases can be compared with the reductions observed in this study during milking under ALT, SEQ and SIM pulsation at a flow rate of 4.0 l/min in the b- and d-phases. For the b-phase, reductions of 6.2 and 17.0 kPa were observed for the CON and SD-QIMS cases, respectively, whereas the mean reduction for the ALT, SEQ and SIM settings in this study was only 1.5 kPa. In the d-phase, a different trend can be found. The reductions were 11.5 and 25.0 kPa for CON and SD-QIMS, respectively, whereas the mean reduction for the ALT, SEQ and SIM settings in the QIMS was approximately 20 kPa. In comparison with the single teat cup unit investigated by O'Callaghan and Berry (2008), the pulsation regimes tested in the present study showed considerably lower vacuum reductions during the b-phase. The main reason for the desirably higher b-phase reductions of the CON and SD-QIMS configurations tested in the former study compared with the QIMS under different pulsation regimes in this study is that both systems considered in the earlier study were constructed with high-line installations. By contrast, the QIMS (for each pulsation regime) was equipped with a periodical air inlet system. Therefore, during the d-phase, the vacuum reductions in the SD-QIMS and the QIMS were more similar, whereas a greater difference was evident in the CON case. The differences between the milking systems led to much higher differences in the teat-end vacuum conditions compared with the differences between the three pulsation regimes (ALT, SEQ and SIM) in the QIMS.

Öz et al. (2010) showed that a modern conventional milking cluster with a 160 cm^3 claw volume induces fluctuations during the b-phase of between 4.0 and 5.0 kPa for flow rates between 0.8 l/min and 6.0 l/min per udder. The regression line for the SIM pulsation setting, which yielded the lowest fluctuations in the b-phase, lies between 4.1 and 4.3 kPa at the same flow rates. The other two pulsation regimes, especially ALT, yielded higher fluctuations in the b-phase. Data between 10.0 and 8.5 kPa were recorded for the ALT pulsation setting, and values between 7.3 and 7.6 kPa were found for SEQ pulsation. Thus, the comparison indicates that the QIMS under SIM pulsation shows similarly low vacuum fluctuations to those of the modern conventional milking cluster observed by Öz et al. (2010). In the QIMS, however, this is achieved by means of quarter-individual tube guidance because there is no vacuum buffer in the milk tube system, such as that provided by the claw in a conventional milking system.

Nordegren (1980), Schlaiß (1994) and Spohr et al. (1996) found that cyclic vacuum fluctuations have an effect on udder health. Thus, the higher b-phase vacuum fluctuations produced by the QIMS under ALT or SEQ pulsation may be a problem for some cows, even when the absolute values of the fluctuations are only moderately higher than those in the case of SIM pulsation. Tancin et al. (2006) found that vacuum modifications and proper preparation of the cows for milking can play an important role in ensuring a successful milking process. In addition, appropriate vacuum settings in combination with suitable preparations can greatly influence the milkability of the cows during the decline phase of the milk flow curves at the quarter level. The duration of the decline phase seems to be an important variable in the physiological response of dairy cows to milking machines (Tancin et al., 2006). Thus, the optimal pulsation regime and, with it, the optimal vacuum adjustment at the teat end in a milking system is essential for a successful milking process, with low vacuum fluctuations during the b-phase, a short decline phase and continuous milk ejection. As mentioned, the difference in vacuum conditions between the different pulsation settings of a milking system, when they vary widely, can be critical because an appropriate combination of a low vacuum reduction during the b-phase with a high vacuum reduction during the d-phase, as well as a proper massaging effect of the liner and high hygienic standards for milking, can help to optimize the milking process and protect the udder from inflammation and teat injury. When a cow becomes unprofitable because of illness, injury, reproductive inefficiency or low milk production, it is likely to be culled (Zavadilova et al., 2009). In this case, the farmer must cover the costs. Thus, it is very important for farmers to find the best pulsation regime for each milking system that exerts the most positive influence on the teat-end vacuum conditions during the suction and release phases, which are partially affected by the pulsation setting.

In addition to the effect of the pulsation setting, Tancin et al. (2007) showed in a study that milking without prestimulation negatively influences the milk flow, not only at the beginning of milking but also at the end of milking. The alveolar milk ejection induced by the release of oxytocin in response to machine milking throughout the entire milking procedure is an essential factor in ensuring fast and complete milk removal in dairy cows (Tancin and Bruckmaier, 2001). For example, stress caused by pain from an excessively high vacuum at the teat end can disturb milk removal and thus hinder a successful milking process. Therefore, the pulsation regimes of each milking system should be tested, and it should be ensured that at the beginning of the milking process, the open teat will not be exposed to high vacuum values of 45 kPa or more, which can cause pain for the cow and cause the stimulation process to cease. However, a low vacuum at low flow rates in milking systems is possible only when the vacuum reduction at the highest flow rates is not too great, as is the case for the ALT, SEQ and SIM pulsation settings in the QIMS, because a high vacuum reduction in combination with a low machine vacuum leads to frequent teat cup fall-offs, which farmers cannot accept.

A technical reason for the finding that the SIM setting results in lower vacuum reduction may be that in SIM pulsation, all b-phases in each of the four quarters begin at the same time. This leads to the summing of the vacuum fluctuations in all four quarters of a milking cluster, resulting in higher vacuum fluctuations, especially during the d-phase of the pulsation cycle. However, in the QIMS, in which the milk tubes cover a greater length before the tubes from all four quarters meet, no such cluster effect was observed. Moreover, lower or similar vacuum reductions were observed under SIM conditions compared with SEQ and ALT. The authors believe that the technical reason that this additive effect on the fluctuations was avoided is, as mentioned, the comparatively long milk tubes in the QIMS (3.095 mm).

5 Summary and Conclusions

QIMSs, especially those that offer ALT or SEQ pulsation, are a relatively new class of products on the market. By virtue of their quarter-individual tube guidance, these systems have the potential to offer solutions for several common problems encountered with regard to milk production in milking parlours. Tests conducted to observe the effects of three pulsation settings on the teat-end vacuum conditions show that the milking system should preferentially be used in the ALT or SEQ pulsation regime, which leads to a lower range of vacuum reductions during the suction phase. However, for some applications, when low vacuum fluctuations during the suction phase are desired, the use of SIM pulsation could also be advantageous for farmers. Compared with the differences in the vacuum conditions that exist between differently constructed milking systems (with different geometric configurations), the differences between the ALT, SEQ and SIM pulsation regimes are minor, although these differences are significant. The authors expected to find larger differences in vacuum when they defined the hypothesis for this paper. Based on a comparison of all findings, the authors believe that both the ALT and SEQ settings can help to improve the udder health of a dairy herd, or at least that these settings will help to guarantee that udder health will not deteriorate. In many cases, under all three pulsation settings, the tested QIMS generates a stable vacuum curve with a distinct vacuum reduction at the teat end during the release phase. Thus, it can contribute to reducing the stress on the teat tissue, as is required for modern animal-friendly milking systems. A construction proposal for the designers of the QIMS is to improve the QIMS by allowing it to choose the most suitable pulsation setting autonomously. This could be achieved by inserting a pressure sensor into the milk tube for each quarter. The installation of such sensors would allow the mean teat-end vacuum in each quarter to be calculated automatically. With the additional installation of decision-control software, the QIMS would be able to autonomously decide which pulsation setting is the best for each milking stall in the parlour. Moreover, the pulsation setting could be changed after the milking of each cow depending on the cows' individual milking characteristics.

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Thünen Baseline 2015 – 2025: Agri-economic projections for Germany

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Abstract

This article presents the Thünen Baseline 2015 – 2025, a projection of medium-term developments of the agricultural sector in Germany, addressing agricultural trade, prices, production, land use, income and environmental aspects. The Baseline was established using and combining several models of the Thünen Modelling Network. In the Thünen Baseline 2015 – 2025, a favourable outlook for world agricultural markets, in combination with a weak Euro, contribute to the positive development of many agricultural product prices and farm incomes in Germany. The abolishment of the milk quota and rising milk prices are key factors in the projected increase of milk production to 37 million tons by 2025. However, a sensitivity analysis, based on a scenario which assumes an appreciation of the Euro, highlights the extent to which export-oriented sectors (e.g., the milk sector) depend on macro-economic developments. Germany is the only member state without voluntary coupled support payments in the Baseline. The use of coupled payments in the other EU member states has only small negative effects on Germany. Reduction of ammonia emissions and high regional nitrogen soil surpluses remain among the key environmental challenges for agricultural policy.

Keywords: *agricultural policy, impact assessment, modelling, Germany, modelling network*

Zusammenfassung

Thünen-Baseline 2015 – 2025: Agrarökonomische Projektionen für Deutschland

Dieser Artikel stellt ausgewählte Ergebnisse der Thünen-Baseline 2015 – 2025, einer Abschätzung zukünftiger mittel- bis langfristiger Entwicklungen des deutschen Agrarsektors, dar. Für die Erstellung der Thünen-Baseline wurden mehrere agrarökonomische Modelle im Verbund eingesetzt. Dargestellt werden Projektionsergebnisse für Agrarhandel, Preise, Produktion, Landnutzung, Einkommen und Umweltwirkungen. In der Thünen-Baseline 2015 – 2025 tragen günstige Aussichten auf dem Weltagrarmarkt in Kombination mit einem schwachen Euro dazu bei, dass sich die Einkommen vieler Betriebe in Deutschland bis 2025 positiv entwickeln. Vor dem Hintergrund des Auslaufens der Milchquote sowie steigender Milchpreise wird bis zum Jahr 2025 eine Ausdehnung der Milcherzeugung auf gut 37 Millionen Tonnen projiziert. Jedoch zeigt eine Variationsrechnung, die eine Wiederaufwertung des Euro unterstellt, wie stark gerade die exportorientierten Sektoren (wie z. B. Milch) von der Entwicklung gesamtwirtschaftlicher Kennzahlen abhängig sind. Die aktuelle Verwendung gekoppelter Zahlungen in anderen EU-Mitgliedsstaaten hat nur geringe negative Auswirkungen auf die Landwirtschaft in Deutschland, dem einzigen Mitgliedsstaat mit vollständiger Entkopplung aller Direktzahlungen. Die Reduzierung von Ammoniakemissionen und die Vermeidung regional hoher Flächenbilanzüberschüsse von Stickstoff gehören auch in Zukunft zu den größten Herausforderungen für die Agrarumweltpolitik.

Schlüsselwörter: *Agrarpolitik, Politikfolgenabschätzung, Modellierung, Deutschland, Modellverbund*

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1 Introduction

The so-called 'Thünen Baseline' provides projections of medium-term developments of the agricultural sector in Germany, addressing agricultural trade, prices, production, land use, income and environmental aspects. It is established and published regularly every two years. This article presents and discusses selected results of the Thünen Baseline 2015 – 2025 as well as the assumptions upon which these results are based. [1] The projections are based on data and information available in July 2015. It is important to stress that the Thünen Baseline is not a forecast about the future. Rather, the Baseline describes expected developments in accordance with specific assumptions about the development of exogenous drivers and provided that the current agricultural policy is continued. The Thünen Baseline thus serves as a reference scenario for analysing the impacts of alternative policies and developments. It complements the more general and highly aggregated results of the baseline reports of the European Commission (2015) and the OECD-FAO (2015) by offering a detailed picture of the projected situation of German agriculture in 2025, taking national policies into account.

The assumptions for the development of the exogenous factors and the agricultural policy conditions selected for the Baseline were chosen in close consultation with experts from the German Ministry of Food and Agriculture. Preliminary Baseline results were discussed with representatives from the federal and federal state ministries. This approach enabled the integration of expert knowledge as well as the definition of a scenario that is widely accepted as a relevant basis for further policy impact analyses.

2 Methodology

The Thünen Baseline was established using and combining several models of the Thünen Modelling network, each describing various decision-making levels (Figure 1). In the analysis, a coordinated, parallel and/or iterative implementation of the models takes place. This joint use of different models has a number of advantages. The parallel use of models allows exploitation of the comparative advantages of different model types and implementations regarding result quality, coverage or resolution (Britz, 2008). The linked use of models, which includes feedback between the models, increases the consistency of scenario definitions as well as the consistency of overall results and at different levels of aggregation, and can also improve the quality of results (Helming and Banse, 2008; Offermann, 2008). Compared to (a series of isolated) single-model analysis, the use of the Thünen Modelling network for the establishment of the Thünen Baseline has the following specific advantages:

– A wide range of trade, agricultural and environmental policies can be analysed, while in one model it would be difficult to capture all the policies' different aspects

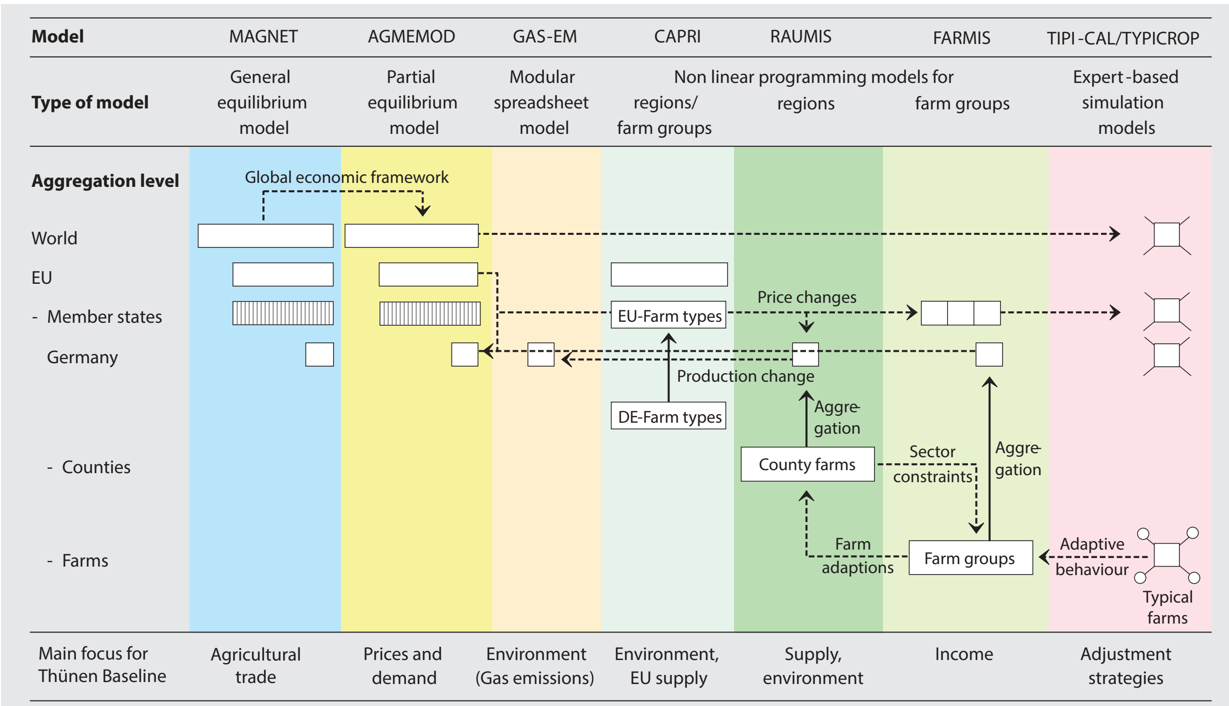


Figure 1
The use of models of the Thünen Modelling Network for the establishment of the Thünen Baseline 2015 – 2025

[1] The full report with detailed results is published in German as Offermann et al. (2016).

comprehensively and in detail. Policies can be modelled using the most appropriate model. For example, policies that target farms and whose impacts depend on farm characteristics are generally best modelled at farm level. Typical examples of such policies are the crop diversification requirement and the set-aside regulations. The upscaling of farm level impacts and the linkage to market models then allows to asses potential market effects of such policies – and to analyse the impacts of induced price effects on the farms in subsequent feedback loops.
- The impacts of policy and market changes can be analysed for a large number of various facets of the agricultural sector, e.g., trade, markets, production, environment and income, which would be difficult to incorporate comprehensively in one model.
- Projections of the development of agriculture can be presented at different levels (e.g. sector level and farm level; or national and regional level). They thus provide information on aggregate impacts, which is often important for identifying the need for political action. At the same time, information on the heterogeneity of results is provided, which is important for designing targeted and efficient policy instruments.
- The coordinated implementation allows for the alignment of important assumptions, an exchange of results between models, and the mutual monitoring and control of model results. This approach ensures a consistent overall result.

The various models [2] project different aspects relevant for the Baseline according to their individual scopes and strengths:
- The MAGNET model is a multiregional, general equilibrium model covering global economic activity as well as single countries and regions. Its specification includes a very detailed representation of agricultural trade policies and treaties. For the Thünen Baseline, MAGNET is applied to assess the development of bilateral agricultural trade flows.
- AGMEMOD is a partial, multi-national, multiple-product model which covers production, consumption, trade, inventories and prices for agricultural and processing sectors of the EU member states, accession candidates and other neighbouring countries. Its specification accounts for the specific characteristics of agricultural price formation in the individual EU member states. For the Thünen Baseline, AGMEMOD projects the prices of agricultural products in Germany, which are used as an input in the regional and farm level supply models.
- CAPRI is a comparative-static partial equilibrium model, which iteratively links regional or farm-level supply models representing the EU with a global spatial multi-commodity market model. For the Thünen Baseline 2015 – 2025, it assesses the impacts of the voluntarily coupled payments (VCS) of the Common Agricultural Policy (CAP) in the EU. The assessment uses the very detailed implementation of national CAP schemes and options in CAPRI.
- RAUMIS is based on mathematical programming models representing agricultural land use and production in Germany at regional level. The high regional resolution of RAUMIS and the integration of biophysical relations facilitate the calculation of environmental indicators. For the Thünen Baseline, it provides projections of land use, production and nitrogen surplus at regional and sectoral levels.
- Farm level aspects are covered by FARMIS, a process-analytical programming model for farm groups. The scope of the model's data basis enables providing a representative picture of farm level developments while capturing the heterogeneity of farms in Germany. For the Thünen Baseline, FARMIS projects the income of different farm groups.
- TIPI-CAL is a production and accounting model for selected typical farms, applied within the framework of the global agri benchmark network. For the Thünen Baseline 2015 – 2025, it is used to assess the impact of the reform of direct payments on suckler-cows and beef finishing farms in selected European countries, capturing the highly diverse historic payment levels, re-introduced coupled payments, and planned new schemes as well as the influence of the different production systems predominant in different regions of Europe.
- For the projection of greenhouse gas and ammonia emissions from agriculture in the Baseline scenario, the Thünen Modelling Network is linked to the model GAS-EM, a modular spreadsheet programme that uses the definitions and calculation procedures according to the current guidance documents of IPCC. The projections of gaseous emissions in 2025 build on the respective RAUMIS projections for land use and livestock numbers.

A particular strength of applying the models jointly in a network is the consistent consolidation of different areas and aspects covered by the individual models, allowing us to capture the complex interactions between the decision-making levels. For the Thünen Baseline, the core of this process is the consolidation of the price-supply relationships of AGMEMOD, RAUMIS and FARMIS.

Generally, the base year of the models is a 3-year-average around 2010 (i.e. 2009 to 2011). [3] If more recent data was available, then these are highlighted in the diagrams as observed values.

3 Assumptions

3.1 General economic framework

The Thünen Baseline 2015 – 2025 builds on external projections for macroeconomic developments from 2015 to 2025,

[2] The databases and characteristics of the models used for the establishment of the Thünen Baseline 2015 – 2025 are briefly described in the Annex.

[3] Small differences between models may occur (e.g., due to the accounting laws, the 3-year period for the farm models is 2009/10 to 2011/12). To improve readability, some table / maps refer to 2010 rather than 2009 to 2011.

as compiled in secondary sources like the USDA (USDA, 2014a; USDA, 2014b). The Baseline scenario is characterized by an annual growth of the gross domestic product of the world economy of 3.4 %, and a more modest growth in Germany (1.6 % p. a.). World population growth is projected to increase by 1 % p. a., while the population in Germany is slightly declining (-0.2 % p. a.). The Baseline scenario assumes that the Euro remains comparatively weak at an exchange rate of 1.15 $/€ in 2025 (OECD-FAO, 2015). As international trade mostly takes place in US-Dollar, a weak Euro stimulates exports and makes imports more expensive for countries of the eurozone.

Inflation in Germany remains low at 1.6 % p. a. Agricultural land in Germany is assumed to continue to decrease at an annual rate of -0.1 %, accompanied by constant structural change rates with a decline of farm numbers (-3.4 % each year; own calculations based on the Farm Structural Survey; see also Offermann et al., 2016). Yield projections are based on trends, taking into account the relation of product and input prices. For arable crops, this implies annual yield growth rates of around 1 % p. a. Dairy yields are assumed to increase by 1.1 % p. a. Autonomous technical change is driven by historical trends, while overall technical change in the agricultural sector is also influenced by structural change (especially by the increase in farm size).

The assumptions for the development of input prices in Germany are generally based on trends from 2005 to 2014. For energy inputs, the oil price projections used in the OECD-FAO-outlook (2015) are applied, which imply an oil price of 88 $/barrel in 2025. Due to the high importance of energy costs for the production of nitrogen fertilizers, fertilizer prices were linked to the price forecasts of oil. World market price projections [4] for agricultural products from the OECD-FAO (2015) are used as a calibrated basis in the AGMEMOD model to establish price developments in the EU and Germany. For the projection period international prices for livestock products, expressed in Euro, rise further (+10 % - +30 %) compared to the already high price level during 2009 to 2011 despite the downswing observed during 2011 to 2014, whereas world market prices for crop products remain constant or decrease slightly.

3.2 Policy framework

The Baseline assumes a continuation of the current policy framework and the implementation of already decided policy changes. For the Thünen Baseline 2015 – 2025, this implies that the direct payment system established by EU-Regulation 1307/2013 and its national implementation (BMEL, 2015) will be continued until the year 2025. The most important policy assumptions of the Baseline can be summarized as follows:

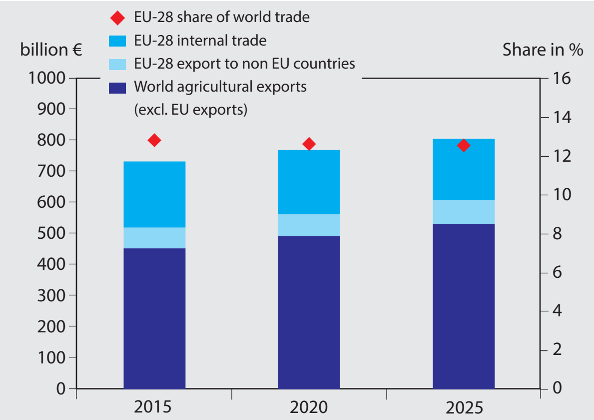
– Trade policy framework: The Baseline accounts for 14 trade agreements which will be implemented by the EU and its trading partners between 2015 and 2025 (e.g., with countries in South America and North Africa and the Balkan States). A graphical overview of these agreements is presented in Offermann et al. (2016).
– Price and quota policies: EU regulation No. 1308/2013 foresees a safety net with public intervention mechanisms for selected products. In addition, the EU commission has a reserve fund for crisis prevention and management measures at its disposal, to be able to react to general market disturbances. The Thünen Baseline presumes that neither these measures nor export support for milk products are applied during the projection horizon due to the prevailing world market conditions. The Baseline scenario takes into consideration the abolishment of the milk quota in 2015 and the end of the sugar quota regime in 2017 while maintaining border protection. Based on the OECD-FAO projection of world market prices, an EU-internal sugar price of 419 €/t in 2025 is assumed.
– Direct payments of the first CAP pillar: The redistribution of funds between EU member states, the national redistribution of 4.5 % of the budget to the second pillar, and support for young farmers lead to a base payment of 176 €/ha and a greening payment of 85 €/ha. To support smaller farms, a top-up of 50 €/ha for the first 30 ha and 30 €/ha for the next 16 ha is granted.
– Voluntary coupled support: With the exception of Germany, all EU member states notified their plans to make use of the option of introducing voluntary coupled support payments for specific sectors and regions. Based on these plans, 10.5 % of overall direct payments in the EU-28 are coupled to production levels.
– Greening: Eligibility for a part of the direct payments depends on the fulfilment of the so-called 'greening' requirements. These comprise protection of permanent grasslands, minimum crop diversity and provision of ecological focus areas (EFA). For the Thünen Baseline it is assumed that the share of EFA remains fixed at 5 % of arable area throughout the projection period.
– Support measures of the second CAP pillar: The reduced EU funds for second pillar measures in Germany are compensated by the national redistribution of funds from the first pillar. The baseline assumes that the national and regional rural development programmes implemented for the period 2014 to 2020 will be continued to 2025 with a constant budget and a continuation of the currently planned distribution of financial resources to individual measures.
– Support for bioenergy: Electricity stemming from biogas is supported in Germany by the Renewable Energy Sources Act (EEG), which guarantees a certain price for electricity generated from renewable energy sources. It is expected that the latest amendment to the EEG will significantly restrict the expansion of biogas plants and lead to a demand for 1.1 million ha of energy maize in 2025. Taking into account the projections for fuel demand, it is expected that the new policy framework will reduce demand for biofuels until 2015, with only a modest increase in the following years, whereas demand for ethanol from cereals remains constant.

[4] All price developments refer to nominal prices.

4 Results

4.1 Changes in agricultural trade patterns

In the Baseline, trade flows are influenced by macroeconomic developments as well as changes in agricultural and trade policies. Here, e.g., the implementation of 14 bilateral trade agreements, the end of the sugar quota regime, and the biofuel targets have effects on agricultural trade patterns. Figure 2 provides an overview of the changes in world trade between 2015 and 2025. Total agricultural exports (including EU intra trade) increase from 732 bn € in 2015 to 805 bn € in 2025. In contrast to this development, internal trade of the EU decreases from 213 bn € to 197 bn €. EU exports to non-EU countries increase slightly from 67 bn € to 76 bn €. This increase in EU exports lags behind export increases of other countries. Thus, exports of the EU (without internal trade) as percentage of exports of total agricultural trade decrease from 12.8 % in 2015 to 12.5 % in 2025.



Source: Own calculations with MAGNET (2015).

Figure 2

Agricultural world trade and share of EU-28 (exports)[1)]

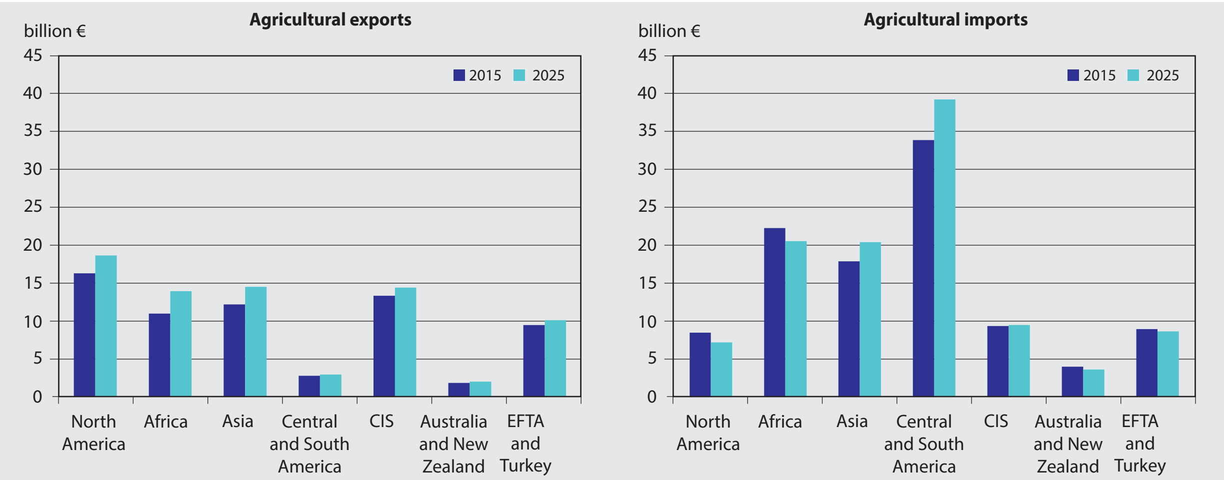
[1)]*The values in 2015 are already projected.*

A regional disaggregation (Figure 3) shows that EU-exports to all regions of the world increase slightly. The situation concerning the imports into the EU is different. Here, additional imports from Central and South America are expected due to trade agreements with the EU that will be implemented in the coming years and are therefore included in the Baseline scenario. Imports from Asia are also expected to rise. The import increase can be explained in particular by an increase of imports from China. The EU imports from other Asian countries increase only slightly in the period under consideration. Japan and the Asian-LDCs (Least Developed Countries) even show a slight decrease in exports to the EU. With the growth in imports from Central and South America as well as Asia, the trade of other regions, such as Africa and North America, is diverted. A successful conclusion of the TTIP (Transatlantic Trade and Investment Partnership) with the United States as well as the ratification of CETA (Comprehensive Economic and Trade Agreement) with Canada could counteract this effect for North America in the coming years.

4.2 Farm gate prices

Important determinants of prices for agricultural products in Germany are the projected development of world market prices (OECD-FAO, 2015) and changes in domestic policies like dairy quota abolition and the politically influenced demand of biofuels and biogas. In addition, the assumed relatively weak Euro implies that in countries of the Eurozone, prices of traded goods are higher (in national currency, i.e. Euro) than they would be in a scenario with a strong Euro, which stimulates exports and makes imports more expensive.

Until 2025, wheat prices are projected to slightly increase to reach almost 210 €/t. In the short term, a steady wheat price is expected due to low export demand. Since 2013, the wheat harvest has reached top records leading to replenished wheat stocks in typical importing countries. In the long term, the German wheat price will be oriented towards world



Source: Own calculations with MAGNET (2015).

Figure 3

Agricultural exports and imports of EU-28 in 2015 and 2025[1)]

[1)]*The values in 2015 are already projected.*

prices, which are supported by the increasing demand in the Mediterranean and the Arabian Gulf region. Feed cereal crops prices stabilize at the comparatively high level of approx. 190 €/t for maize and 170 €/t for winter barley. In this projected development, a stronger demand growth for corn has been taken into account. Despite the drop in domestic demand for rapeseed for biofuels, the decrease of the rapeseed price is moderate and prices remain almost constant at 360 €/t due to favourable world market developments. This means that the rapeseed price will stay significantly lower than in the record year 2012.

Several adverse factors were observed in the years 2015 and 2016 for animal products, especially for dairy products and pig meat. High levels of milk production worldwide in 2015 and 2016 driven among other factors by high prices in the period before, the import embargo from Russia as well as the lower demand for milk from China induced a price drop. In the case of Germany, international factors met national conditions: With the end of March 2015, milk quotas were abolished leading to higher milk production in the EU market adding to low prices. Even though the milk production in Germany was relatively steady, in most of the other EU countries production considerably expanded, negatively

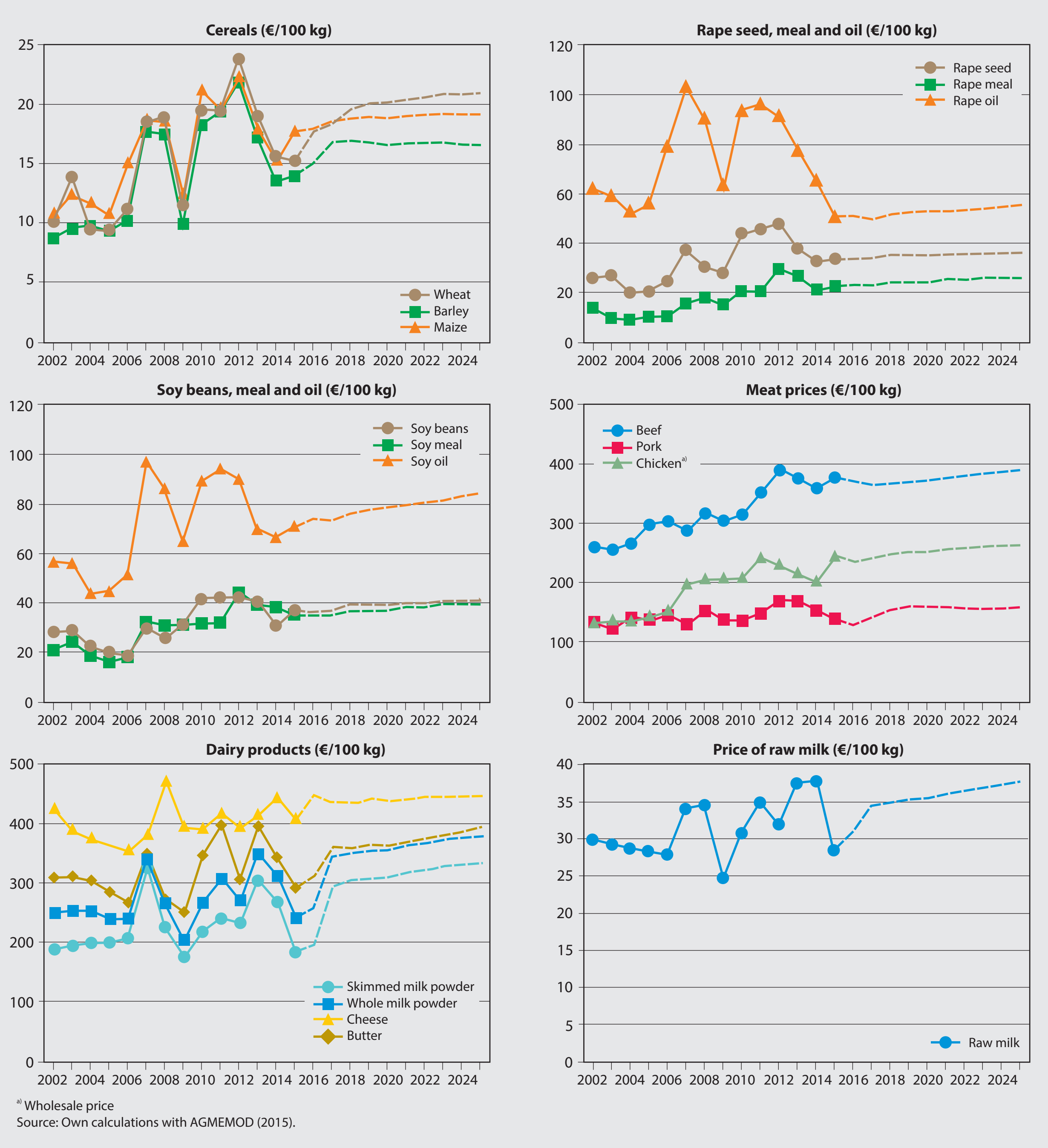


Figure 4
Development of farm gate prices in Germany

affecting the milk prices. After the period of consolidation, milk prices are projected to catch-up again until 2025 due to backlog demand in China and Near East, which is currently curbed by a slowdown in global economic development. The German milk price is projected to almost reach 38 €/100 kg raw milk with 4 % fat and 3.4 % protein.

