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Analysis of diesel fuels/biodiesel blends and identification of biodiesel using time-resolved laser-induced fluorescence spectroscopy (TRLFS)

Z. Fan, O. Schröder, and J. Krahel *

Abstract

A method based on time-resolved laser-induced fluorescence spectroscopy (TRLFS) was developed to characterize different fossil diesel fuels and biodiesel blends. The frequency behavior and decay behavior of fluorescence excited at 266 and 355 nm were measured. Differentiation of fuels was achieved by principal component analysis (PCA) of their fluorescence-lifetimes at characteristic emission wavelengths. For the quantification of biodiesel in blends, the quenching-effect on the fluorescence was determined. The results showed that the quenching-effect at the characteristic emission wavelengths (422 nm, 438 nm and 525 nm) with 355 nm laser excitation was unique for biodiesel blends. Based on that, the identification and quantification of the biodiesel was possible. TRLFS is useful for in-situ detection of the biogenic content of biodiesel blends.

Keywords: *time-resolved laser-induced fluorescence spectroscopy (TRLFS), diesel fuel, biodiesel, identification, quantification*

Zusammenfassung

Analyse und Identifizierung von Dieselkraftstoffen und Biodieselmischungen mittels zeitaufgelöster laser-induzierter Fluoreszenzspektroskopie (ZLIF)

Durch die zeitaufgelöste laserinduzierte Fluoreszenzspektroskopie (ZLIF) gelingt die Identifizierung verschiedener fossiler Dieselkraftstoffe und deren Mischungen mit Biodiesel. Das Frequenz- und Abklingverhalten der Fluoreszenz wurde bei Anregungswellenlängen von 266 nm und 355 nm bestimmt. Die Unterscheidung der Kraftstoffe erfolgte mittels mathematischer Hauptkomponentenanalyse (PCA). Zur Quantifizierung des Biodieselgehalts von Dieselkraftstoffen wurde der Fluoreszenzlöscheffekt genutzt.

Im Ergebnis zeigt sich, dass für Biodieselmischkraftstoffe der Fluoreszenzlöscheffekt bei Emissionswellenlängen von 422 nm, 438 nm und 525 nm unter der Anregungswellenlänge von jeweils 355 nm charakteristisch ist. Auf dieser Basis sind die Identifizierung der Biodieselsorte und die Quantifizierung der Biodieselskonzentration möglich.

Schlüsselwörter: *Zeitaufgelöste laserinduzierte Fluoreszenzspektroskopie (ZLIF), Dieselkraftstoff, Biodiesel, Identifizierung, Quantifizierung*

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1 Introduction

The limited resources of fossil fuels and the negative climate impacts of greenhouse gases released from their combustion desire for alternative, renewable and CO₂-neutral fuels. One such fuel is biodiesel which produced by the triglyceride transesterification from vegetable, animal or waste oil (Knothe, 2001). Due to the variety of sources of raw materials used and natural variations of the content of the individual ingredients in raw materials, the optimum performance and emissions of diesel engine operation is a particular challenge. Therefore, it is of great economic and ecological importance to identify biodiesel in diesel fuel blends to achieve optimum performance and emissions.

In this context Munack and Krahel developed a biodiesel sensor which enables to determine the concentration of biodiesel (main components are Fatty Acid Methyl Ester – FAME) in conventional diesel fuel. The sensor operates on the measurement of the dielectric number and is suitable for biodiesel and its blends with diesel fuel as well as for the quantification of ethanol in gasoline (Munack and Krahel, 2003). However this sensor could not identify the composition of conventional diesel fuel and biodiesel.

Some analytical laboratory techniques, e. g. GC-MS and HPLC, can analyze the fuel components (Glover and Bullin, 1989; Plank and Lorbeer, 1995; Lechner et al., 1997; Foglia et al., 2005). However these techniques need sample preparation and are cost and time intensive, so that they cannot be applied for in-situ detection of fuels.

Chuck et al., 2010 report about FT-IR spectroscopy, refractive index and UV-vis spectroscopy to determine biodiesel in blends. Their work showed that FT-IR could be used on-vehicle for the determination of biodiesel content with refractive index measurement providing the fatty acid composition. However because of the cost and complexity both techniques may not be commercially viable. Application of UV-vis for on-vehicle is not considered feasible (Chuck et al., 2010).

The aim of this paper is to introduce fluorescence sensing technology to identify different fuels and their biodiesel blends. Methods based on fluorescence spectroscopy are easy to use and provide quick and accurate results (Hengsternann and Reuter, 1980; Barbini et al., 1992; Camagni et al., 1991; Patsayeva et al. 2000; Steffens et al., 2011; Scherer et al., 2011; Ralston et al., 1996; Kulkarni et al., 2008; Zawadzki et al., 2007) and may be also used in the future to identify the fuels and determine biodiesel content in the blend. However, these methods are challenging in remote sensing application because it requires the use of tunable lasers which usually have too weak intensities (Quinn et al., 1994; Ryder et al., 2002).

A method of time-resolved laser-induced fluorescence spectroscopy is suitable for remote sensing applications using an intense pulsed Q-switched laser. It has been applied in the identification of fossil fuels (Hegazi et al., 2005; Jacob et al., 2006). Spectral characterization of crude oils was attempted by using the contour diagrams of equal fluorescence intensities. This served as unique fingerprints for the crude oils from the TRLFS-techniques (Hegazi and Hamdan, 2002; Hegazi et al., 2005).

Due to interference of the individual spectra by numerous fluorophores, fluorescence of diesel fuels is complex. The compounds with large conjugated double-bonds or benzene rings are major sources of fluorescence in diesel fuel. The absorption of light in the conjugated system excites a π -electron into an anti-bonding π^* orbital (π - π^* transition). The fluorescence peaks of aromatic compounds are therefore shifted to longer wavelengths (red shift) with increasing alkylation (Dumke and Tescher, 1988; Khorasani, 1987).

The fluorescence lifetime from the TRLFS-measurements characterizes the unique fluorescence property of the fluorophores in diesel fuels and biodiesel blends. Therefore, it can be used for characterization and identification of fuels (Fan and Krahel, 2013). In our previous work we found that TRLFS with 266 nm pulsed laser excitation was able to detect and distinguish the fossil diesel fuels and the biogenic fuels; especially the blends with different biogenic content.

Just like the technique of face recognition and fingerprint identification, for the exploratory analysis of the oils and fuels by the means of fluorescence spectroscopy, the principal component analysis (PCA) can be applied (Guimet, 2005; Schmid, 2009; Sikorska et al., 2012; Fan et al., 2013). PCA was invented in 1901 by Karl Pearson (Pearson, 1901) and the application has been widely described in literature (Bünting, 1999; Jolliffe, 2002; Scott et al., 2003; Guimet, 2005; Schmid, 2009; Kongbonga et al., 2011; Sikorska et al., 2012).

Hence the PCA-technique was used to analyze a two-way matrix of life times. With this method, we achieved a quick and accurate analysis. The result makes the TRLFS-method attractive for online identification of diesel fuels and biodiesel blends.

Caires et al. (2012) reported on quantification of biodiesel content in biodiesel blends by a fluorescence spectrophotometer. In their work, the different blends were prepared from four refined vegetable oils (canola, sunflower, corn and soybean biodiesel; biodiesel content up to 10 % v/v). Using a fluorescence spectrophotometer with excitation at 260 nm, the fluorescence behavior at about 470 nm was same for all blends. This means that quantification of biodiesel based on the fluorescence method at this emission wavelength is independent of the vegetable oil feedstock. However, it is still doubtful whether this conclusion is really true for other FAME. In our previous work, the fluorescence intensity of blend from CEC Reference Diesel Fuel (DF_{Ref}) and RME at the emission wavelength of maximum intensity (338 nm) excited by the 266 nm laser was measured. Very little RME fluorescence was found by the TRLFS at 266 nm laser excitation. We reported that the fluorescence quenching-effect must be considered in determining biodiesel concentrations (from 0 % to 100 % v/v) in biodiesel blends (Fan and Krahel, 2013). This means that at least the fluorescence behavior of RME was not same as the other FAME.

Rapeseed oil and soybean oil are the most important vegetable raw materials for biodiesel in Germany (Bockey, 2013). So blends with biodiesel from rapeseed oil methyl ester were preferentially studied in this work and soybean oil methyl ester (SME) as well, because of its importance for

South Europe and North America. Clear fluorescence could be detected for both biodiesels (RME and SME) when using the TRLFS-technique with 355 nm laser to detect differences between fluorescence intensity and content of two biodiesels. Moreover, when excited by the 355 nm laser, the quenching-effect of biodiesel turned out to be unique. Based on this, not only the identification but also the quantification of biodiesel in the biodiesel blends could be determined.

2 Spectroscopic methods and materials

2.1 Theoretical background

The fluorescence emission in time-resolved measurements can be described like monomolecular reactions if the laser pulse width is very short. Thus, the temporal emission can be described by the simple exponential decay function $I(t)$ with fluorescence lifetime τ (Lampert et al., 1983; Lakowicz et al., 1991):

$$I(t) = I_{t=0} \cdot e^{\left(-\frac{t}{\tau}\right)} \quad (1)$$

Where $I_{t=0}$ is the fluorescence intensity at $t = 0$.

According to this equation, the fluorescence lifetime is the time at which the fluorescence intensity is decayed to $1/e$ (~ 36.8 %) of the original value.

In practice, the influence of the laser pulse width on the fluorescence lifetime must be considered. In this case, the experimentally measured $I_{exp}(t)$ is not the true fluorescence response function from the sample under investigation. The experimentally recorded $I_{exp}(t)$ is a convolution of the instrument response function (excitation laser pulse) $I_{pulse}(t)$ and the exponential decay function $I(t)$ (Grinvald et al., 1974; Terzic et al., 2008):

$$I_{exp}(t) = \int_0^t I_{pulse}(t') \cdot I(t - t') dt' \quad (2)$$

For a complex mixture of N fluorophores, $I(t)$ is the sum of fluorescence intensities of all fluorophores i :

$$I(t) = \sum_{i=1}^N I_{i,t=0} \cdot e^{\left(-\frac{t}{\tau_i}\right)} \quad (3)$$

This equation is in accordance with Linear-Mixture-Model (LMM) (Bünting, 1999; Martens and Naes, 1998) which is the basis for the analysis of the overlaying or interfering signals in this work.

With PCA, an orthogonal linear transformation of observations of the correlated variables into values of uncorrelated variables in a new coordinate system can be made. In this system, the greatest variance of the data is on the first coordinate (also called the first principal component, PC1), the second greatest variance on the second perpendicular

coordinate, and so on. The number of principal components should be much less than the number of original variables. From PCA analysis, usually the terms of component scores also called factor scores (the transformed variable values corresponding to a particular data point), and loadings (the weight by which each standardized original variable should be multiplied to get the component score) are obtained (Pearson, 1901; Jolliffe, 2002; Abdi et al., 2010). The unfold principal component analysis (U-PCA), also named multi-way principal component analysis, is usually applied to analyze a two-way matrix ($\in \mathbb{R}^{I \times (J \times K)}$) obtained after unfolding a three-way array ($\in \mathbb{R}^{I \times J \times K}$) (Westerhuis et al., 1999; Henrion, 1994). In this example, a data set of TRLFS-measurements is "I" the number of samples, "J" the number of emission lengths (λ_{em}) and "K" the number of decay times. In this work, the life times of different fuels were calculated from the TRLFS-spectra and a two-way array ($\in \mathbb{R}^{I \times F}$) was built. Here "F" is the number of selected emission wavelengths at which the lifetime was calculated. Then the dataset was analyzed using the PCA-technique. Compared to the U-PCA, this process avoided unfolding the spectra and also greatly reduced amount of data.

In this work the TRLFS-data were processed using the software MATLAB (MathWorks R2010b).

2.2 Measuring system

The TRLFS system, OPTIMOS, delivered by Optimare (Wilhelmshaven, Germany) is based on the pulse method (time domain) and harmonic wavelength generation.

The remote sensing experimental setup is shown in Figure 1. All components of the OPTIMOS (Nd:YAG laser with Q-switch, harmonic generator, delay generator, detector (ICCD camera with spectrograph) and computer) are integrated into an aluminum rack with operation panel. The OPTIMOS-system has been described in the literature (Optimare, 2005; Fan and Krahel, 2013).

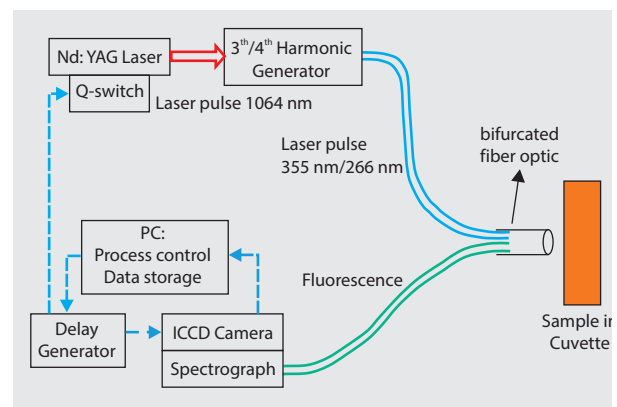


Figure 1
Schematic diagram of remote sensing experimental setup of OPTIMOS-System

The TRLFS measurement was performed on diesel fuels in a quartz cell. The emission spectra of different diesel fuels were

recorded in the range 200 to 600 nm with a specific time gate width (2 ns) and gate step (2 ns) excited at 266 and 355 nm.

2.3 Fuels

Most of the fuels were bought from filling stations or delivered by mineral oil or biofuel companies (e.g. Shell, Aral, China National Petroleum Corporation CNPC) in Europe, Asia and North/South America. Additionally, the Thünen Institute of Agricultural Technology, Braunschweig, Germany, delivered different biodiesel qualities and blends of conventional and advanced biofuels. The fuels were analysed by TRLFS without any prior treatment. To validate how specific the fluorescence of diesel fuel brand is, the fluorescences of the diesel fuel brand from up to five filling stations were tested. No significant differences were detected between the different filling stations. For study of the dependence between fluorescence intensity and biodiesel content, we prepared different biodiesel fuel blends (0 to 100 % v/v).

3 Results

3.1 Exploratory analysis of diesel fuels

3.1.1 TRLFS-spectra of diesel fuels

Figure 2 shows 3D-TRLFS fluorescence spectra of nine different fuels with pulsed 266 nm laser excitation (top, left to

right: Aral Diesel (up to 7 % biodiesel), Aral Ultimate Diesel (biodiesel free, new generation high performance diesel fuel), Shell V-Power Diesel (biodiesel free, new generation high performance diesel fuel); middle: Co-ordinating European Council (CEC) Reference Diesel Fuel by Haltermann (DF_{Ref} , ca. 20 % aromatics), Biodiesel Blend (blend of CEC Reference Diesel, Biodiesel RME and Octanol), hydrotreated vegetable oil HVO (Neste Oil); bottom: Diesel Fuel from CNPC in South China, Diesel Fuel from Argentina, Swedish miljöklass 1 (MK1, aromatics free). These spectra represent fluorescence intensities with color bar as a function of wavelength (x-axis) and decay time (y-axis).

In contrast to the set of 3D-TRLFS spectra with 266 nm excitation, the fluorescence spectra for the same nine fuels with pulsed 355 nm laser excitation are shown in Figure 3.

In Figures 2 and 3, the discriminations of the shapes in the TRLFS spectra are clearly visible to differentiate with both excitations between diesel fuels and their blends with biodiesel. However, it should be noted that for the TRLFS measurement with 355 nm laser excitation, the signals of some fluorophores were lost or shaded out. These fluorophores are usually PAH with two or three aromatic rings (for example, Acenaphthene, Fluorene, Phenanthrene and Naphthalene) or the derivatives of PAH (for example, 1,3-Dimethylnaphthalene and 1,6-Dimethylnaphthalene). Their emission wavelengths are usually shorter than 355 nm (Bünting, 1999; Jacob et al., 2006; Fan et al., 2013). Therefore, it is recommended that for analysis of fluorescence spectra of diesel fuels, the 266 nm laser should be used.

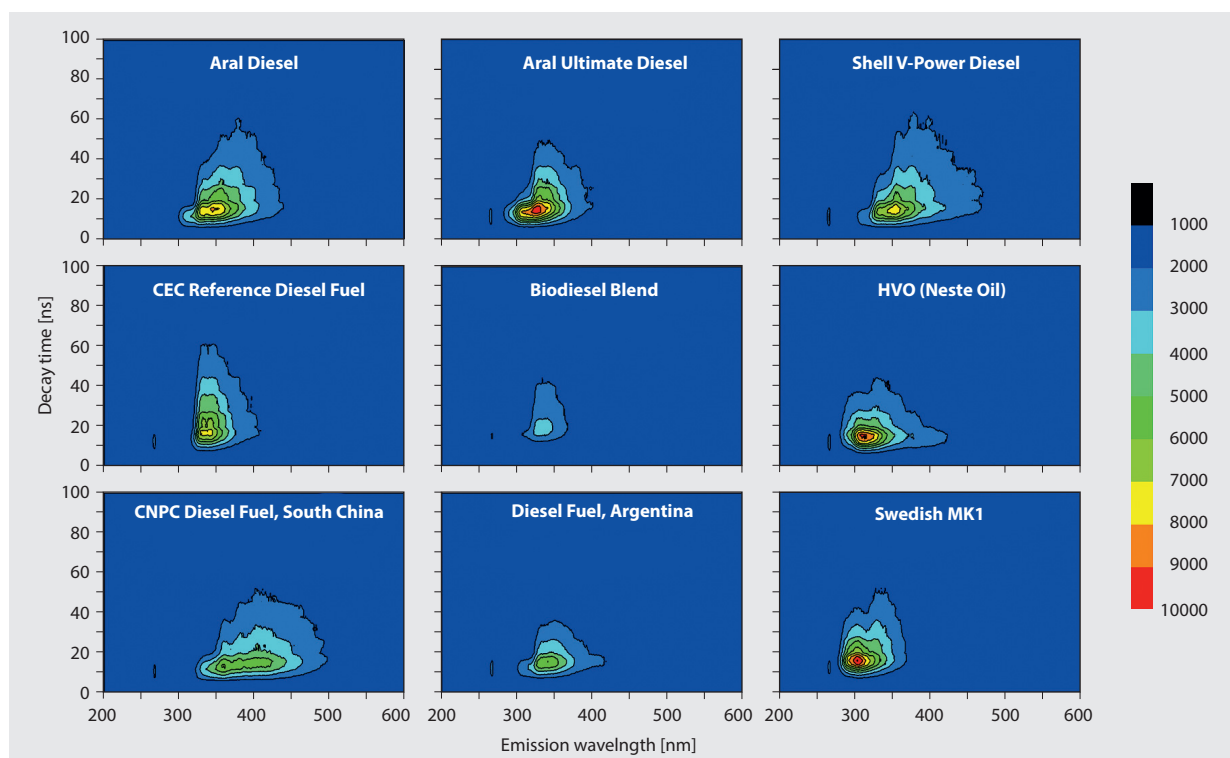


Figure 2
3D-TRLFS fluorescence spectra of nine different fuels, excitation at 266 nm