Similar negative conditions affect the pork meat markets. Again, the import embargo from Russia as well as a further (cyclical) rise in pork production are to be mentioned. For poultry meat, the increasing production rates will contribute to a steady meat price. The differences in prices for pork and poultry meat presented in this study are due to differences in the conception of the prices. The broiler prices shown in Figure 4 represent wholesale prices. The prices on farm gate level are expected to rise less dynamically due to an assumed substantial increase in the trade margin that could already be observed in the past.

In the case of beef meat, the close link of beef and milk production needs to be considered. Thus, if milk production is driven by productivity growth, then the beef meat production will develop in the same direction, though the potentially significant increase in live animal trade also needs to be taken into account.

4.3 Agricultural production

Table 1 provides an overview of the development of land use and agricultural production in the Thünen Baseline. Despite the projected increase of cereal prices by about 26 % in 2025, cereal area decreases slightly (-1 %) compared to the average of the period 2009 to 2011. This decrease results from an increase of energy maize to approx. 1.1 million ha, the increase of set aside to approx. 0.4 million ha and the continuing loss of agricultural land. Cereal production shifts from more extensively produced cereals like summer barley to more intensive wheat production. This intensification is complemented by crop yield increases due to technological progress. Therefore, in 2025 cereal production increases by approx. 52 million t, despite the smaller cropping area.

The oilseed production remains constant at 5.6 million tons, although the oilseed acreage is reduced by 17 % due to the unfavourable development of the price for oilseeds. The cultivation area of silage maize and other arable fodder crops is slightly reduced because fodder yield increases while cattle numbers remain more or less constant.

With the abolishment of the milk quota and rising milk prices, milk production increases to 37 million t by 2025. Compared to the period 2009 to 2011, this corresponds to a growth of milk output in Germany by 23 %. It is important to stress that this high increase of milk production is based on high price projections which are mainly driven by the assumption of increasing demand for milk on the world

Table 1

Development of production and land use in German agriculture

	Unit	1999	2007	2010	Baseline 2025	*Baseline 2025 vs. 2010 in %*
		absolute				
Land use						
Cereals	1 000 ha	6 840	6 763	6 571	6 517	*-1*
Wheat	1 000 ha	2 706	3 098	3 298	3 535	*7*
Barley	1 000 ha	2 196	1 968	1 641	1 408	*-14*
Rye	1 000 ha	851	649	627	589	*-6*
Oilseeds	1 000 ha	1 137	1 475	1 499	1 249	*-17*
Root Crops	1 000 ha	804	651	633	624	*-1*
Potatoes	1 000 ha	298	270	255	253	*-1*
Pulses	1 000 ha	112	119	91	171	*87*
Maize silage	1 000 ha	1 203	1 017	1 050	973	*-7*
Other arable fodder	1 000 ha	469	599	750	706	*-6*
Energy maize	1 000 ha	51	444	809	1 075	*33*
Set aside [a)]	1 000 ha	720	593	245	367	*50*
Cattle	1 000 head	14 831	12 749	12 772	12 701	*-1*
of which: Dairy cows	1 000 head	4 765	4 123	4 191	4 443	*6*
Milk production [b)]	1 000 t	26 768	28 057	30 051	37 040	*23*
Beef and veal production	1 000 t	1 396	1 136	1 221	1 130	*-7*
Pork production	1 000 t	3 863	4 019	4 908	5 116	*4*
Poultry production	1 000 t	799	959	1 588	1 909	*20*

[a)] Incl. unused grasslands.

[b)] Actual fat and protein content.

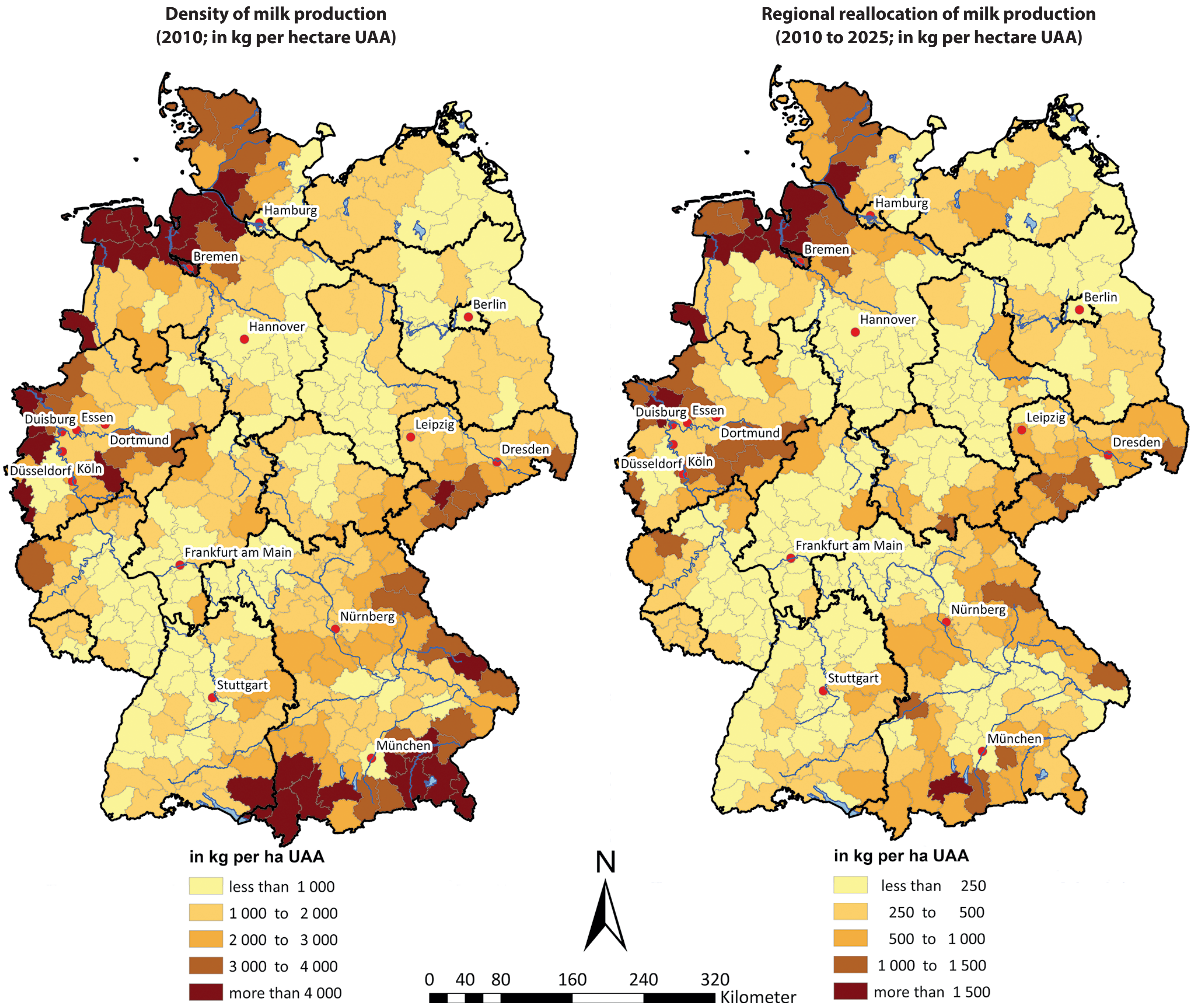
market. Breaking the historic trend, the number of dairy cows increases slightly. The total number of cattle remains almost constant. Thus changes in beef production are minor. Only moderate increases are projected for veal and pork production. In contrast, the poultry meat production is projected to increase by 20 % until the year 2025.

The trend of a regional concentration of dairy production (Kreins and Gömann, 2008) is accelerating after the end of the dairy quota system. On average, milk production increases by approx. 400 kg/ha of utilisable agricultural area (UAA) from 2009/11 to 2025. According to the model results, an above-average expansion of dairy production will take place in the coastal regions and in the lower Rhine region, in some areas of the Mittelgebirge (middle mountain areas), as well as in the Allgäu and the Voralpen (pre-Alpine regions) (Map 1). These grassland and lower-yielding arable crop areas have generally shown a particularly competitive dairy production in the past, and already exhibit high dairy production densities. A withdrawal from dairy production can particularly be observed in arable locations, such as for example the Köln-Aachener Bucht (Cologne-Aachen area), the Hildesheimer Börde (plain, fertile soils around Hildesheim) and the northeast of Brandenburg. In addition, some grassland regions lose production shares. This affects, for example, the Black Forest as well as parts of Hesse, and thus grassland regions that have proven to be less competitive for dairy production in the past and in which dairy production has been declining. These regions are often found near urban centres that offer comparatively good off-farm job opportunities.

4.4 Income

The following analysis of income developments at farm level focuses on the indicator 'Farm Net Value Added (FNVA) per agricultural working unit (AWU)'. FNVA measures the return to the factors land, labour and capital, and is put in relation to the amount of labour input to account for differences and changes in farm size. All income figures are adjusted for inflation and refer to 2010 prices.

Compared to the base period of 2009/10 to 2011/12 (Figure 5), the average FNVA/AWU once again increases slightly, and is thus higher than average income over the

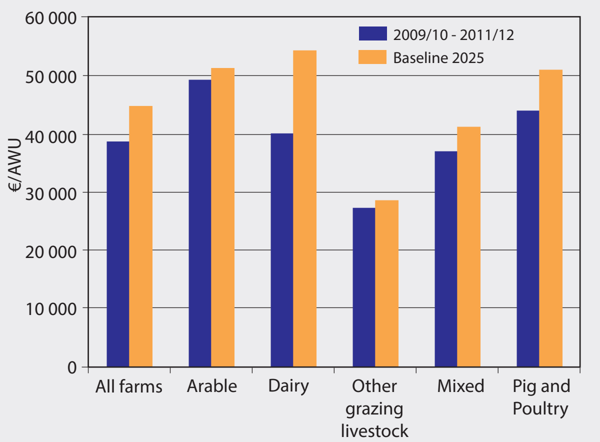


Source: Own calculations with RAUMIS (2016).

Map 1
Regional relevance and reallocation of milk production in Germany

last ten years. The decrease of farm gate prices in real terms and the reduction of direct payments are partly offset by

- the continuing structural change, with high exit rates especially of small farms with below-average income potential and the resulting opportunity for growth for remaining farms;
- the reduced labour requirements as a consequence of technical change; and
- improvements in crop and dairy yields.



Source: Own calculations with FARMIS (2015).

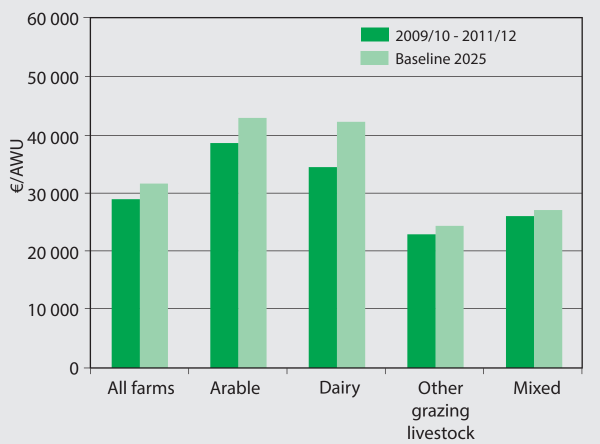
Figure 5
The development of farm net value added per agricultural work unit by farm type (in real terms in prices of 2010)

However, income developments differ by farm type. Arable farms are especially affected by significantly lower prices for sugar beet, but benefit from the still growing demand for energy maize. The average land area of arable farms increases markedly, due to the high exit rates of small arable farms with lower incomes. Income of arable farms stabilizes at the level of the base period. Dairy farms profit from projected milk prices being significantly higher than during the period 2009 to 2011, and benefit from a strong increase in the average milk production quantity. The income of dairy farms rises by 35 % and thus surpasses that of other farm types. Other grazing livestock farms, which include many smaller, part-time farms, can only slightly increase their income above the low level of the base period (+5 %).

While pork prices significantly decline in real terms, mixed and pig and poultry farms profit from rising poultry meat prices and a comparatively favourable development of prices for energy and imported feed. In addition, pig and poultry farms are less affected by the reduction and reformation of direct payments than other farm types. While on average farms receive 50 €/ha less than in the base period, the payments in pig and poultry decrease by only 7 €/ha. Compared to the base period, income increases by 11 % in mixed and 16 % in pig and poultry farms, and thus reaches the comparatively high level of the farming years 2012/13 and 2013/14. However, it should be noted that higher regulatory requirements currently under discussion, e.g., as part of the fertilizer directive, which could increase production costs for these farms in the future, have not been accounted for in the Baseline scenario.

Expenditures for land rent are not taken account of in FNVA, and the impact of changing rental prices on farm profits depends on farm specific rental shares. The projected increase of rental prices for grassland thus especially affects other grazing livestock farms due to the high share of grassland in combination with a high share of rented land. According to the model results, rents are projected to increase strongly especially in regions with intensive livestock farming.

The income of organically managed farms increases by 10 % in the Baseline compared to the base year period as shown in Figure 6. This development is mainly due to the growing size of the average farm in the wake of structural change, higher yields and higher support payments for organically managed land, which compensate for lower farm-gate prices and higher costs for labour and farm inputs. An increase in income can be observed particularly for organic dairy farms (+23 %) and organic arable farms (+12 %). In contrast to this, there is only a slight increase of FNVA/AWU in organic mixed (+4 %) and other grazing livestock farms (+7 %). These farms receive higher revenues due to an expansion of production, but have also to bear substantially higher production costs.



Source: Own calculations with FARMIS (2015).

Figure 6
The development of farm net value added per agricultural work unit in organic farms (in real terms in prices of 2010)

4.5 Environmental impacts

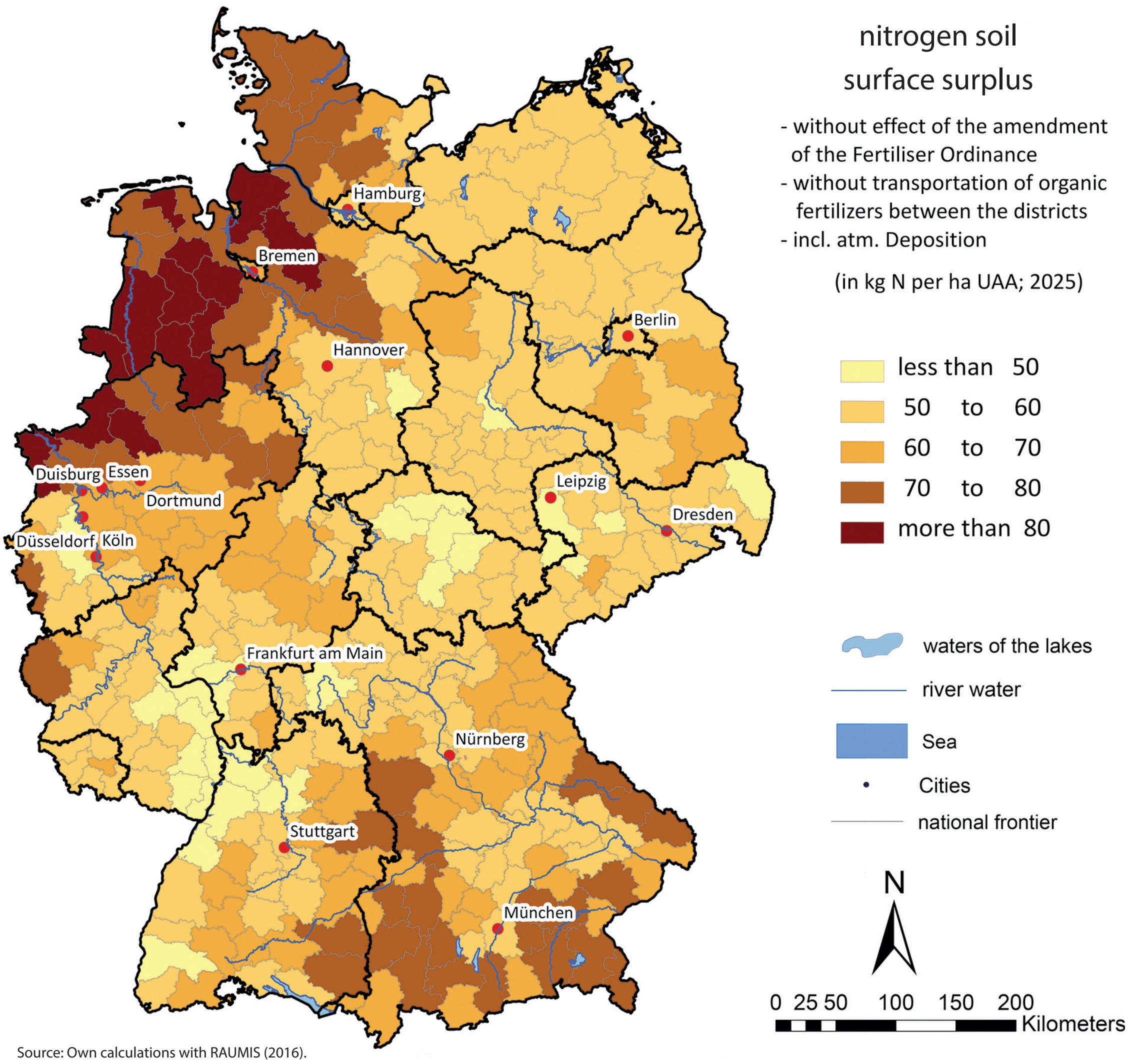
One of the key indicators for the environmental impacts of agriculture is the N-balance, which is the difference between all nutrient inputs and outputs on agricultural land. For the calculation of the soil surface nitrogen balance, inputs include mineral and organic fertilizers (including fermentation residues), atmospheric deposition, and symbiotic and asymbiotic N-fixation, while output refers to the quantity of nitrogen in harvested crop production. A positive balance reflects inputs that are in excess of crop and forage needs. A modified calculation of the N-balance is used to assess the potential impact of excess nitrogen on water: to this end, nitrogen loss through the volatilisation of ammonia to the atmosphere is subtracted from animal husbandry and stored manure.

Compared to the previous developments during the past decade, the trend of declining livestock numbers does not continue in the Baseline scenario. The increase of biogas production leads to a rise in nitrogen quantities from fermentation residues, which have a lower utilisation rate than mineral fertilizers. With an increasing efficiency of the utilization of organic fertilizer [5], the use of manure rises by 8 % until 2025 (Table 2). In addition, the use of mineral fertilizer increases by 9 % during the same period. The expected yield increase and the corresponding nutrient requirements account for the decline of the sectoral nitrogen soil surface surplus from 70 kg/ha UAA in 2010 to 64 kg/ha UAA in 2025.

Table 2
Development of the nitrogen balance

Elements of the nitrogen balance		2009/11	2025	*Change in % to 2009/11*
		in kg N/ha UAA		
Inputs	Organic fertilizer	84	92	*8*
	Mineral fertilizer	97	105	*9*
	Symbiotic fixation, asymbiotic fixation and atmospheric deposition	38	38	*0*
Total inputs		219	234	*7*
Outputs and gaseous losses	N in harvested yield and ammonia losses	-149	-170	*14*
Nitrogen balance (soil surface balance)	Denitrification, leaching and accumulation in soils	70	64	*-8*

Source: Own calculations with RAUMIS (2016).



Source: Own calculations with RAUMIS (2016).

Map 2
Regional nitrogen soil surface surplus (2025)

[5] Based on the developments during the last 20 years, the Thünen Baseline 2015 – 2025 assumes that nitrogen use efficiency of mineral fertilizers increases by 0.25 percentage points per year, and by 0.8 percentage points per year for organic fertilizers.

Map 2 provides an overview of regional nitrogen soil surface surplus until 2025. Regional nitrogen balances are to a large extent influenced by the quantities of regionally produced manure and energy maize. The livestock densities vary significantly, and while the average value is 0.9 livestock units (LU) per ha, stocking rates exceed 2 LU/ha in some areas (e.g. in the northwest of Germany). High nitrogen inputs from organic fertilizers are projected especially for the northwestern part of Germany and some regions in Schleswig-Holstein and Bavaria. While nitrogen input from organic fertilizers is on average around 94 kg N/ha UAA, values exceed 300 kg N/ha UAA regionally due to intensive livestock production (e.g., in Lower Saxony). In these regions, average nitrogen surpluses can be exceeded significantly with values of more than 80 kg/ha UAA.

Ammonia is one of the most important airborne pollutants. Directive 2001/81/EC of the European Parliament and the Council on National Emission Ceilings for certain pollutants (NEC Directive) stipulates a reduction of ammonia emissions in Germany to less than 550,000 t after 2010. The European Commission already suggested further reductions of up to 39 % until 2030 on the basis of 2005 emissions (implying a reduction of ammonia emissions to approximately 415,000 t). Figure 7 provides an overview of the past and projected development of ammonia emissions in Germany. Using new emission factors for mineral fertilizers, between 2010 and 2014 the emissions exceeded the NEC emission ceiling by 90 to 125 kt. The reduction of livestock numbers in the eastern part of Germany in the early 1990s, the continuous decrease of cattle numbers and technical progress with respect to the management of organic fertilizers all have contributed to the decrease of ammonia emissions in the past. Since 2010, emissions from livestock are slightly increasing. Emissions from biogas residues stemming from anaerobic digestion of energy plants are not considered in the NEC limit, but will be included in the 2030 objective. The projections thus highlight that additional measures for ammonia reductions will be necessary to ensure full compliance with legal emission limits. The reduction targets discussed for 2030 are even more ambitious, because the biogas sector has significantly expanded since the year 2005, the basis for calculating the new reduction targets.

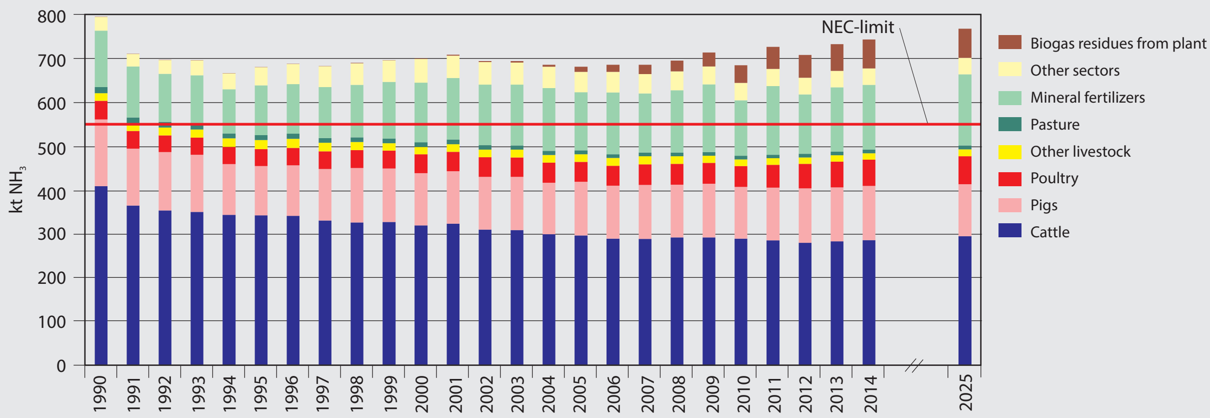
Greenhouse gas emissions will increase by 6 % compared to 2005, especially due to the rise in cattle numbers. According to the so-called 'effort sharing decision' (406/2009/EC), an average reduction of 14 % compared to 2005 emissions is required for German sectors not included in the emission trading. The projection shows that additional actions in the farm sector are required to contribute to the intended emission reductions.

5 Coupled payments and Single Farm Payment reform in other EU member states

Important elements of the latest CAP reform, like the internal convergence of direct payments within the Member States and the changes to coupled payments, do not directly affect German farmers, as the system of regional per ha payment rates was already implemented in the past, and the abandonment of coupled payments has been confirmed for the new CAP period. However, as these reforms could potentially have significant impacts on the profitability of production systems in other EU member states, this might indirectly affect the relative competiveness of Germany farmers. The next section looks in detail at beef cattle farms, which will be particularly affected by the changes in the payment schemes, followed by an analysis of the impact of an abolishment of the voluntarily coupled payments in all EU member states.

5.1 Impact of the CAP-reform on cow-calf and beef finishing farms in selected EU-member states

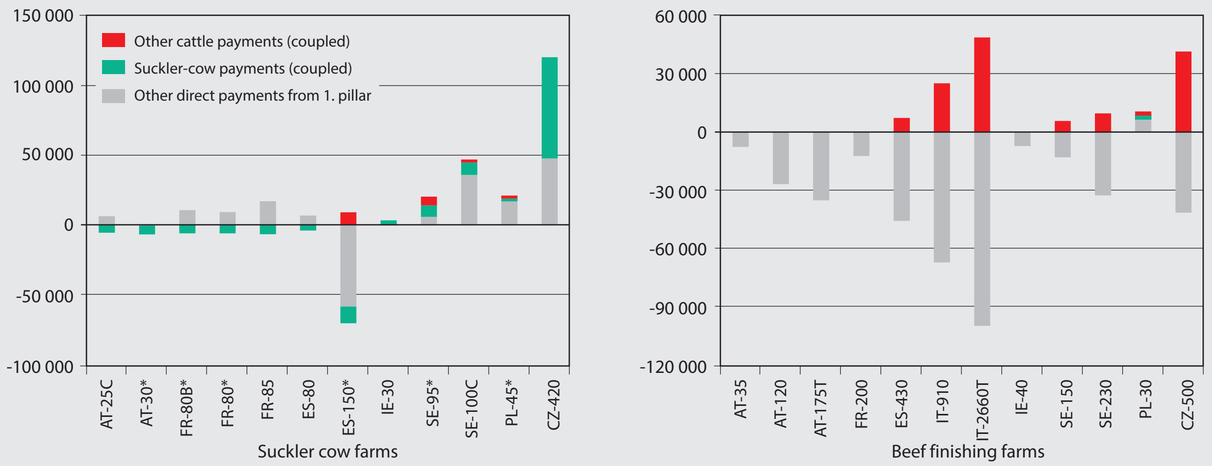
The previous sections were dealing with rather aggregated model results which cannot reflect differences between farm types in great detail. Due to the fact that policy changes in the European CAP can be expected to particularly affect beef



Source: Own calculations with GAS-EM (2016).

Figure 7

Development of ammonia emissions in Germany



* With finishing of own weaners.
The farm names on the y-Axis have the following syntax: country prefix plus the number of suckler cows or the number of finished beef cattle per year.
AT: Austria. FR: France. ES: Spain. IE: Ireland. IT: Italy. SE: Sweden. PL: Poland. CZ: Czech Republic.

Source: Own calculations with TIPI-CAL (2015).

Figure 8
Payment changes in EUR per farm, 2025 compared to 2014

farms (cow-calf and beef finishing), a special analysis using the typical farms from the agri benchmark Beef and Sheep Result Data Base was carried out. Farms with suckler-cows and beef finishing used to enjoy relatively high payment levels through coupled suckler-cow payments and/or decoupled Single Farm Payments (SFPs), the latter based on the historic reference from the years 2000 to 2002. With the present CAP-reform, suckler-cow payments are reduced or abolished and SFPs are transferred into per hectare payments. The change in payment type leads to significant payment losses for beef finishing farms in those countries where the decoupled payments were mainly disbursed as a SFP (Belgium, France, Greece, Ireland, Italy, Netherlands, Austria, Portugal, Spain, Scotland, Wales). In contrast to those countries where the transfer had already been completed by 2013/14 (England, Finland, Germany), it cannot be expected that rising beef prices will compensate for the loss of payments. This is the main reason why several member states re-introduced coupled payments for beef production.

As a consequence, the analysis focuses on those member states which are likely to be most affected by the changes listed above. Figure 8 shows the changes in payments in selected suckler-cow and beef finishing farms.

The following main conclusions can be drawn from the analysis:

- The changes in the payment systems tend to benefit farms with high proportions of grassland and low stocking rates and worsen the economic situation of farms with high shares of arable land and high stocking rates.
- The newly introduced voluntary coupled support payments for suckler cows and other cattle cannot compensate for the reduction of SFPs.
- The regulation on the first hectares in France result in a stabilisation of incomes in farms with less than 100 hectares.
- The development of the profit per labour unit reflects the situation described above: mainly positive in the cow-calf farms, mainly negative in beef finishing farms.
- The negative impact of the policy changes on the finishers in the EU-countries improves the relative competitive position of the German beef finishers, mainly in terms of a cash flow deficit and the delay of necessary investments on the side of their EU-colleagues.
- In contrast, the German cow-calf producers seem to lose competitiveness against at least some of the cow-calf farmers in other EU member states.
- However, it can be expected that the losses in beef finishing will be passed on to cow-calf producers in terms of lower weaner prices, reducing to a certain extent the gains shown above.

5.2 Implications of a complete de-coupling of direct payments in the EU

The implementation of measures under the voluntary coupled support scheme results in approximately 4.16 billion Euros of sector or region specific support. Almost 90 % of these payments accrue to five sectors, namely beef and veal (41 %), milk and milk products (20 %), protein crops (11 %), sheep and goat meat (12 %) and sugar beet (4 %). This sectoral focus is closely linked to the structure of the agricultural sector in the member states that make the most use of this instrument, France, Spain, Italy, Poland and Romania. Together, these five countries account for roughly 70 % of total voluntary support payments.

As the Baseline projection assumes a continuation of current policies up to the year 2025, a supplementary scenario was defined and analyzed. This scenario assumes a complete de-coupling of the voluntary coupled support

Table 3
Supply in 2025 following a complete de-coupling of direct payments

	Beef from suckler cows	Sheep and goat milk	Sheep and goat meat	Protein crops	Sugar beet
			in 1 000 tons		
EU-28	**4 782**	**4 366**	**750**	**2 027**	**112 432**
	-4.5 %	***-1.9 %***	***-1.0 %***	***-6.6 %***	***-0.9 %***
EU-15	**4 530**	**3 491**	**645**	**1 548**	**91 143**
	-4.4 %	***-2.1 %***	***-0.8 %***	***-4.7 %***	***0.1 %***
Germany	275	55	16	230	27 638
	4.7 %	*0.8 %*	*-0.4 %*	*1.0 %*	*0.1 %*
France	1 699	948	72	58	25 509
	-8.2 %	*-3.6 %*	*-0.6 %*	*-29.3 %*	*0.7 %*
Spain	782	1 059	154	499	3 030
	-8.8 %	*-3.0 %*	*-0.5 %*	*-7.4 %*	*-1.9 %*
Italy	51	254	11	105	3 671
	-4.7 %	*-0.4 %*	*-2.6 %*	*-3.3 %*	*-3.4 %*
EU-13	**252**	**875**	**105**	**479**	**21 290**
	-6.5 %	***-1.1 %***	***-2.1 %***	***-12.2 %***	***-5.0 %***
Poland	65	8	1	220	10 981
	-5.3 %	-15.0 %	-22.4 %	-7.9 %	-7.1 %
Romania	0.3	728	88	80	536
	7.4 %	-0.7 %	-1.2 %	2.3 %	-4.2 %

* Percentage deviation to the Baseline, i.e. a situation where the voluntary coupled support payments are maintained up to 2025.
Source: Own calculations with CAPRI (2015).

payments and analyzes the effects on production, prices and incomes in the EU28 for the year 2025.

Table 3 highlights the implications of a complete de-coupling of direct payments for the EU28 as well as selected countries and products. The values depicted in Table 3 reflect the supply quantity in 2025 for the scenario of a complete de-coupling, as well as the relative difference to the supply situation in the Baseline (i.e., a situation where the voluntary coupled support payments are maintained).

At the EU28 level the impacts of a complete de-coupling are moderate. For individual member states, the most discernible implications arise in France and Spain, i.e., two countries that account for roughly 41 % of total payments under the voluntary coupled support scheme. This regional focus is also reflected in the sectoral results with the most noticeable differences accruing to suckler cows and protein crops. These moderate decreases in supply result in a slight increase in prices for beef and protein crops. The funds released by the complete de-coupling of payments are transferred to the basic payment scheme, thus the increase in prices only results in a modest increase (+0.94 %) in EU incomes.

For Germany, the only member state without voluntary coupled support payments in the Baseline, effects of a complete decoupling of payments by the other EU member states are generally small and slightly positive. These effects are triggered by changes in prices at the EU level resulting from a moderate decline in production in the other member states. The greatest benefits arise in the beef sector. Nevertheless, while average agricultural incomes remain fairly stable due to the general transfer of funds to the basic payment scheme, deviations in agricultural incomes for farms specialized in beef production can be more pronounced.

6 Sensitivity of results to exchange rate developments

The assumption concerning the development of the exchange rate of Euro and US-Dollar is characterized by high uncertainty. At the same time, it has a relatively large impact on a wide range of projection results. Based on the OECD-FAO Outlook (2015), the Thünen Baseline 2015 – 2025 assumes that the Euro remains comparatively weak at an exchange rate of 1.15 $/€ in 2025. While several market observers expect a further weakening of the Euro at least in the short- to medium-term, the EU Commission (2015), based on projections by IHS Global Insight, assumes an appreciation of the Euro and an exchange rate of 1.37 $/€ in 2025 for their projection of agricultural markets development until 2025.

A sensitivity analysis was implemented to illustrate the importance of the exchange rate assumption for the results of the Thünen Baseline. The Scenario “Strong Euro” has the same assumptions and framework conditions as the Baseline, with the exception of the exchange rate, which was fixed at 1.37 $/€ in 2025. For the German agricultural sector, this implies that the prices for many products decrease, especially for those products where trade is important for the market balance. Intermediate inputs with a high share of imports (e.g., imported feedstuff, oil-price dependent energy inputs and fertilizers) will become less expensive from the view of the German producers, while at the same time many output prices will also decrease markedly. The impact on the German agricultural sector and the extent to which individual farms are affected depends on the size of price effects and the importance of the respective cost and revenue items for individual producers.

The assumed appreciation of the Euro leads to a decrease of market and farm gate prices in the EU. The impact is strongest for crop products, where prices are strongly influenced by world market developments as import protection is relatively low (Table 4). While milk prices are also strongly affected due to the high dependency on exports, the effect on beef and pork prices is somewhat lower.

Table 4
Price development of selected products in the Scenario „Strong Euro" in comparison to the Baseline

Product	Change in % to Baseline
Wheat	-15
Milk	-13
Beef	-8
Pork	-7
Soy meal	-16

Source: Own calculations with AGMEMOD (2015).

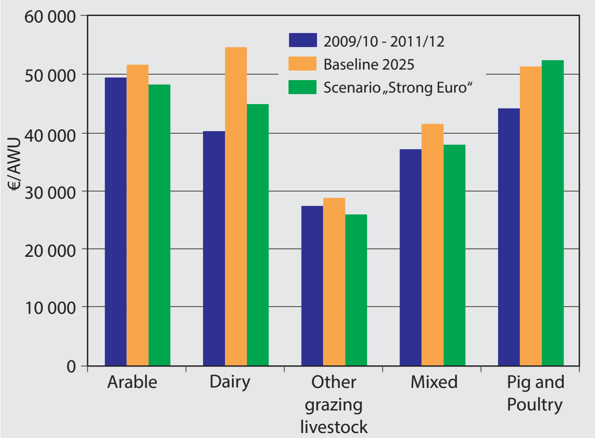
Table 5
Development of land use and production in the Scenario „Strong Euro" in comparison to the Baseline

	Unit	Scenario „Strong Euro" in 2025 absolute	*Relative change to 2010 %*	*Relative change to Baseline %*
Land use				
Cereals	1 000 ha	6.379	*-3*	*-2*
Root crops	1 000 ha	644	*2*	*3*
Pulses	1 000 ha	148	*63*	*-13*
Maize silage	1 000 ha	933	*-11*	*-4*
Other arable fodder	1 000 ha	753	*0*	*7*
Energy maize	1 000 ha	1 087	*34*	*1*
Set-aside	1 000 ha	418	*71*	*14*
Cattle	1 000 head	12 480	*-2*	*-2*
of which: Dairy cows	1 000 head	3 829	*-9*	*-14*
Milk production a)	1 000 t	31 955	*6*	*-14*
Beef and veal production	1 000 t	1 067	*-13*	*-6*

a) Actual fat and protein content.
Source: Own calculations with RAUMIS (2015).

While the level of individual crop production activities hardly changes (Table 5), significant impacts are projected for milk production. Compared to the Baseline, milk production is reduced by 14 %, and the number of dairy cows decrease by 600,000. This contributes to the decrease of beef production by 6 %.

The negative effects of lower output prices, which are not fully compensated by partly lower input prices, dominate income effects. On average, farm income in the Scenario "Strong Euro" is 10 % lower than in the Baseline. However, there are significant differences between farm types (Figure 9). Dairy farms are affected most, with FNVA/AWU decreasing by 22 % compared to the Baseline, which is still above the level of the base period. While the income of arable, other grazing livestock and mixed farms is 7 % lower than in the baseline, pig and poultry farms profit from lower prices for feedstuff and energy-intensive inputs and can expect a small increase in income (+2 %) despite lower product prices.



Source: Own calculations with FARMIS (2015).

Figure 9
Development of farm net value added per agricultural work unit in the Scenario „Strong Euro", by farm type (in real terms in prices of 2010)

7 Discussion and conclusions

The Thünen Baseline is based on a number of assumptions concerning the development of factors and variables not explicitly covered in the models. Some of the areas concerned are characterized by high uncertainties:

– The assumption concerning the development of the exchange rate of Euro and US-Dollar is characterized by high uncertainty. Its implications are illustrated and discussed in Section 6.
– Against the background of the recent decline of revenues in oil-exporting countries and the lower economic growth in China, the projections of the OECD-FAO (2015) for the development of world agricultural markets, which provide the basis for the Thünen Baseline, may prove to

be overly optimistic, especially for livestock products at least in the mid-term.
- For some time now, stricter regulations to improve the protection of water bodies (e.g., adjustments to the fertilizer ordinance) are being discussed in Germany. Such regulations could increase costs especially for farms with intensive livestock production. However, as no final policy decisions had been made at the time of analysis, the potential implications are not taken into account in the Thünen Baseline 2015 – 2025.
- Potential impacts of the current migration processes in Germany (e.g., increase in overall demand due to population growth, increase of product-specific demand, e.g., for lamb) are not accounted for.

All the models used for this study are based on a detailed depiction of policies and economic relationships and interdependencies in agricultural production, and are continuously being developed further. Still, due to specific model characteristics and restricted data availability, it is inevitable that some policy instruments or new technical developments cannot be modelled, or only in a simplified way. The most important restrictions in this respect are:
- The static models are not explicitly taking into account short-term fluctuations, e.g., of world market prices. During the last years, especially world market prices of milk fluctuated markedly within a single year, often due to climate events in some export countries. These effects are not covered.
- The end of the milk quota scheme in 2015 represents a structural break. The impacts are difficult to project, especially during the first years. Higher price fluctuations may occur, in particular if climatic events or demand shifts occur during this period. These phenomena cannot be projected with the model system applied, which simulates equilibrium markets.

In the Thünen Baseline 2015 – 2025, a favourable outlook for world agricultural markets in combination with a weak Euro contribute to the positive development of farm incomes in Germany. The projections of the Baseline scenario also indicate a number of issues that could remain or emerge as key challenges for the agricultural stakeholders and agricultural policy in the medium-term:
- A sensitivity analysis highlights the extent to which export-oriented sectors (e.g., the milk sector) depend on macro-economic developments. In addition, the developments of the dairy sector serve as a reminder of the challenges which volatility, disequilibria and adjustments processes pose for many stakeholders even if medium-term prospects are positive. This indicates the need for farmers and policy makers to further strengthen contingency planning and to implement additional measures that increase the resilience of farms.
- Farm incomes of extensive cattle production systems are projected to remain low. These systems often contribute to a number of societal objectives and public goods (e.g., landscape management, environmentally and animal friendly production systems). Therefore, careful monitoring of the evolution of these systems is needed to be able to act timely if undesired developments occur.
- While the currently planned implementation of voluntary coupled support payments in other EU member states has only small impacts on German agriculture, the increasing renationalisation of agricultural policy (via national implementation options for the CAP) bears the danger of distorting competitiveness. Policy makers should continue to watch and prevent any related developments that could endanger a level playing field within the EU.
- Ammonia emissions are projected to continue exceeding current national emission ceilings, and planned future targets will be missed by a significant margin. Additional measures for ammonia reductions will be necessary, including curbing ammonia emissions from biogas residues.
- Regional nitrogen soil surpluses remain excessively high. Significant changes to current production practices and the policy frameworks at different governance levels are required to reduce these surpluses.

The Thünen Baseline 2015 – 2025 provides the basis for subsequent policy impact analysis. Potential future studies include the analysis of the impacts of adjustments to the fertilizer ordinance, as well as the investigation of a CAP reform after 2020.

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Annex

The MAGNET model (Modular Applied GeNeral Equilibrium Tool) is a multiregional, general equilibrium model covering global economic activity as well as single countries and regions (Woltjer and Kuiper, 2014). It provides a detailed representation of the interactions between agriculture, the input sector and the food industry as well as commercial economics and the service sector, and accounts for the intra- and inter-regional linkages between markets and actors. MAGNET is based on a simultaneous system of non-linear equations, which ensures an equilibrium in the model and the identity between expenses and income. Linking supply and demand, the model endogenously determines prices and quantities that lead to balanced product and factor markets. Trade modelling differentiates products by origin, based on the Armington assumption (Armington, 1969). Additionally transport requirements and bilateral trade flows are considered (Hertel and Tsigas, 1997). MAGNET is built on the GTAP database 8.2 [6] and is updated regarding GDP, population, capital and yield growth as well as changes in the market for skilled and unskilled labour. MAGNET extends the GTAP database in the fields of grain and oilseeds and takes 66 sectors into account. Furthermore, MAGNET allows for a more detailed illustration of the common EU agricultural policy and includes, for example, milk and sugar quotas as well as the production of biofuels and associated policies. For a description of the model extension see Woltjer and Kuiper (2014) and Junker et al. (2014).

AGMEMOD (http://www.agmemod.eu) is a partial, multinational, multiple-product model based on econometrically estimated parameters and a recursive-dynamic approach. It covers production, consumption, trade, inventories and prices for 20 agricultural and 17 processing sectors of the EU member states, accession candidates and other neighbouring countries. The German model provides a detailed representation of grains and oilseed, potatoes, cattle and calves, sheep, pigs, poultry and milk as well as their processed products (Salamon and von Ledebur, 2005). Coupled with each other and to the appropriate world markets, the models create a combined EU Model for all EU Member States (van Leeuwen et al., 2011). In the present model, Version 7, the world markets are endogenous and calibrated to fit to the OECD price projections (OECD-FAO, 2015). The database covers the years 1973 to 2014.

CAPRI is a comparative-static partial equilibrium model, which iteratively links regional or farm-level supply models with a global multi-commodity market model (Britz and Witzke, 2014 [7]). It is used for regional and/or global policy impact analyses on production, incomes, supply and demand as well as trade and the environment. The supply models afford a detailed representation of the European agricultural sector and can be used at different aggregation levels. The higher aggregated level comprises 270 regional models at

[6] A detailed documentation is available on the GTAP-website: https://www.gtap.agecon.purdue.edu/databases/v8/v8_doco.asp

[7] Additional information is available at http://www.capri-model.org

NUTS2 level, whereas a more detailed level includes roughly 2500 farm-type models (Gocht and Britz, 2011). In the supply models, supply and yields are endogenous and based on different degrees of technological progress. The available arable area is calculated endogenously based on land rents with the possibility of substituting arable land and grassland. Environmental indicators are calculated at the regional level. The market model depicts agricultural trade and is based on profit and consumption maximizing behaviour of producers and consumers, respectively. Equilibrium is reached by iteration where the market model passes prices to the supply models, which in turn pass production effects back to the market model.

The regionalized agricultural and environmental information system RAUMIS (Henrichsmeyer et al., 1996) is employed to analyse medium and long-term agricultural and environmental policy impacts. The model consolidates various agricultural data sources with the national agricultural accounts as a framework of consistency. It comprises of more than 50 agricultural products, 40 inputs with exogenously determined prices, and reflects the German agricultural sector with its sector linkages. According to data availability, the spatial differentiation is based on administrative bodies, i.e., 326 regions (NUTS III level) treated as single "region farms." Production adjustments caused by changes in the general framework conditions such as agricultural policies are determined by using a comparative-static mathematical programming approach that maximizes a non-linear objective function for regional farm income. The model is calibrated to observed production decisions using a positive mathematical programming approach (Howitt, 1995; Cypris, 2000). Model base years are available in four-year intervals from 1979 to 2010.

Farm level aspects are covered by FARMIS, a process-analytical programming model for farm groups (Bertelsmeier, 2005; Offermann et al., 2005; Deppermann et al., 2014) based on information from the Farm Accountancy Data Network (FADN). Production is differentiated for 27 crop and 15 livestock activities. The matrix restrictions cover the areas of feeding (energy and nutrient requirements, calibrated feed rations), intermediate use of young livestock, fertilizer use (organic and mineral), labour (seasonally differentiated), crop rotations and political instruments (e.g., set-aside and quotas). The model is calibrated to observed production decisions and elasticities using a positive mathematical programming approach. For this study, the model specification is based on data from the accounting years 2009/10, 2010/11 and 2011/12. The farm sample was stratified by region, type, system and size, resulting in 646 farm group models (of which 90 groups represent organic farming). Results are aggregated to the sector using farm group specific weighting factors. To account for structural change, econometrically estimated farm exit probabilities were applied to the aggregation factors for the projection. Within regions, farms compete for land on rental markets (Bertelsmeier, 2005).

TIPI-CAL is an accounting model applied within the framework of the global agri benchmark network (www.agribenchmark.org). It represents in detail production systems, technology and physical interrelationships at farm level. As part of the Thünen Modelling Network, this model is mainly used to analyse the impacts of changes in policy, economic, and regulatory framework on selected farms, and to investigate the financial consequences of different alternative farm adjustments and development strategies. The database comprises typical farms, which are established based on a globally harmonised Standard Operating Procedure together with more than 40 partners in different countries. Data are collected annually, and the validation of results and specification of adjustment strategies is done in cooperation with farms and advisors.

For the projection of greenhouse gas and ammonia emissions from agriculture in the Baseline scenario, the Thünen Modelling Network is linked to the model GAS-EM. GAS-EM is a modular spreadsheet programme to estimate gaseous and particulate emissions from animal agriculture and crop production including professional horticulture. GAS-EM was first described in Dämmgen et al. (2002) and has been developed further continuously since then. The assessment of emissions within GAS-EM uses the definitions of agriculture according to the definitions of IPCC. All calculation procedures involved are based on the rules provided by the respective conventions and the current guidance documents. In addition, the German agricultural inventory uses differing methods in specific circumstances in order to improve the description of national emission conditions. The results are based on the calculation methods implemented at the end of 2015, which were also used to generate the official National Emission Inventory Reports for Germany (Haenel et al., 2016). For this study, the projections of gaseous emissions in 2025 are based on the RAUMIS projections for land use and livestock numbers in the Baseline scenario.

Response time of soil microbial biomass after conversion from conventional to several different organic farming systems

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Abstract

Organic farming was implemented on a 660 ha area of agricultural land with a long history of conventional farm management in Trenthorst, Northern Germany. The arable land was divided in five different organic farming systems differing in crop rotations and organic fertilization in addition to grassland plots. The plots were monitored over a period of seven consecutive years from 2001 to 2008 together with four adjacent plots which remained under conventional management. To assess the impact of soil management on the microflora, soil microbial quality indicators such as total microbial biomass (C_{mic}), the C_{mic}-to-C_{org} ratio together with soil carbon (C_{org}) were analyzed annually.

C_{mic} and C_{mic}-to-C_{org} ratio were sensitive parameters which differed in their responses dependent on the farming system and varied from no effects, to beneficial or adverse effects. Field plots under the system "DAIRY" with a high presence of legumes in the crop rotation in addition with FYM and slurry applications were the most favorable for microbial development with significant C_{mic} increases up to 87 % within seven years, with an annual growth rate of 12 to 53 µg C_{mic} g^{-1} soil and an increase of the C_{mic}-to-C_{org} ratio of up to 60 %. Plots under the system "PIG" showed losses in C_{mic} of up to 25 % and a decreased C_{mic}-to-C_{org} ratio of up to 27 %. The type of crop management here could be the reason for the insufficient microbial growth. A gradual loss of N_t and P was noted in most of the organic plots over the years. As a general observation it seems necessary to examine in closer detail the nutrient composition of plots under transition to organic farming for an optimal stimulation of microbial growth.

The conventionally managed plots had consistently high microbial indices, which correspond to those of plots under conversion to organic farming.

Keywords: *long-term soil monitoring; transition to organic farming systems; microbial biomass (C_{mic}); C_{mic}-to-C_{org} ratio; organic vs. conventional farming*

Zusammenfassung

Reaktionszeit der mikrobiellen Biomasse im Boden auf unterschiedliche ökologische Bewirtschaftungssysteme nach Umstellung von konventionellem Landbau

In Trenthorst, Norddeutschland, wurde auf einer Fläche von 660 ha mit langer konventioneller Nutzung Ackerland und Dauergrünland auf Ökologischen Landbau umgestellt. Fünf verschiedene Fruchtfolge- und Düngungssysteme wurden etabliert. Die 49 Flächen wurden zusammen mit vier Flächen, die unter konventioneller Bewirtschaftung blieben, von 2001 bis 2008 jährlich untersucht. Der Einfluss der Bodenbewirtschaftung auf die Mikroflora wurde anhand von Daten zur mikrobiellen Biomasse (C_{mic}), zum C_{mic}-zu-C_{org}-Verhältnis und zum Bodenkohlenstoff (C_{org}) ermittelt.

C_{mic} und das C_{mic}-zu-C_{org}-Verhältnis waren empfindliche Parameter, die abhängig vom Bewirtschaftungssystem unterschiedlich reagierten: von keiner, förderlicher oder bis zur negativen Wirkung. Flächen unter dem System „Milchvieh", mit hohem Anteil an Leguminosen in der Fruchtfolge und Stall- und Flüssigmist-Einbringung, waren mit Zunahmen von bis zu 87 %, mit einer jährlichen Zuwachsrate von 12 bis 53 µg C_{mic} g^{-1} Boden und einem Zuwachs des C_{mic}-zu-C_{org}-Verhältnisses bis zu 60 % am förderlichsten. Flächen unter dem System „Schweinehaltung" zeigten dagegen Verluste im C_{mic} und einen Rückgang der C_{mic}-zu-C_{org}-Verhältnisse. In den ökologisch bewirtschafteten Böden wurde ein gradueller Verlust an N_t und P festgestellt. Die unter konventioneller Bewirtschaftung verbliebenen Böden hatten beständig hohe mikrobielle Indizes, die denen der ökologisch bewirtschafteten Flächen entsprachen.

Schlüsselworte: *Boden-Dauerbeobachtung; Umstellung auf ökologischen Landbau; mikrobielle Biomasse (C_{mic}); C_{mic}-zu-C_{org}-Verhältnis; ökologische vs. konventionelle Landwirtschaft*

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1 Introduction

Along with the "Industrial Revolution" during the second half of the 18th century synthetic fertilizers and pesticides (the inorganic methods) were introduced in agriculture which seemed superior at that time for an efficient food production. These today so-called "conventional" farming practices replaced the traditional form of farming, the basis of the so-called "organic farming", to a great extent in the western world. However, during the last decades, world-wide concern has been growing that agricultural intensification leads to soil erosion, loss of organic matter and of biodiversity (Francaviglia, 2004) with an associated loss of soil fertility. The propagation of organic farming management and research again became an issue (review Diacono and Montemurro, 2010) as an alternative and with it the rise in "organic" food products in Europe and world-wide, concomitant with an increasing share of organic agricultural land in comparison to conventional practices (Yussefi et al., 2000; Willer et al., 2013).

Existing research-oriented long-term organic farming systems aroused the interest of a broader scientific community, since organic farming touches many areas – from soil development, productivity or environmental protection (e.g., Lindenthahl et al., 1996; FIBL, 2000; Emmerling et al., 2001; Stockdale et al., 2001; Agroscope FAL Reckenholz, 2004; Quintern et al., 2006; Birkhofer et al., 2008). Since the soil microflora was known to be the main driving agent for organic matter transformations (e.g., overview Lynch, 1991; review Emmerling, 2005), soil development, fertility and sustainability it seemed obvious to test the microflora as a possible soil quality indicator. Reviews on the interrelationship between the microbial compartment and biogeochemical cycling are given by Elliott (1997) and Pankhurst et al. (1997). A strong relationship between the amount of soil organic carbon and the soil microbial biomass carbon was detected (e.g., Adams and Laughlin, 1981; Jenkinson and Ladd, 1981; Brookes et al., 1984) and a direct linear relationship between these two parameters reported (Anderson and Domsch, 1980). It became evident that agricultural management practices influenced the C_{mic}-to-C_{org} ratio. It could be shown that percent C_{mic}-to-C_{org} was significantly higher in continuous crop rotation plots in comparison to monoculture plots (Anderson and Domsch, 1989). Any change in field management will obviously have effects on the soil microbial biomass. Particularly litter quality of the harvest residues is a key factor regulating microbial biomass activity (Dickinson and Pugh, 1974).That is, the status of soil microbial biomass provides an early indication of a change in comparison to soil chemical indices such as soil carbon (Powlson et al., 1987). Further studies supported evidence that the microbial biomass and further the C_{mic}-to-C_{org} ratio could be taken as soil quality indicators (e.g., Anderson and Domsch, 1986; Powlson et al., 1987; Witter et al., 1993; Anderson, 2003; Höper and Kleefisch, 2001; Joergensen and Emmerling, 2006).

The present study was carried out at the Thünen Institute of Organic Farming in Trenthorst/Wulmenau, Northern Germany. The concept encompassed research on organic cattle husbandry (dairy), organic sheep-, goat- and pig husbandry, organic grassland management and organic cash crop systems (stockless). Further information on the history, structure and management of these organic farming systems can also be found elsewhere (Rahmann, 2001; Schaub et al., 2007; www.thuenen.de/en/ol/, see project: Long-term effects of organic farming systems).

In the present investigation the microbiological parameters "microbial biomass and the C_{mic}-to-C_{org} ratio" were used as indices for estimating the impact and development of the microflora in the soils under the different organic farming management practices over a period of seven years aiming to understand better which soil treatment conditions provide the best environmental conditions for microbial growth and to examine the sensitivity of the C_{mic}-to-C_{org} parameter which denotes the availability of carbon to the microflora in a particular soil system. The study differs from similar investigations in its wide-ranging organic farming system approach and in that all farming systems are located in the same geographical area.

The present analysis should be seen as an interims report since from ecosystem analyses it is known that after a change it can take decades until a new final stable condition (climax) is reached (Odum, 1969).

2 Material and methods

2.1 Experimental site and soil properties

The research area of the Thünen Institute of Organic Farming at Trenthorst/Wulmenau encompasses 660 ha and is located in Northern Germany (farm midpoint 53°47' N, 10°32' E). The property has a long history of agricultural use going back to the Middle Ages. For that reason nearly all current experimental plots at the site have been used as permanent grassland or agricultural land for centuries, but at least for more than 40 years. Soil types on the site are classified as stagnic Luvisols (BGR, 2008) from boulder clay with silty-loamy texture. Bulk densities of the top soils are around 1.3 to 1.5 g cm^3. Average temperature and rainfall are 8.8 °C and 685 mm a^{-1}, respectively. Soils are characterized by sufficient plant available nutrients (N, P, K and Mg). Soil pH was on average 5.5 in grassland and 6.5 in arable land (Böhm et al., 2014; Ohm et al., 2015) and had remained quite stable over the years until the end of the monitoring period. Some initial soil properties are presented in Table 1.

2.2 Experimental design and soil sampling

The plots established for the organic farming trial comply with the EU directive No 834/2007 of June 2007 on organic production and labelling of organic products and repealing regulation (EEC) No 2092/91. During conversion to organic farming in 2001/02, the agricultural land of the research farm was divided into four permanent farming systems designated by the terms "DAIRY", "PIG", "STOCKLESS1" and "MIXED" and one free crop rotation "STOCKLESS2" together with permanent "GRASSLAND". These organic systems had different

Table 1
Initial soil conditions 2001 and one year after conversion 2003.

Plot No.	C_{org} [%]	pH $CaCl_2$	C_{mic} [µg g^{-1} soil]	C_{org} [%]	N_t [%]	P* CAL mg 100g^{-1}	pH $CaCl_2$	Clay [%]	C_{mic} [µg g^{-1} soil]
	Year 2001			Year 2003					
1	1.10	6.4	292	1.25	0.12	10.0	6.7	16.0	298
2	1.15	6.5	288	1.85	0.18	8.9	5.0	10.5	326
3	1.10	6.4	270	1.07	0.13	9.3	6.6	14.1	276
4	1.23	6.4	258	1.13	0.11	9.7	6.7	15.6	296
5	1.21	6.7	409	2.07	0.21	12.4	6.7	16.9	719
6	1.30	6.9	380	3.67	0.41	20.9	6.2	15.4	765
7	1.23	6.8	350	2.06	0.20	11.7	6.8	18.1	622
8	1.20	6.6	350	1.34	0.13	9.8	6.9	17.8	359
9	1.20	6.6	353	1.30	0.12	8.1	6.8	19.0	367
10	1.14	6.3	346	1.21	0.12	6.4	6.6	17.2	281
11	1.18	6.4	328	1.12	0.09	6.2	6.8	12.8	332
12	1.22	6.6	451	1.48	0.14	8.6	6.9	17.6	337
13	1.23	6.2	360	1.27	0.09	7.7	6.9	16.2	234
14	1.09	6.5	397	1.36	0.13	n.d.	6.7	18.8	359
15	1.27	6.6	463	1.40	0.13	11.7	6.8	18.5	344
16	1.22	6.4	382	1.33	0.13	10.8	6.6	16.5	453
17	1.23	6.4	493	1.44	0.15	9.2	6.6	20.5	494
18	1.30	6.4	466	1.49	0.15	10.3	6.9	18.5	301
19	1.23	6.3	428	1.38	0.15	11.0	6.8	18.0	326
20	1.31	6.2	476	1.45	0.15	9.6	6.8	18.4	308
21	1.16	6.3	576	1.31	0.13	10.3	6.8	16.4	379
22	1.20	6.4	453	1.20	0.11	7.5	6.5	15.8	268
23	1.20	6.5	427	1.20	0.12	7.2	6.8	17.1	292
24	1.13	6.4	394	1.26	0.12	7.8	6.5	19.1	326
25	1.18	6.6	300	1.40	0.13	8.9	7.1	18.8	293
26	1.12	6.3	411	1.29	0.12	7.4	6.9	16.8	260
27	1.20	6.5	420	1.53	0.15	7.8	7.1	18.6	259
28	1.15	6.4	470	1.59	0.16	11.2	6.8	19.8	390
29	n.d.	n.d.	n.d.	3.31	0.34	16.0	5.4	15.1	667
30	n.d.	n.d.	n.d.	3.76	0.38	16.2	5.6	14.9	789
31	1.07	6.3	330	1.15	0.11	7.4	6.4	12.1	306
32	n.d.	n.d.	n.d.	4.98	0.52	12.7	7.8	15.9	1240
33	n.d.	n.d.	n.d.	4.47	0.46	19.0	5.7	18.1	1148
34	1.13	6.3	390	1.14	0.11	8.7	6.8	17.0	285
35	1.18	6.4	326	1.27	n.d.	8.0	6.4	20.3	n.d.
36	1.22	6.5	362	1.15	0.12	9.4	6.6	21.0	271
37	1.23	6.5	405	1.18	0.12	8.5	6.5	18.7	294
38	1.23	6.6	382	1.27	0.14	7.2	6.9	19.7	407
39	1.24	6.4	360	1.35	0.14	8.0	6.6	19.3	372
40	1.25	6.4	368	1.10	0.11	5.7	6.5	18.0	328
41	1.30	6.3	388	1.22	0.13	7.3	6.9	20.6	272
42	1.20	6.7	338	1.38	0.14	10.3	6.8	18.2	586
43	1.34	6.3	440	1.72	0.17	10.5	6.5	14.8	471
44	1.20	6.3	331	1.96	0.18	13.6	6.3	9.9	430
45	1.30	6.5	389	1.12	0.12	10.1	6.7	18.0	652
46	1.20	6.1	317	1.22	0.12	7.7	6.6	18.8	522
47	n.d	n.d.	n.d.	1.45	0.15	7.9	6.3	17.0	360
48	1.07	6.4	474	1.26	0.13	9.5	6.5	18.5	572
49	n.d.	n.d.	n.d.	1.61	0.18	9.8	5.8	17.4	728
50	n.d.	n.d.	n.d.	3.52	0.38	11.1	6.0	27.5	977
51	n.d.	n.d.	n.d.	1.67	0.16	3.8	6.8	20.5	504
52	n.d.	n.d.	n.d.	1.64	0.17	6.7	6.5	21.7	324
53	n.d.	n.d.	n.d.	1.62	0.17	10.5	6.8	21.9	435
pooled CV (%)	5.4	2.0	15.1	18.40	35.30	5.8	3.0	12.8	18
pooled mean	1.2	6.4	386	1.68	0.17	9.7	6.6	17.6	440

* Plant-available phosphate; n.d. = no data.

numbers of replicated plots (Figure 1). Under the "STOCKLESS2" rotation, the choice of crops was adapted to the market conditions of each year. Generally both stockless rotations received no livestock manure (Table 3) whereas on the other rotations livestock manure was applied regularly. Plots in pasture areas were grazed by cattle, sheep and goats. Clover grass fields under DAIRY were partially grazed by pigs in 2002 and 2003, and under PIG in 2006 (Table 2 and 3). Manure type and application as well as grazing of livestock in the year prior to soil sampling is indicated in Table 2.

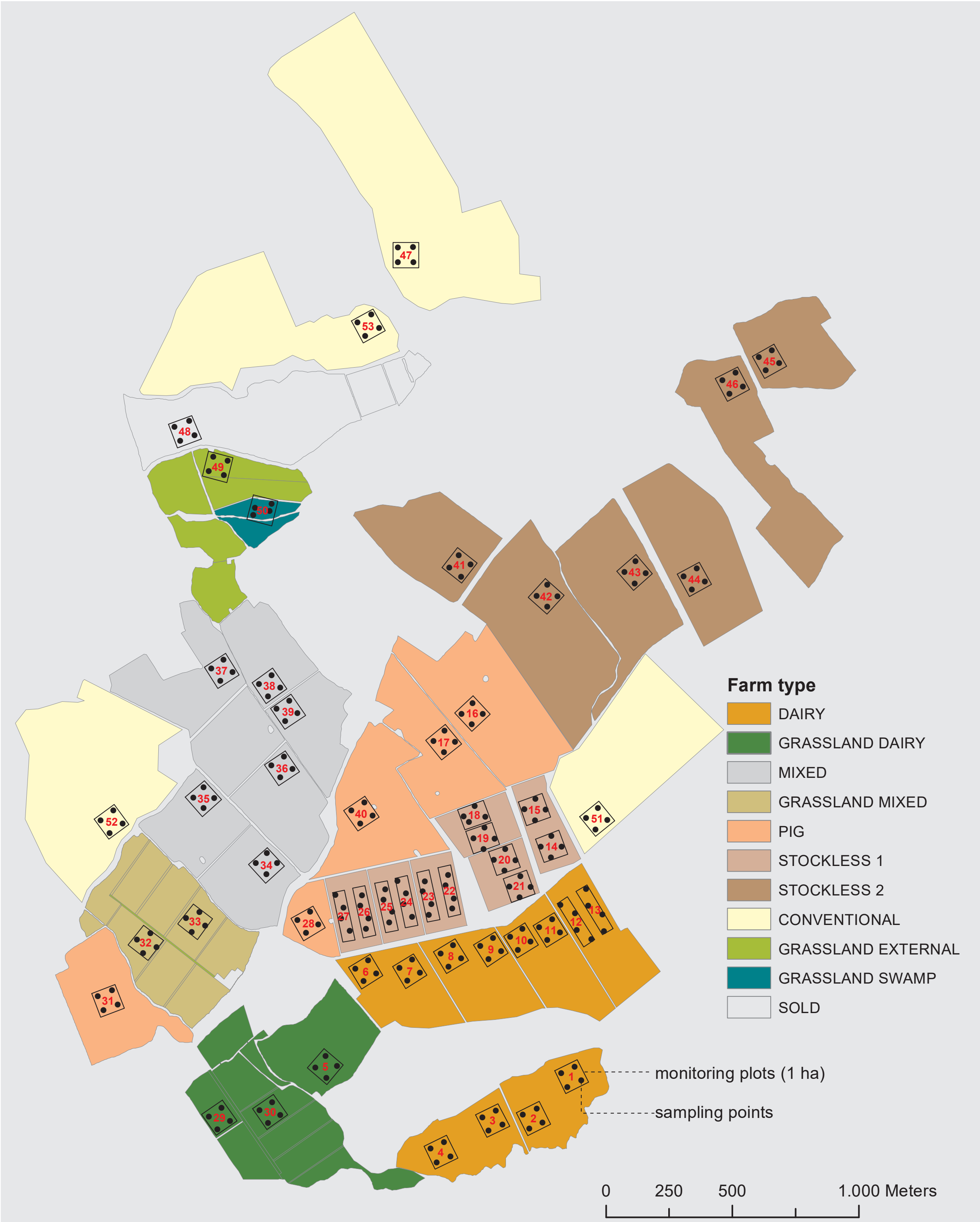

Figure 1
Structure of the long-term monitoring experiment at the Institute of Organic Farming, Trenthorst. Positions of different farming systems and position of fixed soil sampling points and monitoring plots.