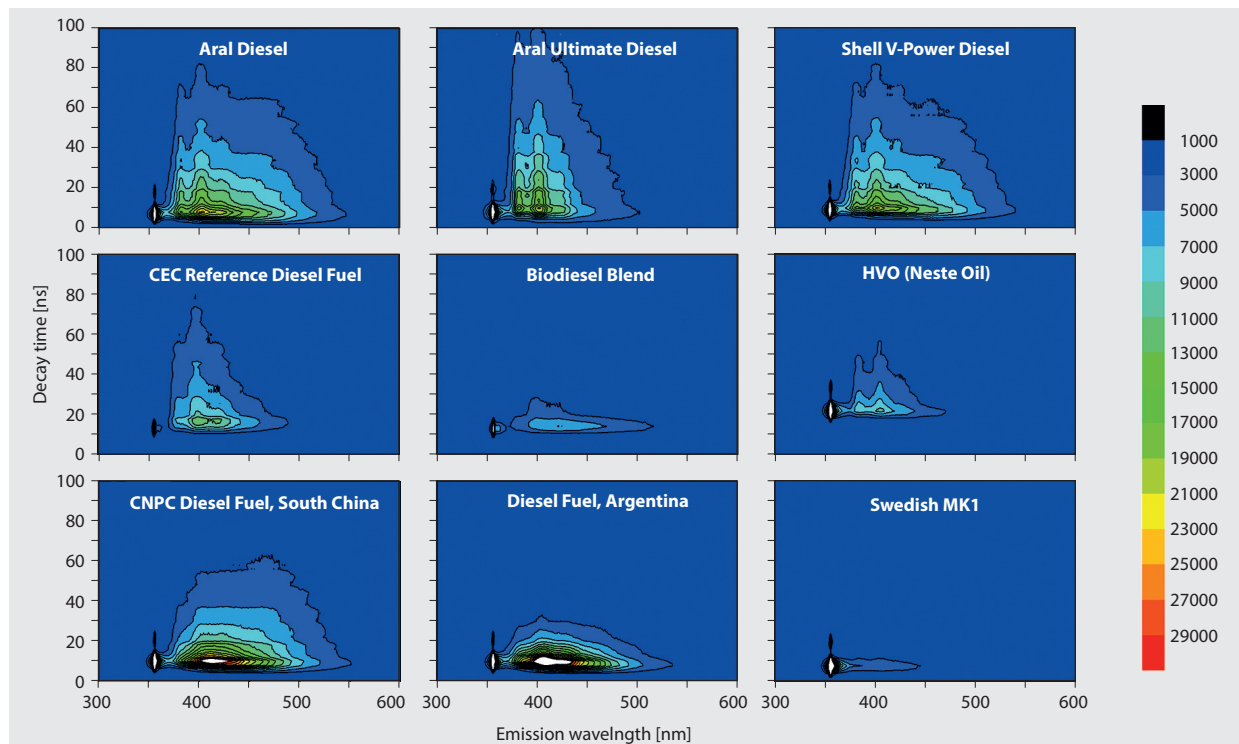


Figure 3
3D-TRLFS fluorescence spectra of nine different fuels, excitation at 355 nm

3.1.2 Principal component analysis

The fluorescence lifetimes for characteristic emission wavelengths were calculated. The characteristic emission wavelengths are the minimal wavelengths at which a maximum fluorescence of a fuel was detected. By comparing the spectra of these diesel fuels and biodiesel blends, nine characteristic emission wavelengths (300, 328, 340, 355, 377, 396, 407, 414 and 423 nm) were selected. The fluorescence lifetimes for these characteristic emission wavelengths were calculated from the decay curve $I_{\lambda}(t)$. The mean fluorescence lifetimes of the different fuels are listed in Table 1.

As mentioned above, the loadings from PCA-method of the measured original variables (fluorescence lifetimes) of fuels

could build a new coordinate system and their scores represent the transformed values of original variables in the new coordinate system. A differentiation of these diesel fuels and biodiesel fuel blends can be obtained by analysis of fluorescence lifetime database using the PCA method.

The score biplot of the first two principal components PC1, PC2 (86.1 % of explained variance) is shown in Figure 4. It shows that the score of the first two principal components of diesel fuels can be well distinguished. That is, first, the score-cluster of same fuels is within a certain range. Second, the score-cluster of diesel fuels can be separated from each other very well.

Table 1

Mean lifetimes (in nanoseconds) of nine fuels at characteristic emission wavelengths

Fuels	Emission wavelengths [nm]								
	300	328	340	355	377	396	407	414	423
Aral Diesel	15	12	12	19	29	37	36	39	41
Aral Ultimate Diesel	7	16	16	18	35	57	58	69	82
Shell V-Power Diesel	14	14	15	22	34	44	44	45	49
CEC Reference Diesel Fuel (DF_{Ref})	27	23	22	24	37	54	47	48	48
Biodiesel Blend from DF_{Ref} , RME and Octanol	14	24	24	28	40	64	53	76	102
HVO (Neste Oil)	12	16	19	21	22	22	21	22	23
CNPC Diesel Fuel, South China	45	9	9	15	21	22	22	22	24
Diesel Fuel, Argentina	14	11	11	13	16	17	16	18	18
Swedish MK1	11	21	26	31	33	40	39	48	55

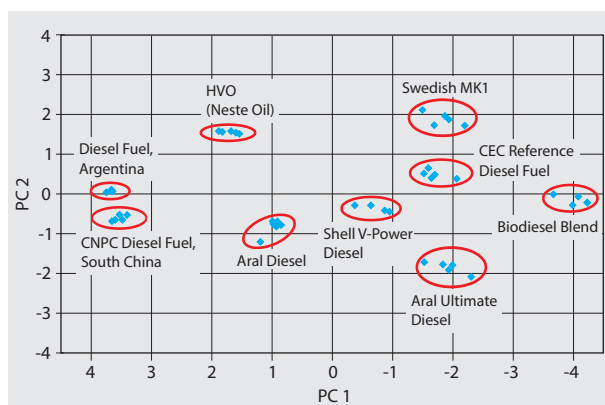


Figure 4
Score biplot from PCA of the first two principal components (PC1: 70.6 % und PC2: 15.5 %)

These nine diesel fuels and biodiesel blends are separated mainly along PC1. Diesel Fuel, Argentina and CNPC Diesel Fuel, South China have the most negative scores; in contrast Biodiesel Blend has the most positive scores.

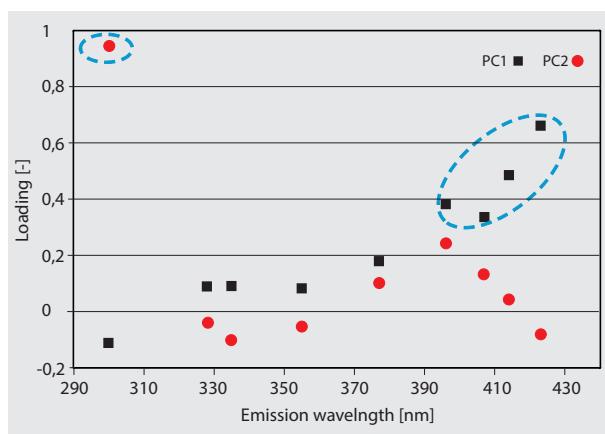


Figure 5
Loading plot from PCA of PC1 and PC2 of the fluorescence lifetime matrix at nine emission wavelengths

The loadings in Figure 5 indicate that a high score in PC1 (70.6 % variance is explained) is mostly related to high emission wavelengths (396, 407, 414 and 423 nm). The fluorescence in the wavelength range was related to PAH with more than three benzene rings (for example, chrysene, dibenz [a,h] anthracene, Benzo [g,h,i] perylene or their derivatives) (Ma et al., 1996; Fan et al., 2013). Despite their low content in the reference diesel fuel (< 0.1 % (m/m), see Appendix A), the fluorescence life time could be determined very well and used to identify diesel fuels, because fluorescence is a very sensitive technique and TRLFS provides excellent measurement stability for the fluorescence life time. The most positive scores of Biodiesel Blend have the longest fluorescence lifetime at these high emission wavelengths. Also the most negative scores in PC1 of Diesel Fuel, Argentina and CNPC

Diesel Fuel, South China have the shortest fluorescence lifetimes at these emission wavelengths.

Conversely, a high score in PC2 (15.5 % variance is explained) is mostly related to a low emission wavelength (300 nm). The fluorescence at this wavelength was related to PAH with two or three benzene rings (e.g. naphthalene, fluorine, anthracene or their derivatives). PC2 doesn't distinguish the diesel fuels as well as PC1, however, it can be seen that HVO (Neste Oil) and Swedish MK1 (which have the most positive scores in PC2) own the longest fluorescence lifetime at low emission wavelength (300 nm). The most negative score in PC2 of Aral Ultimate Diesel had the shortest fluorescence lifetime of 300 nm.

For comparison, U-PCA of the emission spectra of fuels between $\lambda_{EM} = 300$ nm and 530 nm, as well as decay time from 0 to 200 ns, was carried out. The wave length step is 0.383 nm and decay time step is 2 ns. The dimension of a TRLFS spectrum is 624 x 101. The variances accounted for the first two PCs for both analyses and are shown in Table 2.

Table 2

Percentage of explained variance of the PCA and U-PCA models

PCA ^a (life times at nine EMs)		U-PCA ^b (time-resolved emission spectra)	
PC1	PC2	PC1	PC2
70.6 %	15.5 %	47.8 %	31.1 %

a: matrix dimension of life times: 9 x 9
b: matrix dimension of a TRLFS spectrum: 9 x 63024

This shows that for PCA of the life time of fuels, PC1 and PC2 cumulatively explained 86.1 % of the total variance. For U-PCA of the emission spectra of fuels this value was by contrast 78.9 %.

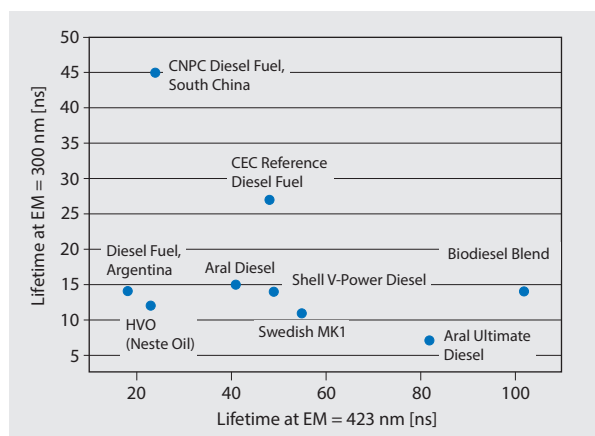


Figure 6
Biplot of the mean fluorescence lifetimes (at EM = 300 nm und 423 nm) of nine fuels

It is possible to distinguish the different diesel fuels and biodiesel fuel blends by their lifetimes at characteristic

wavelengths (300 nm and 423 nm), because the PC1 and PC2 is mostly based on the fluorescence lifetime of these wavelengths. Figure 6 shows a biplot of mean fluorescence lifetimes at these wavelengths from Table 1.

It shows that, just like PCA, by using the two fluorescence lifetimes, that these diesel fuels can be easily well distinguished. Biodiesel Blend has the longest fluorescence lifetime at EM = 423 nm. In contrast, Diesel Fuel, Argentina, CNPC Diesel Fuel, South China and HVO (Neste Oil) have short lifetimes. This correlates to the analysis by PC1 (Figure 4).

At EM = 300 nm, Aral Ultimate Diesel showed the shortest fluorescence lifetime. It is also in parallel to the analysis by PCA. In contrast to PCA, CNPC Diesel Fuel, South China and CEC Reference Diesel Fuel have the longer lifetimes.

3.2 Identification of biodiesel in biodiesel blends

According to Beer's law and the Linear-Mixture-Model under constant experimental conditions (e. g. temperature, pressure, pH), when a fluorophor is analyzed at low concentrations in a homogeneous solution with negligible matrix interference, a simple relationship between fluorescence intensity I_f at a given emission wavelength and biodiesel concentration BX (X is the percentage of biodiesel blended) is given by the following formula (4):

$$I_f = I_{fossil} \cdot (1 - BX) + I_{bio} \cdot BX = k \cdot BX + b \quad (4)$$

Here I_{fossil} and I_{bio} are the fluorescence intensity of pure fossil diesel and pure biodiesel.

To determine the biodiesel content in diesel fuel, blends (B0, B5, B7, B10, B20, B30, B40, B50, B60, B70, B80, B90, B92, B95, B98, B100) were prepared from CEC Reference Diesel Fuel (DF_{Ref} , Appendix A) and biodiesels (RME and SME, Appendix B).

Figure 7 shows that with 266 nm excitation, the fluorescence for the ultraviolet and visible region derived only from the CEC Reference Diesel Fuel and not from RME or SME since the fluorescence of the possible fluorophore (Vitamin E, natural antioxidants) in biodiesel at excitation of 266 nm was undetectable. The TRLFS-spectrum of neat reference diesel showed that the emission wavelength for the maximum fluorescence intensity was 340 nm. Therefore, for the excitation wavelength of 266 nm, the diesel fuel content in fuel blend could be referred to by the fluorescence intensity at the emission wavelength of 340 nm. The biodiesel content can be indirectly calculated using Formula (4).

At 355 nm excitation, the fluorescence derives both from the reference diesel fuel, RME and SME (Figure 8). The emission wavelength for the maximum fluorescence intensity of neat reference diesel is 422 nm. At this emission wavelength, there is no fluorescence from RME. The emission wavelength for the maximum fluorescence intensity of neat RME is 525 nm, which belongs to Vitamin E (Kyriakidis and Skarkalis, 2000; Sayago et al., 2004; Kongbonga, et al. 2011). For neat SME, there are strong fluorescences between 400 nm and

500 nm, which correspond to the remaining fluorophores (oxidation products or tocopherols) of SME from refinement processes (Sayago et al., 2004; Kongbonga et al., 2011). The emission wavelength for the maximum fluorescence intensity of neat SME is 438 nm.

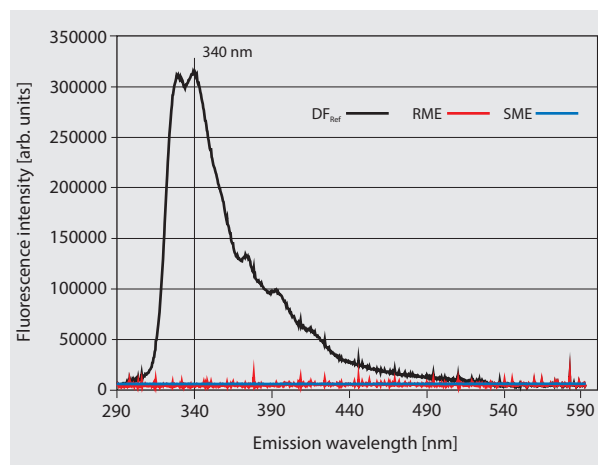


Figure 7
Fluorescence frequency behavior of CEC Reference Diesel Fuel (DF_{Ref}) and biodiesel fuel RME under excitation at 266 nm

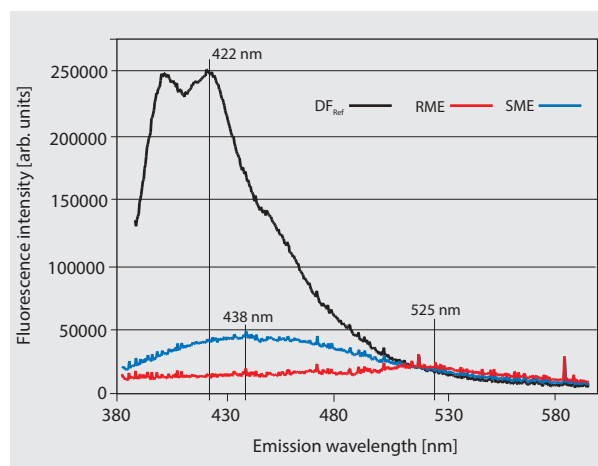


Figure 8
Fluorescence frequency behavior of CEC Reference Diesel Fuel (DF_{Ref}), RME and SME under excitation at 355 nm

For the excitation wavelength of 355 nm, the fossil diesel fuel content in fuel blend could be determined by the fluorescence intensity at the emission wavelength of 422 nm. In contrast, the content of RME in fuel blend could be determined by the fluorescence intensity at the emission wavelength of 525 nm. The content of SME could be referred at the emission wavelength of 438 nm. It is noticeable that the fluorescence intensity at 438 nm from fossil diesel fuel is about three times higher than that from SME. The emission bands observed in diesel are principally due to aromatic

compounds/conjugated double bonds and could be a strong influence on the fluorescence of SME. The fluorescence intensity from fossil diesel fuel at 525 nm is similar to that from RME. So it is possible that there is an influence on the fluorescence of RME by fossil diesel.

3.2.1 Measurement with 266 nm laser excitation

The fluorescence intensities (with 266 nm laser excitation) are normalized to the maximum value of the pure fossil diesel (at 340 nm). The fluorescence at 340 nm can be ascribed to PAH in CEC Reference Diesel Fuel. The normalized fluorescence intensity for the emission wavelength of 340 nm is plotted against the concentration of RME (Figure 9).

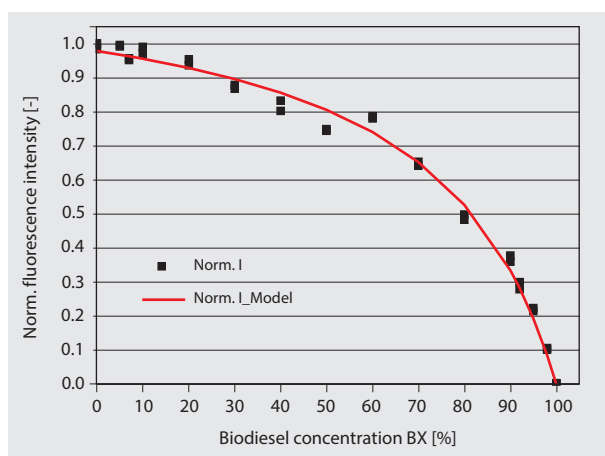


Figure 9

Adaption of the Stern-Volmer equation with normalized fluorescence intensity for the given emission wavelength of 340 nm versus content of RME in Biodiesel Blend, excitation at 266 nm

It was observed that the fluorescence intensity decreased in general with the increase of biodiesel concentration. However, there were some differences: the fluorescence of the blends was higher than expected (above the diagonal, see Figure 9). The possible reason being secondary absorptions by the compounds in fuels. Figure 9 showed a change of the gradient in dependency of the biodiesel concentration. Especially at low biodiesel concentrations (B0 to B30), when the amount of concentration of fluorophores in the blends is very high, the fluorescence will be quenched by the fluorophores. This means that the fluorescence of blends with low biodiesel concentration increases were not as strong as with high biodiesel concentration. This phenomenon is similar to the static self-quenching of fluorophores.