Table 2
Crops in the long term monitoring plots and crop rotations of the different farming systems at the experimental farm Trenthorst, 2002 to 2008.

Plot	Farming system	Management	2001 (conversion)	2002 (conversion)	2003	2004	2005	2006	2007	2008
1-2	DAIRY[1]	organic	WRA	WT-OA	**CG1**	**CG2**	**WW**	**OA/FB[SF]**	**FP/SB[SF]**	**WT**
3-4	DAIRY	organic	WRA	WT	FB/OA[L]	FP/SB	WT+CG[F]	CG1[SF]	CG2[F]	WW[F]
6-7	DAIRY	organic	WRA	CG1-CG1	CG2[P]-CG2	WW[PF]	OA/FB[L]	FP/SB[SF]	WT[SF]	CG1[SF]
8-9	DAIRY	organic	WB	WW	WT+CG[U]	CG1[U]	CG2[U]	WW	OA/FB[U]	FP/SB[L]
10-11	DAIRY	organic	WB	CG1[U]	WW	OA/FB[F]	FP/SB	WT+CG[S]	CG1	CG2[S]
12-13	DAIRY	organic	WB	SM[UF]	FP/SB	WT	CG1[UF]	CG2	WW[S]	OA/FB
5	DAIRY	organic	WRA	FP/CA[F]	OA	GR[C]	GR	GR[S]	GR	GR[S]
14-15	STOCKLESS1	organic	WB	CG1[U]	SP+CG	CG1	WW	OA	FP	WRA[L]
18-19	STOCKLESS1	organic	WW	CG1	FP	WRA	WT	CG	WW	OA/LI
20-21	STOCKLESS1	organic	CG1	WRA	WRA	SP	CW	WW	OA/LI	FP
22-23	STOCKLESS1	organic	WRA	CG1	OA	FP	WRA	WT	CG	WW[L]
24-25	STOCKLESS1	organic	WRA	CG1	WW	OA	FP	WRA[L]	WT	CG1
26-27	STOCKLESS1	organic	WRA	CG1	**CG2**	**WW[L]**	**OA**	**FP**	**WRA**	**WT**
16	PIG	organic	WB	CG1	CG2	SW	BL	CG1	SM	FB[S]
17	PIG	organic	WW	CG1	CG2	BL	CG1	SM	FB	WW
28	PIG	organic	WRA	CG1	CG2	CG3[U]	CG4	CG5	SB[P]	BL
31	PIG	organic	CG1	WRA	OA	FB[US]	SB	CG1[FL]	CG2	SM[S]
40	PIG	organic	WRA	CG1	**CG2**	**CG3**	**SM**	**FB**	**BL[F]**	**WT[S]**
34	MIXED	organic	WW	LI	FP/CA	WW[FL]	LI	WT	CG	WRA
35	MIXED	organic	WW	FP	SW	LI	WT[F]	CG[FL]	WRA	FP/CA
36	MIXED	organic	WW	FP/CA	SP+CG	CG	WRA	FP/CA[UF]	WW[UF]	LI[UF]
37	MIXED	organic	WW	WW	LI	SP+CG[F]	CG	WRA[PF]	FP/CA	WW[SF]
38	MIXED	organic	WW	BL	**CG1**	**WRA[L]**	**FP/CA**	**WW[F]**	**LI**	**WT**
39	MIXED	organic	WW	CG1	WRA	FP/CA	SW[UF]	LI[F]	WT	CG1
47	CONVENTIONAL	conventional	FB	WW	**WRA**	**WW**	WRA	WW	WRA	WW
52	CONVENTIONAL	conventional	WW	WW	**WRA**	**WW**	**WW**	WRA	WW	WW
53	CONVENTIONAL	conventional	WB	**WRA**	**WW**	**WB**	WRA	WW	SRA	WB
51	CONVENTIONAL	conventional	WBS	WRA[S]	WW[S]	WB[S]	**WRA[S]**	**WW[S]**	**WB[S]**	WRA[S]
41	STOCKLESS2	organic	FP/SB	CG1	CW	CW[UFL]	SW	FB+CP	CW	WW
42	STOCKLESS2	organic	WB	CG1	CG	SW	CW	WW	FB	CW
43	STOCKLESS2	organic	WW	SW	OA	CP	WW	FB/ SW+CG	CW	SP
44	STOCKLESS2	organic	WB	SP	OA	FB+CP	SRA+CW	CW	WW	OA/FB
45	STOCKLESS2	organic	CG1	CG2	CG3	SW	CP/OA	SP	FB	SW
46	STOCKLESS2	organic	CG1	CG2	CG3	SW	FB/SB	CW	FP	FP/SB
29	GRASSLAND DAIRY	organic	GR	GR	GR[C]	GR[C]	GR[C]	GR[CS]	GR	GR[C]
30	GRASSLAND DAIRY	organic	GR	GR	GR[C]	GR[C]	GR[C]	GR	GR[S]	GR[CS]
49	GRASSLAND EXTERNAL	organic	GR	GR	GR[R]	GR[R]	GR[R]	GR[R]	GR[C]	GR[C]
32	GRASSLAND MIXED	organic	GR	GR	GR[R]	GR[R]	GR[R]	GR[RS]	GR[R]	GR[R]
33	GRASSLAND MIXED	organic	GR	GR	GR[R]	GR[R]	GR[R]	GR[R]	GR[R]	GR[R]
50	GRASSLAND SWAMP	organic	GR	GR	GR[R]	GR[R]	GR[R]	GR[CR]	GR[C]	GR[C]
48	SOLD 2005	organic	CG1	CG2	CG3	CG4	-	-	-	-

[1]Fixed crop rotation schemes in the farming systems during the harvest years 2003 to 2008 are underlined; [F] = farm yard manure (solid) or [S] = slurry (liquid) or [U] = urine and seepage from stables, application in the year before soil sampling; [L] = lime application in the year before soil sampling, [C] = cattle, [P] = pigs, [R] = small ruminants (goats and/or sheep) grazing in the year before soil sampling; / = indicates mixed cropping; + = indicates undersown clover varieties

Crops in harvest year: BL = *Lupinus angustifolius* – blue lupin, CA = *Camelina sativa* – false flax, CG = *Trifolium pratense* or *T. repens* – red or white clover grass, CG1 = clover grass first year, CG2 = clover grass second year, CGn = clover grass year n, CP = *Trifolium resupinatum* – persian clover, CW = *T. repens* – white clover, FB = *Vicia faba* – field beans, FP = *Pisum sativum* – field peas, GR = permanent grassland, LI = *Linum usitatissimum* – linseed, OA = *Avena sativa* – oats, SB = *Hordeum vulgare* – spring barley, SM = *Zea mays* – silage maize, SP = *Triticum spelta* – spelt wheat, SRA = *Brassica napus* – spring rape, SW = *Triticum aestivum* – spring wheat, WB = *Hordeum vulgare* – winter barley, WRA = *Brassica napus* – winter rape, WT = *xTriticosecale* – winter triticale, WW = *Triticum aestivum* – winter wheat.

Additionally four plots with permanent CONVENTIONAL management (two-to-three field rotations, cereal-rapeseed or cereal-cereal-rapeseed, respectively) were surveyed (Figure 1, Table 2).

Altogether 53 long-term monitoring plots were implemented in the fields of the different farming systems (31 in organic ploughland, 4 in conventional ploughland and 6 in organic grassland) (Figure 1, Table 2). Fields differed in size (3 to 25 ha). Conventional fields and the majority of organic fields consisted of one monitoring plot of 1 ha each with the exception of “DAIRY” and “STOCKLESS1” farming systems, where two monitoring plots were established in each field for further in-field comparisons. Per plot four sampling points at a distance of 60 m from each other were generally arranged in squares. In narrow fields the monitoring sites were stretched (rectangular) to cover one hectare and the points are located in (zig-zag) with distances of 30 m from each other (Figure 1). Their geographical positions were determined and re-addressed each year for sampling by a real-time DGPS system with sub-meter accuracy (Trimble Pro XR/ GPS Beacon). In practice this means a deviation of up to 0.3 m from a fixed point. In total 212 soil samples were taken each year between February and March. Samples were taken as mixed samples with a gouge auger in an area of five meter diameter around the permanent sampling points. Sampling depths were 30 cm in arable land (plough layer) and 10 cm in permanent grassland.

The long-term plot No. 48 “GRASSLAND” was sold and therefore only analyzed until 2005. This field came from arable farming in 2001 and was left under clover grass from this year onwards. The long-term plot No 5 (DAIRY) changed from arable cropland to permanent grassland in 2004 (Table 2).

Prior to conversion the initial values for soil microbial carbon (C_{mic}), soil organic carbon (C_{org}) and pH were determined in spring 2001 for all plots with the exception of CONVENTIONAL and GRASSLAND plots where measurements started the year 2003. The first soil analyses after conversion began with the year 2003; in addition to $C_{mic,}$ C_{org} and pH determinations also N_t, P and clay content were determined (Table 1) and the development of these variable parameters was followed each year until 2008. Crop roations were changed to the demands of organic farming after harvest in 2001. Clover grass and grain legumes as biological N sources were introduced (Table 2).

2.3 Soil handling and analysis

After air drying and sieving of the top soil at 2 mm, total C and total N in soils were determined after dry combustion in a HEKAtech elemental analyser EuroEA 3000.

The absence of carbonates in the top soils at the experimental site is generally known. This was frequently re-checked by testing the effervescence of the soil samples after addition of 1M HCl. So total C contents from elemental analy-sis were taken as C_{org} contents of the soils.

The plant available P fraction was determined as P (CAL) by photometrical determination after Schüller (1969).

The clay content was determined by the Köhn pipette technique (Köhn, 1928).

Soil pH was determined in the sieved probe by measurement in 25 ml 0.01 mol/l $CaCl_2$ with a pH electrode after two hours.

For C_{mic} analyses soils were stored in cool boxes in the field immediately after sampling and frozen at -20 °C on the same day. C_{mic} contents were analysed in the same year.

2.4 Microbial biomass determinations

Frozen samples were left to thaw at +4 °C and left at room temperature for ~ 4 days before measurements were made.

Table 3
Overview of the main treatments to the soil sites under different farming systems after conversion to organic farming and the conventional sides.

Farming system	soil cultivation (times per annum)	type of fertilizer*	main crop category	with crop residues	way of weed control	disease control	with livestock
GRASSLAND	-	slurry (some sites)	permanent	1-2 cuts, grazing	mowing	-	yes
DAIRY		**FYM, slurry**, seepage	2/3 with legumes	1/3	mechanical	-	yes, grazing pigs on plots 6/7 in 2002 resp. 2003
STOCKLESS1		a)	1/3 with legumes	1/1	mechanical	-	-
STOCKLESS2	Stubble cultivation 2x ploughing 1x seedbed preparation 2x	b)	1/3 -2/3 with legumes	2/3	mechanical	-	-
PIG		**slurry, seepage**, FYM	1/3-2/3 with legumes	2/3	mechanical	-	yes, grazing pigs on plot 28 in 2006
MIXED		**FYM**, slurry, seepage	1/2 with cereals/ linseed	1/2	mechanical	-	-
CONVENTIONAL		**one site slurry + mineral; rest mineral**	1/2 to 2/3 cereals	1/1	herbicides	pesticides	-

*Manure type in descending order of the number of applications of each type in the different farming system; types: FYM = farm yard manure (solid); slurry = faeces and urine (liquid); seepage = urine and other seepages from stables; a) Plots 14-15 received seepage in 2002; b) Plot 41 received FYM+slurry in 2004.

Soils were sieved (2 mm) and adjusted to a water holding capacity (WHC) of ~50 % (~240 kPa) prior to soil microbial analyses.

Microbial biomass was determined using the Anderson and Domsch (1978) substrate-induced respiration technique (SIR) . Samples of 25 g (dry weight) of soil were amended with 2000 µg g^{-1} glucose in 500 mg talcum. The CO_2 production rate was measured at 22°C using an automated infrared-gas analyzer system (Heinemeyer et al. 1989). The C_{mic}-to-C_{org} ratio is given as the percentage of C_{mic} in total C_{org}.

Mean values of C_{mic} and C_{mic}-to-C_{org} ratio of the 53 plots are based on four replicated samples per plot with three measurements per sample.

2.5 Procedure to collect and aggregate the data for long-term monitoring

A statistical analysis (one-way ANOVA) of the initial C_{mic} data (2001 or 2003) of replicated plots of the implemented organic farming systems revealed that the level of the microbial biomass was in part significantly different. That is, the initial starting situation of replicated plots was not homogeneous and could be related to a lower or higher C_{org} content. Therefore those C_{mic} data of replicated plots were pooled which were not statistical different. As listed in Table 4, this was done for DAIRY-, PIG-, GRASSLAND- and CONVENTIONAL farming systems.

The analyses of the development of C_{mic} in the farming systems "STOCKLESS1" and "MIXED" did not start until 2003. This step proved to be necessary, as these two soil systems

Table 4

Impact of farming systems on microbial biomass indices and C_{org}. Comparison was made between the initial arithmetic mean values previous to the change of the farming system and the final values. The probability value (*P*) depicts the strengths of change.

Farming system	Plot No.	(n)	Year	C_{mic} (µg g^{-1}soil)	*P*-value	Year	C_{mic}-to-C_{org} (%)	*P*-value	Year	C_{org} (%)	*P*-value
DAIRY	1- 4	(16)	2001 2008	278 ± 15.7 363 ± 31.6	*< 0.001*	2001 2008	2.4 ± 0.18 2.8 ± 0.20	*< 0.001*	2001 2008	1.14 ± 0.10 1.28 ± 0.05	*< 0.001*
DAIRY	6-13	(32)	2001 2008	353 ± 14.8 432 ± 43.4	*< 0.001*	2001 2008	2.6 ± 0.40 2.9 ± 0.60	*0.022*	2001 2008	1.21 ± 0.08 1.50 ± 0.50	*0.001*
DAIRY	5	(4)	2001 2008	409 ± 81.7 764 ± 11.4	*0.002*	2001 2008	3.4 ± 0.70 5.5 ± 0.90	*0.010*	2001 2008	1.20 ± 0.08 1.40 ± 0.05	*0.007*
STOCKLESS1	14, 15, 18-27	(48)	2003+ 2008	310 ± 40.2 394 ± 47.3	*< 0.001*	2003 2008	2.2 ± 0.30 3.0 ± 0.40	*< 0.001*	2003 2008	1.35 ± 0.11 1.30 ± 0.12	*0.036*
PIG	16, 31, 40	(12)	2001 2008	360 ± 26.9 298 ± 16.9	*0.007*	2001 2008	3.1 ± 0.30 2.7 ± 0.30	*0.004*	2001 2008	1.18 ± 0.10 1.16 ± 0.10	*0.629*
PIG	17, 28	(8)	2001 2008	482 ± 16.3 360 ± 61.2	*< 0.001*	2001 2008	4.0 ± 0.20 2.9 ± 0.26	*< 0.001*	2001 2008	1.20 ± 0.06 1.40 ± 0.23	*0.032*
MIXED	34-39	(24)	2003+ 2007	326 ± 60.0 347 ± 38.2	*0.159*	2003 2007	2.7 ± 0.30 2.9 ± 0.30	*0.040*	2003 2007	1.20 ± 0.08 1.20 ± 0.07	*1.000*
CONVENTIONAL	47, 52	(8)	2003+ 2008	342 ± 25.0 381 ± 64.9	*0.135*	2003 2008	2.2 ± 0.30 2.6 ± 0.40	*0.040*	2003 2008	1.54 ± 0.13 1.70 ± 0.51	*0.404*
CONVENTIONAL	51, 53	(8)	2003+ 2008	450 ± 20.6 425 ± 5.80	*0.006*	2003 2008	2.7 ± 0.14 2.6 ± 0.05	*0.078*	2003 2008	1.64 ± 0.04 1.61 ± 0.02	*0.079*
STOCKLESS2	41-46	(24)	2001 2008	367 ± 46.8 344 ± 66.2	*0.164*	2001 2008	2.9 ± 0.49 2.8 ± 0.48	*0.479*	2001 2008	1.26 ± 0.06 1.21 ± 0.20	*0.247*
GRASSLAND DAIRY	29, 30	(8)	2003 2008	728 ± 86.3 895 ± 8.0	*< 0.001*	2003 2008	2.8 ± 0.12 3.1 ± 0.30	*0.02*	2003 2008	3.50 ± 0.3 2.90 ± 0.30	*0.001*
GRASSLAND EXTERNAL	49	(4)	2003 2008	728 ± 217.3 702 ± 114.3	*0.839*	2003 2008	4.5 ± 1.3 3.7 ± 0.55	*0.30*	2003 2008	1.60 ± 0.3 1.89 ± 0.09	*0.114*
GRASSLAND MIXED	32, 33	(8)	2003 2008	1194 ± 65.0 1158 ± 68.9	*0.314*	2003 2008	2.5 ± 0.16 3.0 ± 0.10	*0.001*	2001 2008	4.70 ± 0.2 3.85 ± 0.04	*< 0.001*
GRASSLAND SWAMP	50	(4)	2003 2008	977 ± 142.5 1435 ± 58.8	*0.001*	2003 2008	3.0 ± 0.19 2.9 ± 0.30	*0.59*	2001 2008	5.10 ± 0.3 4.90 ± 0.50	*0.518*
GRASSLAND SOLD	48	(4)	2001 2005*	474 ± 44.5 552 ± 68.2	*0.104*	2001 2004	4.4 ± 0.49 5.5 ± 1.00	*0.099*	2001 2004	1.07 ± 0.06 1.00 ± 0.15	*0.423*

+Sites with deviating start and end measurements (see Material and methods, Section 2.5). (n) Number of sampling points. ± Standard deviation of the mean. *P*-value was calculated using Student`s t-test. C_{mic} = soil microbial biomass; C_{org} = organic carbon content. *Plot was sold 2005 (see Material and methods, Section 2.2).

showed an extreme loss in C_{mic} of 30 % (STOCKLESS1) and 17 % (MIXED), respectively, after conversion. The initial values for 2001 were 438 µg C_{mic} g^{-1} soil for "STOCKLESS1" and 390 µg g^{-1} for "MIXED" plots, respectively. Also, the analyses for plots under "MIXED" management were discontinued the year 2007, since C_{mic} values had again declined (Table 4).

2.6 Re-measurements of C_{org} and N_t of some plots the years 2012 to 2014

Since the end of the monitoring period in the year 2008, the development of C_{org} and N_t was determined further yearly in all fields under "DAIRY", STOCKLESS1", "GRASSLAND" and "MIXED"; the remaining farming systems were resampled every fifth year (see Result section 3.4).

2.7 Statistics

A SigmaPlot 11.0 statistic package (Copyright© Sysstat Software Inc., 2008, Chicago, U.S.A) was used for one-way ANOVA analyses (Holm-Sidak method, significance level at least = 0.05) and Student's t-test.

3 Results

3.1 Microbial biomass development

The most favorable conditions for microbial development after conversion from conventional to organic farming were found in field plots under "DAIRY" farming. With respect to the initial microbial biomass values in the year 2001, increases from 22 % up to 87 % (plot No. 1 to 4, 6 to 13 and 5, respectively) were registered 2008 at the end of the monitoring period. These increases were highly statistically significant in the range from $p < 0.001$ to 0.002 (Table 4). This was followed by some field plots under "GRASSLAND": GRASSLAND DAIRY (plot No. 29, 30) had significant increases of 23 %, GRASSLAND SWAMP (plot No. 50) 47 %, followed by GRASSLAND SOLD (plot No. 48) with 17 % (here within four years only). Further, plots under "STOCKLESS1" (plot No. 14, 15, 18 to 27) showed a mean increase of 27 % within six years starting here from the year 2003 onwards (Table 4). The positive trend in microbial biomass development is exemplarily presented in Figure 2a,b showing plots under "DAIRY" management. No change of the microbial biomass status was registered in plots under either "MIXED" or "STOCKLESS2" while the farming system "PIG" showed indications of microbial biomass losses of 17 % (plot No. 16, 31, 40) and 25 % (plot No. 17, 28) which were highly statistically significant (Table 4).

Plots left under CONVENTIONAL management remained relatively stable with respect to the level of microbial biomasses during the monitoring period (Figure 3).

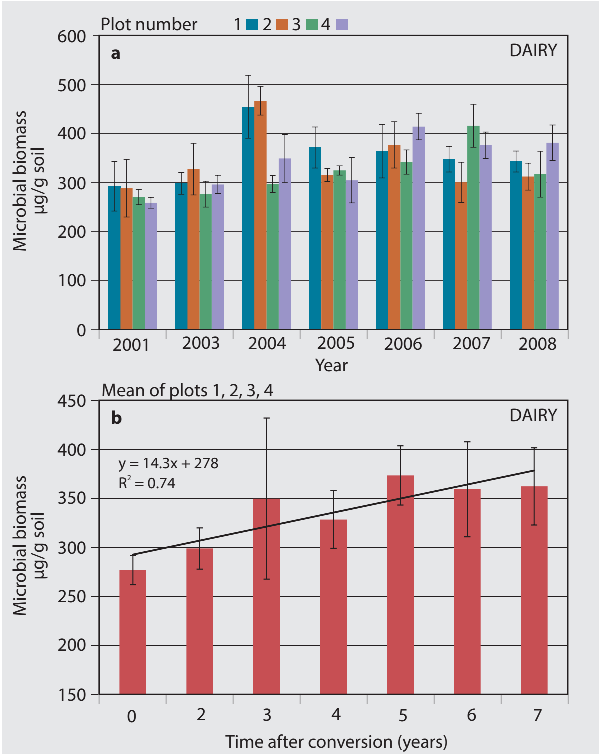

Figure 2a, b
(a) Example of microbial biomass-C content over time of plot No. 1, 2, 3, 4 under "DAIRY" management (n = 4) and **(b)** the annual mean values of those plots and generated regression analysis after conversion to organic farming (n = 16). Error bars show standard deviation of the mean.

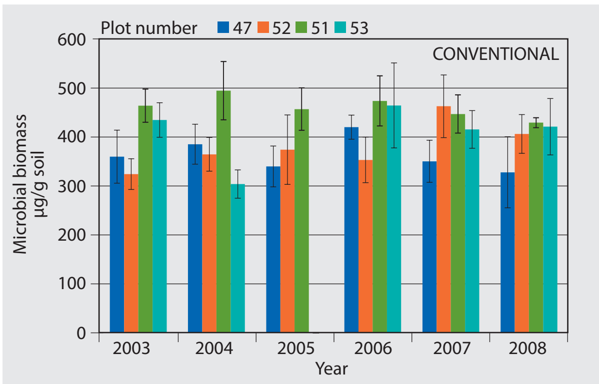

Figure 3
Microbial biomass-C content over time of four plots left under "CONVENTIONAL" management. Error bars show standard deviation of the mean; (n = 4).

3.2 C_{mic}-to-C_{org} development

In order to determine which farming system exerts the most positive effect in terms of microbial biomass development, the C_{mic}-to-C_{org} development was monitored, since this quotient reflects the carbon and nutrients in soil available for growth by the soil microflora. Along with the increase of the soil microbial biomass there are also significant increases in the C_{mic}-to-C_{org} ratios in plots of "DAIRY" and "STOCKLESS1" farming systems. Also here the DAIRY plot number 5 showed the highest increase of >60 % (Table 4, Figure 4). Also significant increases were seen for two "GRASSLAND" systems, GRASSLAND DAIRY and GRASSLAND MIXED, respectively. The systems "MIXED" and "STOCKLESS2" showed neither a positive nor negative trend, while the system "PIG" pointed to a negative trend which was significant. In the "CONVENTIONAL" managed systems this quotient remained relative stable. The apparent increases here for plots No. 47 and 52 are due to the fact that the initial value of the year 2003 started with 2.2 % C_{mic}-to-C_{org}, however in the following years this quotient remained around 2.6 (Table 4).

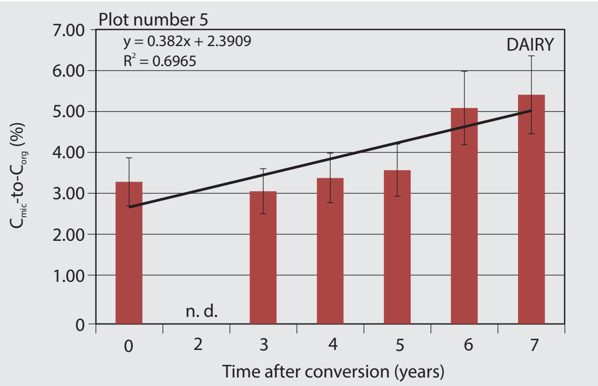

Figure 4
Example of the C_{mic}-to-C_{org} development over time and generated regression analysis depicting plot No. 5 under "DAIRY" management after conversion to organic farming being replaced by permanent "GRASSLAND" after three years. Error bars show standard deviation of the mean; (n = 4).

3.3 Growth rate determination by linear regression analysis of microbial indices

In order to verify whether the farming systems with beneficial qualities for microbial biomass development (as seen in Table 4) are real and in how far already increases could be regarded as a sustainable trend, the results were submitted to linear regression analyses on a yearly basis (Figure 2b and Figure 4**)**. Table 5 shows the coefficient of variation (r^2) together with the *p*-value. Considering these units it can be stated that only in plots under "DAIRY" farming system and "STOCKLESS1" farming system the microbial indices (C_{mic} and C_{mic}-to-C_{org}) are lastingly promoted already within seven years after conversion from conventional to organic farming management with an annual growth rate between 12 µg C_{mic} to 50 µg C_{mic} g^{-1} soil, respectively, here again plot 5 under "DAIRY" showed the highest annual increase rate. The C_{mic} increases as seen in some plots under "GRASSLAND" (GRASSLAND DAIRY, GRASSLAND SWAMP) should be considered as a positive trend only; the insufficient r^2 and *p*-values were due to the greater fluctuations over the monitoring period (Table 5).

Table 5
Linear regression analysis of soil microbial parameters of plots with significant increases or trends of increases during the years after start of the experiment until 2008.

Farming system	Plot No.	Dependent parameter	Equation	R^2	*P*-value
DAIRY	1-4	C_{mic}	y = 14.3x + 278.6	0.74	*0.008*
		C_{mic}-to-C_{org}	y = 0.14 + 2.2	0.60	*0.05*
DAIRY	6-13	C_{mic}	y = 12.5x + 331.5	0.74	*0.02*
		C_{mic}-to-C_{org}	y = 0.11x + 2.31	0.60	*0.07*
DAIRY	5	C_{mic}	y = 52.73x + 288.7	0.72	*0.05*
		C_{mic}-to-C_{org}	y = 0.38x + 2.40	0.70	*0.02*
STOCKLESS1⁺	14, 15,	C_{mic}	y = 15.4x + 297	0.69	*0.04*
	18-27	C_{mic}-to-C_{org}	y = 0.17x + 2.0	0.82	*0.013*
GRASSLAND⁺	29, 30	C_{mic}	y = 10.9x + 982	0.01	*0.56*
DAIRY		C_{mic}-to-C_{org}	y = 0.047x + 3.37	0.010	*0.85*
GRASSLAND⁺	50	C_{mic}	y = 103.9x + 1042	0.27	*0.76*
SWAMP		C_{mic}-to-C_{org}	y = 0.19x + 2.80	0.105	*0.53*

⁺Sites with deviating start measurements (see Material and methods, Section 2.5).

3.4 Observations on C_{org} and other soil parameters

With respect to the C_{org} development significant increases in all "DAIRY" plots and "PIG" managed systems (plot No.17, 28) were found. In the other plots no changes or reductions were registered (Table 4). After termination of the experiment in the year 2008, C_{org} together with N_t development has been pursued further in some selected field plots (Paulsen, 2015, personal communication). Some final measurements of the year 2014 on C_{org} are given in Table 6. Comparing these results with the data of 2008 (Table 4) some plots under GRASSLAND and MIXED showed increases in C_{org}, while C_{org} values of the other farming systems stayed relatively stable with the exception of some plots under "DAIRY" (plots 6 to 13, Table 4). The differences in the microbial mode of growth activity cannot be explained by the underlying soil conditions so far, since the ploughland plots of the different organic systems had similar levels of C_{org}, N_t, pH (2001), P or clay (2003) (Table 1) with the exception of DAIRY plot No 5 with the highest growth rate and the highest level in C_{org}, N_t and P.

Since P is considered to be a growth promotor for microbial cells, re-analysis were made 2008. All ploughland and some GRASSLAND plots showed lower values in plant available soil P (CAL), with decreases over 30 % for the system STOCKLESS2 when compared to 2003 (data not shown), yet, with no corresponding decrease of C_{mic} or C_{mic}-to-C_{org} indices.

Also a general trend of a slow decline in N_t over an observation period of 14 years (Paulsen, 2015, personal communication) was noted; this trend already became apparent in 2008, which is reflected in a slight increased C:N ratio in the majority of fields (Table 7).

For comparative purposes additional information and analyses on i.a. microbial indices can be extracted from the compilation of organic farming systems which were implemented world-wide (Table 8).

Table 6

C_{org} in soils after continuous cropping in long term plots of the systems DAIRY, STOCKLESS1, CONVENTIONAL, GRASSLAND in 2014 (Paulsen, 2015, personal communication).

Farming system	Plot No.	(n)	C_{org} (%)
DAIRY	1, 3	8	1.22 ± 0.15
	7, 9, 10, 12	16	1.24 ± 0.16
STOCKLESS1	15, 18, 20, 23, 25, 27	24	1.30 ± 0.20
PIG	17	4	1.41 ± 0.10[a]
MIXED	37-39	12	1.30 ± 0.20[b]
CONVENTIONAL	51, 53	8	1.69 ± 0.21
GRASSLAND DAIRY	29, 30	8	3.58 ± 0.43
GRASSLAND EXTERNAL	49	4	2.21 ± 0.17
GRASSLAND MIXED	32, 33	8	4.29 ± 1.71

[a]year 2013, [b]year 2012.

Table 7

The carbon-to-nitrogen ratio (C:N) in the year 2003 and 2008 in the different managed soil systems.

Farming system	Plot No.	C:N Year 2003	C:N Year 2008
DAIRY	1- 4	9.7	10.5
DAIRY	6-13	10.7	10.8
DAIRY	5	9.9	10.4
STOCKLESS1	14, 15, 18-27	10.3	11.3
PIG	16, 31, 40	10.0	10.0
PIG	17, 28	10.1	10.0
MIXED	34-39	9.7	9.4
CONVENTIONAL	47, 52	9.6	10.1
CONVENTIONAL	51, 53	9.7	9.9
STOCKLESS2	41-46	10.0	10.0
GRASSLAND DAIRY	29, 30	9.8	10.2
GRASSLAND EXTERNAL	49	9.2	10.3
GRASSLAND MIXED	32, 33	9.8	10.4
GRASSLAND SWAMP	50	9.3	10.0
GRASSLAND SOLD (2005)	48	9.7	9.4

4 Discussion

In view of the results available from this long-term study, it must be noted that conversion from conventional to organic farming systems will not in all cases immediately initiate beneficial effects with respect to microbial growth development. The development of the microbial biomass indices in the six different organic farming systems after conversion from conventional management (changing crop rotations, grassland use and fertilizer inputs) varied considerably after seven years – ranging from beneficial to detrimental effects. The results of this study are in accordance with data from a number of single case studies from literature research as provided in Table 8. Although here many of the study sites recorded positive effects after farming conversion at even shorter time intervals as in our study, sometimes no beneficial effects were recorded, or only after a matter of decades, as is exemplified by the sequence of publications of the study site DOK, Reckenholz, Switzerland. According to Odum (1969), after a change, ecosystems in general again tend to develop towards a stable final condition (climax) with a balance in energy and bio-element economy, if the new conditions remain constant over long periods of time. It can be assumed that the soil of the agricultural area where the different organic farming systems were implemented was in a quasi-steady state after decades of classical conventional farming management. This may be evidenced by those plots which were left under conventional management where biomass and C_{org} values remained quite even during the monitoring period with only minor fluctuations and with no detectable positive or negative trends (Figure 3, Table 4). The work of Smith (2004) displays how long it may take until a change in C_{org} can be detected – the higher the annual carbon input to the soil the higher the increase in C_{org} within a shorter time period. In our study, the soils which were converted from conventional to different organic farming systems are still in a transitional phase to a new equilibrium. This is since re-measurements of C_{org} and N_t the years 2012 to 2014 showed still no constancy of these parameters for most of the farming systems as can be seen by slight increases of the respective C:N ratios (Table 7).

The degree of impact of the type of field management of the implemented organic farming systems on the microflora is different whereby plots under DAIRY showed the fastest microbial growth rate in comparison to all the other implemented organic systems whereas microbial indices under the system PIG declined. This direct influence which field management can exert on the microflora is exemplified with DAIRY plot No. 5, which had changed from the initial ploughland to permanent grassland in the year 2004 with additional grazing and manure application; this plot showed the highest increase in C_{mic} and C_{mic}-to-C_{org} (Table 4, Figure 4). Soil plots of two farming systems (STOCKLESS1 and MIXED) showed microbial biomass decreases of 12 % and 30 %, respectively, after the first year of conversion (Material and methods section 2.5). Whereas microbial indices in plots under "STOCKLESS1" recovered the following year with continuing increases annually, microbial indices under "MIXED"

Table 8
Reported responses of microbial indices after conversion from conventional to organic farming listed by publication date.