Generally, the static quenching effect can be described by the Stern-Volmer equation (Somoogyi et al., 1993; Lakowicz, 2010; Eftink, 1991; Eftink et al., 1981; Lakos et al., 1995):

$$\frac{I_{f,0}}{I_f} = \frac{k_1 \cdot [FL] + k_2 \cdot BX}{I_f} = 1 + K_{SV} \cdot [Q] \quad (5)$$

Here $I_{f,0}$ is the fluorescence intensity without quenching and has a linear dependence with fossil diesel concentration $[FL]$ and biodiesel concentration BX with factor k_1 and k_2 . I_f is the fluorescence intensity with quenching. K_{SV} is the Stern-Volmer constant and $[Q]$ is the quencher concentration. For self-quenching the fluorophore concentration $[FL]$ is equal to $[Q]$.

By fitting the Stern-Volmer equation with the experimental data, the two constants were determined: $K_{SV} = 3.66$, $k_1 = 4.56$ and $k_2 = 0$. From Figure 9, it can be found that the Stern-Volmer equation was very well adapted to the experimental data.

3.2.2 Measurement with 355 nm laser excitation

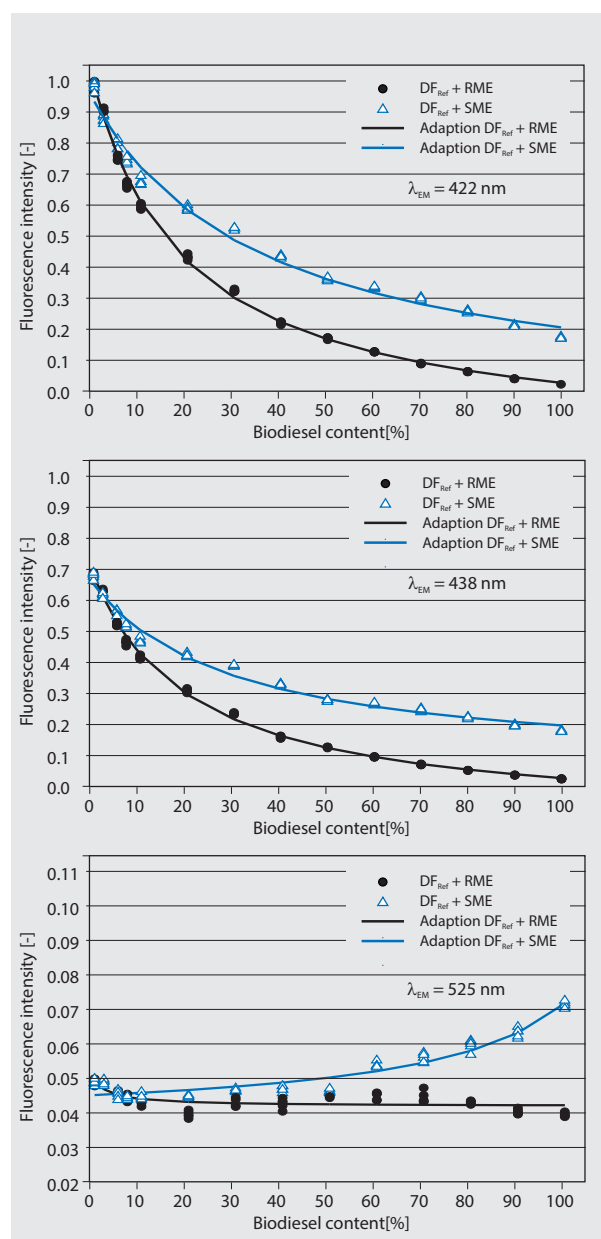


Figure 10

Adaption of the Stern-Volmer equation with experimental data of blends, for the given emission wavelength of 422 nm (top), 438 nm (centre) and 525 nm (bottom)

The fluorescence intensities (at 355 nm laser excitation) were normalized to the maximum value of the pure fossil diesel (at 422 nm). Then, the normalized values for the emission wavelengths of 422 nm, 438 nm and 525 nm were plotted against the biodiesel concentration (Figure 10).

The fluorescence with the emission maximum at 422 nm was ascribed to the CEC Reference Diesel Fuel. The fluorescence at 438 nm can be ascribed both to the fluorophores of SME and the CEC Reference Diesel Fuel. The fluorescence at 525 nm was ascribed to the fluorophores of RME.

It was observed, that for the blends, the fluorescence intensities at 422 nm did not show a linear relation with the content of biodiesel because of the strong secondary absorption of biodiesel. This quenching effect of biodiesel could be solved by the Stern-Volmer model. At the other emission wavelengths of 438 nm and 525 nm, the relation between the fluorescence intensity and biodiesel content could also be described by the Stern-Volmer equation (Figure 10). The results of model analysis were verified by the results of experiments. The parameters of the Stern-Volmer equation are shown in Table 3. The quenching-effect is unique for the blends with different diesel and biodiesel at varying concentrations. At 525 nm wavelength, the blends whose data were fitted using the Stern-Volmer equation showed a general trend. This was because the fluorescence intensity of all fuels was in the same range and near the noise level. Therefore, only a general trend was noted after using the Stern-Volmer equation.

Table 3

Parameters fitted for the Stern-Volmer equation for emission wavelengths at 422, 438 and 525 nm

Blends	EM	k_1	k_2	K_{SV}
DF _{Ref} + SME	422 nm	0.9337	0.7599	2.7100
	438 nm	0.6511	0.8445	3.3365
	525 nm	0.0454	0.0169	-0.7658
DF _{Ref} + RME	422 nm	0.9854	0.1487	4.8279
	438 nm	0.6796	0.1397	4.7092
	525 nm	0.0496	1.1088	25.1363

In Figure 11, the diagram of fluorescence intensities for biodiesel blends are shown for these emission wavelengths. Although only a general trend for the dependence between fluorescence intensity at EM = 525 nm and biodiesel concentration could be found, the distinction of the blends at this wavelength was so significant that the fluorescence at this wavelength could be used to identify the blends. The results suggest that the fluorescence at three characteristic emission wavelengths (422 nm, 438 nm and 525 nm) could be used for identification and quantification of biodiesel.

In order to validate this assumption, these fluorescence intensities and the correspondent concentrations were used as training dataset for a calibration to quantify the biodiesel content in unknown blends.

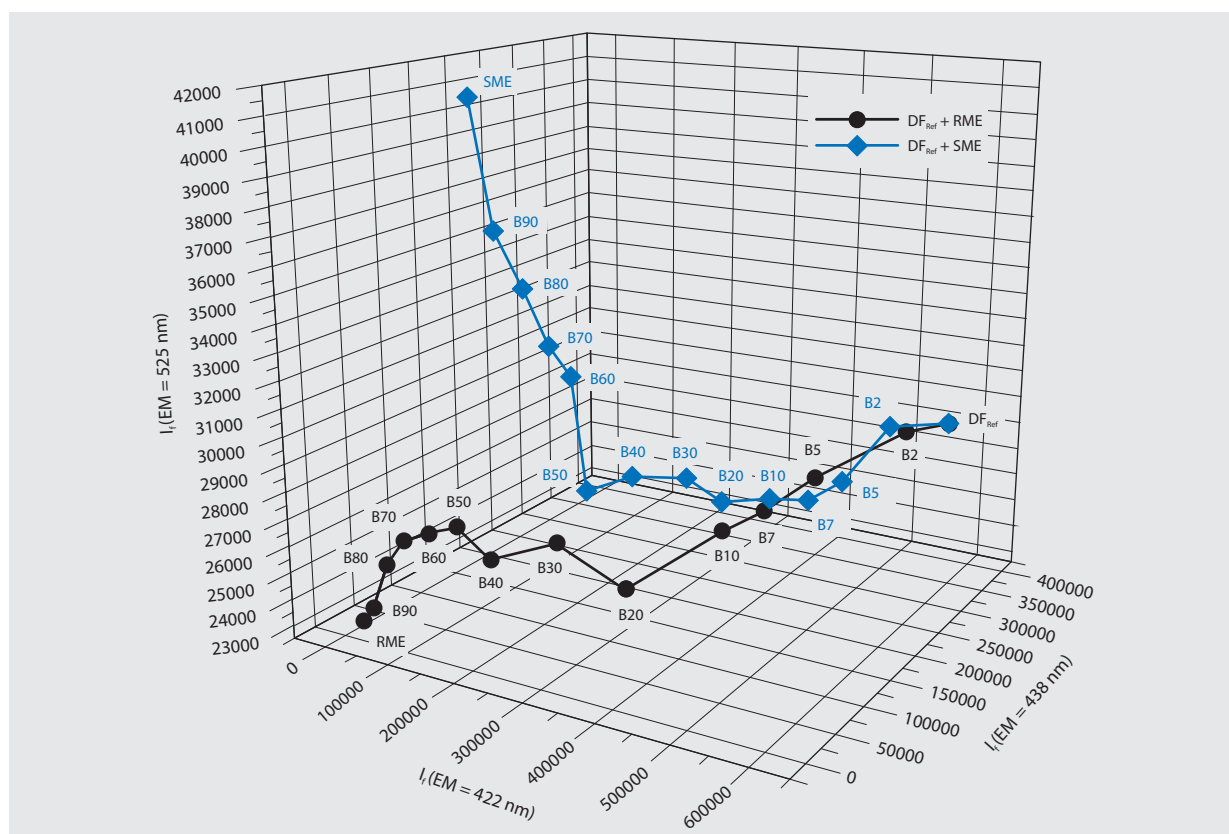


Figure 11

3D diagram of fluorescence intensities for the biodiesel blends

3.2.3 Validation

This calibration was tested with blended samples with different biodiesel content. In all, 40 test samples were mixed consisting of DF_{Ref} and SME or DF_{Ref} and RME to evaluate the true predictive ability of the calibrated model. Identification and quantification of biodiesel in the test samples were carried out according to the similarity of the test samples by the variables ($I_f(\text{EM} = 422 \text{ nm})$, $I_f(\text{EM} = 438 \text{ nm})$ and $I_f(\text{EM} = 525 \text{ nm})$) with the calibration samples. In this work, we used Euclidean distance, D , between test samples i and known samples j to indicate the similarity (Vandeginste et al., 1998):

$$D_{i,j} = \sqrt{\sum_{k=1}^K (I_{f,i,k} - I_{f,j,k})^2} \quad (6)$$

where K is the number of variables, here it is 3.

The smallest distance $D_{\min 1}$ means the test sample was almost similar to the corresponding known sample. Thus according to the $D_{\min 1}$ the biodiesel in the blend could be identified. Also the second smallest distance $D_{\min 2}$ could be calculated. Finally, according to $D_{\min 1}$ and $D_{\min 2}$ the biodiesel content c in test blend could be calculated: using a linear interpolation between these two known concentrations (BX_1 and BX_2):

$$\frac{D_{\min 1}}{D_{\min 2}} = \frac{c - BX_1}{c - BX_2} \Rightarrow c = \frac{(BX_2 \cdot D_{\min 1} - BX_1 \cdot D_{\min 2})}{(D_{\min 1} - D_{\min 2})} \quad (7)$$

The results of quantification of DF_{Ref}, RME and SME in biodiesel blends are shown in Figure 12, 13 and 14. Table 4 shows the prediction ability for identification of biodiesel type.

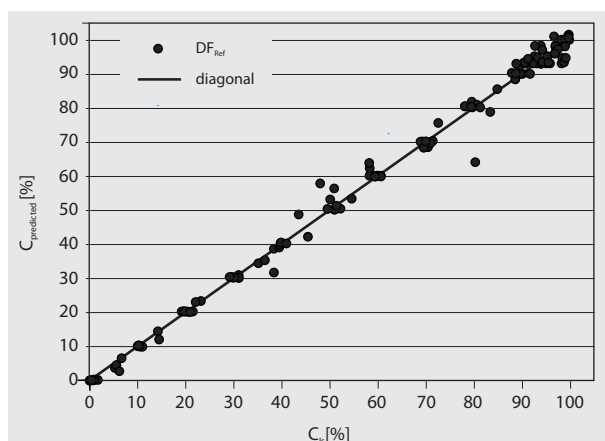


Figure 12

Predicted vs. true concentration for DF_{Ref} in biodiesel blends

Fossil diesel can (Figure 12 and Table 4) be identified and quantified even at low concentrations (DF_{Ref} % smaller than 1 %). RME and SME (Figure 13, Figure 14 and Table 4) in most

blends could also be determined. Table 4 shows the high identification ability of this method: more than 90 % of the fuels were identified.

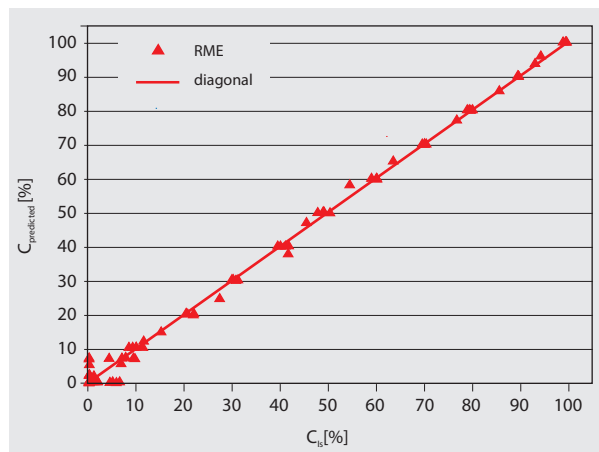


Figure 13

Predicted vs. true concentration for RME in biodiesel blends

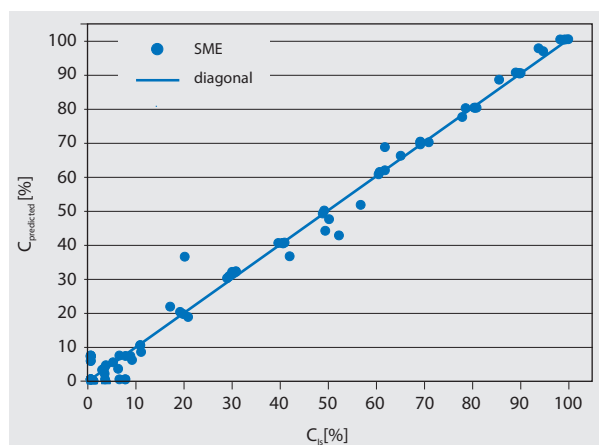


Figure 14

Predicted vs. true concentration for SME in biodiesel blends

Table 4

Prediction ability for identification of biodiesel type in biodiesel blends.

	DF	RME	SME
true	40	37	37
false	0	3	3

It should be noted that the high residuals (greater than 10) were caused by false identification of biodiesel. For example, a blend of 93 % DF_{Ref} and 7 % RME, showed that there should be 85 % DF_{Ref} and 15 % SME. Therefore, a high residual occurred. It means that correct identification of biodiesels plays a very important role for the quantification. Therefore, the

identification method needs to be improved. For example, the expansion of the measuring range of emission wavelength in the detector and adjustment of the wavelength of the laser light may need improvements.

4 Conclusions

In this work, the fluorescence properties of over 50 diesel fuels and biodiesel mixtures were determined by TRLFS at 266 nm and 355 nm pulse laser excitations. Using fluorescence characteristics, a variety of different fuel sources could be distinguished. The studies have shown that under constant experimental conditions, the fluorescence lifetime at each emission wavelength is dependent on the interaction between fluorophores and non-fluorescent substances in diesel fuels. The time-resolved fluorescence spectra can show the main fluorescence characteristics of diesel fuels. Therefore, fluorescence allows you to distinguish the lifetime of diesel fuels.

The PCA method used as the pre-processing could provide a very intuitive analysis for different diesel fuels. Compared to U-PCA which requires to process the whole three-dimensional spectral information, the proposed method can significantly reduce the amount of data.

Compared to the traditional analytical methods such as GC-MS, HPLC, etc., the TRLFS method provides faster and more accurate distinction and does not require sample preparation. By considering these advantages, it can be used at the gas station or in the car, for example to prevent misfuelling and to provide in-situ information of the diesel fuels and biodiesel content for the engine control system of the vehicle.

In addition, by determination of fluorescence intensity at characteristic emission wavelengths, the content of diesel

fuels and biodiesel in the blends can be quickly and easily quantified. This has a major significance for optimizing vehicle performance and reducing engine emissions. In contrast to the measurement at 266 nm laser excitation, the detectable fluorescence emission of biodiesel at 355 nm laser excitation was found. Also noted for the different biodiesel blends, the relationships between biodiesel content and the fluorescent intensity at a specific wavelength are unique and are caused by fluorescence of fluorophores and also by the fluorescence quenching-effect of fossil diesel and biodiesel. By comparison, with a calibration dataset of fluorescence at three characteristic emission wavelengths (422 nm, 438 nm and 525 nm), biodiesel in biodiesel blends in most instances (over 90 %) could not only be identified but also quantified.

To optimize the method the measuring range of the detector and the excitation wavelength of the laser source must be varied. On the global market other FAME, e.g. palm oil methyl ester (PME), coconut oil methyl ester (CME) and used cooking oil methyl ester (UCOME) are also relevant. Their impact on fluorescence must be investigated, too.

Because the huge variety of fossil diesels especially regarding aromatics the accuracy of biodiesel quantification in blends is the main challenge.

Acknowledgements

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Appendix A

Fuel data in accordance with CEC RF-06-03 of the fossil diesel fuels used (DF_{Ref})

Properties	Methods <i>DIN EN</i>	Units	Limit <i>Min.</i>	Limit <i>Max</i>	DF _{Ref}
cetane number	ISO 15195	-	52	54	53.4
cetane index	ISO 4264	-	46	-	
density (15 °C)	ISO 12185	kg/m ³	833	837	834.3
polycyclic aromatic hydrocarbon	ISO 12916	% (m/m)	3	6	4.6
sulphur content	ISO 20884	mg/kg	-	10	3
flashpoint	ISO 2719	°C	> 55	-	92
carbon residue	ISO 10370	% (m/m)	-	0.2	< 0.01
ash content	ISO 6245	% (m/m)	-	0.01	< 0.001
water content	ISO 12937	mg/kg	-	200	23
total contamination	ISO 12662	mg/kg	-	20	
copper strip corrosion (3 h to 50 °C)	ISO 2160	degree of corrosion	1	1	1A
oxidation stability	ISO 12205	g/m ³	-	25	< 1
HFRR (at 60 °C)	ISO 12156-1	µm	-	400	235
kin. viscosity (40 °C)	ISO 3104	mm ² /s	2.3	3.3	3.126
CFPP	116	°C	-	-5	-17
distillation curve 95 % point	ISO 3405	°C	345	350	347.7
FAME content	ISO 14078	% (v/v)	-	-	best.
hydrogen	ASTM D 3343	%	-	-	13.74
carbon	ASTM D-3343	%	-	-	86.28
oxygen			-	-	-
caloric value	ASTM D 3338	MJ/kg	-	-	43.226
cloudpoint	EN 23015	°C	-	-	-15
neutralisation number	ASTM D 974	mg KOH/g	-	0.02	< 0.02
mono-aromatic	(IP 391)	% (m/m)	-	-	15.4
di-aromatic	(IP 391)	% (m/m)	-	-	4.6
tri+furter	(IP 391)	% (m/m)	-	-	<0.1
total aromatics	(IP 391)	% (m/m)	-	-	20

Appendix B

Fuel data in accordance with DIN EN 14214 of the biodiesel fuels used (RME and SME)

Properties	Methods <i>DIN EN</i>	units	Limit <i>Min.</i>	Limit <i>Max</i>	RME	SME
ester content	14103	% (m/m)	96.5	-	98.2	98.4
density (15 °C)	ISO 12185	kg/m ³	860	900	883.1	885.7
kin. viscosity (40 °C)	ISO 3104	mm ² /s	3.5	5.0	4.458	4.123
flashpoint	ISO 3679	°C	101	-	182	168
CFPP	116	°C	-	0/-10/-20	-14	-6
sulphur content	ISO 20884	mg/kg	-	10.0	< 1	< 1
carbon residue	ISO 10370	% (m/m)	-	0.3	0.17	0.16
cetane number	15195		51		54	52.9
ash content	ISO 3987	% (m/m)	-	0.02	< 0.01	< 0.01
water content	ISO 12937	mg/kg	-	500	230	221
total contamination	12662	mg/kg	-	24	8	2
copper strip corrosion (3 h to 50 °C)	ISO 2160	degree of corrosion	1	1	1	1
oxidation stability	14112	h	6	-	8.4	6.5
acid number	14104	mg KOH/g	-	0.5	0.429	0.339
iodine number	14111	gr iodine/100gr	-	120	113	132
linolenic acid content	14103	% (m/m)	-	12	10	8.1
ME > = 4 double bonds	15779		-	1	0.06	0.09
methanol content	14110	% (m/m)	-	0.20	0.01	0.01
free glycerol	14105	% (m/m)	-	0.02	0.02	< 0.01
Monoglycerides	14105	% (m/m)	-	0.80	0.8	0.7
diglycerides	14105	% (m/m)	-	0.20	0.2	0.11
triglycerides	14105	% (m/m)	-	0.20	0.2	0.01
total glycerine content	14105	% (m/m)	-	0.25	0.25	0.2
phosphorous content	14107	mg/kg	-	10	4	< 0.5
alkali content	14538	mg/kg	-	5	5	< 0.5
alkaline earth content	14538	mg/kg	-	5	5	< 0.5

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What influences farmers' acceptance of agri-environment schemes? An ex-post application of the 'Theory of Planned Behaviour'

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Abstract

A better understanding of farmers' behaviour regarding agri-environment schemes (AES) can be one step towards further improving these voluntary schemes. In order to assess farmers' acceptance and perception of agri-environment schemes, the 'Theory of Planned Behaviour' (TPB) was applied ex-post to identify factors influencing farmers' willingness to join agri-environment schemes. This ex-post application is a new approach of using the TPB and also the analysis of farmers' acceptance towards AES by using the TPB has not been done before. In the 'Yorkshire and The Humber' region of northern England, standardized face-to-face interviews were conducted with 32 farmers already participating in an AES. The results demonstrate that the general attitude and acceptance of the English scheme are high. Biodiversity, landscape, and natural resources are perceived to be improved by the scheme and to be valuable. An increase in weeds was perceived as an undesirable outcome. Farmers' families were ranked to have the highest and most positive social pressure on farmers' decisions to join AES. Interestingly, the opinion of other farmers or of the farm advisor did not influence the farmers much. More paperwork and more demanding management requirements would make it much more difficult to join the scheme. The provision of advice and greater consideration of environmental conservation in policy development were perceived to make joining the scheme more attractive. Most of the gained results are confirmed by the literature. This shows that the ex-post application of the TPB is feasible and that acceptance of AES can be analysed by using the TPB.

Keywords: *environmental conservation, Theory of Planned Behaviour, farmers' values, farmers' behaviour, farmers' beliefs, farmers' decision-making process*

Zusammenfassung

Was beeinflusst die Akzeptanz von Landwirten gegenüber Agrarumweltmaßnahmen? Eine ex-post Anwendung der „Theory of Planned Behaviour“

Ein besseres Verständnis des Verhaltens von Landwirten in Bezug auf Agrarumweltmaßnahmen (AUM) kann zur weiteren Verbesserung dieser Programme beitragen. Um dies zu untersuchen und Einflussfaktoren auf die Teilnahmebereitschaft zu identifizieren, wurde die 'Theory of Planned Behaviour' (TPB) ex-post angewendet, was ein neuer Ansatz ist. In der 'Yorkshire and The Humber' Region im Norden Englands wurden standardisierte, persönliche Interviews mit 32 Landwirten durchgeführt, die bereits an AUM teilnahmen. Die generelle Einstellung und Akzeptanz gegenüber den Programmen sind hoch. Als positive Auswirkung der Programme wurde eine Verbesserung von Biodiversität, Landschaft und natürlichen Ressourcen wahrgenommen; als negative das vermehrte Vorkommen von Unkräutern. Der größte und positivste Einfluss auf die Landwirte bezüglich einer Programmteilnahme wurde ihren Familien zugeordnet; die Meinung anderer Landwirte und des Betriebsberaters beeinflusste kaum. Mehr Schreibarbeit sowie noch strengere Bewirtschaftungsauflagen würden die Teilnahme wesentlich erschweren, Beratung und mehr Berücksichtigung von Umweltschutz in der Politik die Teilnahme erleichtern. Der Großteil der gewonnenen Ergebnisse wird durch die Literatur bestätigt; ferner ist die ex-post Anwendung der TPB zur Analyse der Akzeptanz von AUM praktikabel.

Schlüsselwörter: *Umweltschutz, Theory of Planned Behaviour, Wertvorstellungen der Landwirte, Verhalten der Landwirte, Überzeugungen der Landwirte, Entscheidungsprozesse der Landwirte*

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1 Introduction

The availability and condition of public goods such as landscape, wildlife or ecosystem functioning cannot be controlled by normal market mechanisms. As a result it is the responsibility of the public authorities, such as the government, to provide access to and maintain the supply of those goods (Koester, 2005). To address this responsibility, European Union policy has, since the 1980s, paid an increasing amount of attention to environmental conservation in general, and also to environmental friendly agricultural practices in particular (Kirschke et al., 2004). With the 'McSharry reforms' of the Common Agricultural Policy (CAP) in 1992 it was first obligatory for the EU member states to develop and introduce agri-environment schemes (AES) (EC, 2010). The political agreement reached on the 26th June 2013 on the CAP after 2013 (EC, 2013), illustrates the continuing importance of environmental aspects in European agricultural policy; AES will continue to be a major mechanism to protect public goods. However, both the European Court of Auditors (2011) and the European Commission have criticised agri-environment schemes as not being efficient enough and have demanded further improvements. Since AES are voluntary for farmers, their acceptance is one essential requirement for the success of a scheme (Falconer, 2000). Acceptance means participation by farmers, but also including farmers in a more sustainable way in terms of awareness, attitudes, and perception of the policy objectives behind AES. Therefore, and to address the above-mentioned challenge, this paper assesses farmers' acceptance and perception of AES. Here, the 'Theory of Planned Behaviour' (TPB) is applied ex-post in a case study in the 'Yorkshire and The Humber' region of northern England to assess the behaviour of existing AES agreement holders. The TPB was selected because it clearly defines the different elements that are important drivers for the performance of certain behaviour. This enabled the TPB to be used as a construct to help understand what drives farmers to join AES, what influences their intentions, and which issues might make them insecure. Finally, potential strengths and weaknesses of the English 'Environmental Stewardship' agri-environment scheme are identified. This information can help to better understand farmers' behaviour regarding AES, to keep farmers in AES, and to further improve the schemes.

1.1 Agri-Environmental Schemes in England

The first AESs in England were the 'Environmentally Sensitive Areas' (ESA) established in 1987 and, from 1991, the 'Country-side Stewardship Scheme' (CSS). Following a major policy review in 2002 (Curry et al., 2002) these schemes were closed for new agreements in 2005 and a new AES named 'Environmental Stewardship (ES)' was launched (Peel and Chaplin, 2008). ES is developed, administered and evaluated by 'Natural England'¹ (NE) (Peel, 2010). It is comprised of two

main tiers: 'Entry Level Stewardship' (ELS) and 'Higher Level Stewardship' (HLS).

The ELS tier of the ES was designed as a so-called 'hands off scheme': easy for farmers to understand and to implement without any need for advice and open to all kind of farmers. Farmers can choose any management options from a menu of over 60 options. The menu of options contains, e.g., boundary, historical or landscape features and arable or grassland options (Natural England, 2010a). Each option has a points tariff per unit and an overall points target for the farm is established based on the area and land type of the holding. Provided the points target is achieved, a five year agreement is offered with an annual payment of £30 per ha (for lowlands).

NE allocates HLS agreements only where they are likely to achieve the greatest environmental benefit. The ten-year HLS agreements are drawn up in discussion with NE advisers. HLS is not based on a fixed payment rate, each option is worth a certain amount of money per unit and the overall agreement payment reflects the combination and area of individual options within the agreement. The menu of HLS options covers a wide range of potential habitats and features, similar to ELS, but the management requirements are typically more complex and demanding. The scheme also has similar additional options designed for specific habitats e.g., moorland, lowland heathland, coastal locations, and wetland. Extra payments are offered selectively for capital investments, to support changes in land management practice and deliver access improvements and maintain and conserve cultural heritage features on farmland. Compared to ELS a key difference of HLS is its high supply of support and advice. Regular farm visits monitoring progress against 'Indicators of Success' established for each agreement allow progress to be assessed and the need for adjustments to agreements to be identified (Natural England, 2010b).

In May 2013 ES- and remaining ESA- or CSS-agreements covered in total an area of 6,513,389 ha in England, which is 70 % of all English agricultural land. Within this, ELS uptake is the dominant component in terms of area (Natural England, 2013a). Spending on support and improvement of the environment and countryside with land management accounts for about 80 % of England's total share of the EU-second pillar funding (Peel, 2010). After the first five years of scheme operation, a range of studies confirmed that the ES can be an appropriate tool to protect valuable ecological sites and to make progress towards delivering the schemes' environmental objectives (Natural England, 2008; Natural England, 2009; Peel, 2010; Tucker, 2010). The simple structure of ELS allows for a high rate of scheme participation providing some environmental benefits over a large area with relatively low administrative costs. The more complex structure and support offered by HLS, in contrast, allows more flexibility in targeting, agreement set ups, and farmers' management with a focus on the outcomes.

With regard to this targeted approach for an AES and the high effort which is put into it, it would be interesting to find out how farmers' intention to join the ES is influenced and to assess how advantages and disadvantages of participation are perceived by farmers with agreements under the

¹ Natural England is an independent public body and a government advisor, providing practical advice, grounded in science, to protect and improve England's environment.

scheme. This could lead to findings helpful to further improve ES and AES in general and to gain knowledge about farmers' behaviour regarding environmental measures. To address this challenge the 'Theory of Planned Behaviour' was chosen to serve as study construct.

1.2 The Theory of Planned Behaviour

The TPB was developed by Ajzen in 1985 to predict human intentions to exhibit certain behaviour and is an extension to the 'theory of reasoned action' (Ajzen and Fishbein, 1980). As Figure 1 shows, within the approach of the TPB, human behaviour is determined by the intention towards certain behaviour and the actual behavioural control over this behaviour. The intention in turn is a result of three determinants: the attitude towards the behaviour (favourable or unfavourable), subjective norms (social pressure through others), and the perceived behavioural control over certain behaviour. The source of these determinants and the basis of the whole theory are the related salient beliefs (outcome, normative and

control) which are then multiplied by their corresponding judgements. The products of these factors reflect the whole range of personal experiences, varying influences or received information readily accessible in memory. Whereas the behavioural beliefs consist of the perceived personal outcomes of certain behaviour (advantages, disadvantages or other associations), the normative beliefs reflect other groups of people or individuals who are noticed to have influence or an opinion on the intention to perform the behaviour. The control beliefs are a perception of factors that may allow or facilitate certain behaviour but also factors that hamper or preclude somebody from this.

2 Material and methods

2.1 Applying the 'Theory of Planned Behaviour': Conceptual framework

In this study, the TPB was not applied to predict a behaviour but to serve as construct for assessing aspects that influence

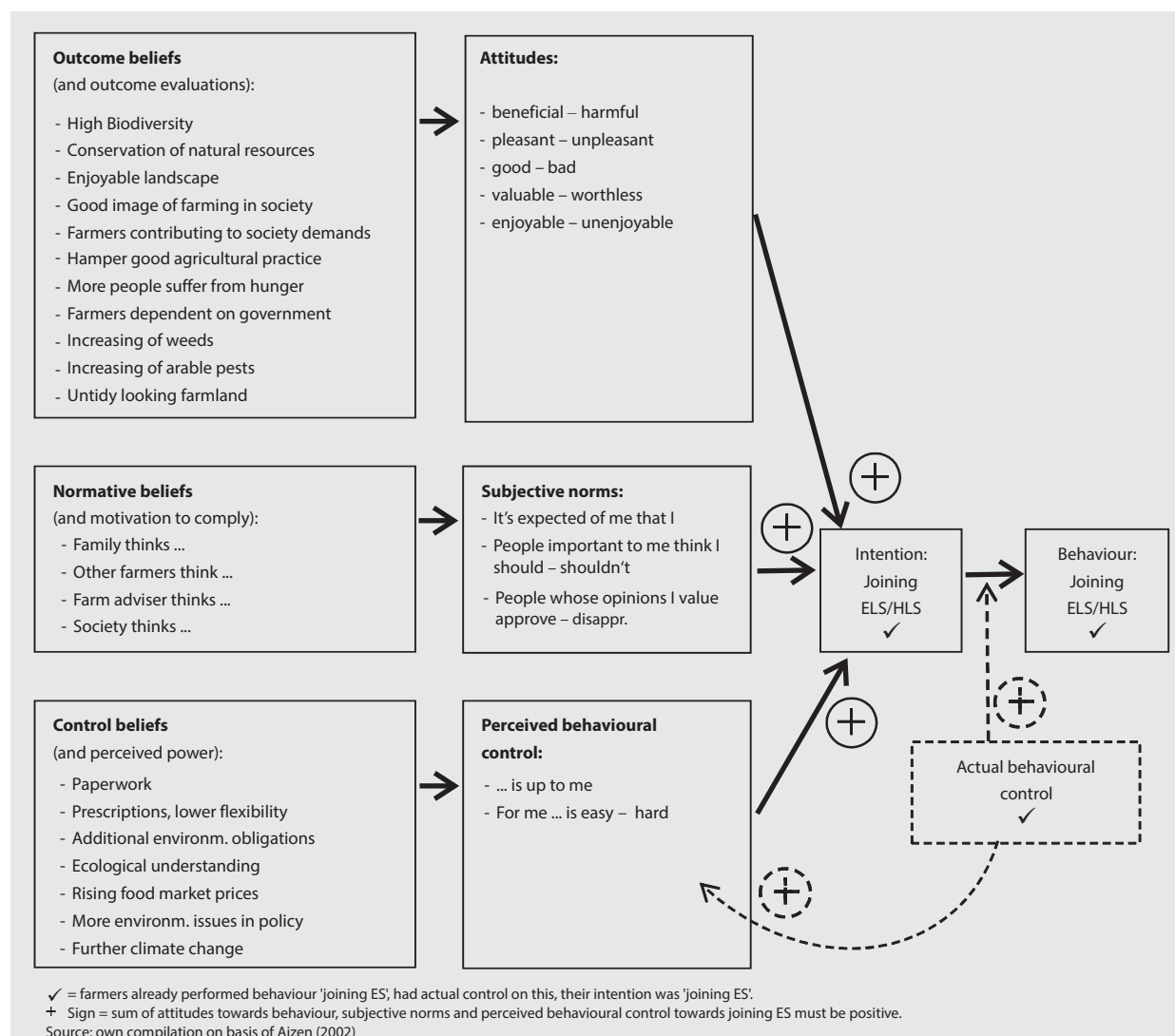


Figure 1

Conceptual framework for ex-post application of the Theory of Planned Behaviour regarding farmers' behaviour 'joining the ES'

the decision to 'join the ES'. Also Beedell and Rehman (1999) showed that the TPB can be a good tool to explain behavior. Figure 1 illustrates how the different elements of the TPB were defined in this case study and which items or questions were set to measure them. Since the interviewed farmers had already joined ES, the actual behaviour, their control on the behaviour and their intention was already defined. This in turn means that the sum of attitudes towards the behaviour, the subjective norms and the perceived behavioural control towards joining the ES must be positive. To design questions assessing the different TPB elements not yet pre-defined, appropriate literature was reviewed. Subsequently, the content of behavioural beliefs likely to be shared by the target population was identified and potential influencing groups and other controlling factors were defined. The most often listed statements were selected and converted into a set of statements which should reflect the beliefs that might affect the behaviour of the target population.

All questions regarding the TPB were designed in close connection to Ajzen (2002), whereby questions regarding the personal beliefs are supposed to be relatively concrete, questions to assess farmers' attitudes, perceived subjective norms, and perceived control are asked more indirectly in order to obtain also subconscious perceptions and feelings of the farmers.

2.2 Interview procedure, sample and data analysis

Based on the conceptual framework, interviews with farmers were conducted in summer 2010 in the 'Yorkshire and The Humber' region of northern England. Interviewed farmers had to meet both of the following sample criteria: i) be located in one of the selected authority regions; ii) hold an HLS-agreement. A non-probabilistic sample of 44 farmers fulfilling these criteria was contacted and 32 face-to-face interviews with farmers were conducted. This resulted in a response rate of 73 % and enabled us to perform statistical tests (Raab-Steiner and Benesch, 2010). The interviews were carried out on the holdings of the farmers as investigative, individual interviews using a standardised questionnaire as in Schroeder et al. (2013). The interviewer explained the questionnaire to the farmers and directly transcribed their answers step by step, which minimized the risk of bias with regard to e.g., misunderstanding the Likert scale or the questions. When farmers asked how to define term 'society', which was the relatively often used in the questionnaire, the interviewer answered: "the general public, the neighbours, but also the media and the politicians."

The total area of the study (summing up the area of all farmers interviewed) comprised 9,694 ha. The smallest farm in the sample was 10 ha, the largest 1,342 ha. 27 farmers (84 %) ran their farm as their main business. Two farmers (6 %) managed their land organically. All 32 farmers (100 %) had permanent grassland and had HLS agreements, 28 farmers (88 %) had ELS agreements. 17 farmers (53 %) managed land that was identified as a 'Site of Special

Scientific Interest' (SSSI ²). The age of the farmers was between 29 and 75 years and interviewed farmers were mainly male (27 farmers = 84 %). To test whether the sample reflects the region and to assess the potential transferability of the results, variables assumed to be relevant and for which data was available were compared to the corresponding averages of the region (see Table 1).