Experimental system/Site	Years under observation	Microbial parameter	Response	References
Kutztown, Pennsylvania, USA	1	C_{mic}	0 - 37 % increase	Doran et al. (1987)
Frankstone, Victoria, Australia	3	fungi, bacteria	increases	Sivaplan et al. (1993)
SAFS, UC Davis, California, USA	4	C_{mic} (CFE) basal CO_2	~25 % increase increase	Gunapala and Scow (1998)
SAFS, UC Davis, California, USA	7	C_{mic} (CFE) microbial biomass-N SIR diversity (PLFA)	0-55 % increase ~8-50 % increase ~66 % increase similar	Bossio et al. (1998)
DOK, Reckenholz, Switzerland[1]	18	C_{mic} C_{mic}-to-C_{org} qCO_2	similar decrease - 4 % increase similar	Fließbach and Mäder (2000)
Ensmad, Suttgart-Hohenheim, Germany	22	C_{mic} C_{mic}-to-C_{org}	0-32 % increase no difference	Friedel (2000)
Southern Germany, Nine locations	10	C_{mic} C_{mic}-to-C_{org}	~10-15 % increase ~10-15 % increase	Emmerling et al. (2001)
DOK, Reckenholz, Switzerland[2]	21	microbial diversity qCO_2	increase decease	Mäder et al. (2002)
Burgrain, Schweiz	10	C_{mic}	inconclusive	Oberholzer (2004)
SKAL farms in Netherland	3	oligotrophic bacteria basal CO_2	65 % increase 70 % increase	van Diepeningen et al. (2006)
Colle Valle Agricultura, Viterbo, Italy	6-7	C_{mic} C_{mic}-to-C_{org} qCO_2	increase increase decrease	Marinari et al. (2006)
CEFS, Goldsboro, NC, USA	3	C_{mic} basal CO_2	> 50 % increase > 80 % increase	Tu et al. (2006)
CARDC, Wooster, Ohio, USA	4	microbial biomass-N	43 % increase	Briar et al. (2007)
DOK, Reckenholz, Switzerland[2]	21	C_{mic} (CFE) C_{mic}-to-C_{org} dehydrogenase activity basal CO_2 qCO_2	0-43 % increase 30-40 % increase 71-100 % increase no difference 27-30 % decrease	Fließbach et al. (2007)
DOK, Reckenholz, Switzerland[2]	25	bacterial and fungal diversity (PLFA)	increase	Esperschütz et al. (2007)
Parnaiba, Piauí State, Northeast Brazil	2	C_{mic} C_{mic}-to-C_{org} qCO_2	51-121 % increase 60-120 % increase 19-37 % decrease	Araújo et al. (2008)
DOK, Reckenholz, Switzerland[2]	27	C_{mic} (CFE) bacterial-C muramic acid fungal/bacterial ratio ATP	87 % increase 35 % increase 33 % increase 19 % decrease 92 % increase	Joergensen et al. (2010)
NESC, Nafferton, Northeast England	6	free-living N-fixers (qPCR)	decrease	Orr et al. (2011)
Darmstadt trial, Darmstadt, Germany[3]	10	C_{mic} C_{mic}-to-C_{org}	12.5 % decrease 8.5 % decrease	Heinze et al. (2011)
Parnaiba, Piauí State, Northeast Brazil	10	C_{mic} C_{mic}-to-C_{org} qCO_2	400 % increase 11-70 % increase 40 % decrease	Santos et al. (2012)

For this compilation data from the [1]Conventional vs. BIORG, [2]CONMIN vs. BIOORG and [3]INORG vs. FYM plots were chosen for comparison. Microbial parameter: C_{mic} = microbial biomass-C; SIR = substrate induced respiration; C_{mic}-to-C_{org} = % C_{mic} of total C_{org}; qCO_2 = unit CO_2 released per unit C_{mic} (specific respiration); ATP = adenosine triphosphate.

management remained unchanged during the monitoring period (Table 4). This difference in mode of biomass development could not be attributed to a lack of manure application (Table 3) since plots under "MIXED" with no increases had inputs of different types of farm manure in comparison to "STOCKLESS1" with hardly any manure application; however this difference may be attributed to differences in crop residue input. The leading crop under "STOCKLESS1" were legumes (clover grass, field peas), which are crops with humus reproduction, in comparison to cereals/linseed under "MIXED" (Table 2). The latter are crops with humus demand with respect to humus balances (Kasper et al., 2015; Kolbe, 2013 and Table 2). A recycling of 100 % of the grain crop residues and clover grass material in plots under "STOCKLESS1" are a further significant difference with respect to the management under "MIXED" with only 50 % of residue material remaining (Table 3). Accordingly it can be assumed that all six implemented organic farming systems will have a different pace of development towards a new equilibrium. From the earlier studies on organic matter turnover it is known that it can take many decades until a new equilibrium is reached, particularly in those soils with manure application (i.e. Jenkinson et al., 1987; van der Linden et al., 1987).

As mentioned before the parameter C_{mic}-to-C_{org} denotes the availability of C_{org} and nutrients for microbial growth. This intricate relationship between microbial growth and metabolic activity to C:N:P ratios in soils has recently been investigated (Ehlers et al., 2010; Li et al., 2012; Hartman and Richardson, 2013) whereby P again was identified as an important growth promotor. In our field system "DAIRY", the carbon additives in the form of different types of manure applications plus legumes as crop residues seem to supply the soils with sufficient N and P, which enables the microflora to use more carbon for growth in comparison to the starting situation and to the other organic systems, since the % C_{mic} of total C_{org} rose from 2.4 to 2.8 (Table 4). Although these plots lost 8.4 to 25 % P over time, they were plots with the highest C_{mic} and C_{mic}-to-C_{org} increases for ploughland in the year 2008 which indicates these plots still have a sufficient P level. Under controlled laboratory conditions it could be shown that micro-organisms stop growing under carbon surplus if N but moreover P is a limiting factor (Anderson and Gray, 1991). Under such conditions the C_{mic}-to-C_{org} ratio would decrease with time. This can be demonstrated with plots changed to "PIG" land use initially under conventional farming with the highest C_{mic}-to-C_{org} ratio of 3.1 to 4.0. Conversion to organic farming, with respect to the chosen cropping system, was negative since plots lost microbial biomass and the use of C_{org} was sub-optimal since this initially high C_{mic}-to-C_{org} ratio had decreased by 13 % to 27 %.

The microflora has to compete with plants for nutrients. The C:N:P ratio of the micro-environment must be optimal for growth in order to sustain a cell-internal C:N:P: ratio of fungi and bacteria which amounted on average to 10:2:1 under pure culture condition (Anderson and Domsch, 1980) and to 36:5:1 under soil condition (Griffiths et al., 2012). This C:N:P relations and microbial activity can be largely influenced by input and quality of organic matter (Amaral and Abelho, 2016). To evaluate the fate of microbial growth potentials more precisely in organic farming systems, analysis of the nutrient transfer and nutrient status respectively seems necessary. Such an approach was recently attempted for plots under the organic system DAIRY with respect to phosphate (Ohm et al., 2015).

5 Conclusions

After conversion to organic farming the framework conditions of the soils will determine whether or how fast the microflora will respond to the diversity of organic substances entering the soil system. Of major importance seems to be here an optimal C:N:P ratio that organic inputs and management can develop their full potential for enhancing microbial growth and activity with respect to organic matter decomposition. This would necessitate knowledge about the nutrient transfer and how nutrients can be controlled (managed) to avoid nutrient limitations for optimal microbial conditions. Here the C_{mic}-to-C_{org} ratio is a sensitive indicator of nutrient deficits.

Crop rotation systems under conventional management with mineral and organic fertilization correspond to results obtained with organic farming with respect to C_{mic} growth and the C_{mic}-to-C_{org} ratio in our study.

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Bewertung ausgewählter Methoden zur Erfassung und Analyse des Heu- und Grünfutteraufnahmeverhaltens von Milchziegen

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Zusammenfassung

Erstes Ziel war die Identifikation einer geeigneten Methode zur ethologischen Erfassung des Raufutteraufnahmeverhaltens von Ziegen unter Freilauf-Haltungsbedingungen. Je 3 Stunden im Stall und auf der Weide wurden alle 3 Minuten Momentaufnahmen simultan mittels Direktbeobachtung, Fotografien und Videoaufnahmen gemacht. Keine Methode erlaubte die Identifizierung des Futteraufnahmestatus jedes Tiers (Stall: n = 51, Weide: n = 41) zu jedem Zeitpunkt. Dies wurde nur durch Komplettierung der Videodaten mittels Vor-und-zurück-Spulen erreicht (= Referenzdatensatz). Im Vergleich der instantanen Methoden mit dem Referenzdatensatz mittels Kasten- und Bland-Altman-Grafiken sowie Medianen der prozentualen Abweichungen zeigten die Videobilder die größte Reliabilität, jedoch ohne das Gütekriterium (≥ 90 % Übereinstimmung) zu erfüllen. Zur Ermittlung des effizientesten Zeitrasters für die Auswertung der komplettierten Videodaten wurden 3-, 5-, 8- und 12-Minuten-Intervalle mit dem Referenzdatensatz (1 Minute) verglichen. Die Reliabilitätstests erfolgten wie beim Methodenvergleich. Bei den Stalldaten erfüllten einzig 3 Minuten das Kriterium, bei den Weidedaten 3, 5 und 8 Minuten. Diese Eignungsbewertung ist teilweise restriktiver als in vergleichbaren Studien. Die Differenzen zwischen den für Heu- und Grünfutteraufnahme geeigneten Intervallen werden v. a. auf Unterschiede in der zeitlichen Struktur des jeweiligen Verhaltens zurückgeführt. Für methodische Entscheidungen kann die Relevanz der zeitlichen Struktur (Anteil, Häufigkeit, Dauer) größer sein als die der Zugehörigkeit zum Verhaltensbereich.

Schlüsselwörter: *Methodenvergleich, Foto, Video, Direktbeobachtung, Reliabilität, Effizienz, Intervalllänge, Raufutter, Futteraufnahme, Verhalten*

Summary

Assessment of selected methods for recording and analyzing hay feeding and grazing behaviour of dairy goats

The first aim was to identify an adequate ethological recording method for the roughage feeding behaviour of goats under loose-house conditions. Over 3 hours in the barn and at pasture, respectively, instantaneous data were collected every 3 minutes simultaneously by direct observation, still photography and video recordings. None of the methods allowed identification of the feeding status of every animal (barn: n = 51, pasture: n = 41) at every sampling point. This was only achieved by complementing the video data by winding recordings back and forth (= reference dataset). Comparing the instantaneous methods with the reference dataset by boxplots, Bland-Altman plots and medians of percental deviations, the video images had the highest reliability, but still failed the goodness-of-fit-criterion (≥ 90 % correspondence). In order to identify the most efficient sampling interval for the complemented video data, 3-, 5-, 8- and 12-minute intervals were compared with the reference dataset (1 minute). Reliability tests were conducted in the same way as those of the method comparisons. For the barn data, only 3 minutes were sufficiently reliable; for the pasture data 3, 5 and 8 minutes met the criterion. This assessment of aptitude is more restrictive than in a number of comparable studies. Differences between the intervals appropriate for hay versus grass feeding are attributed mostly to different temporal structures of these behaviours. For methodological decisions, the temporal structure of a behaviour (proportion, frequency, duration) may be more relevant than its general category.

Keywords: *method comparison, photo, video, direct observation, reliability, efficiency, interval length, roughage, feeding, behaviour*

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1 Einleitung

Die Balance zwischen ökonomischer Effizienz und Wohlbefinden eines Tieres zu halten, ist eine der großen Herausforderungen für jeden kommerziellen Tierhalter (zum Beispiel McGlone, 2001; Rahmann, 2009) und bietet zugleich die Möglichkeit, Aspekte des anthropozentrischen und ethischen Tierschutzes gleichermaßen zu berücksichtigen. Die wirtschaftliche Leistung von Ziegen wird auf den meisten Betrieben durch Parameter wie Milchmenge und -inhaltsstoffe, Anzahl an Nachkommen sowie Gewichtszunahmen quantifiziert und die Bestimmung dieser Leistungsparameter ist Routine. Demgegenüber ist das Messen des Tierwohls (Animal Welfare) in der alltäglichen Praxis weniger üblich, komplexer und wissenschaftlich bisher nur mittels multidisziplinärer Datenerhebung bewertbar (zum Beispiel Broom, 1988; McGlone, 2001; Dawkins, 2003). Es lässt sich anhand ethologischer, physiologischer, pathologischer und leistungsbezogener Indikatoren messen (Zusammenstellung beispielsweise bei Köhler, 2005) und im Falle eines biologischen Ungleichgewichts, wie zum Beispiel Futtermangel, negativer Stress, Krankheit, wird physiologischen Veränderungen stets eine Verhaltensänderung vorausgehen. Aufgrund dieser höheren Sensibilität von ethologischen Modifikationen als Indikatoren für eine Beeinträchtigung des Tierwohls besitzt die Verhaltenserfassung ein Potenzial von wirtschaftlicher Relevanz für die Tierhalter (Keeling und Gonyou, 2001; Wasilewski, 2003; Schaefer, 2012). Die quantitative Erfassung des Heu- und Grünfutteraufnahmeverhaltens als ethologischer Indikator ermöglicht, Veränderungen im Raufutteraufnahmeverhalten frühzeitig festzustellen und ernährungsbedingten negativen Auswirkungen auf die Tiergesundheit vorzubeugen.

Zur zuverlässigen Erfassung und Bewertung des Futteraufnahmeverhaltens sind adäquate quantitative Methoden essentiell. Eine grundsätzliche Entscheidung bei der Auswahl für die jeweilige Fragestellung geeigneter Erfassungsmethoden ist die Wahl zwischen nicht-visuellen und visuellen Methoden: Unter nicht-visuellen Methoden werden zum Beispiel Ortungssysteme, Bewegungssensoren und optoelektronische Systeme zusammengefasst (Tabelle 1). Bei ihnen erfolgt die Datenerfassung vollständig automatisiert und die Auswertung der aufgezeichneten Signale mittels spezieller Computer-Software. Visuelle Methoden wie Direktbeobachtung sowie Fotografien und Videoaufzeichnungen erfordern die unmittelbare beziehungsweise nachträgliche Interpretation des Futteraufnahmestatus anhand von „gesehenen Bildern" (Tabelle 2, s. S. 5).

Für die Quantifizierung des individuellen Heu- und Grünfutteraufnahmeverhaltens aller Individuen einer größeren Herde, wie die der vorliegenden Studie (n > 40), sind sämtliche elektronischen Geräte allein durch ihre hohen Anschaffungskosten ungeeignet; dies schließt auch automatische Fütterungssysteme ein, sofern sie nicht ohnehin bereits etabliert sind. Hinzu kommt ein großer Zeitbedarf für die Auswertung der umfangreichen und komplexen Daten, die in der Regel zudem die kostenpflichtige Anschaffung von Spezial-Software erfordert. Allen nicht-visuellen Methoden gemeinsam ist der bedeutende Nachteil, dass sie keine Kontextinformationen erfassen. Sensoren, die beispielsweise nur Kopf- oder Kaubewegungen aufzeichnen, sind für weitere Einflussfaktoren (zum Beispiel etwaige „Störungen" durch den Menschen, gesundheitliche Beeinträchtigungen) „blind". Eine korrekte Bewertung der erhobenen Daten fällt dann – vor allem, wenn die Messwerte nicht eindeutig sind – schwer. Die visuelle Erfassung hingegen lässt die Registrierung dieser weiteren Einflussfaktoren zu.

Bisher gibt es keine standardisierten Methoden, das Raufutteraufnahmeverhalten von Wiederkäuern quantitativ zu erfassen, unter Berücksichtigung des Kontextes zu bewerten und somit vergleichbar zu machen und es wurde unseres Wissens bisher kein Versuch unternommen, Heu- und Grünfutteraufnahmeverhalten in ein und derselben Studie zu vergleichen. Zudem wurde bisher die Eignung digitaler Fotografien zur Erfassung des Futteraufnahmeverhaltens von Milchziegen im Stall und auf der Weide nicht im direkten Vergleich mit anderen visuellen Methoden überprüft. Die vorliegende Studie soll, am Beispiel der gewählten Ziegenherde, zur Wahl und Etablierung einer geeigneten Methode beitragen sowie Orientierungshilfen bei der Konzeption und Durchführung von Methoden-Reliabilitätstests für ähnliche Untersuchungen anbieten.

Die Studie ist zweistufig aufgebaut: Das erste Ziel liegt in der grundsätzlichen Identifikation einer reliablen visuellen Erfassungsmethode (Direktbeobachtung, Fotografien und instantane Videostandbilder), das zweite in der Optimierung von Praktikabilität und Effizienz in der Anwendung (Identifikation des effizientesten Auswertungsintervalls der Videoaufzeichnungen).

2 Methoden zur Erfassung des Futteraufnahmeverhaltens domestizierter Wiederkäuer

2.1 *Nicht-visuelle Methoden*

Bei der vollständig automatisierten, nicht-visuellen Erfassung der Futteraufnahme (Tabelle 1) kommen hauptsächlich elektronische Geräte wie GPS-basierte Ortungssysteme, Beschleunigungs-, Dehnungs- und Drucksensoren sowie optoelektronische Systeme (zum Beispiel Wiegetröge mit Lichtschranken und elektronischer Tiererkennung) zum Einsatz.

Die nicht-visuellen Methoden sind aus den bereits in Kapitel 1 dargelegten Gründen für die vorliegende Studie nicht geeignet. Je nach Herdengröße und (technischer) Betriebsausstattung können sie aber bei zukünftigen Anwendungsstudien das Spektrum der zur Auswahl stehenden Methoden erweitern.

2.2 *Visuelle Methoden*

Direktbeobachtungen, Fotografien und Videoaufzeichnungen ermöglichen das Erfassen des Futteraufnahmeverhaltens jedes Individuums auch bei größeren Herden. Bei den Vorüberlegungen zur Methodenwahl ist neben der

Tabelle 1
Ausgewählte Studien zu nicht-visuellen Erfassungsmethoden des Futteraufnahmeverhaltens von Wiederkäuern. Bei den meisten dieser Methoden wird das einzelne Tier mit dem entsprechenden Sensor ausgestattet. Nur bei den optoelektronischen Systemen tragen die Tiere lediglich Responder und die Sensoren sind an Komponenten der Stalleinrichtung angebracht.

Methode	Exemplarische Studien	Datentyp (und ggf. Befestigungsart)	Tiere
Ortungssysteme			
Global Positioning System (GPS)	Schlecht et al., 2004	Aufenthaltsbestimmung auf der Weide (Rückenbefestigung)	Rinder
GPS und Bewegungssensoren (Lotek©)	Brosh et al., 2006	Aufenthaltsbestimmung beim Grasen und Erfassung der Aktivitäten an den jeweiligen Standorten (Halsbandbefestigung)	Rinder
Local Positioning Measurement (LPM® ABATEC electronics)	Gygax et al., 2007 Neisen et al., 2009	Aufenthaltsbestimmung im Laufstall (Halsbandbefestigung)	Rinder
Echtzeit-Positionierungssystem (Ubisense 7000©)	Georg et al., 2012 Bender et al., 2012	Nutzung verschiedener Außenbereiche: Weide, Futterhecken, Hütten (Brustgurtbefestigung)	Ziegen
Accelerometer (Beschleunigungssensoren)			
IceTag3DTM, Hobo® PendantTM G	Blomberg, 2011	Graseverhalten (Halsband- und Hinterlaufbefestigung)	Rinder
Hobo® PendantTM G	Moreau et al., 2009	Auf- und Abbewegungen des Kopfes beim Grasen (Halsbandbefestigung)	Ziegen
IceTag3DTM	Nielsen et al., 2010	Lokomotorische Aktivität im Laufstall (Hinterlaufbefestigung)	Rinder
Actiwatch® (Activity Monitoring System = AMS)	Müller und Schrader, 2003	Lokomotorische Aktivität im Laufstall (Hinterlaufbefestigung)	Rinder
ETHOSYS® (Beschleunigungs- und Kopfpositionssensor)	Scheibe et al., 1998	Graseverhalten und Aktivität (Halsbandbefestigung)	Schafe (Pferde)
Jaw-Movement-Recorder (Dehnungs- und Drucksensoren)			
„jaw-recorder" (mit „Dehnungsmessstreifen": Veränderung des elektrischen Widerstands bei Dehnung)	Matsui, 1994	Anzahl an Kauschlägen und Pausen zwischen einzelnen Kauschlägen	Ziegen Schafe Rinder
APEC®Drucksensor: luftgefüllter Silikonschlauch	Abijaoudé et al., 1999 Desnoyers et al., 2009	Kieferbewegungen beim Aufnehmen, Zerkauen und Wiederkäuen von Nahrung	Ziegen
MSR®145-Logger: Drucksensor: ölgefüllter Silikonschlauch	Nydegger et al., 2011	Kieferbewegungen beim Aufnehmen, Zerkauen und Wiederkäuen von Nahrung	Rinder
Optoelektronische Systeme			
Wiegetröge und elektronische Tiererkennung (Ohr-Responder und Infrarotsensoren)	Kaufmann et al., 2007	Häufigkeit, Dauer und jeweils aufgenommene Futtermenge pro Aufenthalt am Futtertisch	Rinder
„Rechnergesteuerter Futterstand" (Tiererkennung: elektronisch und über Lichtschranke)	Wendl et al., 1999	Häufigkeit, Dauer und jeweils aufgenommene Futtermenge pro Aufenthalt am Futtertisch	Schafe
GrowSafe Systems®: Überwachungssystem am Futtertisch	DeVries et al., 2003 DeVries et al., 2004	Häufigkeit und Dauer pro Aufenthalt am Futtertisch	Rinder

Reliabilität (siehe weiter unten) die Effizienz (Aufwand-Nutzen-Relation) ein ausschlaggebendes Kriterium. Sie wird bei der Datenaufnahme und anschließenden Auswertung vor allem von Aspekten wie dem Datentyp und den entsprechenden Dateneigenschaften, dem Ausrüstungs- und Arbeitsaufwand sowie den Fehlerquellen bestimmt.

Bei der Direktbeobachtung entfallen Zeit- und Kostenaufwendungen für die Auswahl, Anschaffung und Wartung von geeigneten Foto- und/oder Videokameras samt Zubehör. Ein weiterer Vorteil liegt darin, dass Kontextinformationen genau erfasst werden können (Martin und Bateson, 2007). Nachteilig ist, dass der Beobachter während der Datenaufnahme durchgängig anwesend sein muss. Die Direktbeobachtung des Futteraufnahmeverhaltens von 41 bzw. 51 Individuen beinhaltet, selbst bei hoher Intra-Observer-Reliabilität, eine unvermeidbare potentielle Abweichung, da die Protokollierung der futteraufnehmenden Tiere zwangsläufig sukzessiv erfolgt (Scan Sampling sensu: Lehner, 1996; Martin und Bateson, 2007).

Nachteilig ist weiterhin, dass mittels Direktbeobachtung meist nur wenige Verhaltensaspekte gleichzeitig erfasst werden können, denn die Wahrscheinlichkeit, wichtige Verhaltensweisen zu übersehen, steigt mit der Anzahl an Aspekten, die der Beobachter wahrnehmen muss. Zudem ist die Beeinflussung des Tierverhaltens durch die Anwesenheit eines Beobachters nicht auszuschließen.

Beim Einsatz von Fotografien stellt der geringe Datenerfassungsaufwand den größten Vorteil dar, vor allem wenn eine automatische Intervallaufnahme-Funktion der Kamera(s) die Abwesenheit des Beobachters ermöglicht. Dann beschränkt sich der Aufwand auf Aufbau und Einrichtung der Kamera(s) sowie die Ausstattung mit hinreichend großen Speichermedien und das Sicherstellen der Stromversorgung. Die manuelle oder automatische Anfertigung der Fotografien entscheidet darüber, ob die einzelnen Momentaufnahmen jeweils sukzessiv oder zeitlich synchron entstehen. Die größte Fehlerquelle, trotz moderner Fototechnik, können unscharfe oder den wechselnden Lichtverhältnissen nicht angepasste Fotografien sein, die eine Auswertung erschweren oder unmöglich machen. Nachteilig ist zudem, dass auf einer Fotografie – wie auf allen reinen Momentaufnahmen – mitunter wichtige Kontextinformationen fehlen oder Tiere verdeckt sind. Nur solche Verhaltensweisen, die aus der Körperhaltung des Tieres eindeutig hervorgehen, können den Momentaufnahmen entnommen werden. Verhaltensweisen hingegen, die nur unter Einbeziehung seiner Bewegung eindeutig identifizierbar sind, werden möglicherweise fehlinterpretiert oder gar nicht erfasst.

Üblicher als Fotografien finden in der Literatur Zeitraffervideoaufnahmen Anwendung. Aufnahmen mit niedriger Geschwindigkeit (Tabelle 2; dort Intervalle von 20 Sekunden und 1 Minute) entsprechen in ihren „technischen Bildeigenschaften“ weitgehend Fotografien, hochfrequente Zeitrafferaufnahmen (Tabelle 2, dort 1 Bild und 5,56 Bilder pro Sekunde) ähneln Normalzeitvideoaufzeichnungen (vergleiche zum Beispiel Vansdadiya und Kothari (2014): 25 Bilder/Sekunde).

Eine Videokamera, die kontinuierlich oder im hochfrequenten Zeitraffer aufzeichnet, verbraucht deutlich mehr Strom als eine Fotokamera oder niederfrequente Zeitrafferaufnahme, sodass vor allem im Freiland die Stromversorgung technisch aufwendig sein kann. Bei einer kontinuierlichen Datenauswertung ist der Auswertungsaufwand im Vergleich zu Direktbeobachtungsdaten, Fotografien und niederfrequenten Zeitrafferaufnahmen um ein Vielfaches höher (zum Beispiel Martin und Bateson, 2007). Allerdings erlaubt die Verwendung von kontinuierlich oder hochfrequent angefertigten Videoaufzeichnungen durch Vor- und Zurückspulen das Erschließen des zeitlichen Kontextes sowie die sichere und synchrone Identifikation idealerweise aller Tiere inklusive ihres Verhaltens.

Die Auswertung instantaner Videostandbilder ist mit der von Fotografien vergleichbar und das Komplementieren uneindeutiger Videostandbilder durch Vor- und Zurückspulen bietet einen Mittelweg. Videoaufzeichnungen lassen nachträglich verschiedene Auswertungsmethoden zu, sodass dasselbe Video, je nach Fragestellung, zum Beispiel in unterschiedlichen Intervallen ausgewertet werden kann. Sofern das Verhalten in der Körperhaltung oder -bewegung gut abgebildet wird, ist eine große Anzahl an unterschiedlichen Verhaltensaspekten erfassbar. Die Entwicklung der Videotechnik ist in den vergangenen Jahren stark vorangeschritten, sodass die Bildqualität früherer und heutiger Videos kaum noch vergleichbar ist und inzwischen sogar 3D-Kameras erhältlich sind. Eine mögliche Fehlerquelle für dennoch schlechte Bildqualitäten kann die Verwendung ungeeigneter Videokameras sein: Je nach Lichtstärke und -empfindlichkeit sind gegebenenfalls Schwarz/Weiß-Kameras Farbkameras überlegen.

Ein gemeinsamer Vorteil von Fotografien und Videoaufnahmen liegt darin, dass sie dokumentenecht und für Kontrollsichtungen sowie spätere Auswertungen archivierbar sind (Naguib, 2006). Bei der Direktbeobachtung hingegen ist die Zuverlässigkeit der protokollierten Daten im Nachgang nicht mehr überprüfbar.

Keine der drei visuellen Methoden zeichnet sich durch systemimmanente qualitative Vorteile oder finanzielle und/oder arbeitsaufwandsbezogene Kostengünstigkeit in allen Bereichen aus. Daher hängt die Identifikation der geeignetsten visuellen Erfassungsmethode letztendlich von der Reliabilität (= Zuverlässigkeit = Übereinstimmung des erfassten mit dem tatsächlichen Verhalten) ab. Diese wird nachfolgend durch simultane Anwendung aller drei Methoden ermittelt, wobei die Videoaufzeichnungen im Anschluss an die Datenerfassung sowohl ohne als auch mit Komplementierung durch Vor- und Zurückspulen ausgewertet werden (Kapitel 3.3).

2.3 Zeitintervalle bei visuellen Momentaufnahmen

Zur visuellen Erfassung des Futteraufnahmeverhaltens von Wiederkäuern mittels Instantaneous-Time-Sampling werden in der Literatur Zeitintervalle im Sekundenbereich sowie zwischen 1 und 120 Minuten verwendet (Tabelle 2).

Die Mehrzahl der Studien verwendete Intervalllängen zwischen 5 und 15 Minuten (Tabelle 2). Der Fokus der in der vorliegenden Studie untersuchten Intervalllängen liegt im kürzeren Bereich und bezieht Abstände von 1 bis 12 Minuten ein.

3 Tiere, Material und Methoden

3.1 Untersuchungsherde und Verhaltenskategorien

Die Datenerhebung fand im April und Juni 2013 auf dem Versuchsbetrieb des Thünen-Instituts für Ökologischen Landbau in Trenthorst (Schleswig-Holstein) statt. Die Untersuchungsherde bestand aus behornten, adulten, weiblichen Milchziegen (*Capra hircus*) der Rasse „Bunte Deutsche Edelziege“ und wurde unter Bedingungen der EU-Öko-Verordnung Nr. 834/2007 gehalten. Die Tiere wurden vor Ort aufgezogen und waren in der Zeitspanne der Datenerhebung zwischen 2 und 7 Jahre alt. Die Tiere wurden zweimal täglich – um 06:00 und 16:00 Uhr – gemolken.

Witterungsbedingt verbrachten die Ziegen bis einschließlich April den gesamten Tag im Stall und angrenzenden Auslauf. Im Juni waren sie täglich knapp 8 Stunden (zwischen circa 08:00 und 15:30 Uhr) auf der Weide und anschließend inklusive der Nacht im Stall. Durch die zeitliche Trennung der Erhebung von Stall- und Weidedaten konnte die Datenerfassung an beiden Orten zu übereinstimmenden Tageszeiten stattfinden.

Tabelle 2
Längen von Sampling-Intervallen ausgewählter Studien, die das Futteraufnahmeverhalten von Wiederkäuern mittels zeitgerasterter visueller Methoden erfassten. Die Übersicht enthält sowohl Methodenstudien (= M) als auch reine Anwendungsstudien (= A). Oft erfolgte die Untersuchung an mehreren kleineren Gruppen, mitunter auch an einzeln untergebrachten oder einzeln beobachteten Tieren. Videoaufnahmen in Normalzeit: 25 Bilder/Sekunde.

Sampling-Intervall	Exemplarische Studien	Verhalten (und Ort)	Tiere und Anzahlen: n = Gesamtzahl (Gruppenanzahl x -größe)
Direktbeobachtungen			
2 Minuten (+ Videoaufnahmen, siehe dort)	Tosi et al., 2006 (M)	Fressen, Kauen, Lecken, exploratives Verhalten (Stall)	Rinder: n = 54 (24 x 1 + 6 x 5)
5 Minuten	Kronberg und Malechek, 1997 (A)	Wiederkäuen, Futtersuche, Gehen, soziale Interaktionen (Weide)	Ziegen, Schafe: n = 10 pro Spezies
5 Minuten	Cozzi und Gottardo, 2005 (A)	Futteraufnahme, Wiederkäuen, Liegen (Stall)	Rinder: n = 20 (4 x 5)
5 Minuten	Safari et al., 2011 (A)	Grasen, Stehen und Wiederkäuen, Liegen und Wiederkäuen, Gehen, Ruhen, Kratzen/Fellpflege, Spielen (Weide)	Ziegen: n = 16
15 Minuten	Celaya et al., 2007 (A)	Grasen (Weide)	Ziegen, Schafe: n = 40 pro Spezies; Rinder: n = 7
15 Minuten	Sanon et al., 2007 (A)	Grasen, Wiederkäuen, Futtersuche, Trinken, Gehen, Liegen (Weide)	Ziegen: n = 30; Schafe: n = 25; Rinder: n = 75 (jeweils Einzeltierbeobachtung)
Fotografien und niederfrequente Zeitraffervideoaufnahmen			
20 Sekunden (Zeitraffer)	Vasilatos und Wangsness, 1980 (A)	Futteraufnahme (Stall)	Rinder: n = 5
1 Minute (Zeitraffer)	Friend und Polan, 1974 (A)	Futteraufnahme (Stall)	Rinder: n = 21
7 und 10 Minuten (verschiedene Jahre, ohne Intervallvergleich) (automatische Fotografien)	Prache und Damasceno, 2006 (A)	Grasen (Weide)	Schafe: n = 20 (2 x 6 + 1 x 8)
Videoaufzeichnungen in Normalzeit und hochfrequente Zeitraffervideoaufnahmen (jeweils kontinuierliche Aufnahmen mit instantaner Auswertung im Nachgang)			
1, 5, 10, 15, 30, 60 Minuten (im Vergleich mit kontinuierlicher Auswertung: 1-15 Minuten geeignet) (Normalzeit)	Mitlöhner et al., 2001 (M)	Fressen, Trinken, Gehen, Stehen, Liegen (Stall)	Rinder: n = 24 (12 x 2)
2 Minuten (+ Vergleich mit Drucksensor) (Normalzeit)	Desnoyers et al., 2009 (M)	Ingestion, Kauen, Wiederkäuen (Stall)	Ziegen: n = 12 (12 x 1)
2 Minuten (Auswertung) (Zeitraffer: circa 5,56 Bilder/Sekunde) (+ Direktbeobachtung, siehe dort)	Tosi et al., 2006 (M)	Fressen, Kauen, Lecken, exploratives Verhalten (Stall)	Rinder: n = 54 (24 x 1 + 6 x 5)
5 Minuten (Normalzeit)	Lexer et al., 2004 (A)	Fressen, Liegen, Sonstiges (Stall)	Rinder: n = 60 (2 x 30)
10 Minuten (Normalzeit)	Jørgensen et al., 2007 (A)	Futteraufnahme (Stall)	Ziegen: n = 48 (8 x 6)
20, 30, 60, 120 Minuten (im Vergleich mit 10 Minuten: 10-60 Minuten geeignet) (Normalzeit)	Mattachini et al., 2011 (M)	Fressen, Trinken, Stehen, Liegen (Stall)	Rinder: n = 69

In der rund zweimonatigen Pause zwischen den Beobachtungen wurde die Herdengröße um zehn Tiere reduziert, sodass diese während der Untersuchung im Stall aus 51 Tieren und während der auf der Weide aus 41 Mitgliedern bestand. Zur sicheren individuellen Identifikation wurden im Vorfeld der Studie alle Ziegen beidseitig lateral mit, in ihr Fell gebleichten, ein- bis zweistelligen Nummern (Größe: circa eine DIN A4-Seite pro Ziffer) gekennzeichnet.

Der Ziegenherde stand ein Tiefstreulaufstall (circa 8,4 m^2 pro Ziege; Abbildung 1) mit angrenzendem, betonierten Auslauf (circa 2,9 m^2 pro Ziege) zur Verfügung. Das Platzangebot des jeweils für die Beobachtungen eingezäunten Weidestücks entsprach in etwa 12 m^2 pro Tier.

Abbildung 1
Innenansicht des Tiefstreulaufstalls. Futtertisch mit Palisadenfressgitter mittig im Bild; schwarz eingekreist = eine der vier Schwarz/Weiß-Videokameras über dem Futtertisch.
(Foto: Laura Schneider)

Das Tier-Fressplatz-Verhältnis betrug rund zwei Fressplätze pro Tier, mit einer Fressplatzbreite von 40 cm. Um den Ziegen eine Selektion der besten Futterteile zu ermöglichen, lag das Heu auf dem Futtertisch immer „im Überfluss" vor und wurde spätestens bei 50 % ausselektierten Futterresten frisch vorgelegt. Der Futtertisch bestand aus einem rechteckigen, ebenerdigen Beton-Plateau in der Mitte des Laufstalls (Abbildung 1). Zu beiden Seiten verlief ein Palisadenfressgitter aus Holz mit Sichtblenden. Kraftfutter in Form von Weizenschrot-Pellets wurde zweimal am Tag im Melkstand (um circa 06:00 und 16:00 Uhr) gefüttert, wo die Tiere während des Melkens kurzzeitig fixiert waren.

Die Aufnahme von Heu und Grünfutter sowie die Kategorien des Futteraufnahmestatus wurden wie folgt definiert:

- Heufressen (Stall): Eine Ziege steht am Futtertisch, ihr Kopf ist innerhalb eines Futterplatzes abgesenkt, sodass der Lippen-Nasen-Bereich das Heu berührt. Die Ziege nimmt Heu vom Futtertisch auf und zerkaut dieses.
- Grasen (Weide): Eine Ziege nimmt im Stehen oder schrittweisen Gehen Grünfutter auf und zerkaut dieses. Dabei ist der Kopf nach unten abgesenkt und der Lippen-Nasen-Bereich berührt die Weideoberfläche.
- Futteraufnahme: Für eine Ziege wurde zum Datenaufnahmezeitpunkt ein Verhalten erfasst, das der Definition von Heufressen oder Grasen entspricht.
- keine Futteraufnahme: Für eine Ziege wurde zum Datenaufnahmezeitpunkt ein Verhalten erfasst, das nicht der Definition von Heufressen oder Grasen entspricht.

3.2 Aufnahme und Auszählung der Verhaltensdaten

Für die Methodenvergleiche wurde das Futteraufnahmeverhalten über jeweils 3 Stunden im Stall und auf der Weide mit allen drei visuellen Methoden (Direktbeobachtung, Fotografien, Videoaufzeichnungen) simultan erfasst. Die Datenaufnahmen wurden zwischen circa 08:00 und 15:30 Uhr über den Tag verteilt und sind im Stall und auf der Weide miteinander vergleichbar.

Es wurden immer dieselbe Person als Direktbeobachter und eine weitere Person zur Bedienung der digitalen Fotokamera (Canon® PowerShot G12; 6,1-30,5 mm Brennweite, CCD-Sensor) eingesetzt. Im Stall erfolgten Direktbeobachtung und Fotoaufnahmen von zwei Leitern (Höhe circa 1,5 bis 2,0 m) direkt vor dem Futtertisch aus, auf der Weide aus einem mobilen, überdachten Hochsitz (Höhe circa 2,0 bis 3,0 m) am Rand des Weidestücks heraus. Direktbeobachter und Fotograf waren sowohl im Stall als auch auf der Weide eng benachbart und zwischen den Videokameras positioniert.

Die Videoaufnahmen entstanden vollautomatisch: Im Stall wurden jeweils zwei digitale, lichtempfindliche Schwarz/Weiß-Videokameras (Panasonic® WV-BP109; 2,8 mm Brennweite, 30 Bilder/Sekunde, CCD-Sensor) an den Metallkonstruktionen über den beiden Futtertischlängsseiten montiert (Abbildung 1), sodass alle Bereiche des Tischs mindestens von einer Kamera erfasst wurden. Für den Einsatz auf der Weide erwiesen sich die Schwarz/Weiß-Videokameras als zu lichtempfindlich. Stattdessen wurden zwei digitale Full HD-Farb-Videokameras (Panasonic® HX-WA30; 4,0-20,0 mm Brennweite, 60 Bilder/Sekunde, MOS-Sensor) auf mobilen Dreibein-Stativen (Abbildung 2) so aufgestellt, dass sie etwaige tote Winkel wechselseitig abdeckten.

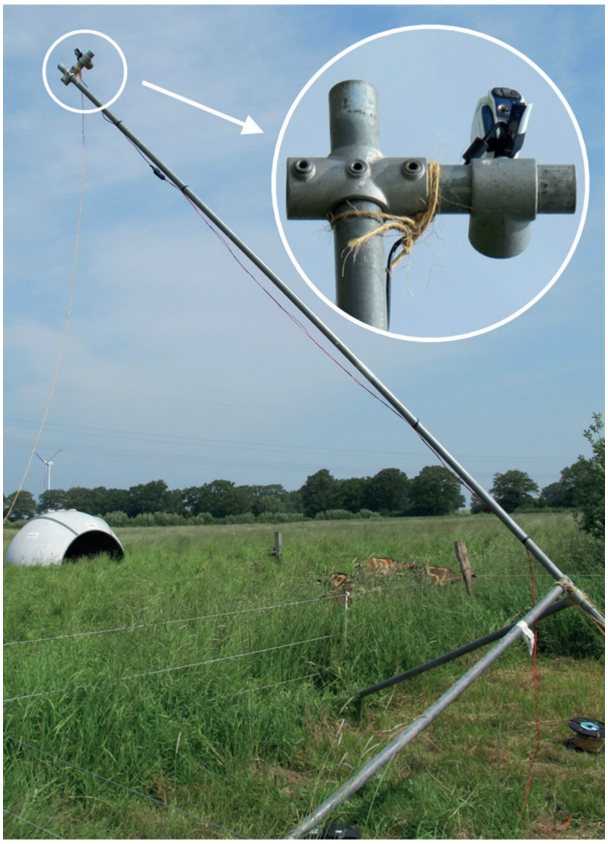

Abbildung 2
Mobiles Dreibein-Stativ mit aufgeschraubter Farb-Videokamera (siehe Vergrößerung) neben der Ziegenweide. Weiße Schutzhütte am linken Bildrand. *(Foto: Sybille Schaefer)*

Unmittelbar vor Beginn der Datenaufnahmen wurde ein frisches Weidestück in der Größe entsprechend des konstanten Weitwinkelbereichs der Videokameras angepasst. Um eine durchgängige mobile Stromversorgung über 8 Stunden zu gewährleisten, wurden die beiden Kameras jeweils über eine separate Autobatterie gespeist.

Die Videoaufzeichnungen liefen kontinuierlich (Continuous Recording). Direktbeobachtung sowie Fotoaufnahmen erfolgten zeitlich gerastert (Time Sampling) und pro Datenaufnahmezeitpunkt jeweils zeitlich sukzessiv (Scan Sampling) (Altmann, 1974; Lehner, 1996; Martin und Bateson, 2007). Alle 3 Minuten notierte der Direktbeobachter in einem Protokollbogen die Identitäten aller Ziegen, die zu diesem Zeitpunkt Futter aufnahmen. Das Beobachtungsareal wurde immer in derselben Reihenfolge und Geschwindigkeit mit den Augen auf Futter aufnehmende Ziegen hin abgesucht. Die Fotoaufnahmen wurden manuell im 3-Minuten-Takt ausgeführt. Da es trotz der erhöhten Aufnahmeposition aufgrund der Größe des Bildausschnitts notwendig war, pro „Sample Point" in der Regel vier Fotografien anzufertigen, fotografierte der Beobachter die Teile des Beobachtungsareals mit Überlappungen und immer in derselben Reihenfolge und Geschwindigkeit (circa 20 Sekunden pro Durchgang). Anschließend wurden die Fotografien am Bildschirm gesichtet und die Identitäten der zum betreffenden Zeitpunkt Futter aufnehmenden Tiere notiert.

Die kontinuierlichen Videoaufnahmen wurden mittels Standbildfunktion im 3-Minuten-Takt in diskrete Einheiten zerlegt. Die Auswertung dieser instantanen Standbilder erfolgte auf dieselbe Weise wie die der Fotografien.

3.3 Referenzstandards der Methoden- und Intervalllängenvergleiche

Bei sämtlichen Berechnungen wurden die im Stall und auf der Weide aufgenommenen Datensätze getrennt voneinander ausgewertet. Die Auswertung erfolgte durchgängig mit dem Statistikprogramm „R" (Version 3.0.3).

Im Zuge der Auszählung der individuenspezifisch erhobenen Daten (Stall: t = 3060, Weide: t = 2460 Datenpunkte) wurden für jedes Tier nur die Zeitpunkte, zu denen es eindeutig als Futter aufnehmend erfasst worden war, über die Gesamtbeobachtungszeit summiert. Dieser Häufigkeitswert repräsentiert den Zeitanteil, den das betreffende Tier mit Futteraufnahme verbrachte. Zeitpunkte, zu denen ein Tier oder sein Futteraufnahmestatus mit der entsprechenden Methode nicht eindeutig identifiziert werden konnte, wurden nicht mitgezählt.

Als Referenzstandards für den Methoden- und Intervallvergleich diente jeweils ein vollständiger Vergleichsdatensatz. Hierfür wurden die Videostandbilder unter Nutzung der Vor- und Rückspulmöglichkeiten ausgezählt. So konnten die Identitäten aller Herdenmitglieder und ihr jeweiliger Futteraufnahmestatus zu jedem Zeitpunkt eindeutig ermittelt werden.

Für die Reliabilitätsprüfung der drei visuellen Methoden erfolgte die Auszählung im 3-Minuten-Intervall (= Methodenvergleichsstandard). Bei der Direktbeobachtung als der zeitintensivsten Aufnahmemethode stellten 3 Minuten – unter den gegebenen äußeren Bedingungen dieser Untersuchung – den kleinstmöglichen praktikablen Zeitabstand dar. Das Raufutteraufnahmeverhalten bei Ziegen findet in der Regel in zeitlich relativ langen, ununterbrochenen Einheiten statt. Da diese zeitliche Struktur der eines Verhaltenszustands (behavioural state; Altmann, 1974) entspricht, konnte bei beiden Vergleichen auf eine vollständig-kontinuierliche Videosichtung und -auswertung verzichtet werden.

Die mit den drei Methoden erhaltenen Datensätze wurden anschließend durch paarweisen Vergleich mit dem Methodenvergleichsstandard auf ihre Reliabilität hin überprüft (Engel, 1996; Martin und Bateson, 2007).

Fotografien und Videoaufnahmen ermöglichen gegenüber der Direktbeobachtung eine höhere zeitliche Taktung. Während bei der Direktbeobachtung das Verhalten manuell, direkt und fragestellungsspezifisch festgehalten wird, entkoppeln die beiden (semi-)automatischen visuellen Methoden die reine Aufzeichnung des Verhaltens von den zeitaufwendigen Schritten der fragestellungsspezifischen Auswertung (wie das Auffinden der Individuen, die Identifikationen von Tier und Verhaltensstatus und so weiter). Durch die Möglichkeit einer wiederholten und beliebig langen Sichtung ließ sich das Zeitintervall für die Reliabilitätsprüfungen der Intervalllängen daher weiter verringern. Für die Verwendung als Intervalllängenvergleichsstandard wurde der Video-Datensatz im 1-Minuten-Takt ausgewertet.

Aus diesem Datensatz wurden die Alternativintervall-Datensätze generiert, die einer Erfassung des Futteraufnahmeverhaltens mittels Intervalllängen von 3, 5, 8 und 12 Minuten entsprechen. Für jede dieser Intervalllängen wurden die individuellen Futteraufnahmehäufigkeiten ermittelt und in Prozentwerte umgerechnet (100 % = Anzahl Datenzeitpunkte des im 1-Minuten-Takt erhobenen Referenzdatensatzes = 180 Datenpunkte pro Tier).

3.4 Reliabilitätsprüfungen: Diagrammtypen und Kennwerte

Klassische statistische Tests wie Korrelationen, Regressionen und Mittelwertvergleiche, die bei Methodenvergleichen zum Quantifizieren des Übereinstimmungsausmaßes mitunter Anwendung finden, sind mathematisch-methodisch hierfür lediglich eingeschränkt geeignet; eine fundierte, umfassende Darstellung der Vorbehalte ist vor allem den Arbeiten von Altman und Bland (1983), Bland und Altman (1986, 1999 und 2003) und Grouven et al. (2007) zu entnehmen. In der vorliegenden Studie erfolgten die Reliabilitätsprüfungen, sowohl beim Methoden- als auch beim Intervalllängenvergleich, daher mittels einer Kombination dreier deskriptiv-statistischer Methoden und eines zusätzlichen numerischen Akzeptanzkriteriums: Kasten- und Bland-Altman-Diagramme visualisieren das Ausmaß der Übereinstimmung zwischen dem Vergleichsstandard und der jeweiligen Alternativmethode (Bland und Altman, 1986; Hoff, 2005). Während mit Kastendiagrammen die Gesamtverteilungen der zu vergleichenden Daten charakterisiert werden (Tukey, 1977), stellen Bland-Altman-Diagramme direkt die Verteilungen der jeweiligen Differenzen dar. Die Berechnung des in der vorliegenden Studie vorgestellten Medians der prozentualen Abweichungen quantifiziert das Ausmaß der paarweisen Übereinstimmungen mit dem jeweiligen Vergleichsstandard durch eine Kennzahl.

In den Bland-Altman-Diagrammen (Abbildungen 4 und 5 sowie 7 und 8) repräsentiert die durchgezogene horizontale Linie den Mittelwert der Differenzen. Je weiter sie von null entfernt ist, desto stärker über- beziehungsweise unterschätzt eine Methode die andere. Ob die mittlere Differenz im positiven oder negativen Y-Achsenbereich liegt, ist von der Richtung der Differenzbildung abhängig; in der vorliegenden Studie wird der Methodenvergleichsstandard von der Alternativmethode unterschätzt, wenn der Mittelwert der Differenzen über null liegt. Die gestrichelten horizontalen Linien stellen die Übereinstimmungsgrenzen dar. Sie repräsentieren die 1,96-fache Standardabweichung der mittleren Differenz und quantifizieren die Streuung der Werte um diesen Mittelwert; 1,96 entspricht dem 97,5 %-Quantil der Normalverteilung (vergleiche zum Beispiel Grouven et al., 2007). Je näher die Einzelwerte an der Linie der mittleren Differenz liegen, und je enger somit die Übereinstimmungsgrenzen sind, desto ähnlicher sind sich die Methoden bezüglich ihrer Messsystematik. Im Idealfall, das heißt bei einer vollständigen Übereinstimmung der mit den beiden unterschiedlichen Methoden ermittelten Werte, liegen die mittlere Differenz und die Übereinstimmungsgrenzen bei null.

Da die mittleren Differenzen und Übereinstimmungsgrenzen anhand der Bland-Altman-Diagramme nur grob abgelesen werden können, wurden diese Kennwerte, auf zwei Nachkommastellen gerundet, zusätzlich separat berechnet (Tabellen 3 und 4).

Bei Bland-Altman-Berechnungen werden die Vorzeichen der Differenzen der zwei jeweils korrespondierenden Einzelwerte beibehalten, sodass sich negative und positive Werte in der Summe gegenseitig aufheben können. Um die „wahre" Abweichung deutlicher herauszustellen, wurde zusätzlich der Median der prozentualen Abweichungen als Grenzkriterium neu eingeführt. Hierzu wurden zunächst jeweils die individuellen prozentualen Abweichungen zwischen dem Vergleichsstandard (= 100 %) und der jeweiligen Alternativmethode berechnet. Aus den Beträgen dieser individuellen Abweichungen wurde anschließend für jede Alternativmethode der Median der prozentualen Abweichungen gebildet (Tabellen 3 und 4). Eine hinreichende Reliabilität wurde angenommen, wenn der Median der prozentualen Abweichungen vom Vergleichsstandard maximal 10 % betrug (vergleiche Martin und Bateson, 2007).

4 Ergebnisse

4.1 Leistungsstärken der visuellen Methoden

Der Median des Methodenvergleichsstandards ist auf der Weide 3,50 Mal so hoch wie im Stall (Abbildung 3: 42 versus 12 Zeitpunkte mit Futteraufnahmeverhalten von jeweils insgesamt 60).

Alle drei Alternativmethoden (Direktbeobachtung, Fotografien und Videostandbilder) unterschätzen die Vergleichsstandardwerte sowohl bei den im Stall als auch auf der Weide erhobenen Daten.

Bei den Weidedaten weichen die Werte der drei Alternativmethoden sowohl hinsichtlich der Lage des Medians als auch der Höhe des Interquartilsabstands stärker von denen des Methodenvergleichsstandards ab als bei den Stalldaten. Bei beiden kommt das Videostandbild dem Standard am nächsten, gefolgt von der Direktbeobachtung und den Fotografien; bei den Stalldaten liegen die Werte der Direktbeobachtung und der Fotografien ungefähr gleich weit unter

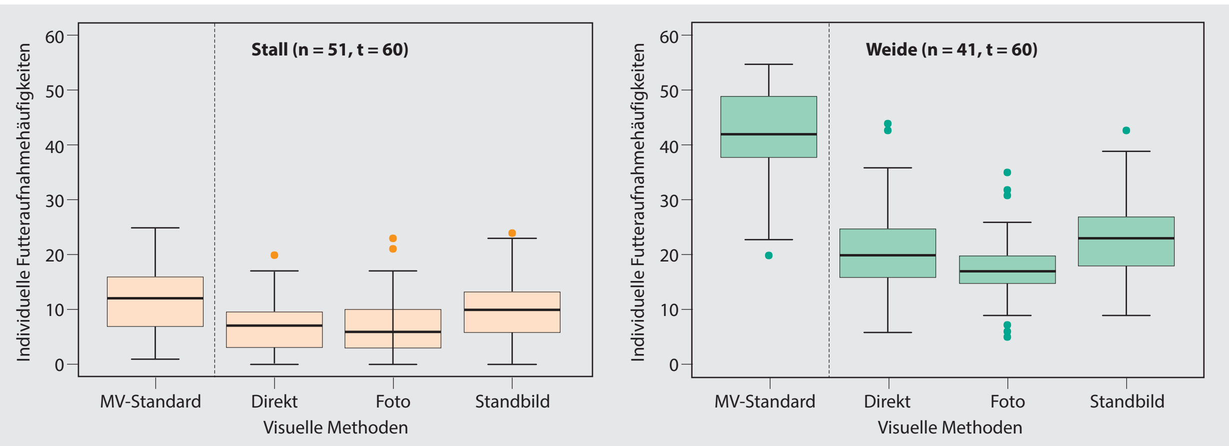

Abbildung 3
Gesamt-Methodenvergleich anhand von Stall- und Weidedaten. n = Anzahl Herdenmitglieder, t = Anzahl Sampling-Zeitpunkte; X-Achse = visuelle Methoden zur Erfassung des Futteraufnahmeverhaltens (Heu, Gras): „MV-Standard" = Methodenvergleichsstandard = Videoauswertungen mit Vor- und Zurückspulen, „Direkt" = Direktbeobachtung, „Foto" = Fotografien, „Standbild" = Videostandbilder ohne Vor- und Zurückspulen; vertikale gestrichelte Linie = optische Trennung des Standards von den Alternativmethoden; Y-Achse = individuelle Futteraufnahmehäufigkeiten innerhalb von 3 Stunden Datenerfassung im 3-Minuten-Intervall.

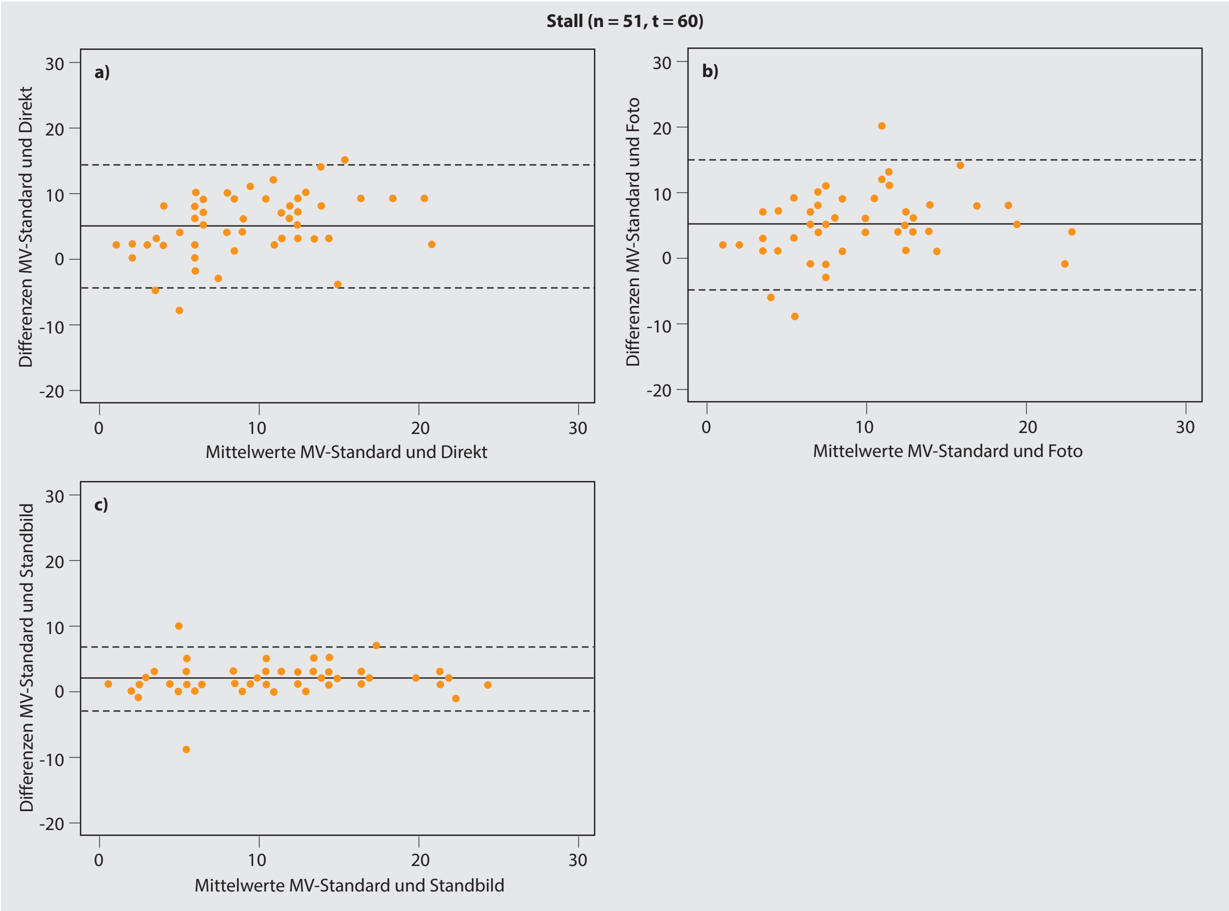

Abbildung 4

Paarweise Methodenvergleiche anhand der Stalldaten (Heuaufnahme). n = Anzahl Herdenmitglieder, t = Anzahl Sampling-Zeitpunkte; „MV-Standard" = Methodenvergleichsstandard = Videoauswertungen mit Vor und Zurückspulen, „Direkt" = Direktbeobachtung, „Foto" = Fotografien, „Standbild" = Videostandbilder ohne Vor- und Zurückspulen; X-Achse = Mittelwerte von MV-Standard und Alternativmethode; Y-Achse = Differenzen MV-Standard minus Alternativmethode; durchgezogene horizontale Linie = Mittelwert der Differenzen, gestrichelte horizontale Linien = Übereinstimmungsgrenzen (= Mittelwert der Differenzen ± 1,96 x Standardabweichung der Differenzen).

denen des Videostandbildes. Bei den Weidedaten hingegen liegen die Werte der Fotografien nochmals niedriger als die der Direktbeobachtung und unterschätzen den Methodenvergleichsstandard somit am stärksten.

Dass bei den Stalldaten die Alternativmethoden den Referenzdatensatz lediglich etwas unterschätzen, wird in den Bland-Altman-Diagrammen deutlich (Abbildung 4): Die mittlere Differenz liegt stets im positiven Bereich (Differenzbildung: Methodenvergleichsstandard minus Alternativmethode), die untere Übereinstimmungsgrenze aber bleibt im negativen Bereich. Auch die Überlegenheit der Videostandbilder gegenüber den anderen beiden Alternativmethoden wird hier besonders deutlich: Die mittlere Differenz und die Breite der Übereinstimmungsgrenzen sind bei den Videostandbildern nur circa halb so hoch wie bei Direktbeobachtung und Fotografien (Tabelle 3).

Die Kennwerte der Direktbeobachtung zeigen im Vergleich mit dem Methodenvergleichsstandard eine minimal höhere Reliabilität als die der Fotografien. Betrachtet man die Mediane der prozentualen Abweichungen (Tabelle 3), so kann jedoch selbst für die Videostandbilder (circa 14 %) keine hinreichende Übereinstimmung mit dem Methodenvergleichsstandard angenommen werden. Die Kennwerte von Direktbeobachtung und Fotografien (jeweils 50 %) betragen das Fünffache des Grenzwerts; diese beiden Methoden sind somit vollständig ungeeignet.

Auch bei den Weidedaten liegt die mittlere Differenz stets über null (Abbildung 5, Tabelle 3), das Ausmaß der Unterschätzung durch die Alternativmethoden ist hier jedoch so groß, dass auch die unteren Übereinstimmungsgrenzen im positiven Wertebereich liegen. Anders als bei der Heuaufnahme im Stall zeigen hier alle drei Vergleiche des Methodenvergleichsstandards mit jeweils einer Alternativmethode ausgesprochen ähnliche Ergebnisse. Das heißt, bei der Grünfutteraufnahme auf der Weide lässt sich für keine der Alternativmethoden eine eindeutige Überlegenheit feststellen. Die Bland-Altman-Kennwerte der Videostandbilder zeigen eine minimal höhere Übereinstimmung mit dem Methodenvergleichsstandard als die der beiden anderen Alternativmethoden. Von den übrigen beiden Alternativmethoden

Tabelle 3
Kennwerte der Methodenvergleiche anhand von Stall- und Weidedaten (Bland-Altman-Werte und Mediane der prozentualen Abweichungen). Methoden: „Direkt" = Direktbeobachtung, „Foto" = Fotografien, „Standbild" = Videostandbilder ohne Vor und Zurückspulen; mittlere Differenz = Mittelwert der Differenzen; Übereinstimmungsgrenzen = Mittelwert der Differenzen ± 1,96 x Standardabweichung der Differenzen; Median der prozentualen Abweichungen = Mittel der individuellen Abweichungsbeträge, eine hinreichende Reliabilität wird bei einem Wert von maximal 10 % angenommen.

Methode	Direkt	Foto	Standbild
Stall (Heuaufnahme)			
Mittlere Differenz	4,90	5,06	1,86
Lage der Übereinstimmungsgrenzen	-4,44 und 14,25	-4,82 und 14,94	-3,05 und 6,77
Breite der Übereinstimmungsgrenzen	18,69	19,76	9,82
Median der prozentualen Abweichungen	50,00	50,00	14,29
Weide (Grünfutteraufnahme)			
Mittlere Differenz	20,17	23,95	18,70
Lage der Übereinstimmungsgrenzen	4,65 und 35,69	10,02 und 37,89	5,32 und 32,10
Breite der Übereinstimmungsgrenzen	31,04	27,87	26,78
Median der prozentualen Abweichungen	52,00	58,97	42,22

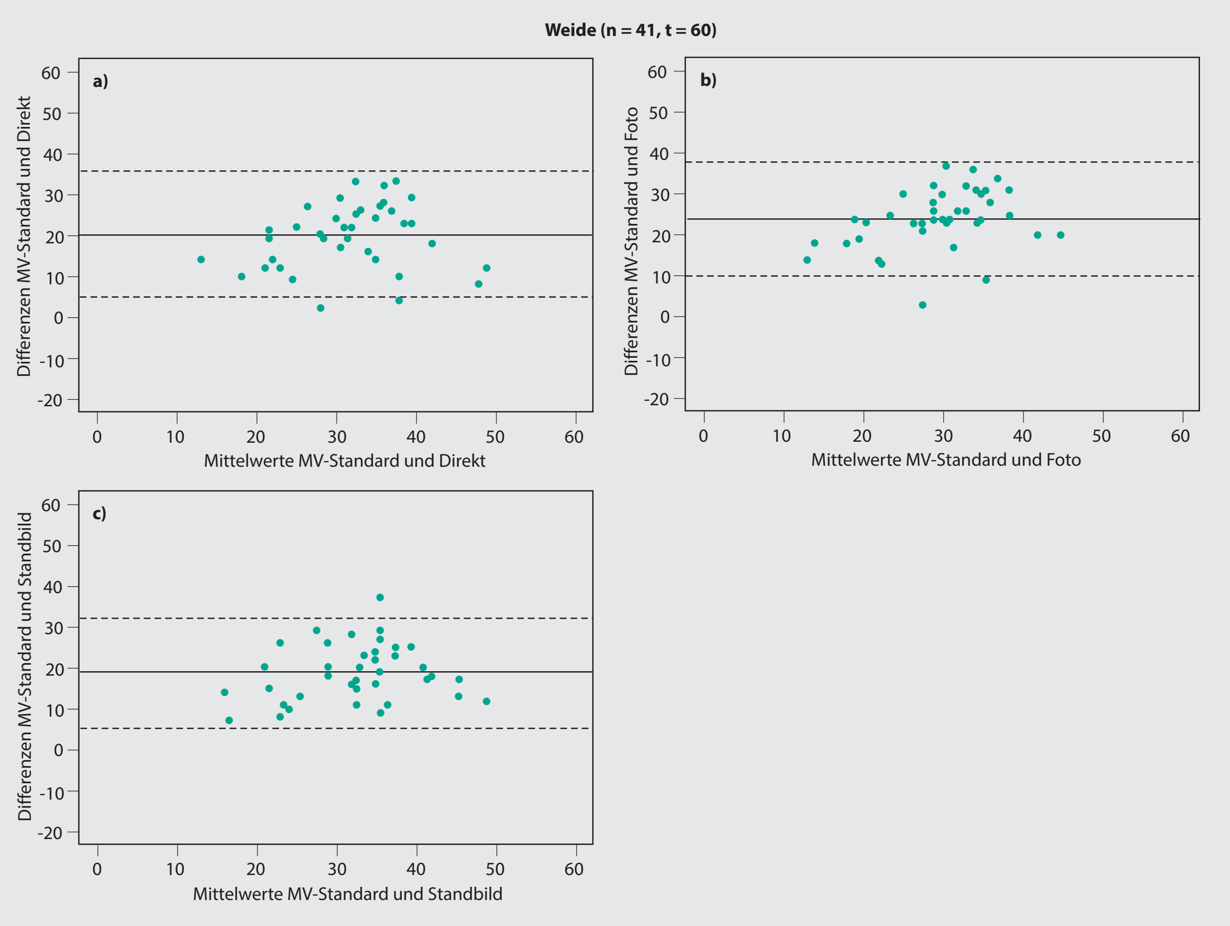

Abbildung 5
Paarweise Methodenvergleiche anhand der Weidedaten (Grünfutteraufnahme). n = Anzahl Herdenmitglieder, t = Anzahl Sampling-Zeitpunkte; „MV-Standard" = Methodenvergleichsstandard = Videoauswertungen mit Vor- und Zurückspulen, „Direkt" = Direktbeobachtung, „Foto" = Fotografien, „Standbild" = Videostandbilder ohne Vor- und Zurückspulen; X-Achse = Mittelwerte von MV-Standard und Alternativmethode; Y-Achse = Differenzen MV-Standard minus Alternativmethode; durchgezogene horizontale Linie = Mittelwert der Differenzen, gestrichelte horizontale Linien = Übereinstimmungsgrenzen (= Mittelwert der Differenzen ± 1,96 x Standardabweichung der Differenzen).

besitzt die Direktbeobachtung die geringfügig kleineren mittleren Differenzen, bei der Breite der Übereinstimmungsgrenzen ist es umgekehrt. Die durchgängig sehr geringen Übereinstimmungstendenzen der Alternativmethoden mit dem Methodenvergleichsstandard (vergleiche Kapitel 3.3) sind auch anhand der Mediane der prozentualen Abweichungen erkennbar, die jeweils ein Vielfaches des akzeptablen Maximalwerts betragen (Werte zwischen circa 42 % und 59 %; Tabelle 3).