Table 1

Comparison of sample characteristics with population

Variable	Study area 'Yorkshire and The Humber' ^a	Case study sample
Farm size of HLS-agreement holding farms	159.5 ha (mean)	155.5 ha (median)
Average area of land in ES-grassland options per farm	ELS = 15 ha; HLS = 14 ha	ELS = 16 ha; HLS = 11 ha
^a Study area = 'Yorkshire and The Humber'. Own calculation for 2010 on basis of data from 'Natural England', York		

Since these tests resulted in comparable values, it can be presumed that the characteristics of the sample of farmers interviewed in this case study, and hence also their answers are relatively representative of all farmers already joining ES in the region 'Yorkshire and the Humber' and they could serve as orientation for further studies.

The questionnaire contained questions about the general farm business structure, farming characteristics and ES-agreements, 23 items for beliefs (OB see Figure 8 in the annex, NB see Figure 4, CB see Figure 6), each for ELS and for HLS, and 23 items for their evaluative components (OE see Table 3 in the annex, MC see Table 4 in the annex, PP see Figure 6). The questionnaire ends with demographic questions. Different scales were used to categorize the answers (nominal, ordinal, and interval). However, predominantly a five-point Likert scale was used. A pilot test served as proof of the questionnaire and its further development.

For the description of the data obtained, frequencies, median, and inter-quartile range were calculated. The TPB belief constructs were calculated in order to obtain an overall level of a belief and the corresponding personal evaluation for each farmer:

$$[1] \quad OBC = OB_i \times OE_i$$

$$[2] \quad NBC = NB_j \times MC_j$$

$$[3] \quad CBS = CB_k \times PP_k$$

² Areas of special nature value due to their flora, fauna, geological or physiographical conditions, protected by law (Natural England, 2013b).

Furthermore, a score was calculated summing up all these products for each farmer of the whole sample:

$$[4] \quad OBC \text{ Score} = \sum OB_i \times OE_i$$

$$[5] \quad NBC \text{ Score} = \sum NB_j \times MC_j$$

$$[6] \quad CBS \text{ Score} = \sum CB_k \times PP_k$$

To assess the consistence of farmers' evaluations gained in this study their given answers were tested for correlations. Because two ordinal scaled variables had to be compared for this, non-parametrical bivariate correlations were carried out according to Spearman (two-tailed). The Spearman rank correlation can be used to test two ranked variables and if normality cannot be guaranteed (McDonald, 2014).

3 Results

In this section, the results of applying the TPB will be presented. This will be done by describing each of the three constructs with its elements separately. For example, first the results regarding farmers outcome beliefs, then the outcome beliefs multiplied by the corresponding outcome evaluation, and afterwards farmers general attitude towards 'joining the ES' will be presented. The same will be done for the normative construct and the control construct. For the questions regarding ELS, a sample of 28 farmers was interviewed, and for HLS, the sample was 32. This difference is due to the fact that all farmers interviewed had HLS agreements but four farmers had no ELS agreement, which is possible but relatively uncommon.

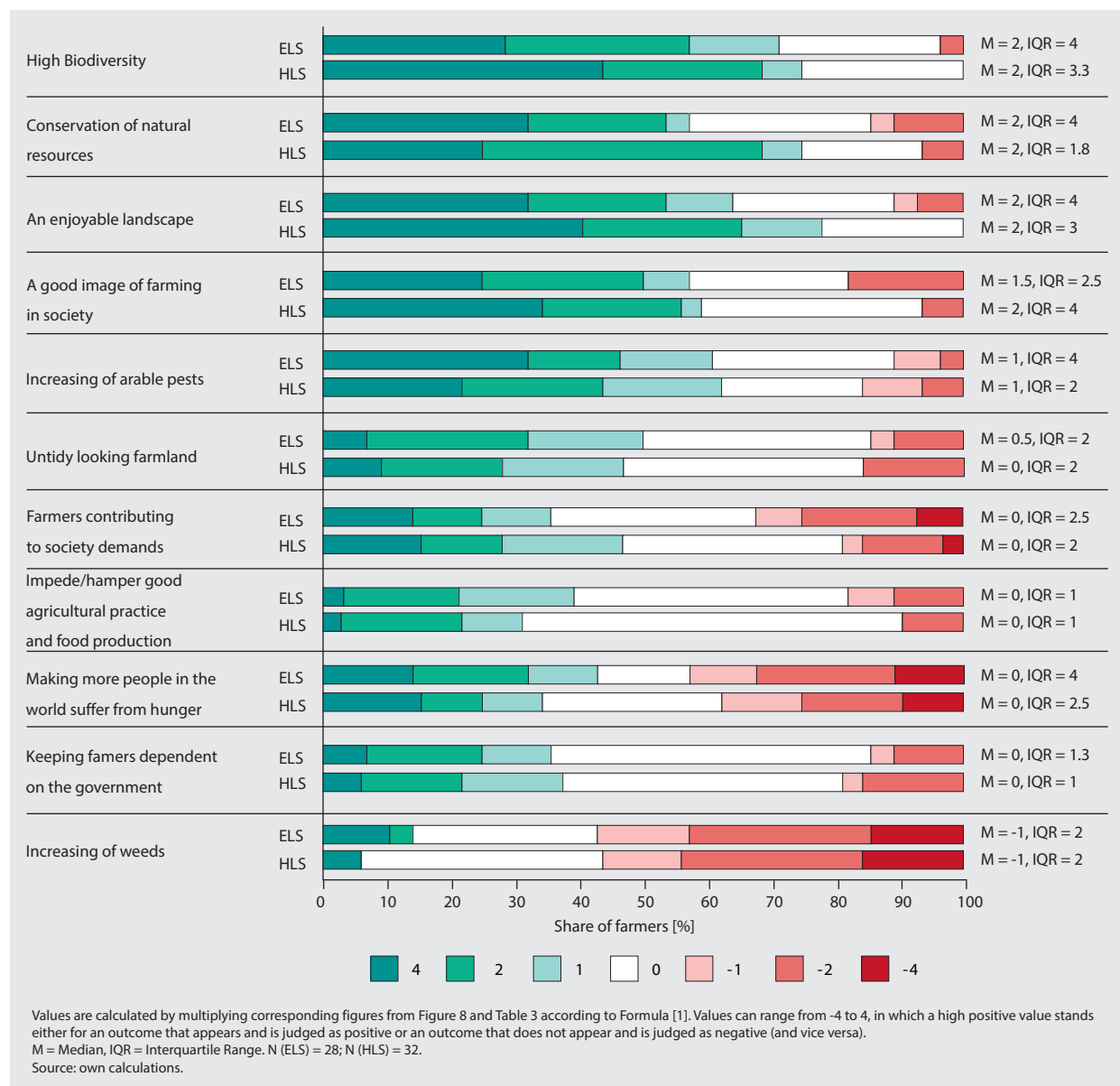


Figure 2

Product (OBC) of ELS and HLS outcome beliefs (OB) and outcome evaluation (OE)

3.1 Outcome beliefs, outcome evaluation and attitude towards the behaviour

Farmers perceived ELS as positive. They saw the advantages and disadvantages also pointed out by former studies. The only neutral/uncertain result was obtained for 'ELS keeps farmers dependent on the government' and 'ELS leads to increase of weeds'. Both statements had high Inter Quartile Ranges (IQR) (see Figure 8, in the annex). For HLS, the statements regarding outcome beliefs were rated similar to ELS. Generally, the outcome of joining HLS was perceived even more positively than of joining ELS.

Because the evaluation of the above listed statements can be very different between individual people and in order to interpret the results presented above correctly from the farmers' point of view, it was required to ask them about their general personal evaluation of aspects contained in the different outcome statements. The results are shown in Table 3 in the annex. The only relatively high IQRs were found for 'Keeping farmers dependent on the government' and 'Increasing of weeds'. However, the median for both statements was still -1.0. All evaluations of each farmer, in which 2 represented '(...) is generally very good', -2 '(...) is generally very bad' and 0 the neutral opinion, were multiplied by the given answer for the corresponding outcome belief (2 = 'totally agree'; -2 = 'totally disagree'). The results of this multiplication are shown in Figure 2.

The only negative product (on average) was gained for the aspect 'increasing of weeds'. Neutral results (on average), meaning that one of the factors was 0 (evaluated neutrally), were calculated for 'Farmers contributing to society demands', 'Impede/hamper good agricultural practice and food production', 'Making more people in the world suffer from hunger' and 'Keeping farmers dependent on the government'.

The variation in results was relatively high for the majority of the statements. The outcome score (sum of all multiplications per farmer, see Formula [4]) for 'joining ELS' was on average 7.5.

For HLS, the results were on average very similar, but for some statements, higher positive frequencies were obtained (e.g., regarding biodiversity, landscape, farming image in society).

The outcome beliefs that a farmer holds regarding 'joining the ES' lead to his general attitude towards this behaviour. To assess this attitude, farmers were asked to judge in general terms their decision to join ES. As Figure 3 shows, a very positive feedback was given for joining ELS as well as for joining HLS, farmers gave generally very similar answers regarding their general attitude towards joining these two tiers. However, for the statements 'Joining ELS/HLS is pleasant – unpleasant' and 'Joining ELS/HLS is enjoyable – unenjoyable' their valuation was not as high as for the other statements.

3.2 Normative Beliefs, motivation to comply and subjective norms

As presented in Figure 4, the highest level of agreement from other people for the farmer to join ELS was assigned to the family of the farmer with a very low IQR of 0.0. The highest indecision of the farmers in this context was obtained for estimating the opinion of their colleagues (mode = 0, median = 0.5, IQR = 2.0). The opinion of the adviser and the society was also judged as affirmative, but both with a relatively high IQR of 2.0.

Also for HLS the highest consensus for joining the programme was assigned to the family with a low IQR of 1.0.

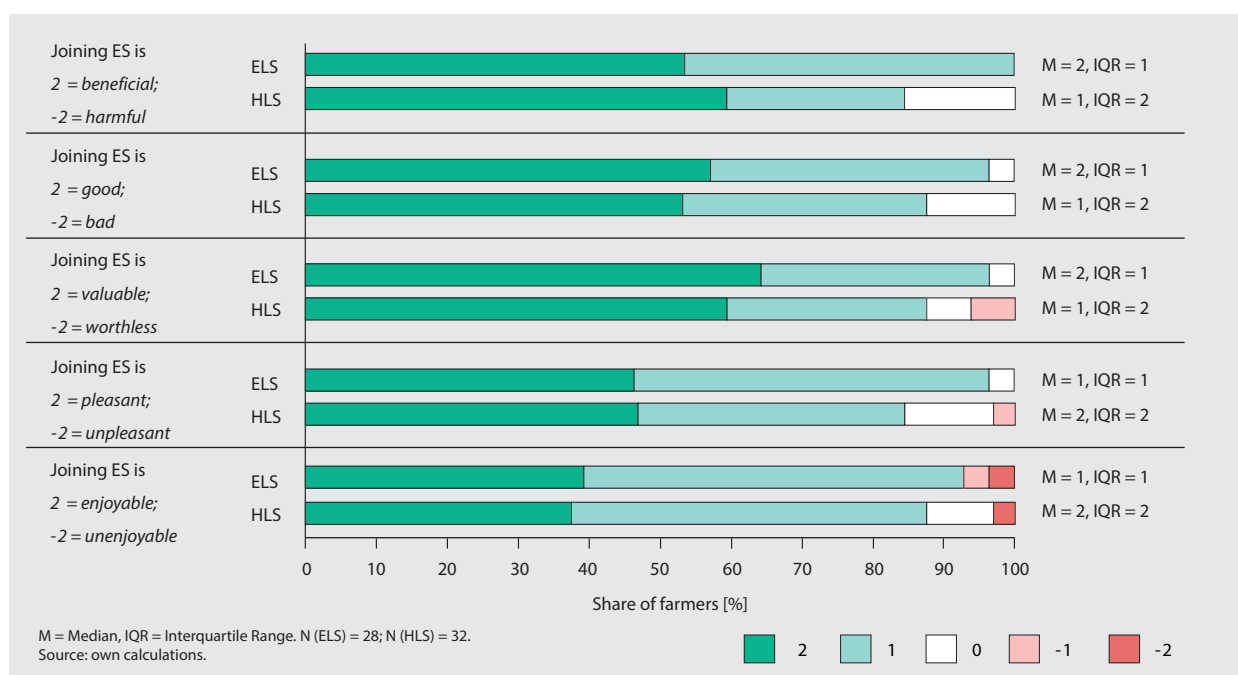


Figure 3
Farmers' attitudes towards joining ELS' joining HLS'

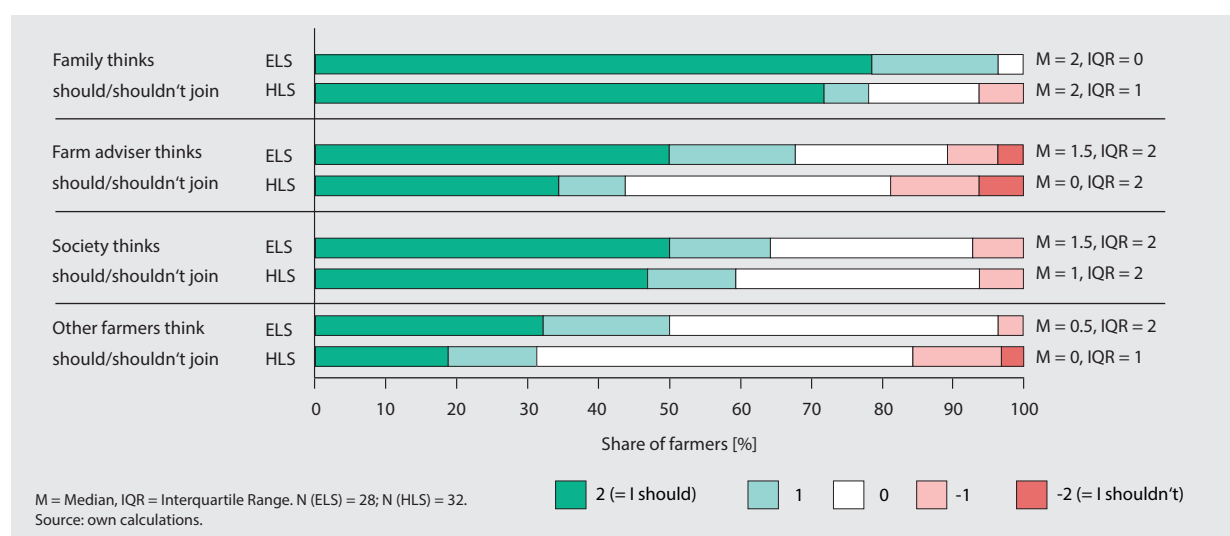


Figure 4
Farmers' normative beliefs (NB) regarding joining ELS' and joining HLS'

Farmers judged the opinion of colleagues as neutral/undecided, like they did also for ELS, with a low IQR of 1.0. Also the opinion of the farmer's adviser was judged undecided in total but two different bigger groups of farmers were observed: one group thinks advisers would strongly welcome farmers joining the HLS and one group being undecided. On average, the farmers thought that the society would relatively appreciate their joining HLS but also here two different groups of farmers were observed: one group thinking that the society would strongly welcome their joining the HLS and one being undecided about it.

The motivation of farmers to generally comply with the opinions of other people was measured with a five-step Likert scale in which 1 represented 'not at all', 3 the neutral evaluation, and 5 'very much'. The highest motivation was observed with regard to their family, followed by their adviser (see Table 4 in the annex). Farmers were on average relatively undecided about their motivation to comply with the opinion

of the society and of other farmers. Their motivation to comply with the opinion of their adviser was slightly higher but still relatively undecided. Table 2 shows the results of multiplying the motivation to comply by farmers' evaluation about the opinions of other people concerning 'joining ELS' and 'joining HLS' (normative beliefs). This was done in order to interpret farmers' evaluation about the opinions of other people concerning joining the ES more correctly. From the farmers' point of view, the highest (positive) social pressure comes from their families and the lowest from other farming colleagues. All potential influencing social groups were perceived to have a positive influence on the behaviour 'joining ELS'. For HLS, the social pressure is generally slightly lower. For 'other farmers' and the farm advisor, the product was 0.

As shown in Figure 5, all farmers stated that people whose opinions are of high value for them approve of them joining the ES. The majority of farmers perceived that it was generally expected for them to join ELS. For HLS, many

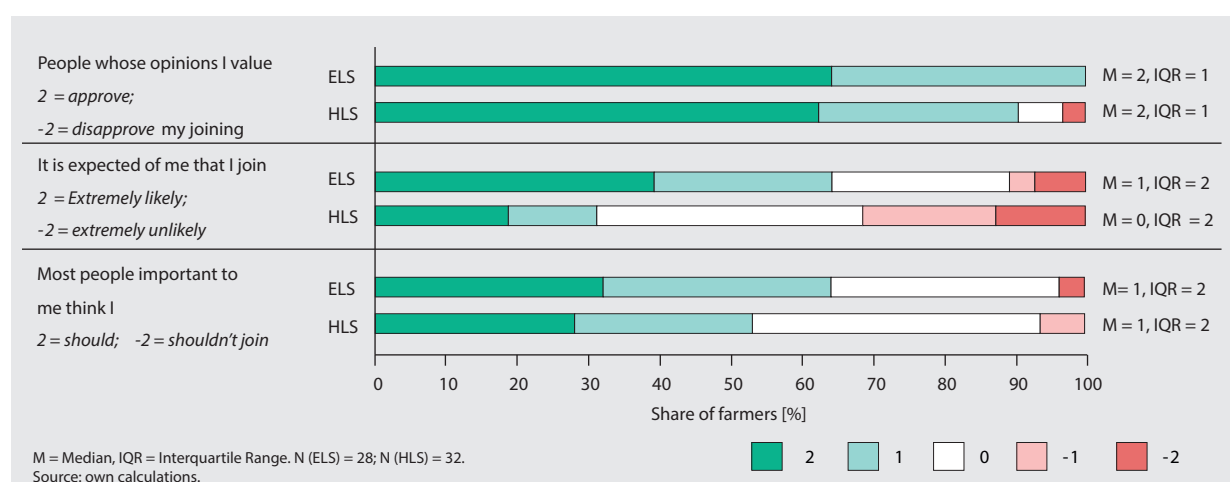


Figure 5
Farmers' evaluation about social pressure concerning their joining ELS' and joining HLS' (subjective norms)

farmers had a neutral opinion in this concern. On average, farmers thought that most people who were important to them appreciate their joining the ELS. For HLS, many farmers thought similarly, but also many farmers had a neutral opinion.