Für die Erfassung des Raufutteraufnahmeverhaltens im Stall und auf der Weide im 3-Minuten-Takt besitzt keine der drei instantanen Methoden, Direktbeobachtung, Fotografien und instantane Videostandbilder, hinsichtlich ihrer Datengenauigkeit eine ausreichende Übereinstimmung mit dem Methodenvergleichsstandard. Eine Datenvervollständigung durch Vor- und Zurückspulen ist demnach unverzichtbar, um Datensätze der erforderlichen Übereinstimmungsgüte zu erhalten. Der mit dem Spulen verbundene Arbeits- und Zeitaufwand verhält sich proportional zur Anzahl der Datenerfassungszeitpunkte und somit antiproportional zur Intervalllänge. Dementsprechend schließt sich als zweiter Schritt der vorliegenden Studie die Suche nach der effizientesten Intervalllänge für die Auszählung von durch Vor- und Zurückspulen komplementierten Videostandbildern an.

4.2 Leistungsstärken der verschiedenen Intervalllängen bei Videoaufzeichnungen

Der Median der individuellen Futteraufnahmehäufigkeiten des Intervalllängenvergleichsstandards (1 Minute) war auf der Weide 4,73 Mal so hoch wie im Stall (104 versus 22; Abbildung 6).

Anhand des Medians des 1-Minuten-Intervalls wurde auch der relative Anteil des jeweiligen Futteraufnahmeverhaltens am Gesamtverhalten innerhalb der beobachteten Zeit (180 Datenpunkte pro Tier) bestimmt. Er betrug im Stall 12,22 % und auf der Weide 57,78 %.

Weder bei den Stall- noch den Weidedaten zeichnet sich hinsichtlich der Lage des Medians eine stetige Unter- oder Überschätzung durch die Alternativintervalllängen ab. Der Interquartilsabstand nimmt bei den Alternativintervallen mit ihrer Länge zu. Dies geschieht zum Teil sprunghaft, bei den Stalldaten nach dem 5-Minuten-Intervall, bei den Weidedaten sowohl nach dem 3- als auch nach dem 8-Minuten-Intervall.

Eine differenziertere Beurteilung ermöglichen auch hier die Bland-Altman-Diagramme (Abbildung 7 und 8) und ihre, um den Median der prozentualen Abweichungen ergänzten, Kennwerte (Tabelle 4).

In allen Bland-Altman-Diagrammen der Stalldaten (Abbildung 7) liegt die mittlere Differenz leicht unter null, die obere Übereinstimmungsgrenze aber weit im positiven Wertebereich. Demnach wird der Intervalllängenvergleichsstandard von allen Alternativmethoden etwas überschätzt (Differenzbildung: Intervalllängenvergleichsstandard minus Alternativintervalllänge).

Der Abstand zwischen den Übereinstimmungsgrenzen vergrößert sich mit zunehmender Intervalllänge und zeigt einen überproportionalen Anstieg nach dem 5-Minuten-Intervall (Abbildung 7 und Tabelle 4). Zudem ist anhand der Punkteverteilung beim 8- und 12-Minuten-Intervall (Abbildung 7c und 7d) eine Tendenz sichtbar, wonach bei niedrigeren Futteraufnahmehäufigkeiten die mittlere Differenz eher unter- und bei hohen Futteraufnahmehäufigkeiten eher überschätzt wird.

Der Median der prozentualen Abweichungen (Tabelle 4) liegt beim 3-Minuten-Intervall unter und beim 5-Minuten-Intervall bereits über der 10 %-Grenze, bei den beiden längeren Intervallen überschreiten die Werte das Akzeptanzkriterium um ein Vielfaches (circa 30 % und 44 %). Somit zeigt für die Stalldaten allein das 3-Minuten-Intervall eine hinreichende Übereinstimmung mit dem Intervalllängenvergleichsstandard.

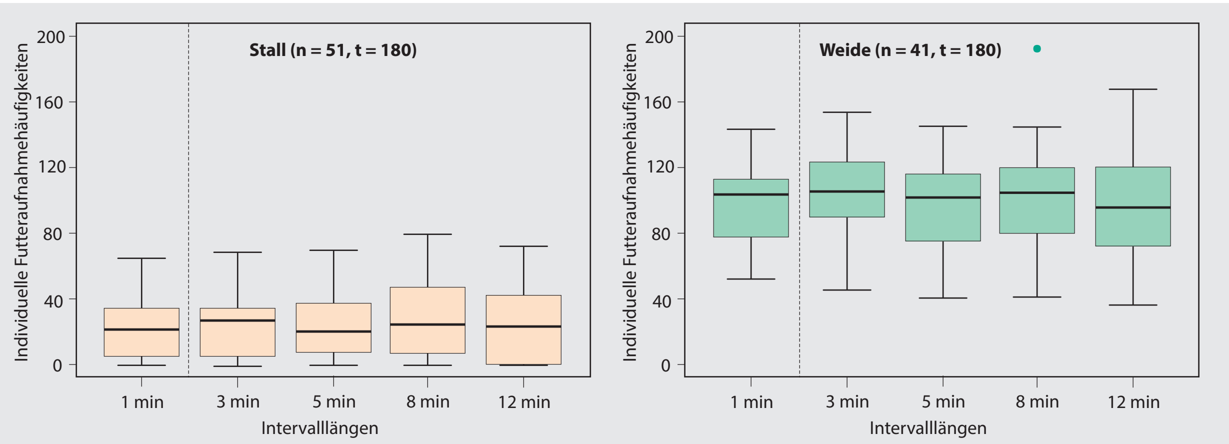

Abbildung 6
Gesamt-Intervalllängenvergleich anhand von Stall- und Weidedaten. n = Anzahl Herdenmitglieder, t = Anzahl Sampling-Zeitpunkte; X-Achse = Intervalllängen zur Erfassung des Futteraufnahmeverhaltens (Heu, Gras) mittels durch Vor- und Zurückspulen komplementierter Videostandbilder; vertikale gestrichelte Linie = optische Trennung des Standards (= 1 Minute) von den Alternativintervalllängen; Y-Achse = individuelle Futteraufnahmehäufigkeiten innerhalb von 3 Stunden Datenerfassung, jeweils auf 180 Sampling-Zeitpunkte extrapoliert.

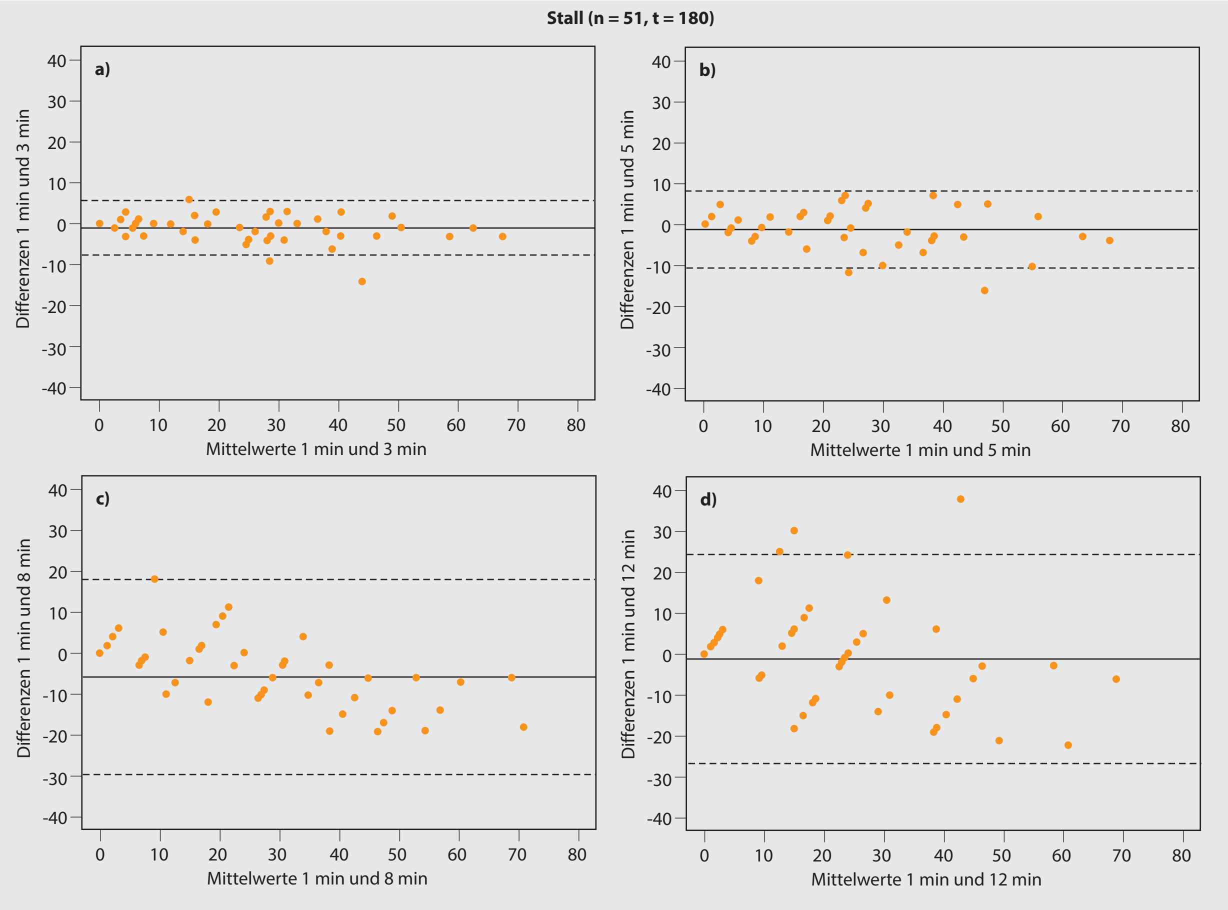

Abbildung 7
Paarweise Intervalllängenvergleiche anhand der Stalldaten (Heuaufnahme). n = Anzahl Herdenmitglieder, t = Anzahl Sampling-Zeitpunkte; X-Achse = Mittelwerte von Intervalllängenvergleichsstandard (1-Minuten-Intervall) und einem der Alternativintervalle (3, 5, 8, 12 Minuten) zur Erfassung des Futteraufnahmeverhaltens (Heu) mittels durch Vor- und Zurückspulen komplementierter Videostandbilder; Y-Achse = Differenzen Intervalllängenvergleichsstandard minus Alternativintervall; durchgezogene horizontale Linie = Mittelwert der Differenzen, gestrichelte horizontale Linien = Übereinstimmungsgrenzen (= Mittelwert der Differenzen ± 1,96 x Standardabweichung der Differenzen).

Tabelle 4
Kennwerte der Intervalllängenvergleiche anhand von Stall- und Weidedaten (Bland-Altman-Werte und Mediane der prozentualen Abweichungen). Intervalllängen = 3, 5, 8, 12 Minuten; mittlere Differenz = Mittelwert der Differenzen; Übereinstimmungsgrenzen = Mittelwert der Differenzen ± 1,96 x Standardabweichung der Differenzen; Median der prozentualen Abweichungen = Mittel der individuellen Abweichungsbeträge, eine hinreichende Reliabilität wird bei einem Wert von maximal 10 % angenommen = *.

Intervall	3 Minuten	5 Minuten	8 Minuten	12 Minuten
Stall (Heuaufnahme)				
Mittlere Differenz	-1,00	-1,10	-5,73	-1,18
Lage der Übereinstimmungsgrenzen	-7,62 und 5,62	-10,59 und 8,39	-29,55 und 18,10	-26,72 und 24,37
Breite der Übereinstimmungsgrenzen	13,24	18,98	47,65	51,09
Median der prozentualen Abweichungen	7,69*	13,79	30,44	44,00
Weide (Grünfutteraufnahme)				
Mittlere Differenz	-3,39	1,90	-1,49	-0,61
Lage der Übereinstimmungsgrenzen	-21,19 und 14,41	-21,51 und 25,31	-22,23 und 30,25	-40,93 und 39,71
Breite der Übereinstimmungsgrenzen	35,60	46,82	52,48	80,64
Median der prozentualen Abweichungen	7,08*	8,73*	9,28*	11,93

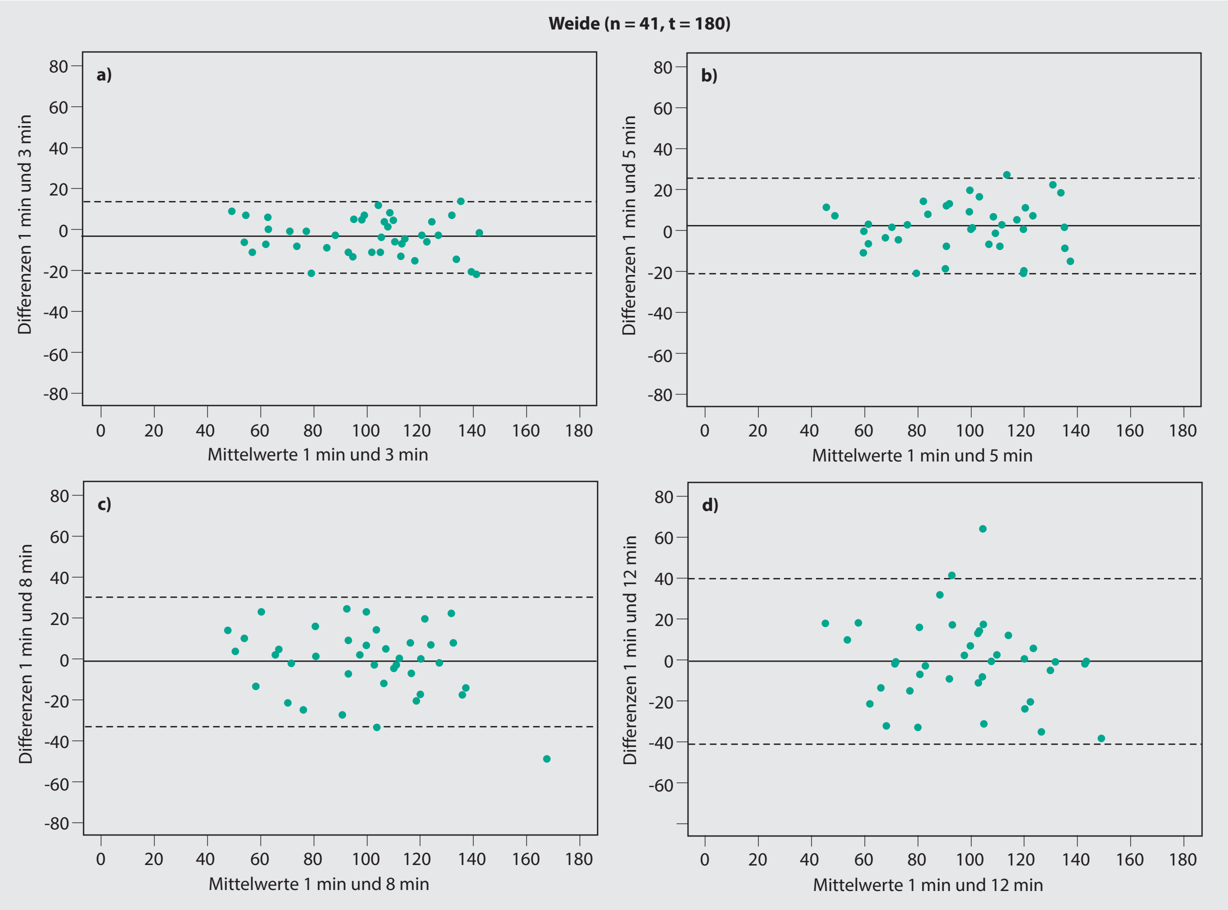

Abbildung 8

Paarweise Intervalllängenvergleiche anhand der Weidedaten (Grünfutteraufnahme). n = Anzahl Herdenmitglieder, t = Anzahl Sampling-Zeitpunkte; X-Achse = Mittelwerte von Intervalllängenvergleichsstandard (1Minuten-Intervall) und einem der Alternativintervalle (3, 5, 8, 12 Minuten) zur Erfassung des Futteraufnahmeverhaltens (Gras) mittels durch Vor- und Zurückspulen komplementierter Videostandbilder; Y-Achse = Differenzen Intervalllängenvergleichsstandard minus Alternativintervall; durchgezogene horizontale Linie = Mittelwert der Differenzen, gestrichelte horizontale Linien = Übereinstimmungsgrenzen (= Mittelwert der Differenzen ± 1,96 x Standardabweichung der Differenzen).

Bei den Weidedaten liegt in allen Bland-Altman-Diagrammen (Abbildung 8) die mittlere Differenz nur leicht über oder unter null; der Betrag wird mit zunehmender Intervalllänge kleiner. Der Abstand zwischen den Übereinstimmungsgrenzen nimmt auch bei den Weidedaten mit ansteigender Intervalllänge zu und vor allem bei Betrachtung der Kennwerte (Tabelle 4) wird ein sprunghafter Anstieg nach dem 8-Minuten-Intervall deutlich.

Auch der Median der prozentualen Abweichungen steigt mit zunehmender Intervalllänge und überschreitet jenseits des 8-Minuten-Intervalls (mit 12 %) die 10 %-Grenze (Tabelle 4).

Auf der Weide ist eine repräsentative Erfassung des Futteraufnahmeverhaltens, alternativ zum 1-Minuten-Intervall, auch bei Verwendung des 3-, 5- und 8-Minuten-Intervalls möglich.

5 Diskussion

5.1 Reliabilitätsbewertung der Methoden inklusive Unterschiedsursachen ihrer Resultate

Die in den Methodenvergleich einbezogenen drei visuellen Methoden besaßen jeweils gegenläufige Ähnlichkeiten hinsichtlich ihrer Datenerfassungs- und „Bildgebungs“-Eigenschaften. Die Fotografien bildeten die „Schnittstelle“ zwischen Videostandbildern und Direktbeobachtung: Mit der Direktbeobachtung gemeinsam haben die Fotografien die jeweils sukzessive Datenaufnahme, mit den Videostandbildern teilen sie die „technischen Eigenschaften“ der Bilder. Grundsätzlich wurden Unterschiede in den Ergebnissen von Direktbeobachtungen, Fotografien und instantanen Videostandbildern erwartet. Richtung und Umfang dieser Unterschiede hängen unter anderem von zahlreichen Rahmenbedingungen (zum Beispiel Herdengröße, räumliche Dimensionen) ab und sind somit nicht vollständig a priori einschätzbar. Die Quantifizierung der Abweichungen war daher das erste Ziel der vorliegenden Methodenstudie.

In der vorliegenden Untersuchung besaßen die Videostandbilder in allen Komponenten des Reliabilitätstests (vergleiche Kapitel 3.4) durchgängig und mit Abstand die höchste Übereinstimmungsgüte mit dem Methodenvergleichsstandard. Dies ist in großen Teilen darauf zurückzuführen, dass es zwischen den instantanen Videostandbildern und denen des Methodenvergleichsstandards keinen räumlichen Versatz gab. Selbst bei geringen Positionsabweichungen zwischen Video- und Fotokamera(s) und Direktbeobachter gibt es Differenzen im Blickwinkel, die darüber entscheiden können, ob Identität und Verhalten eines Individuums zum Datenaufnahmezeitpunkt identifiziert werden können.

Aufnahmepositionen und -winkel der Videostandbilder waren identisch mit denen des Methodenvergleichsstandards. Bei Anlegen des quantitativen Reliabilitäts-Akzeptanzkriteriums (= Median der prozentualen Abweichungen von maximal 10 %), besaßen jedoch selbst sie nicht das geforderte Übereinstimmungsausmaß. Die quantitative Erfassung des Futteraufnahmeverhaltens im Stall und auf der Weide war im 3-Minuten-Intervall lediglich durch Videostandbilder mit Komplettierung durch Vor- und Zurückspulen möglich.

Wenn sich eindeutige Unterschiede zwischen Fotografien und Direktbeobachtung zeigten, dann war die Güte der Direktbeobachtung etwas höher. Auf den ersten Blick überrascht diese Überlegenheit der Direktbeobachtungen in zweierlei Hinsicht. Zum einen ist bei Direktbeobachtungen ein zeitlicher Versatz unvermeidbar, denn hier handelt es sich zwangsläufig um ein Scan Sampling, was bedeutet, dass ab dem Datenaufnahmezeitpunkt die Untersuchungsherde sukzessiv mit den Augen „abgesucht" wird (sensu: Lehner, 1996; Martin und Bateson, 2007). In der vorliegenden Studie lieferte die Standbildfunktion der Videoaufnahmen exakte „Instantaneous Time Sampling-Daten" (zeitliche Ausdehnung gleich Null). Die Anfertigung der Fotografien erfolgte manuell und wegen der Größe des Areals, das nicht mit einem einzigen Bild abzudecken war, ebenfalls in Form eines Scan Samplings. Die zeitliche Ausdehnung eines Foto-Scan-Durchgangs war mit circa 20 Sekunden jedoch deutlich kürzer als die eines Direktbeobachtungs-Durchgangs und die Zeitabstände zwischen den Einzelaufnahmen waren regelmäßiger als die zwischen den einzelnen Individuen bei der Direktbeobachtung. Das Ausmaß des zeitlichen Versatzes war bei den Fotografien daher geringer als bei den Direktbeobachtungen. Zum anderen ist bei Direktbeobachtungen keine beliebig lange Sichtung und nachträgliche Korrektur möglich und sie sollten somit per se fehlerbehafteter sein.

Methodenimmanent bedingt liefert die Direktbeobachtung hinsichtlich der zeitlichen Präzision die „weichsten" Daten. Eine solche Unschärfe wirkt sich allgemein eher negativ auf die Datenqualität aus, im vorliegenden Fall allerdings hatte sie positive Konsequenzen: Fotografien haben rein instantanen Charakter, während die Direktbeobachtung in gewissem Rahmen ein „mentales Vor- und Zurückspulen" zulässt, sodass de facto etwas mehr Informationen einflossen und die Zahl unvollständiger Datenpunkte direkt bei der Datenerfassung reduziert werden konnte. Tosi et al. (2006) fanden einen deutlichen Vorteil der Direktbeobachtung selbst gegenüber Videostandbildern. Sie führten einen Methodenvergleich zwischen Direktbeobachtung und Videoauswertungen (beide im 2-Minuten-Takt) durch, um das „orale Verhalten" bei Kälbern (unter anderem Kauen, Fressen, Belecken oder Beknabbern von Stallgegenständen) zu untersuchen. Die Autoren begründeten die Überlegenheit der Direktbeobachtungen vorrangig mit der hohen Differenziertheit der untersuchten Verhaltensweisen, von denen viele aufgrund der zwangsläufig limitierten technischen Bildauflösung und festen Schärfentiefe nicht identifiziert werden konnten.

In der vorliegenden Studie erstaunte zunächst weiterhin, dass die Fotografien hinsichtlich ihrer Reliabilität mit Abstand hinter die instantanen Videostandbilder zurückfielen, obwohl die „technischen Eigenschaften" solcher Bilder überaus ähnlich sind. Neben dem räumlichen Versatz (siehe oben) liegt die Hauptursache hierfür in der unterschiedlichen Anzahl der eingesetzten Kameras und vor allem der Positionierung der Videokameras: In der vorliegenden Untersuchung wurden jeweils mehrere Videokameras gleichzeitig verwendet (vier im Stall, zwei auf der Weide), die zudem paarweise auf gegenüberliegenden Seiten des Beobachtungsareals (Futtertisch beziehungsweise Weidestück) angebracht waren. Dies reduzierte die Anzahl fehlender Werte, denn wenn der Blickwinkel der einen Videokamera die Identifikation eines Individuums und/oder seines Verhaltens nicht erlaubte, konnte diese Information meist durch die Aufnahmen der gegenüberliegenden Videokamera ergänzt werden. Fotografien und Direktbeobachtung hingegen zeichneten in der vorliegenden Studie jeweils nur von einem Standpunkt aus auf.

In zukünftigen Methoden- und Anwendungsstudien sollten Videoaufzeichnungen möglichst in zweifacher Weise fester Bestandteil sein: zum einen als obligate Komponente des zu testenden Methodenrepertoirs (Videostandbilder mit effizienzoptimierter Intervalllänge); zum anderen als Basis für die Generierung des Referenzstandards (kontinuierliche Auswertung oder hochgetaktete und durch Spulen komplettierte Standbilder). Videoaufzeichnungen bieten den gewichtigen Vorteil, dass sie nachfolgend mit verschiedenen Auszählungsprotokollen ausgewertet werden können und so eine gegebenenfalls mehrstufige Optimierung der Datenauswertung erlauben, ohne eine erneute Datenaufnahme zu erfordern (Martin und Bateson, 2007). Bei den anderen beiden Methoden wäre beispielsweise eine zunächst gröbere Intervallstaffelung zum Eingrenzen eines geeigneten Intervallbereichs mit anschließender feinerer Abstufung stets mit der Neuaufnahme von Daten verbunden. Im Falle der Videoaufzeichnungen entfällt nicht nur der erneute Aufnahmeaufwand, sondern die Daten sind zudem uneingeschränkt vergleichbar, da die Datenbasis identisch ist.

Künftige Studien, die das Einbeziehen von Fotografien in ihren Methodenvergleich gegen einen videobasierten Standard erwägen, sollten Fotokameras in derselben Anzahl wie Videokameras einsetzen, die vollautomatisch auslösen und in unmittelbarer räumlicher Nähe zu den Videokameras positioniert sind. Beim Einbeziehen von Direktbeobachtungen ist es ratsam, die Position des Beobachters so zu wählen, dass sie möglichst nahe an einer der Videokameras liegt, ohne das

Sichtfeld einzuschränken. Sobald in einen Methodenvergleich Direktbeobachtungen eingeschlossen werden, ist durch den dort unvermeidbaren zeitlichen Versatz selbst bei Vollautomatisierung der Video- und Fotoaufnahmen eine vollständig synchrone Datenaufnahme ausgeschlossen.

5.2 Reliabilitäts- und Effizienzbewertung der Intervalle

In den Reliabilitätstests zeigten die Alternativintervalle keine durchgängige Unter- oder Überschätzung des Intervalllängenvergleichsstandards (1 Minute) und die Höhe der Abweichungen war durchgängig gering. Dies geht vor allem auf die durch Vor- und Zurückspulen komplettierten Datensätze zurück. Demzufolge entfielen fehlende Werte als eine Abweichungsquelle und die Unterschiede sind allein auf die verschiedenen Zeitraster zurückzuführen. Als direkte Folge des Hochrechnens der immer geringeren Datenmengen, nahm mit zunehmender Intervalllänge die Unschärfe (repräsentiert durch die verschiedenen Streuungsmaße) teilweise sprunghaft zu; bei den Stalldaten nach dem 5-Minuten-Intervall, bei den Weidedaten nach dem 8-Minuten-Intervall.

Bei den Stalldaten, die sich gegenüber den Weidedaten durch insgesamt deutlich geringere Futteraufnahmehäufigkeiten auszeichneten, deuteten Musterbildungen in den Bland-Altman-Diagrammen ab 8 Minuten auf einen artifiziellen systematischen Fehler hin: niedrige Häufigkeiten wurden eher unterschätzt, höhere eher überschätzt. Auch dies wies auf das Erreichen einer kritischen Datengrenze hin.

Bei strikter Anwendung des numerischen Reliabilitäts-Akzeptanzkriteriums von mindestens 90 % Übereinstimmung ergab bei den Stalldaten einzig die Intervalllänge von 3 Minuten hinreichend reliable Daten. Bei den Weidedaten erfüllten darüber hinaus 5 und 8 Minuten das Gütekriterium. Unter dem reinen Aspekt der Effizienz wäre bei den Weidedaten dem 8-Minuten-Intervall der Vorzug zu geben. Um im vorliegenden Versuch eine unmittelbare Vergleichbarkeit von Stall- und Weidedaten zu erreichen, muss für beide Datensätze die Intervalllänge von 3 Minuten Anwendung finden.

Die in den Vergleich der vorliegenden Studie einbezogenen Intervalllängen von 3 bis 12 Minuten waren in Relation zu anderen Studien im unteren Längenbereich angesiedelt (Tabelle 2). Die Eignungsbeurteilungen der Zeitraster in der vorliegenden Untersuchung fallen teilweise deutlich restriktiver aus als in der vergleichbaren Literatur. Ausschlaggebend hierfür sind wahrscheinlich vorrangig zwei Aspekte: Unterschiede in der Reliabilitätsbestimmung und -bewertung sowie Unterschiede in den Rahmenbedingungen (vor allem Größe der untersuchten Tiergruppen, siehe weiter unten).

Die Vorgehensweisen der Intervallvergleiche sowie die angelegten Reliabilitätskriterien und -grenzwerte, werden vor allem in Anwendungsstudien selten explizit angegeben. Die Mehrzahl der Untersuchungen (Tabelle 2) sind reine Anwendungsstudien, meist ohne vorangestellte Eignungstests. Von den insgesamt vier Methodenstudien in Tabelle 2 verwendete keine die spezifisch für methodische Vergleiche entwickelten Bland-Altman-Diagramme. Zur Bestimmung des Übereinstimmungsausmaßes wurden klassische statistische Verfahren eingesetzt (Korrelationen bei Mitlöhner et al. (2001) und Mattachini et al. (2011), Regressionen bei Desnoyers et al. (2009) und Chi-Quadrat-Tests bei Tosi et al. (2006)). Die Beurteilung der Übereinstimmungsgüte erfolgte durchgängig allein anhand des Signifikanzniveaus.

Neben Unterschieden in der Methodik der Reliabilitätsbewertung erschweren Unterschiede in den Rahmenbedingungen der Untersuchungen die Vergleichbarkeit sowohl untereinander als auch mit der vorliegenden Studie. Zweifelsohne bestehen zwischen den in der Literatur untersuchten und zu Vergleichszwecken herangezogenen Wiederkäuerarten (Ziegen, Schafe und Rinder; Tabelle 2) Unterschiede in der Körpergröße und den Charakteristika ihres Futteraufnahmeverhaltens, die jeweils Auswirkungen auf die Eignung verschiedener Methoden und vor allem Intervalllängen haben. Ein weiterer entscheidender Faktor sowohl bei der Wahl der Methode als auch bei der Wahl des größtmöglichen Intervalls ist die Anzahl der Untersuchungstiere, deren Verhalten gleichzeitig erfasst wird (Lehner, 1996). Meist beträgt sie fünf oder sechs und maximal zehn Tiere (Tabelle 2). Oft wird auch nur das Verhalten eines einzelnen Tiers erfasst. Selten sind Studien mit bis zu 30 Gruppenmitgliedern und Gruppengrößen von über 40 Tieren stellen die Ausnahme dar.

5.3 Stall versus Weide: Relevanz des Anteils des zu untersuchenden Verhaltens

In der vorliegenden Studie wurden alle drei visuellen Methoden sowohl im Stall als auch auf der Weide angewendet. Trotz umfassender Recherche konnte keine andere Untersuchung gefunden werden, die das Raufutteraufnahmeverhalten von Ziegen unter beiden Bedingungen vergleicht.

Bei Datenerfassungen im Stall findet mehrheitlich die Analyse von Videoaufzeichnungen und auf der Weide die Direktbeobachtung Anwendung (Tabelle 2). Dies steht wahrscheinlich weniger im Zusammenhang mit Eignungsunterschieden der Methoden hinsichtlich der Erfassung der beiden Unterkategorien des Futteraufnahmeverhaltens (Heu- und Grasfutteraufnahme, siehe unten) als vielmehr mit den praktischen Schwierigkeiten der Einrichtung eines Videoaufzeichnungssystems auf der Weide (Kapitel 3.2).