Table 2

Product (NBC) of ELS and HLS normative beliefs (NB) and motivation to comply (MC)

		Median	IQR	No.
Family	ELS	8	6	28
	HLS	8	7,3	32
Other Farmers	ELS	1,5	6	28
	HLS	0	3,3	32
Farm adviser	ELS	5	8	28
	HLS	0	8	32
Society	ELS	4	6,5	28
	HLS	3,5	6,5	32
ELS NBC score		17,5	14,5	28
HLS NBC score		11,5	18,5	32

Values are calculated by multiplying corresponding figures from Figure 4 and Table 4 according to Formula [2]. Values can range from -10 to 10, in which a high positive value stands either for a positive attitude of others towards AES and a high desire of the farmers to meet the expectations of this group or a negative attitude of others towards AES and a refusal of the farmers to meet the expectations of this group (and vice versa). NBCi scores: see Formula [5], values can vary from -40 to 40, in which a high positive value stands for a high positive social pressure to join the scheme and vice versa.
Source: own calculations

3.3 Control beliefs, perceived power and perceived behavioural control

Figure 6 shows farmers control beliefs and their perceived power regarding 'joining ELS' and 'joining HLS'. Farmers thought that paperwork is too much for ELS and HLS. If this would become even more, it would get much more difficult for them to join ES. There was a strong consistence between the different farmers for these statements (IQR = 1.0). The prescriptions of ELS were perceived as less constrictive as those for HLS. However, farmers thought their management flexibility to be reduced in both cases. If these restrictions were to increase, farmers assumed that it would become more difficult for them to join the ES. Nevertheless, farmers expect additional environmental farming obligations to come along in the future. Too many of those obligations would make it more difficult for them to join the ES. On the other hand, farmers think that in general, more consideration of environmental conservation in policy would make it easier for them to join the ES. The vast majority of farmers thought that the quality and quantity of environmental advice have big impact on a better understanding of ecological processes and management effects and that this in return makes it easier to join ELS and especially HLS. Farmers were relatively undecided about the future development of food prices and also about potential influence of those developments on joining the ES. Farmers expected climate change to

carry on in the future but could hardly say if this would influence them in joining the ES.

Figure 7 shows the results of general perceived control for the behaviour 'joining ELS' and 'joining HLS'. The vast majority of farmers had the feeling that it is definitely up to them whether they join the ES or not. Furthermore, they find it easy to join ELS. Regarding HLS, this judgement differed greatly; all steps from 2 to -2 were named in comparable frequencies.

4 Discussion

In this study, the TPB was applied not to predict a behaviour (for which it was actually developed) but to serve as construct for assessing influencing aspects on farmers' acceptance of AES in a case study in the 'Yorkshire and the Humber' region. For this purpose, farmers who already performed the behaviour 'joining the ES' were interviewed. Many expectations based on the literature review were confirmed by the results of this study and hence approve the applicability of the TPB ex-post application and for analysing the acceptance of AES. However, unexpected results also emerged and these are discussed and compared to findings from the literature in the following section.

4.1 Outcome beliefs and attitude towards the behaviour to measure the acceptance and perception of the aims behind AES

The farmers link more positive than negative impressions with the outcome of 'joining the ES' (positive OBC score), which leads to a positive attitude towards the ES and can hence be judged as one major issue why the farmers joined the ES. The OBC scores were more positive for HLS than for ELS. Consequently farmers perceived HLS to produce more positive outcomes. The highest OBCs were observed for the ES outcomes 'increasing biodiversity', 'conservation of natural resources', and 'enjoyable landscape'. These observations can be confirmed by findings from Januchowski-Hartley et al. (2012) that farmers value improved landscape aesthetics as private benefit, or Bertke et al. (2010) who found that improvement of the environment is one reason for farmers to join AES and hence perceived as a valuable outcome. On the basis of these results, it is concluded that the major aims of the scheme are recognized by the farmers and that they think that ES is generally delivering these benefits. Regarding HLS, the outcome 'good image of farming in society' resulted in a comparably high OBC, which can be attributed to the success and high acceptance of the 'public access' HLS-options. Also Bertke et al. (2010) and Siebert et al. (2010) found that improving the image of farmers is one reason for them to participate in AES and Januchowski-Hartley et al. (2012) state that public recognition is important for farmers for providing public goods.

Nevertheless, it should be noted that also negative outcomes of 'joining the ES', i.e., 'increase of weeds', were recognized by the farmers. This logic negative effect was also

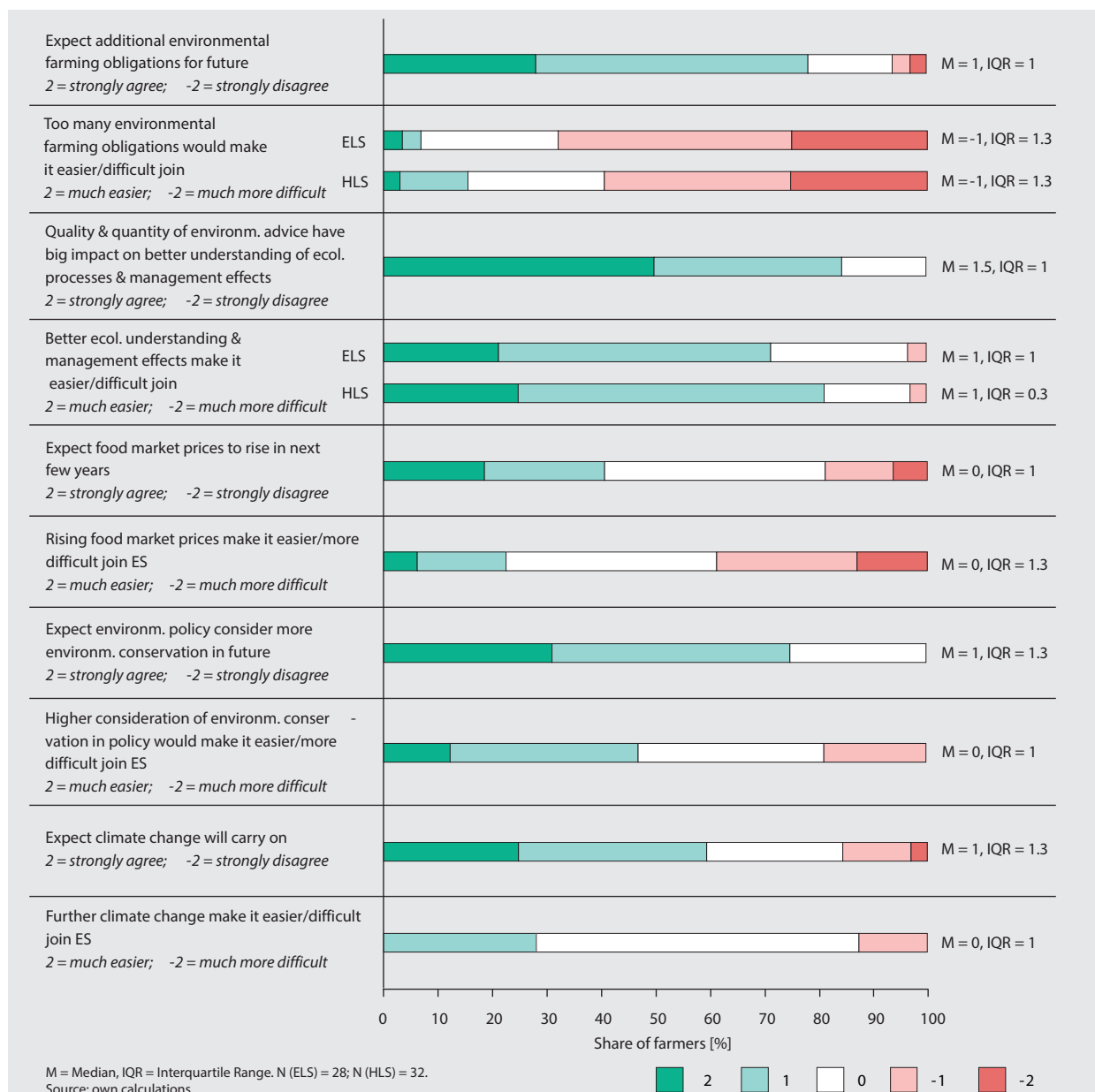


Figure 6
Farmers' control beliefs (CB) for 'joining ELS' and 'joining HLS' and perceived power (PP)

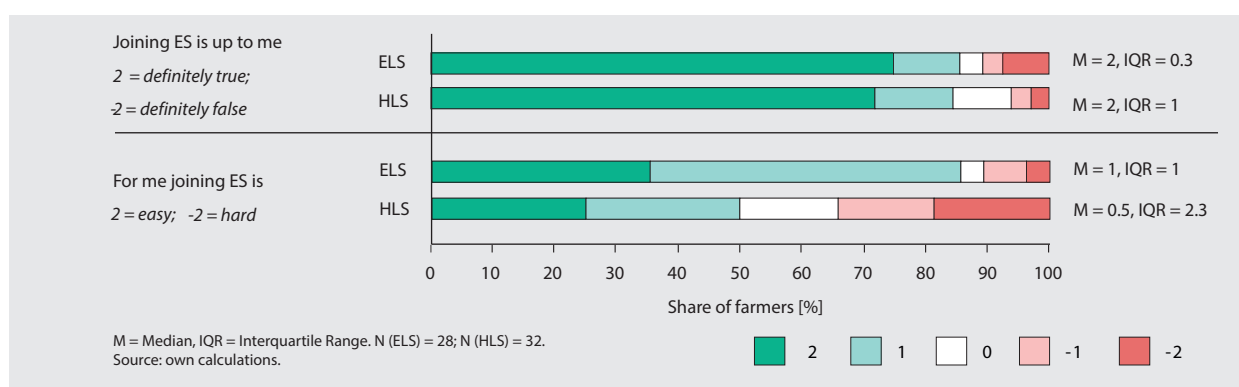


Figure 7
Farmers' perceived behavioural control for 'joining ELS' and 'joining HLS'

perceived by farmers interviewed by Beedell and Rehman (1999) as consequence of environmentally friendly hedge management. Outcomes, which are perceived as negative can have a negative impact on the acceptance of a scheme and should hence either be considered in the amount of payment or in the design of the management options and should be addressed in advisory actions.

Finally, the results for the items measuring farmers' actual attitude towards the behaviour 'joining the ES' were all very positive. Within these, the more emotional statements resulted in a slightly lower positive attitude. A possible explanation could eventually be that farmers perceive the material values or monetary advantages of 'joining the ES' as more positive than the emotional or ideological advantages. However, this issue cannot be proven by the results of this case study and the literature provides contradictory findings in this regard. Siebert et al. (2010) or Franco (2011), for example, stated that financial gain is the main reason for farmers to participate, whereas Januchowski-Hartley et al. (2012) found that anticipated private benefits are strong drivers. It should therefore be considered that it might be a compromise between these extremes and that this is of course case specific.

4.2 Normative beliefs and subjective norms to measure who might influence farmers intention to join AES

Indeed, all three constructs of the TPB influence the intention of farmers to join ES, but the aim of this study was to identify single critical aspects from these constructs. In this regard, it was found that the family is the social group which most influences the intention of a farmer. This is consistent with the literature, which shows that farmers' families have a strong influence on the decision-making process (Siebert et al., 2006; Siebert et al., 2010; Christensen et al., 2011). In this study, the acceptance of the family was pro 'joining the ES' and therefore resulted in a high positive pressure for the farmer. To consider also details and the high complexity of interactions in decision making processes within farmers' families, further investigations and literature analyses need to be carried out.

Interestingly, the opinion of the other farming colleagues was judged as relatively irrelevant. This is in contrast to the general findings in the literature: Defrancesco et al. (2008) and Hynes and Garvey (2009) show that the opinion of neighbours regarding AES has significant influence on the farmers to adopt AES. Also Siebert et al. (2010) found that colleagues influence the decision-making of farmers. A possible explanation for this contradiction could be that in this study, the question was asked too directly and obtained a biased result (Raab-Steiner and Benesch, 2010). Even though it was suggested by Ajzen (2002) to ask directly how much a person wants to comply with the opinion of others, farmers might have felt too dependent on other people's judgements, if they would have stated that they care a lot about the opinion of farming colleagues. Therefore, the operationalization of the study question should be questioned. In open interviews, it would be easier to assess the influence

of farming peers. Another reason for the low influence of neighbours' opinion could be that the scheme was established already five years before the survey was carried out so that it might have been already common behaviour to join the schemes and that colleagues no longer matter in the decision-making process.

Also the opinion of the farm adviser was not ranked as to influence the behaviour of the farmers in this study much, which is in contrast to Siebert et al. (2010), who found that advisers influence farmers' behaviour at least to some extent. The farmers interviewed in this study responded that the farm adviser (agronomist) had a relatively neutral opinion whether farmers should join HLS. Hence, it is very important to include farmers' family and to work closer together with the farm advisers while promoting an HLS-option or conclude new HLS-contracts.

4.3 Control beliefs and perceived behavioural control to measure what drives farmers to join AES and which issues might make them insecure

Regarding aspects that were perceived to have influence on the personal control of farmers to join the ES, paperwork, scheme prescriptions and environmental advice should be noted. It was found that more paperwork or more prescriptions were perceived to make farmers' 'joining the ES' much more difficult, which should be considered when a scheme is designed. The high load of paperwork was also underlined by many farmers during the interview before this question was actually asked. These findings confirm the results of several other studies: Ruto and Garrod (2009) found that farmers require higher payments for schemes, which involve more paperwork; in the survey of Bertke et al. (2010) many farmers criticised that the level of bureaucracy of AES is too high; and Christensen et al. (2011) state the amount of paperwork is very important for farmers' decision to participate in environmental conservation measures. Scheme management restrictions for AES are also widely represented in the literature (Ruto and Garrod, 2009; Bertke et al., 2010; Espinosa-Goded et al., 2010; Christensen et al., 2011).

Aspects that were considered to make the joining of the ES easier were in this study generally higher consideration of environmental conservation in policy in the future and good quality and quantity of environmental advice because this would lead to a better understanding of ecological processes and management effects which was assumed to be helpful, especially for joining HLS. However, ultimately, farmers perceived that it was within their control to join the ES or not and that joining ELS was relatively easy. For HLS, many different opinions regarding this concern were observed. Hence, one aim for the future could be making HLS more easily understandable for farmers and to ease the procedure in which the farmer is involved. Otherwise, the high complexity and difficulty could lead to a lower willingness of farmers to join HLS. At the same time it should nevertheless be kept in mind that to a large part the high complexity of HLS allows for great success regarding environmental goals and is therefore often needed.

4.4 Critical appraisal

While interpreting the results of this study, it should be noted that measuring opinions of people is a difficult task and that some unconscious opinions, personal values, or behaviour might not have been expressible by the farmers and hence not been measurable. For further studies, it could be an option to develop the questions or items on basis of a prior elicitation study in which a smaller number of farmers would be asked openly about their (TPB) beliefs. The most often stated beliefs could subsequently be listed for the questionnaire. Indeed, some given answers in this study were correlated to others, e.g., 'HLS leads to an increase in weeds' and 'HLS makes farmland look untidy', or 'Prescriptions of HLS lead to lower flexibility in farming' and 'HLS impedes/hampers good agricultural practice and food production' (data not shown). This shows the link between farmers' perceptions and the consistence of their evaluations gained in this case study.

For further research, it would be interesting to apply the TPB for farmers who are not joining the ES and subsequently compare the results in order to prove whether reasons for refusal might be in accordance with issues identified to be critical in this study.

5 Conclusions

In this paper, the TPB was applied as theoretical construct to assess the acceptance of English farmers of AES and to identify factors influencing their decision to join the schemes. Interviews were conducted with farmers already participating in ES. The results show that these farmers judge the ES to produce more positive than negative outcomes and that HLS has higher positive impacts than ELS. Positive scheme effects included the increased biodiversity, conservation of natural resources, an enjoyable landscape and a good image of farming in the society and lead to a positive attitude towards joining the ES. It is therefore concluded that the major aims behind the ES are recognized and accepted by the farmers. However, the scheme outcome increasing of weeds was judged as negative and needs to be considered in future developments of the ES to avoid a decreasing scheme acceptance. Another approach could be here to try to change farmers' attitude towards weeds, taking into account that they ranked biodiversity as a positive outcome of AES. The intention of farmers to join AES is, besides their own attitude, also influenced by social pressure through others. The highest social pressure on farmers' decision making process occurs through their family, which is pro joining the ES. The results show that the farm adviser also influences farmers' intention, but to a lower extend. His opinion whether the

farmers should join ES was judged as pro joining ELS but neutral regarding HLS. It is therefore suggested that it is very important to work more closely together with the farmers' advisers while promoting an HLS-option or conclude new HLS-contracts and to involve the farmer families. Also farmers' perceived behavioural control influences their intention to join AES and is a result of their control beliefs. High load of paperwork and tight scheme prescriptions were identified to have negative influence and a good environmental advisory service to have positive influence on farmers' intention to join the ES. This leads to the perception of the farmers that, even though it is within their control to join ELS or HLS and joining ELS was perceived to be relatively easy, some farmers found it difficult to join HLS. Hence, it should be considered for the future to make HLS more easily understandable for farmers and to ease the procedure in which the farmer is involved. The findings from this study and their confirmation through the literature show that an ex-post application of the TPB for analysing the acceptance of AES is applicable and it contributes to a better understanding of farmers' decision making process regarding the participation in AES in general. The results show furthermore the high acceptance of farmers in the 'Yorkshire and the Humber' region already participating in the ES of the scheme and provide essential information required for future development of AES. For the new programming period 2014 to 2020, in-deed, a simplification of scheme design can be expected for the new AES of England called Countryside Stewardship (Defra, 2014).

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Annex

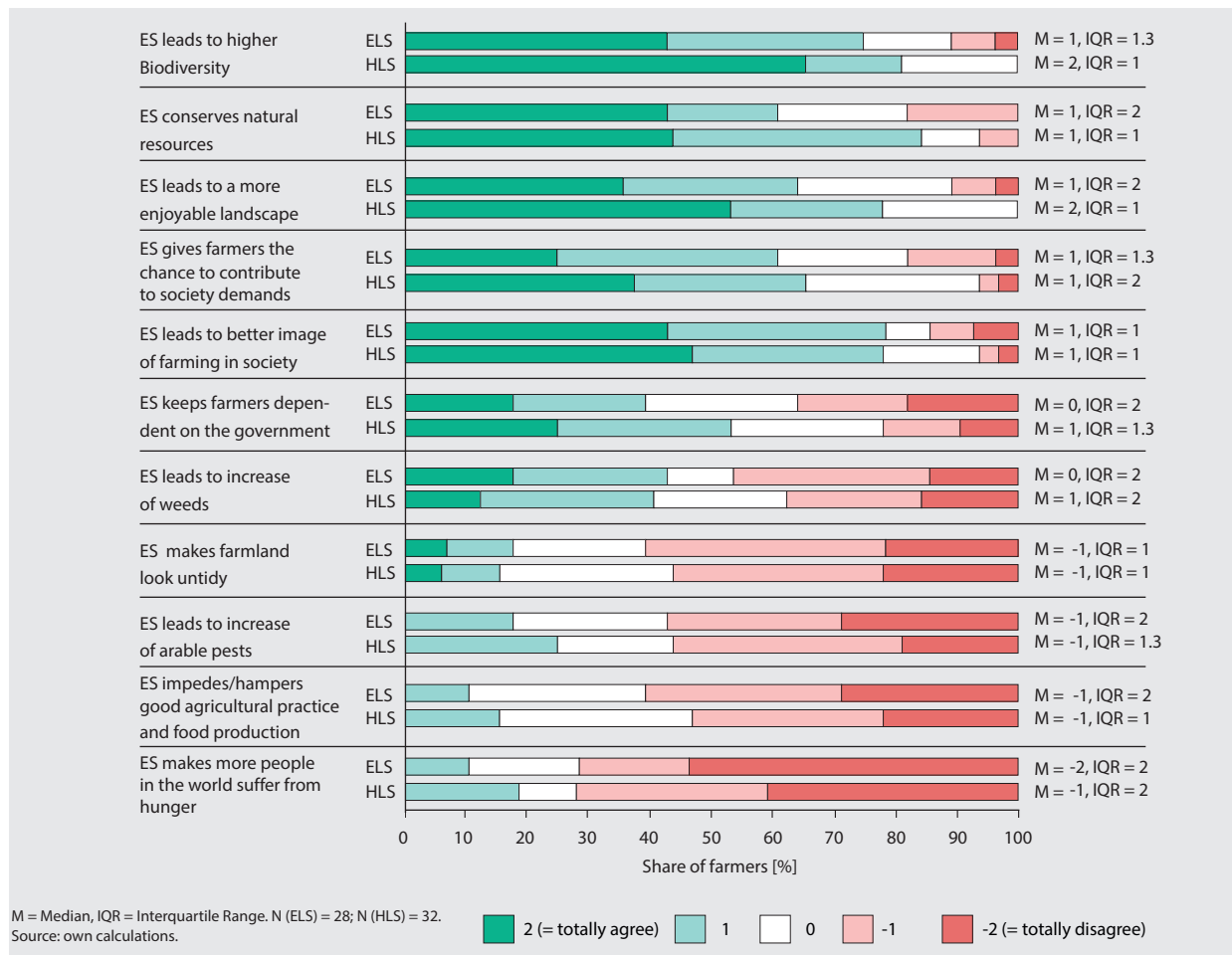


Figure 8
Farmers' outcome beliefs (OB) concerning 'joining ELS' and 'joining HLS'

Table 3
Farmers' outcome evaluations (OE)

	2	1	0	-1	-2	Median	Q1	Q3	IQR	No.
High Biodiversity is	16	11	5	0	0	1.5	1.0	2.0	1.0	32
Conservation of natural resources is	21	8	3	0	0	2.0	1.0	2.0	1.0	32
An enjoyable landscape is	22	10	0	0	0	2.0	1.0	2.0	1.0	32
A good image of farming in society is	23	6	3	0	0	2.0	1.0	2.0	1.0	32
Farmers contributing to society demands is	14	12	6	0	0	1.0	1.0	2.0	1.0	32
Impede/hamper good agricultural practice and food production is	1	0	12	14	5	-1.0	-1.0	0.0	1.0	32
Making more people in the world suffer from hunger is	0	0	3	8	21	-2.0	-2.0	-1.0	1.0	32
Keeping famers dependent on the government is	0	0	10	10	12	-1.0	-2.0	0.0	2.0	32
Increasing of weeds is	1	0	7	9	15	-1.0	-2.0	-0.8	1.3	32
Increasing of arable pests is	0	0	4	14	14	-1.0	-2.0	-1.0	1.0	32
Untidy looking farmland is	1	1	4	12	14	-1.0	-2.0	-1.0	1.0	32

2 = 'extremely good'; -2 = 'extremely bad'. Q1 = first quartile; Q3 = third quartile; IQR = Interquartile Range. N = 32.

Table 4

Farmers' motivation to comply (MC) with opinions of others

	2	1	0	-1	-2	Median	Q1	Q3	IQR	No.
Want to do what family thinks	10	15	3	3	1	1.0	1.0	2.0	1.0	32
Want to do what other Farmers think	1	8	14	5	4	0.0	-1.0	1.0	2.0	32
Want to do what farm adviser thinks	5	11	11	3	2	0.5	0.0	1.0	1.0	32
Want to do what society thinks	2	8	19	1	2	0.0	0.0	1.0	1.0	32

2 = 'very much'; -2 = 'not at all'. Q1 = first quartile; Q3 = third quartile; IQR = Interquartile Range.
Source: own calculations.

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Regional accessibility of supermarkets and discounters in Germany – a quantitative assessment –

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Abstract

Services of general interest fulfill the public's daily needs and are important for well-being. In Europe, interacting socio-economic and demographic processes lead at present to a spatial concentration of basic services. Especially rural areas are thought to be affected by these processes, resulting in a deterioration of the living conditions of people living in these regions. Although this subject is being discussed intensively in policy as well as science, still little quantitative information on the consequences of these processes on people is available. By analyzing the accessibility of supermarkets and discounters, as an important part of the infrastructure of services of general interest near the place of residence in Germany, with a GIS accessibility analysis, this article aims to underscore this discussion with quantitative data.

Thereby it is shown that despite the processes of spatial concentration found in retail sales, supermarkets and discounters are well accessible by car throughout Germany. Nevertheless, considering the accessibility by foot, it becomes apparent that only in cities can supermarkets and discounters be accessed in a reasonable amount of time. So, especially in rural areas, especially in the eastern federal states, supermarkets and discounters are poorly accessible for less mobile people, mainly the elderly or young adults.

Keywords: *Rural development, local supply, supermarkets, discounters, raster based GIS accessibility analysis*

Zusammenfassung

Regionale Erreichbarkeit von Supermärkten und Discountern in Deutschland – eine quantitative Abschätzung –

Daseinsvorsorgeinfrastrukturen decken Bedürfnisse des täglichen Bedarfs und wirken sich auf die Lebensbedingungen der Bürger aus. Aktuell führen in Europa sich wechselseitig beeinflussende sozioökonomische und demographische Prozesse zu einer räumlichen Konzentration von Daseinsvorsorgeinfrastrukturen. Es wird davon ausgegangen, dass von diesen Prozessen besonders ländliche Räume betroffen sind und diese zu einer Verschlechterung der Lebensbedingungen der dort lebenden Bürger führen. Obwohl diese Aspekte aktuell sowohl in der Politik als auch der Wissenschaft thematisiert werden, gibt es bislang kaum quantitative Informationen über die Konsequenzen für die Bürger. Vor diesem Hintergrund befasst sich der Artikel mit der Situation der wohnortnahen Erreichbarkeit von Supermärkten und Discountern in Deutschland als ein für die Bürger wichtiger Teilbereich der Daseinsvorsorgeinfrastruktur basierend auf einer GIS-Erreichbarkeitsanalyse mit dem Ziel, die aktuelle Diskussion mit quantitativen Daten zu unterfüttern.

Als Ergebnis lässt sich festhalten, dass derzeit in Deutschland trotz der zu beobachtenden Konzentrationsprozesse im Lebensmitteleinzelhandel Supermärkte und Discounter mit dem Auto flächendeckend gut zu erreichen sind. Betrachtet man hingegen die fußläufige Erreichbarkeit von Supermärkten und Discountern, so lässt sich feststellen, dass diese nur in den Städten gegeben ist. In ländlichen Räumen und hier besonders in den östlichen Bundesländern sind Supermarkt und Discounter somit für weniger mobile Bürger wie Senioren und junge Erwachsene vergleichsweise schlecht erreichbar.

Schlüsselwörter: *Entwicklung ländlicher Räume, Nahversorgung, Supermärkte, Discounter, Rasterbasierte GIS Erreichbarkeitsanalyse*

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1 Introduction

In Europe, at present interacting socioeconomic and demographic processes are leading to a spatial concentration of basic services (see Küpper and Eberhardt, 2012).

In the food retail sector this development is characterized by concentration processes (in favor of enterprises with greater sales floors and locations with sufficient parking spaces and good transport connections), the reduction of personal services as well as a structural change of the types of offer – away from independent retailers towards standardized retail formats like supermarkets, consumer markets and discounters (KPMG, 2005; Valée and Lenz, 2007; Kuhlicke et al., 2005; Lein, 2012). As a consequence, a closing of enterprises serving the local supply as well as specialized markets not belonging to market-chains can be observed (Kuhlicke et al., 2005; Lein, 2012). Especially in rural areas, this development is supported by the current demographic processes that are characterized by an overall population decrease, an increase in the expectancy of life together with lower birth rates (Statistisches Bundesamt, 2009; Kollmann and Sieker, 2006; Gatzweiler and Kocks, 2004; Tönnies, 2004), and an aging and depopulation of rural areas. That means: demographic processes are causing a change in demand, which in turn leads to an abandonment of unprofitable locations (see Higgs and White, 1997). Expressed in simplified terms, these shrinking processes may lead to a spiraling down, where shrinking leads to a decrease in attractiveness, which in turn leads to further shrinking (Specht et al., 2013). As a consequence, people living in these areas often have to cover greater distances to reach certain parts of the infrastructure (see Higgs and White, 1997; Küpper and Eberhardt, 2012). To counteract these processes, the European Union complemented its cohesion policy with the concept of territorial cohesion. Amongst others, one objective of this policy is to ensure adequate access to basic services (see European Commission, 2014). For this purpose, information on the accessibility of basic services is needed to form an objective and realistic impression of the current situation. This information can function as input for future policy action and intervention (see Schulz and Bröcker, 2007). Although the spatial concentration of basic services is a heavily debated issue (for more information on this discourse see for example Favry et al., 2006; Born, 2009; Jens, 2009; Neu, 2009; Küpper, 2011; Küpper and Eberhardt, 2013; Steinführer et al., 2014; Steinführer, 2014), to date, in Germany, little is known about its true dimensions (see Küpper and Eberhardt, 2012). That is, studies available presenting quantitative data generally focus on selected spatially limited regions only (e.g., a single community or county) – nationwide quantitative data is not known. In this context, one subject area attracting particular attention is the availability and accessibility of retail sales outlets. Against this background we analyze the accessibility of supermarkets and discounters, as an important part of the infrastructure of daily needs, with a raster-based GIS¹ accessibility analysis for Germany based on the EWZ250 250 m

raster, commercial street data and the a-star shortest path algorithm. Thereby special attention is paid to the situation in rural areas. The analysis at hand focuses on the modeling of the nationwide accessibility of supermarkets and discounters in Germany in order to get quantitative data on the current accessibility of services of general interest with retail sales near the place of residence.

The aim of the article is threefold: First, it aims at presenting a methodology for deriving small scale accessibility data on services of general interest. Second, it underscores the discussion about the accessibility of services of general interest with spatially differentiated, reliable, nationwide quantitative data on the accessibility situation of supermarkets and discounters. Third, the article wants to motivate the generation of similar analyzes for other services of general interest. The article does not explicitly aim to derive recommendations for action, to discuss reasons and consequences of the spatial concentration of services of general interest, or the determinants of different living conditions in rural areas, or to discuss accessibility against the background of the discourse on poverty or social justice, as such considerations can already be found elsewhere (e. g., Neu, 2009; Faber, 2013; Kötter et al., 2013; Eib and Braun, 2014; Yeager and Gatrell, 2014).

The remainder of the article is divided into four sections. In Section 2, key data on supermarkets and discounters as well as consumer behavior regarding means of transport selection for shopping purposes and preferred locations for food shopping are presented. This information serves as background information in order to correctly assess the status quo in retail sales concerning supermarkets and discounters as main locations for food shopping. Section 3 introduces the concept of accessibility as well as the data sources and methodology the analysis builds upon. Based on the accessibility model in Section 4, the regional accessibility of supermarkets and discounters in Germany is discussed. The article closes with a conclusion summarizing the main findings.

2 Key information on supermarkets and discounters in Germany

When talking about supermarkets, experts differentiate between the following three categories of markets that are defined according to the sales floor, the number of articles offered as well as the composition of the assortment of goods: supermarkets, consumer markets and SB-warehouses (self-service warehouses) (Table 1).

In the past, discounters could not fully function as true local suppliers because of their limited assortment. Nevertheless, more recently, discounters have gradually developed towards a true local supplier by augmenting their assortment of goods, especially that of fresh foods (Kuhlicke and Petschow, 2005; KPMG, 2005). Nevertheless, today the assortment of discounters is still limited compared to the assortment of supermarkets. Thus, people living in regions where only a discounter is accessible are comparably more

¹ GIS: Geographic Information System.

Table 1

Differentiating characteristics of supermarkets, consumer markets, sb-warehouses and discounters.

	Supermarket	Consumer market	SB-warehouse	Discounter
sales floor in m ²	400 to 2,500	2,500 to 5,000	≥ 5,000	400 to 1,200
Ø sales floor in m ²	1,370	3,254	7,449	761
Ø nr. of articles	10,500	25,016	50,979	800 to 1,700
sortiment	full service grocery store Nonfood I articles small amount of Nonfood II articles	full service grocery store Nonfood I articles Nonfood II articles	full service grocery store Nonfood I articles Nonfood II articles	narrow and flat assortment of goods with high shares of private labels
Ø customers per day	1,531	2,773	3,991	n.s.
Ø annual sales in €	6,250,000	14,480,000	32,930,000	n.s.

Sources: Bernreuther, 2011; Borutta et al., 2012; Bundesverband des deutschen Lebensmitteleinzelhandels, 2013; EHI, 2013; Küpper and Eberhardt, 2013

disadvantaged due to the available range of goods than people with an accessible supermarket. To be able to also take this aspect into account, in the remainder of the article we decided not only to analyze supermarket and discounter accessibility as a whole, but also to differentiate between supermarkets and discounters as well.

2.1 Spatial development of supermarket and discounters

A spatial concentration of basic services in favour of more central locations can be registered throughout Europe as a result of interacting socioeconomic and demographic processes. Especially in rural areas this development leads to a withdrawal of basic services. In Germany, a decrease in retail food businesses from 85,000 in 1990 to 41,348 in 2008 could be observed. Although the decline has lessened since 2008 it still continues, so that in 2012 only 38,866 food retail sale businesses existed in Germany (www 1, 01.10.2013; Handelsverband Deutschland, 2013). Thereby it is striking that since 2008, mainly small scale retail food sale businesses with a sales floor of up to 400 m² closed (2008: 13,900; 2012: 10,064) whereas a slight increase in supermarkets (2008: 9,660; 2012: 10,505); consumer markets (2008: 931; 2012: 10,010); sb-warehouses (2008: 877; 2012: 894), and discounters (2008: 15,970; 2012: 16,393) could be observed at the same time (www 1, 01.10.2013; Handelsverband Deutschland, 2013).

All in all, characteristic for the development of the retail sales are processes of concentration (in favour of businesses with greater sales floors, and locations with sufficient parking spaces and good accessibility by car), the reduction of services and a structural change towards standardized business types like supermarkets and discounters instead of small-scale, privately owned businesses (KPMG, 2005; Vallée and Lenz, 2007, 20; Kuhlicke et al., 2005; Lein, 2012). Simultaneously it can be observed that business locations are increasingly relocated from the city centers to the peripheries of the cities (Valée and Lenz, 2007). Altogether the development resulted in a more wide-meshed grid of food retail sales businesses (Handelsverband Deutschland, 2013). A concentration of businesses can be registered in densely populated regions with high purchasing power (Lein, 2012;

Kuhlicke and Petschow, 2005) and a thinning in sparsely populated peripheral regions that are affected by the demographic changes (Kuhlicke and Petschow, 2005).

2.2 Key information on means of transport selection for shopping purposes

According to a study conducted by the CIMA GMBH, 61.1 % of the consumers use cars, 26.6 % bicycles, 3 % public transportation, 8.7 % walk and 0.5 % use other means of transport like taxis for food shopping (Lein 2012). The study "Mobilität in Deutschland"² (MID), conducted by the Federal Ministry of Transport, Building and City Development (BMVBS), considers the use of means of transport for shopping and comes to slightly different results. According to this study 58 % use cars, 10 % bicycles, 4 % public transportation and 27 % walk. Thereby the time spent for travel to shopping locations amounts on average 13.1 minutes (BMVBS, 2011). Although the results of both studies differ from one another – partly because of the special status of food shopping compared to the shopping behavior in general – both studies allow the conclusion that the majority of customers use cars as the means of transport for food shopping purposes. In this regard it can be observed that in rural areas, more customers use cars than in agglomerations and cities by comparable distances covered (Handelsverband Deutschland, 2013).

2.3 Preferred locations of food supply and subjective satisfaction with the food shopping situation as seen by the customers

According to a study conducted by the CIMA GMBH, analyzing transport use for food shopping, 89 % of the consumers prefer supermarkets (55.3 %) or discounters (33.6 %), whereas only 11 % prefer consumer markets (4.9 %), specialized stores (2.8 %), wholefood-markets (1.5 %) or farmer's markets (1.3 %) (Lein, 2012).

Altogether a survey analyzing the satisfaction with the local supply condition conducted by the Handelsverband Deutschland e.V. (HDE), based on a household survey in

² Mobility in Germany

4,000 selected households throughout all BBSR district types³, revealed that the majority of questioned households are very satisfied or satisfied with the local shopping situation (Handelsverband Deutschland, 2013). Similarly, Heinritz et al. (2003) found that throughout all community classes, only 12 % to 15 % of the consumers are not satisfied with the local shopping situation. For these consumers, not only poor accessibility, but also a lack of alternative shopping possibilities, as well as an insufficient offering, are the main reasons for their dissatisfaction. Nevertheless, at present, all in all the subjective satisfaction with the food supply is relatively high (Handelsverband Deutschland, 2013). Thereby, according to Adamovicz et al. (2009) the subjective satisfaction is slightly higher in metropolises than in rural areas. Nevertheless Ellger (2000), as well as Born (2009), concentrating on rural areas, found that also in rural areas a high share of the population is quite satisfied with the local retail situation, even if the shops cannot be accessed by foot in a reasonable amount of time (Ellger: 91.6 %; Born: 64 %). In addition, Born (2009) states that this applies to all age classes.

This high subjective satisfaction can be explained by the fact that because of the high availability of a car, especially in rural areas, the accessibility at the place of residence is losing its importance (Küpper and Eberhardt, 2013) and leads to an increase in shopping mobility (Kuhlicke et al., 2005). So, at present, poor accessibility by foot is not perceived as problematic (Küpper and Eberhardt, 2013).

3 Analysis of supermarket and discounter accessibility: theoretical background, data sources and methodology

The following chapter introduces the concept of accessibility and deals with common approaches to acquire accessibility indicators followed by a description of the accessibility approach and data sources utilized for the analysis. The chapter concludes with a detailed description of the specific method applied in this paper.