Dass für eine reliable Erfassung des Futteraufnahmeverhaltens im Stall kürzere Intervalldauern erforderlich waren als auf der Weide, steht in direktem Zusammenhang mit den Unterschieden in der relativen Häufigkeit von Heuaufnahme- und Graseverhalten: In der vorliegenden Studie wurden die Ziegen auf der Weide durchschnittlich knapp fünfmal so häufig Futter aufnehmend erfasst wie im Stall (circa 58 % versus circa 12 % Zeitanteil). Heu- und Grünfutteraufnahme unterscheiden sich trotz ihrer Zugehörigkeit zum selben Verhaltensbereich (Futteraufnahme) hinsichtlich der Art des Futterangebots sowie der Rahmenbedingungen der Futteraufnahme deutlich voneinander: Im Stall wurde ausschließlich Heu vorgelegt und die Futteraufnahme konnte nur am Futtertisch stattfinden. Wegen der hohen, räumlich konzentrierten Futterangebotsdichte konnten zum einen relativ schnell große Mengen aufgenommen werden. Zum anderen war das Heu stärker monopolisierbar und das Futteraufnahmeverhalten demzufolge anfälliger für Störungen durch Sozialpartner. Auf der Weide hingegen war die Grünfutterverteilung niedriger und homogener. Die Aufnahme entsprechender Mengen erforderte mehr Zeit, war aber zugleich weniger störanfällig.

Der vorliegende Vergleich der Heu- und Grünfutteraufnahmehäufigkeiten illustriert anschaulich die weitreichende Bedeutung des Anteils der zeitlichen Organisation des zu untersuchenden Verhaltens für methodische Entscheidungen (vergleiche Lehner, 1996). Zum einen führte bei den Stalldaten der geringere Anteil an Datenpunkten, zu denen eine Futteraufnahme stattfand, bei den längeren Alternativintervallen zu grafischen Hinweisen auf eine zunehmend kritische Ausdünnung der Daten. Zum anderen wirkten sich bei den niedrigen Häufigkeiten der Stalldaten die Methodenunterschiede stärker aus. Bei den höheren Häufigkeiten der Weidedaten hingegen waren die Ergebnisse der verschiedenen Methoden bemerkenswert ähnlich. Verhalten, das einen relativ großen Anteil einnimmt, ist „robuster" gegenüber methodenspezifischen Eigenheiten und auch Unterschieden in der Intervalllänge, denn die „Trefferquote" fällt allgemein höher aus. In diesem Fall hat auch die Dauer der einzelnen Verhaltenseinheiten weniger Auswirkungen, da selbst bei kurzen Dauern eine entsprechend höhere Häufigkeit vorliegt. Bei seltenerem Verhalten kommt der Dauer der Verhaltenseinheiten eine sehr viel größere Bedeutung zu. Dies gilt vor allem im Hinblick auf das Verhältnis von (mittlerer) Verhaltensdauer zu Sampling-Intervalllänge (Altmann, 1974).

Bei der Konzeption zukünftiger Anwendungs- und Vergleichsstudien erscheint es daher zum anderen einen empfehlenswert, bei der (Vor-)Auswahl von reliablen Methoden und den effizientesten Intervallen die Orientierung nicht primär anhand des übergeordneten Verhaltensbereichs vorzunehmen (zum Beispiel Futteraufnahme, Lokomotion, Komfortverhalten, Interaktionen). Stattdessen sollte vorrangig die zeitliche Organisation (Dauer und Häufigkeit, Gesamtanteil) herangezogen werden, da diese zwischen Verhaltenskategorien verschiedener Funktionsbereiche mitunter ähnlicher sein kann als innerhalb desselben Bereichs. Dazu ist es ratsam, im Vorfeld den Anteil des zu untersuchenden Verhaltens am Gesamtverhalten zu ermitteln (vergleiche Martin und Bateson, 2007); idealerweise wird auch die mittlere Dauer bestimmt. Bei einem relativ niedrigen Anteil des Zielverhaltens wird ein vorgeschalteter Methodenvergleich empfohlen, da die methodenspezifischen Eigenschaften über das Erfüllen des Reliabilitäts-Akzeptanzkriteriums entscheiden können. Bei einem hohen Anteil hingegen tritt die Bedeutung einer „durchoptimierten" Methodenwahl zurück und die Praktikabilität unter den jeweiligen Rahmenbedingungen kann stärker berücksichtigt werden. Beispielsweise können für die Datenerfassung im Freiland, bei der eine vollständige Videoabdeckung bei größeren Herden und/oder Arealen mit schwer einsehbarer Topografie oft nur mit beträchtlichem Aufwand zu gewährleisten ist, direkt Fotografien oder Direktbeobachtung zum Einsatz kommen.

6 Schlussfolgerungen

Die hinsichtlich Reliabilität und Anwendungseffizienz geeignetste visuelle Methode und Intervalllänge können nicht im Vorfeld allein anhand von theoretischen Überlegungen ermittelt werden, sondern erfordern eine empirische Überprüfung. Das Spektrum potentiell geeigneter Methoden und Zeitraster kann anhand ähnlicher Studien eingegrenzt werden. Dabei ist neben der Herdengröße und Tierart sowie den räumlichen Dimensionen des Untersuchungsareals die zeitliche Organisation des jeweiligen Verhaltens (Häufigkeit, Dauer, Anteil) bedeutsam; ihre Relevanz kann mitunter größer sein als die der Zugehörigkeit zum übergeordneten Verhaltensbereich. Im Vorfeld der Datenaufnahme einer Anwendungsstudie wird eine Reliabilitätsprüfung explizit angeraten. Hierfür bietet die vorliegende Studie ein erprobtes, mehrstufiges Vorgehen an. Für das Erstellen des Referenzstandard-Datensatzes werden Videoaufzeichnungen empfohlen, da bei zeitgerasterten Auswertungen die Vollständigkeit der Daten durch gezieltes Vor- und Zurückspulen erhöht werden kann. Der als Ergänzung zu den Bland-Altman-Kennwerten vorgestellte Median der prozentualen Abweichungen und sein 10 %-Grenzwert geben ein striktes und präzises, quantitatives Akzeptanzkriterium an die Hand. In der vorliegenden Studie fallen die Eignungsbeurteilungen der Intervalllängen vor allem bei Direktbeobachtungen und Videoauswertungen teilweise deutlich restriktiver aus als in der vergleichbaren Literatur.

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Effects of using indigenous heritage sheep breeds in organic and low-input production systems on production efficiency and animal welfare in Romania

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Abstract

Romania ranks third in the EU28 in terms of sheep numbers (9.8 millions), having a self-sufficiency for sheep meat of 150 % and therefore exports are important at national level. Objectives of the current research trials were: i) to evaluate the potential of the Turcana breed to produce organic lamb meat under highland pasture-based conditions; ii) to evaluate the overall resistance of the breed and fitness indicators, in comparison with two native breeds, reared under low-input conditions; iii) to study the genetic base using molecular assisted selection in order to produce hypoallergenic milk and derived milk products. The conventional pasture from the current project had a potential of production of 189 kg/ha for Turcana purebreds, and of 236 kg/ha for F_1German Blackheaded x Turcana (GBxTA) crossbreed lambs. While for the organic pasture, it was estimated a production potential of 191 kg of meat per hectar while rearing Turcana purebred lambs, and of 240 kg/ha for the F_1GBxTA dual-breeds. In the current preliminary study, the genetic polymorphism of ovine β-casein gene in the Romanian Zackel breed was highlighted, using TaqMan assay. β-casein in sheep is strongly correlated to economically important milk quantitative traits, being a first step in introducing genomic selection for the production of organic hypoallergenic sheep milk and derived products.

Keywords: *Romanian Zackel sheep, Turcana sheep, organic lamb production, animal welfare, β-casein*

Zusammenfassung

Bedeutung lokaler Schafrassen für die Produktionseffizienz und das Tierwohl in ökologischen und Low-input-Produktionssystemen in Rumänien

In Rumänien gibt es rund 9,8 Millionen Schafe und damit steht das Land an Platz drei in der EU28. Der Selbstversorgungsgrad liegt bei Schaffleisch bei 150 % und Exporte sind erforderlich. Qualitätsverbesserungen sind die Herausforderungen der Schafhaltung, um auf internationalen Märkten wettbewerbsfähig zu bleiben. Ökologisch zertifiziertes Schaffleisch und Schafmilchprodukte können eine Möglichkeit sein, die Schafhaltung ökonomisch nachhaltig zu betreiben. In aktuellen Versuchen wurde untersucht, wie i) sich die verbreitete Turcana Schafrasse auf Dauergrünland im Hochland für eine ökologische Schaffleischproduktion eignet, ii) sich die Rasse in Widerstandsfähigkeit und Fitness im Vergleich zu anderen lokalen Rassen verhält und iii) welche Rolle die Genetik in der Produktion von anti-allergener Schafmilch und deren Produkten spielt. Es konnten auf konventionell bewirtschafteten Weiden pro Hektar und Jahr 189 kg Lammfleisch mit reinrassigen Turkana und 236 kg mit F_1-Kreuzungen aus Deutsches Schwarzkopf x Turcana produziert werden. Auf ökologisch bewirtschafteten Weiden lagen die Werte in ähnlicher Höhe (191 kg bzw. 240 kg Lammfleisch). Es konnte festgestellt werden, dass β-Kasein in der rumänischen Zackel-Schafmilch besonders hoch ist. Dieses ist ein wertgebender Inhaltstoff und wichtig für die Verarbeitung zu Schafkäse.

Schlüsselwörter: *Rumänisches Zackelschaf, Turcanaschaf, Ökologische Lammfleischproduktion, Tierwohl, β-Kasein*

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1 Introduction

In Europe, sheep production systems vary greatly among countries and regions. In most Mediterranean countries, the production of dairy sheep is predominant (Todaro et al., 2015; Rahmann, 2006), while in North, Central and Eastern Europe, meat has become the main product (Sargison, 2008). The substantial diversity among sheep breeds, production environments and management systems requires systematic and comprehensive breed evaluations, in order to allow producers to identify genotypes that are best suited for their production systems and meet current market demands (Leeds et al., 2012). Furthermore, exotic breeds are often being introduced into various rearing systems without adequate knowledge about the acclimatization ability to those specific conditions (Browning et al., 2011), which can lead to poor efficiency in sheep production and reproduction, and have detrimental impacts on the environment and animal welfare (Hristov et al., 2013; Alemseged and Hacker, 2014; Rahmann, 2013).

Currently 85.5 million sheep are being reared in the EU (Eurostat, 2016), with a total annual production of 925.000 tonnes of sheep meat, having a self-sufficiency rate of 88 %. The EU exports around 8 % of its total production, while imports are around 212.000 tonnes/year, mainly coming from New Zealand and Australia (94 %), which represents 23 % the EU's own consumption (DG-AGRI, 2013). Moreover, the EU sheep numbers have decreased continuously during the last 10 years, reaching 85.2 % in 2014, compared to year 2004.

In Eastern and Southern Europe, majority (over 85 %) of the sheep and goats are being reared in mountainous and disadvantageous areas, called Less Favoured Areas (LFAs) as defined in Dir.75/268/EEC, having an important economic, social and ecological role, and also contributing to the conservation of the environment (Sossidou et al., 2013; Rahmann et al., 2016). With most of the local breeds reared belonging to the Zackel and Tsigai strains (Kusza et al., 2008; Gavojdian et al., 2013).

Romania ranks third in the EU in terms of sheep numbers (9.8 millions), having a self-sufficiency for sheep meat of 150 % and therefore exports are important at national level (DG-AGRI, 2013). Over the last years, exports of live animals increased significantly, with exports of live lambs going mainly to the Middle East and North Africa. Moreover, the country has a pasture surface of 4.9 million ha, which could sustain up to 16 million sheep (Dragomir, 2009). With more than 95 % of sheep being reared under extensive low-input production systems, and the breed structure being dominated by indigenous, unimproved breeds (Turcana and Tsigai).

Romanian indigenous Turcana, accounting for over six million breeding ewes (Ilisiu et al., 2010), is one of the most representative breed belonging to the Zackel group, reared in 14 countries from Central, Eastern and South-Eastern Europe. With adult body weights of 30 to 50 kg in ewes and 60 to 80 kg in rams, growth rates in unweaned lambs of 110 to 180 g/day (Kusza et al., 2015), milk yields estimates of 60 to 150 kg/lactation and prolificacy rates (litter rate) ranging between 105 to 130 % (Budai et al., 2013). Overall, the meat production potential of the breed is modest, making the breed uncompetitive for the current market demands.

Objectives of the current research trials were: i) to evaluate the potential of the Turcana breed to produce organic lamb meat under highland pasture-based conditions; ii) to evaluate the overall organic resistance of the breed and fitness indicators, in comparison with two native breeds, reared under low-input conditions; iii) to study the genetic base using molecular assisted selection in order to produce hypoallergenic milk and derived milk products.

2 Material and methods

2.1 Organic lamb meat production conditions

The trial was initiated starting autumn 2015 at the Research and Development Station for Sheep and Goats from Caransebes (45°25'N/22°13'E). Caransebes region has an elevation of 280 m above sea level and a total annual precipitation of 737.2 mm, with a mean annual temperature of 12.9 °C. The project herd consisted of 90 multiparous purebred Turcana ewes, managed under organic rearing conditions as stipulated by the Council Regulations of the European Comission (EEC, 1991/2092 and EEC, 1999/1804; Rahmann, 2013) on standards of organic animal husbandry. Two breeding herds were set-up, with half of the ewes (n = 45), randomly selected being mated with Tucana purebred rams, while the second group of ewes were exposed to German Blackheaded Mutton (Deutsches Schwarzkoepfiges Fleischschaf) (Rahmann et al., 2001; Rahmann, 2000). Ram/ewe ratio was of 1:25, for three consecutive oestrous cycles (51 days), with the reproduction season starting in mid September. Nutritional flushing was practiced for three weeks before the mating seasons, in addition, all animals had free access to potable water and mineral blocks year around. Animals were housed indoors during winter for a period of 120 days, on deep straw bedding, with a space allowance of 1.8 m^2 and 0.5 m^2 per ewe and lamb, respectively. Ewes received high-quality clovers and pasture hay *ad libitum*, with an additional 200 g of concentrates in late gestation and during suckling period. Hay and concentrates were organically produced on farm. Creep feeding of lambs was not practiced, they were solely reliant on the dams milk production. Lambs were weaned at 65 ± 5 days of age.

After weaning (April, 2016), lambs were divided into two groups of 40 individuals each (20 Turcana purebreds and 20 F_1 German Blackheaded x Turcana), balanced for body weights and sex among groups and genotypes. Group I was managed under conventional conditions, on a cultivated pasture (control group). Group II was managed under organic-pasture conditions (experimental group). Both groups were kept exclusively on pasture for a period of four months, with a gradual transition from indoor housing to pasture of 10 days. Rotational fenced grazing was practiced, each of the two pastures having 6 identical in size areas (1600 m^2). Lambs were provided on pasture with shelter and shade, and had non-restricted access to water and mineral blocks.

Figure 1
Turcana ewe (photo: Gavojdian D.)

Figure 2
Tsigai ewe (photo: Gavojdian D.)

The conventional pasture was fertilized initially in two stages, first in early spring 2012 with a dose of $N_{100}P_{70}K_{70}$, and secondly, after the first harvest with a dose of N_{50}. In 2013, fertilization was made by administrating N_{100} in early spring and N_{50} after the first harvest. During both years, the pasture was used to produce bailed hay, and was not used for grazing.

The organic pasture was fertilized in early-spring 2012 by direct grazing with the animals, at a stocking rate of 1 adult sheep/1.5 m^2, kept for four consecutive nights. After the animals removal from the pasture, minimum tillage works were done and the pasture was over-seeded using a mix of grasses and legumes having the following structure: *Lolium perenne* 40 % (8 kg/ha); *Festuca pratensis* 30 % (6 kg/ha); *Festuca arundinacea* 10 % (2 kg/ha); *Lotus corniculatus* 10 % (2 kg/ha) and *Trifolium repens* 10 % (2 kg/ha). Following a conversion period of two years (between 2013 and 2014), the pasture was used exclusively to produce hay, and was not directly grazed by animals. Data on the current experimental design, data collection and pasture management was previously published in more detail by Sauer et al., 2015.

2.2 Health indicators and fitness outputs

The study was carried out in three commercial farms, as follows: *i)* the first commercial sheep farm was rearing Turcana purebred ewes (Sanpetru Mare, Timis county, 46°5'14.14"N,20°47'26.69"E); ii) the second commercial farm was rearing Tsigai ewes (Chisineu Cris, Arad county, 46°31'21"N,21°30'57"E) and *iii)* third commercial farm rearing Transylvanian Merino ewes, as gene reserve (Sanislau, Satu Mare county, 47°38'16"N,22°19'32"E). All three farms were applying the traditional semi-intensive production system, with ewes being managed under communal natural pastures between April till November, and then indoor housing the ewes during winter, with stock feeding hay (1.5 to 2 kg of alfalfa and pasture hay) and 200 to 300 g/day of concentrates. Lambing season started in mid-February and lasted until end of March.

Ewes were between 1.5 and 8 years old, with age and parity balanced across genotypes and representing a diverse sampling of genetic lines within each flock and breed. The study herds consisted of 226 Turcana, 260 Tsigai and 560 Transylvanian Merino breeding ewes.

Data was collected from the veterinarian records and the farms own records for a period of 12 months (August 2015 to September 2016). All three flocks were included in the official performance recording schemes.

Figure 3
Transylvanian Merino ram (photo: Gavojdian D.)

Occurrence rates of the following health disorders were recorded: mastitis, lameness, pneumonia and abortion. Annual attrition rates were determined by identifying ewes in the herd at the start of the production year not present in the herd at the end of the production year. Death and culling because of all reasons were included when evaluating attrition rates. Data on the reproductive performance of ewes (conception rate, litter size and survival rates of unweaned lambs) were recorded for all three breeds.

In order to assess the effect of the breed on the above mentioned health disorders, as well as on the reproduction performance of the ewes, the STATISTICA StatSoft® Tulsa OK software was used (Hill and Lewicki, 2007). The Main Effect ANOVA analysis of variance was applied. Given that data was recorded in three farms, the model included this as correction factor. The model used for statistical analysis is presented below:

$$y_{ijk} = \mu + PC_i + g_j + e_{ijk}$$

where

y_{ijk} is the studied reproduction or health trait;

μ is the overall mean;

PC_i represents the fix effect of the production system with three levels: farm 1, 2 and 3;

g_j represents the random effect of the genotype with three levels: Turcana, Tsigai and Transylvanian Merino;

and

e_{ijk} is the residual effect.

When significant effects of the genotype were observed, the comparison among populations was tested by performing contrast analysis, using Tukey test.

2.3 Genomic selection for hypoallergenic milk

Turcana purebred animals (n = 111) were sampled in the present study to detect genetic polymorphism at the *CSN2* loci. Hair follicles were collected form adult breeding ewes, between 1.5 and 8 years old, with balanced age and parity within the flock and representing a diverse sampling of genetic lines. All animals included into the study, were part of the official performance recording system, with ancestry of the animals known for at least two generations.

Extraction of genomical DNAs from hair follicles were performed using method of FAO/IAEA (2004) and they were stored on -20 °C until further analysis. Concentration and quality of the extracted DNAs were measured and checked by NanoDrop Spectrophotometer (Thermo Scientific, USA).

Taqman (Applied Biosystems, USA) genotyping probe for ovine β-casein was designed for the fast genotyping of the A>G mutation in part of an exon 7 at position 183 (Met183QVal183). Concentration of the DNAs used for the genotyping assay were 50 ng.

The following primers and probe were designed and used: forward primer: 5'- CGTGCTGTCCCTTTCTCA-3', reverse primer: 5'-TTTTGTAGGGCTCTTAATTACTCAA-3', probe A/G: CCCCAGAGAGAT[A/G]TGCCCATCC.

After the PCR was finished, allelic discrimination analysis was performed using Applied Biosystems software. Samples were automatically grouped according to their genotypes. The results of the TaqMan allelic discrimination assay were graphically interpreted and all of the samples were correctly assigned the right genotype.

The research activities were performed in accordance with the European Union's Directive for animal experimentation (EU-Directive 2010/63/EU).

3 Results and discussion

3.1 Lamb meat production under organic and conventional systems

Under pasture conditions, the Turcana lambs had growth rates of 206.0 ± 0.14 g/day and 182.7 ± 0.13 g/day, under conventional and organic systems, respectively (Table 1). Production system did influence ($p \leq 0.05$) the growth rates in the purebred Turcana lambs. As for the F_1German Blackheaded x Turcana lambs (F_1GBxTA), the production system influenced significantly ($p \leq 0.05$) the growth rates, with average values of 258.0 ± 0.12 g/day and 227.3 ± 0.10 g/day being recorded in the conventional and organic systems, respectively.

Based on lamb growth rates and the pasture production estimates, the potential of meat production for the two genotypes and two pasture types was assessed. The conventional pasture from the current project had a potential of production of 189 kg/ha for Turcana purebreds, and of 236 kg/ha for F_1GBxTA crossbreed lambs. While for the organic pasture, it was estimated a production potential of 191 kg of meat per hectare while rearing Turcana purebred lambs, and of 240 kg/ha for the F_1GBxTA dual-breeds. Current results are in accordance with previous reports of Ghita et al. (2010), which studied the fattening aptitudes of local Romanian sheep breeds, reared under various production systems. Thus, nutritional strategies in low input and easy to apply in pasture based systems can improve the productive performance of sheep and have the potential to lead to profitable and successful commercial enterprises.

Table 1
Mean (± SEM) for performances of Turcana lambs reared under conventional and organic production systems

Trait	Conventional	Organic
Growth rates in Turcana lambs (g/day)	206.0 ± 0.14[a]	182.7 ± 0.13[b]
Growth rates in F_1GBxTA lambs (g/day)	258.0 ± 0.12[a]	227.3 ± 0.10[b]
Meat production estimates in Turcana lambs (kg/ha)	189 kg	191 kg
Meat production estimates in F_1GBxTA (kg/ha)	236 kg	240 kg

Row means with different superscript differ significantly at $p \leq 0.05$

The technical efficiency and viability of organic and conventional lamb meat production were investigated (Table 2). Overall, the production costs in the organic production system were greater, when compared with the conventional management of the pasture. The pasture seeding related costs being higher with 70.6 %, and those of price/tones of pasture of 31.5 % for the organic pasture, compared to the conventional system. Current results are in accordance with previous reports by Sauer et al. (2015) on organic kid meat production in Romania.

Estimated production costs per kg of lamb meat were higher by 68.2 % when rearing Turcana purebreds, and by 68.3 % when F_1GBxTA crossbreeds were concerned. Altogether, higher production costs should be reflected in the economic returns (EUR/kg of sold live lamb), in order for the farmers to adopt the organic production systems, or for those who chosen this production system to respect the additional regulations. This could be achieved either throughout niche marketing of organic lambs meat products (e.g. development of PDO or PGI labelled food products), or by governmental policies and introduction of subsidies schemes into the sector to aid its development.

Table 2
Technical efficiency of organic and conventional production for lamb meat

Costs categories (in EUR)	Conventional	Organic	Differences
Pasture seeding costs/ha	185.55	316.66	131.11 EUR/ha
Production costs/t of pasture	7.77	10.22	2.45 EUR/t
Annual pasture maintenance costs/ha	105.88	180.47	74.59 EUR/ha
Production costs/kg of Turcana lamb meat	1.51	2.54	1.03 EUR/kg
Production costs/kg of F_1GBxTA lamb meat	1.20	2.02	0.82 EUR/kg

Introduction and use of the German Blackheaded Mutton meat specialized breed into crossbreeding schemes with local unimproved sheep populations has led to a significant increase of both growth rates and lamb meat production per hectare. Taking advantage of the German Blackheaded Mutton meat producing potential, the local low-input breeds high levels of adaptation and organic resistance, and also of the heterosis effects.

3.2 Health and fitness indicators in Romanian native breeds

Comparison of the three main Romanian indigenous sheep breeds for their reproductive performance and organic resistance under European temperate conditions were considered necessary knowledge for the sheep industry as sheep breeds adaptation and welfare tend to be matters of concern. This comparative study was the first attempt to provide information on the reproductive efficiency and health traits in Turcana, Tsigai and Transylvanian Merino breeds under temperate climate conditions found in Eastern Europe.

Health, reproductive and fitness indicators in indigenous heritage breeds are of importance under extensive production systems, especially under organic production, where the use of antibiotics and several treatments are being restricted by the regulations. Health of the flock influences decidedly the economic returns of sheep farms, and genotypes which possess a high organic resistance are desirable. However, health indicators and the fitness related traits have been found to have low heritability rates (0.02 to 0.08), making them unsuitable/unattractive for direct selection in the genetic improvement schemes.

Conception rates for the Turcana, Tsigai and Transylvanian Merino ewes are consistent with those estimated by Krupova et al. (2009) and Padeanu (2001) for the breeds. Significantly lower conception rates were found between the Tsigai and Turcana ($p \leq 0.05$) and the Transylvanian Merino ($p \leq 0.01$), respectively (Table 3).

For the Turcana and Transylvanian Merino breeds, the litter size is similar to reports of Ilisiu et al. (2010) and Padeanu (2010). Considerable lower values for litter size in Tsigai were previously reported by Krupova et al. (2009) and Padeanu et al. (2012). Higher litter size in Tsigai ewes during current trial might be attributed to the good feeding and management conditions. In addition, during previous studies, ewes were reared for both meat and milk productions, while in the current study, the reference flock ewes were lactating for only a short period of time (80 ± 10 days), until the lambs were weaned. This might have led to a better body condition of ewes during mating season and thus to higher ovulation rates.

Findings on lambs weaning rates are consistent with reports for the Turcana and Tsigai lambs reared under European temperate conditions (Padeanu et al., 2012; Gavojdian et al., 2013). Breed disparities were found for the lambs survival rates until weaning, with Tsigai lambs having the highest weaning rate ($p \leq 0.05$), when compared to Turcana and Transylvanian Merino lambs.

Under commercial sheep production systems, the importance of fitness relates to the attrition of breeding ewes. The slight genotype disparities in attrition rates could be explained by the considerable lower selection pressure applied for the unimproved Turcana, and as a result, decisions on voluntary culling of ewes were made only in extreme cases for the genotype. In Tsigai and Transylvanian Merino breeds, the voluntary culling of ewes occurred especially based on traits such as milk yield, fertility, weaning ability, body condition, wool production and health disorders. Data on attrition rates for the three breeds are consistent with estimates reported for commercial sheep flocks (Mekkawy et al., 2009; Gavojdian et al., 2015).

Table 3
Mean (± SEM) for reproductive performance and attrition rates in Turcana, Tsigai and Transylvanian Merino ewes

Breed	Conception rate (%)	Litter size (lambs)	Lambs weaned (%)	Attrition rate (%)
Turcana	97.7 ± 0.98^a	1.17 ± 0.02^a	96.9 ± 1.06^a	14.2 ± 2.33^a
Tsigai	94.1 ± 0.11^b	1.40 ± 0.23^b	98.7 ± 1.38^b	24.4 ± 0.28^b
Transylvanian Merino	97.2 ± 0.14^a	1.14 ± 0.29^a	96.1 ± 1.44^a	20.8 ± 0.37^b

Column means with different superscript differ significantly at $p \leq 0.05$

Results for the three studied populations regarding the mastitis occurrence rates (Table 4) are consistent with estimates of Giadinis et al. (2011), which report occurrence rates for mastitis of over 10 % for commercial sheep flocks. Furthermore, occurrence rates of over 30 % in European dairy flocks are being frequently mentioned in the literature (Bergonier et al., 2003; Bishop et al., 2010).

Mastitis has a negative impact on ewe stay-ability, milk yield, lambs growth and survival, veterinary costs and represents a major concern for animal welfare. Importance of clinical mastitis in the Europe was highlighted by Ligda et al. (2003), which found mastitis to be the main cause for culling in the Greek sheep industry, accounting for 46 % of the attrition cases for the Chios dairy breed.

The current study highlights the low resistance to clinical mastitis of the Tsigai breed. As a result, measures such as including the genetic resistance to mastitis as a trait into the breed's selection indexes should be taken. Somatic cell count (SCC) has been found to be a reliable selection trait (Barillet et al., 2001), which can be used as an indicator to enable selection for increased resistance to subclinical mastitis in the French Lacaune breed (Rupp et al., 2003). For SCC in dairy sheep, heritability estimates reported range between 0.03 and 0.24 (Barillet et al., 2001; Bishop et al., 2010; Makovicky et al., 2014; Rahmann, 2013), depending on the breed. The incidence of clinical mastitis in small ruminants is generally lower than 5 % (Arranz et al., 2012), whereas the prevalence of subclinical mastitis ranges from 10 to 50 % (Sechi et al., 2009). If treated, ewes with subclinical mastitis were found to produce less milk with 15 to 20 %, and in the case of a reinfection, the milk yield to drop with 30 % (Petrovic et al., 2005).

Lameness occurrence rates in the Turcana and Transylvanian Merino breeds were in accordance with previous estimates for the English flocks (FAWC, 2011), which range from 8 to 10 %. In the current study, the Tsigai ewes were found to be more susceptible to lameness, with an incidence of 15.4 %. Therefore, selection should be given to future design of genetic improvement schemes for the breed.

Given the low winter temperatures reached in Romania, pneumonia incidence in Merino flocks is of concern to both scientists and breeders, being a lowland fine wool breed originating from Spain. Higher pneumonia incidence in the Transylvanian Merino population could be attributed to the upgrading of the breed with the Australian Merino, which is not adapted to the colder climate during winter found in Central and Eastern Europe. No available data for comparison on pneumonia occurrence in European countries was found, except for information on flocks infected with Maedi-Visna (Benavides et al., 2013).

According to previous reports, in healthy flocks abortion accounts for less than 2 %, with 5 % occurrence rate being considered as an alarm threshold (Menzies, 2011). Out of the four health disorders studied, abortion has to have the most significant economical and welfare implications, given that abortion will most likely result in culling or death of the ewe.

Table 4
Mean (± SEM) for occurrence rates of mastitis, lameness, pneumonia and abortions in Turcana, Tsigai and Transylvanian Merino ewes

Genotype	Mastitis (%)	Lameness (%)	Pneumonia (%)	Abortion (%)
Turcana	3.11 ± 1.16^{a}	2.6 ± 1.08^{a}	1.3 ± 0.76^{a}	1.7 ± 0.88^{a}
Tsigai	4.8 ± 1.18^{b}	15.4 ± 1.43^{b}	1.8 ± 1.29^{a}	3.4 ± 1.46^{b}
Transylvanian Merino	2.14 ± 0.23^{a}	8.7 ± 1.22^{c}	3.1 ± 1.03^{b}	1.4 ± 1.05^{a}
Column means with different superscript differ significantly at $p \leq 0.05$				

3.3 *Molecular marker assisted selection for hypoallergenic sheep milk*

Aim of the current trial was to identify the genetic polymorphism of β-casein gene in Turcana breed, throughout the use of TaqMan genotyping assay, in order to provide information for future selection schemes of the Romanian indigenous sheep breeds, with the ultimate purpose to produce hypoallergenic sheep milk and derived dairy products (Załęcka et al., 2014).

In the studied population the A variant had a significant higher frequency of 0.97, compared to the G variant of 0.03, thus indicating that variant A is more characteristic of Turcana – Zackel sheep population compared to variant G (Table 5). With similar results being previously reported in other European Zackel breeds, with variant A detecting a higher frequency (50 to 80 %) compared with the G variant, as described by Sztankoova et al. (2011) in Czech Sumatra and Valachian sheep and by Ceriotti et al. (2004). The most frequent genotype was AA (94.59 %) followed by AG (5.41 %). Genotype GG was not found in the Turcana breeds. The distribution of genotypes is in agreement with previous results obtained for other European sheep breeds (Ceriotti et al., 2004; Sztankoova et al., 2011).

Table 5
Frequency of genotype and alleles of Turcana sheep

Breed	Genotype	Number	Frequency of genotype	Allele	Frequency of allele
	GG	0	0	A	0.97
Turcana	AG	6	5.41	G	0.03
	AA	105	94.59	0	0

In sheep and goat αS1-casein (αS1-CN), coded by the CSN1S1 gene, is characterized by extensive qualitative and quantitative polymorphisms. Some alleles are associated with null (i.e., CSN1S1*01) or reduced (i.e., CSN1S1*F) expression of the specific protein (Ballabio et al., 2011).

Almost 50 genetic variants have been described in bovine milk protein genes, and, in the sheep and goats, the number of genetic variants is continuously rising (Marletta et al., 2007). The current preliminary trial is the first attempt to produce hypoallergenic sheep milk throughout the use of genomic selection in Romania, in order to aid consumers affected by food-related allergies. Furthermore, given the rising numbers of persons (especially infants, incidence estimates of 5 to 8 %) affected by this type of allergies, the current research could help sheep breeders to produce and market hypoallergenic products, which to benefit both producers and consumers safety.

4 Conclusions

Current results have proved to be encouraging regarding the potential of the sheep extensive farms from Romania to produce lamb meat under organic rearing systems. However, both farmers and policy makers should be aware and keep in mind both the unconsolidated markets for organically sheep meat found in Eastern Europe, as well as the volatility of the small ruminants meat markets and demand. Further in more depth studies concerning the markets need and potential should be advised, in order for the policy makers to have a more consolidated perspective of the sector in order to formulate proper development strategies of the sector.

For the Tsigai and Transylvanian Merino breeds it would be advisable as to include fitness traits into the future breeding selection schemes, with special focus on mastitis genetic resistance, lameness and ewe stay-ability, in order to improve animal welfare and the overall flock productivity.

In the current preliminary study, the genetic polymorphism of ovine β-casein gene in the Romanian Zackel breed was highlighted, using TaqMan assay. β-casein in sheep is strongly correlated to economically important milk quantitative traits, being a first step in introducing genomic selection for the production of organic hypoallergenic sheep milk and derived products.

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