3.1 Theoretical background: Accessibility and accessibility indicators

The concept accessibility is used with slightly different definitions in several fields including city or infrastructure planning, or marketing. But generally accessibility can be conceptualized as the number of opportunities for economic and social life that can be reached with a reasonable effort. All in all, accessibility defines the quality of a point in space constituted by its traffic connections to other points in space. So, accessibility is a main product of the available transport system (see

Bleisch and Koellreuter, 2003; Schürmann et al., 1997; Schwarze, 2005). Accessibility indicators are a measurement of the benefits accruing from the available transport infrastructures (see Bleisch and Koellreuter, 2003). Thereby accessibility indicators can be simple supply indicators (e.g., length of road network, number of pharmacies per community) as well as complex generic indicators (e.g., travel times). Different methods exist to gain accessibility values that can roughly be grouped into three categories: (1) approaches common in transport sciences based on a prognosis of the traffic situation (e.g., gravitation models, opportunity models, random utility theory) (see Bleisch, 2005; Schulz and Bröcker, 2007), (2) approaches common mainly in regional economy based on spatial interaction models (gravitation models, logit-models) (see Bleisch, 2005; Schulz and Bröcker, 2007) and (3) approaches focusing on the geographic accessibility (Euclidean distance, distance within street networks) (see Hemetsberger and Ortner, 2008). One peculiarity of geographic accessibility is that in regions with a dense road network like in urban areas, the Euclidean distance provides accurate enough results, whereas in regions with sparse road networks like in rural areas, the determination of the Euclidean distance is insufficient. This is because the circumvention of anthropogenic and natural barriers is more likely to extend the distances to be covered (see Dahlgren, 2008). Therefore in such regions accessibility within road networks have been shown to deliver more accurate results.

3.2 Accessibility approach followed

The analysis at hand is based on geographic accessibility by considering distances within road networks. Thereby a raster-based approach has been followed (see for example Hemetsberger and Ortner, 2007, 2008; Schürmann, 2008). That means the area under consideration (Germany) is overlain by a vector raster with a specific cell size. The centroids of the single raster cells represent the starting points of the analysis, meaning that the shortest street distance to the next supermarket/discounter is determined from every centroid. The resulting value is attributed to the raster cell representing the distance of this cell. All in all, the accessibility analysis is implicitly based on the simplified assumption that the next supermarket or discounter is chosen according to the shortest street distance from every starting-point. The result is a raster-based statistic that allows supermarket and discounter accessibility to be analyzed below the level of administrative regions or census regions⁴. Furthermore, calculation of areas can easily be achieved based on the single raster cells, e.g., by computing the arithmetic mean of the values attributed to raster-cells covering an area of interest.

3.3 Data sources

The analysis is based on the address data set of supermarkets and discounters of the commercial address re-seller "wer-zu-wem.de". This data set contains the addresses of 15,281

³ In 2009, the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) developed the nine so-called BBSR district types that are meant to assist in an interregional comparison of different types of regions within Germany (NUTS 3). For further information to the BBSR district types please see Section 3.2.

⁴ A detailed introduction on the nature of raster based regional statistics is given by Kaup and Rieffel, 2013

supermarkets and consumer markets, and addresses of 16,080 discounters as of September 2013.

The following supermarkets and consumer markets are included: Edeka with Neukauf; nah&gut; E aktiv markt; Treff 3000; Akzent; AEZRewe (Rewe, Nahkauf, Toom); Kaufland; Bunting (Combi, Famila); Bartels & Langness (Famila); Markant (Bunting, Offenburg); Coop (Sky, Plaza); Kaisers Tengelmann incl. Mema; Real; as well as the regional providers Coma; Feneberg; Globus; Hit; Inkoop; Jibi; Konsum Leipzig; Konsum Dresden; K+K; Markant Saxony; Mini-Preis; Multi; Novo; SBK; Tegut; Ullrich; V-Markt; Wasgau; WEZ; diverse bio-markets; Karstadt Perfetto, Grenshops and Italo-Supermarkets and the C+C providers like Metro, Fegro, SB-Union.

The following discounters are included: Aldi Nord and Süd; Lidl; Penny; Norma; NP-Markt; Netto Marken-Discount, und Netto Stavenhagen.

According to the present statistics of the Bundesverband des deutschen Lebensmitteleinzelhandels (BVLH) in 2012 12,409 supermarkets and 16,393 discounters existed in Germany. The deviation of the “wer-zu-wem.de” dataset from the BVLH statistics can in part be explained by the dynamic in the food-retail sector between the two different acquisition periods (31.12.2012 BVLH; September 2013 “wer-zu-wem.de”), as well as the fact that it is quite likely that differences in the companies considered and allocation to the categories “supermarket” and “discounter” exist. The supermarket and discounter addresses have been geocoded by methods of address geocoding. Thereby one should be aware that a 100 % correct geocoding of addresses can, because of different ways of registering addresses, only be achieved by manually supervising the whole process. This is not possible with a greater stock of addresses as applicable here, so that single misassignments are probable and inevitable. This might in a few regions lead to an under-, respectively, overestimation of the supermarket and discounter accessibility. Thereby single spatially distributed misassignments are less problematic than regional/local cumulative misassignments. The spatial distribution of the geocoded supermarkets and discounter is shown in Figure 1. As can be seen, the density is relatively high in the agglomerations and decreases towards the more rural areas.

The data set EWZ250, developed by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), has been used as the raster of reference. This raster has a cell size of 250 m and contains disaggregated population values based on official population statistics⁵ as well as population data of urban districts for raster cells identified as inhabited based on the ATKIS Basis DLM⁶. More detailed information on these aspects can be found in Burgdorf (2010).

All in all, as common with disaggregated rasterized population data sets, the population counts are to a certain extent underestimated in urbanized areas and overestimated in rural areas (see Burgdorf, 2010). In order to reduce computation costs, only cells defined as inhabited have been incorporated in the accessibility analysis. That means cells of the EWZ250 containing population values greater than zero, plus cells containing buildings according to the data set of building coordinates of the GVHK⁷/Adv⁸. Altogether the analysis raster contains 1,667,191 cells identified as populated.

The street network utilized is based on commercial street data. Due to computation costs it was decided not to consider single lane traffic in the accessibility analysis.

In addition nine “BBSR district types 2009”, developed by the BBSR (see BBSR, 2009b) in order to assist in an inter-regional comparison of different region types within Germany on the level of administrative districts, have been used as an analytical framework (see Krieh, 2011)⁹:

- Type 1: Core cities in agglomerations (core cities, urban districts > 100,000 citizens);
- Type 2: Densely populated districts in agglomerations (more than 300 citizens per km²);
- Type 3: Highly populated districts in agglomerations (more than 150 citizens per km²);
- Type 4: Rural districts in agglomerations (districts with less than 150 citizens per km²);
- Type 5: Core cities in urbanised areas (cities > 100,000 citizens);
- Type 6: Densely populated areas in urbanised areas (more than 150 citizens per km²);
- Type 7: Rural districts in urbanised areas (districts with less than 150 citizens per km²);
- Type 8: Densely populated rural areas (districts with more than 100 citizens per km²);
- Type 9: Sparsely populated rural areas (districts with less than 100 citizens per km²);

3.4 Method of the accessibility analysis

Prior to the distance calculations, the raster centroids as well as the locations of supermarkets and discounters were connected with the route network by adding a vertical line from every start/target point to the nearest street in the route network. The distance calculation was based on the “a-star shortest path” algorithm (see Hart et al., 1968 for further information) and was performed with PostgreSQL using the pg_dijkstra extension. In order to reduce computation costs for the supermarket and discounter locations, voronoi polygons¹⁰ were defined prior to the accessibility

⁵ Unfortunately Burgdorf (2010) does not specify the year of reference for the population values the disaggregation is based on. Considering that in the references he lists a „Qualitätsbericht – Fortschreibung des Bevölkerungszustandes“ of the Federal Statistical Office from 2008, it can be assumed that the population data used for the disaggregation is based on the population as of 2008, too.

⁶ The ATKIS Basis DLM is a digital base landscape model for Germany.

⁷ GVHK: Association for the distribution of building coordinates.

⁸ Adv: Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany.

⁹ Detailed information on the „BBSR district types“ can be found on the homepage of the BBSR: <http://www.bbsr.bund.de/nn_1067242/BBSR/DE/Raumbeobachtung/Raumabgrenzungen/Siedlungsstrukturelle-Gebietstypen/Kreistypen/kreistypen__node.html> (29.04.2013).

¹⁰ These are polygons containing the area closest to the single locations (here, the single supermarket/discounter).

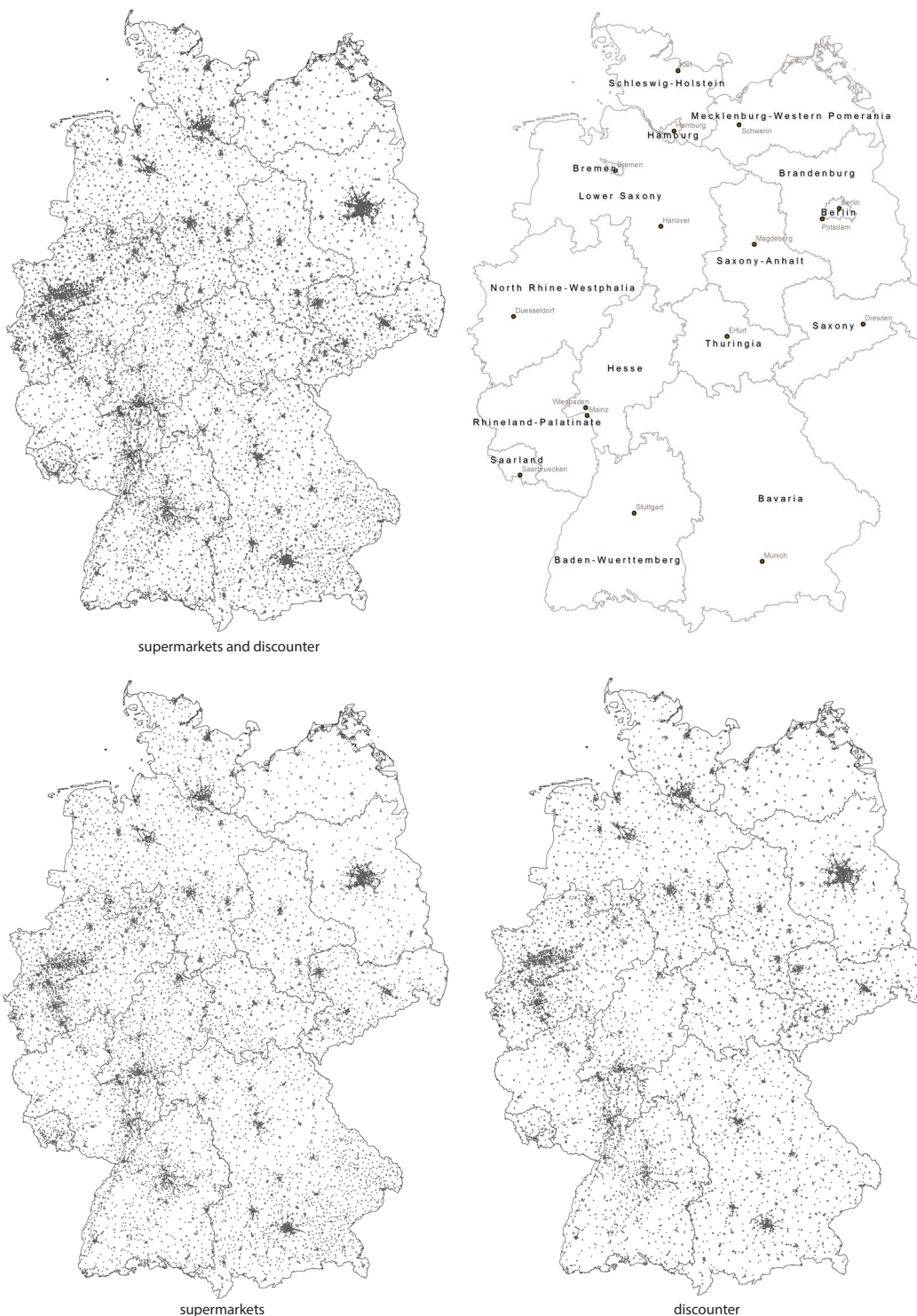


Figure 1

Spatial distribution of the geocoded supermarket and discounter addresses.

(Sources: Administrative boundaries: Bundesamt für Kartographie und Geodäsie, 2010; geocoded supermarkets and discounters: Own calculations based on data from wer-zu-wem.de, Esri's™ "Europe Geocode Service, GVHK/AdV).

analysis (Figure 2). Based on these polygons, the street distance was calculated from every supermarket and discounter to every raster centroid within the single voronoi polygons. This simplification proved to be necessary as otherwise the distance calculation would not have been possible in a

reasonable amount of time. Nevertheless, as a result, the analysis builds upon a simplified image of reality, that may in some regions influence the analysis results to a greater degree, leading to a greater deviation of the estimated accessibility values from reality than on average (e.g., if a river or

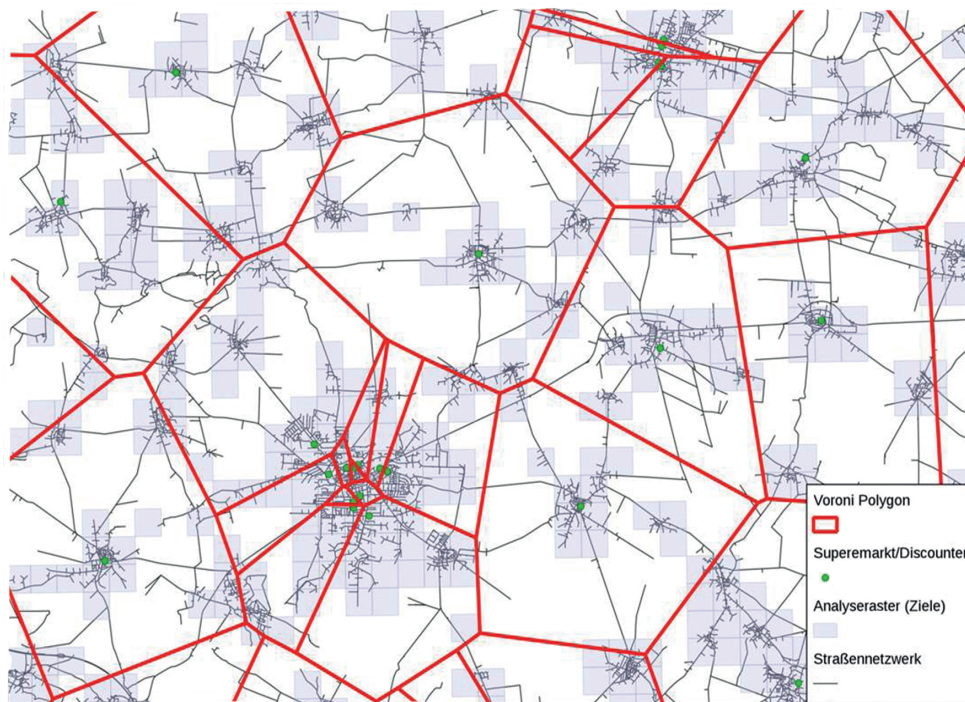


Figure 2
Method of accessibility analysis

highway constitutes a situation where the next supermarket/discounter reachable by street is not that within the voronoi polygon under consideration).

In the result data sets of the accessibility analysis, potential outliers that could mainly be attributed to topological inconsistencies in the route network or to unavoidable simplifications within the accessibility model have been corrected. Thereby distance values above the upper quartile of the value distribution plus three times the interquartile distance have been identified as outliers as this is a well-proved method to detect outliers in uneven distributions.

4 Accessibility of supermarkets and discounter

Before the results on supermarket and discounter accessibility in Germany are presented, the reader shall be reminded that accessibility situations are not static but likely to change during the course of time. In this sense the results represent a snap-shot for the reference years 2013/2014. Furthermore, the results are strongly dependent on the accessibility model used; they do not represent reality, but an ideal typical situation (see Johnston et al., 2000).

A framework of assessment is necessary in order to be able to determine whether a service is close to the place of residence. When discussing the accessibility of basic services in policy, ten minutes by foot or a distance of 500 to 1,000 meters is commonly considered an optimal threshold (see Adamovicz et al., 2009; Beckmann, 2007; Muschwitz et al., 2011; Schrader and Paasche, 2010). Considering the

population's expectations, the office of spatial development and geoinformation of the canton St. Gallen, Switzerland found out that a travel time of 15 minutes to reach a service of basic needs is accepted by most people (see Amt für Raumentwicklung und Geoinformation, Kanton St. Gallen, 2008). In Germany, on average, people need 12 to 17 minutes to reach a shopping opportunity (BMVBS, 2011). Concentrating on the accessibility situation as experienced by the citizens, accessibility values up to 15 minutes can therefore be considered acceptable. Assuming an average speed by car of 60 km/h this corresponds to a distance of 15 kilometers. By foot people commonly have an average walking speed between 1.3 m/s (4.7 km/h) and 1.45 m/s (5.2 km/h) subject to certain socioeconomic characteristics (age, gender, health status,...) (Perry, 1992; Götz-Neumann, 2006; Morgenroth, 2008; Granacher et al., 2010). So, shops at a maximum distance of 1,170 m (1.3 m/s) to 1,305 m (1.45 m/s) can be reached by foot in 15 minutes. In the remainder of the article the lower walking speed of 1.3 m/s will be considered to take special account of less mobile, slow-walking persons. The political limit of 1,000 m will be included in the figures for those who are interested in it, but not be commented on any further as it is merely a synthetic rather than a theoretically grounded value.

4.1 Regional accessibility of supermarkets and discounter

The statistical parameters of the calculated accessibility raster depicted in Table 2 give a first overview of the accessibility situation of supermarkets and discounters in Germany.

Considering supermarkets and discounters as a whole, as well as separately, the distribution of the accessibility values is left skewed. That means, there are many raster cells with short distances to be covered to the next market, and with increasing distance the number of raster cells affected decreases.

Table 2

Summary of statistical parameters of the accessibility analysis

Supermarkets and discounters			
parameter	supermarkets and discounters	supermarkets	discounters
	(values are rounded)		
Minimum in meters	3	3	3
Maximum in meters	89,009	89,001	90,010
1. Quartile in meters	1,277	1,763	1,532
3. Quartile in meters	4,805	6,432	5,251
Median in meters	2,725	3,775	3,073
Mean in meters	3,413	4,523	3,786
Standard error of mean in meters	2	3	2
standard deviation in meters	2,811	3,490	2,983
Variance in meters	7,898,695	12,183,107	8,899,946

All in all, on average, the distance to the next supermarket or discounter amounts to 3.4 km.

Considering only supermarket accessibility, on average the distance amounts to 4.5 km. Last but not least, considering discounter accessibility, on average the distance to the next discounter amounts to 3.8 km. Considering supermarket and discounter accessibility differentiated by federal states and BBSR district types (see Table 3), great differences can be noticed. Tendentially, the distances to be covered increase from the core cities in agglomerations towards the sparsely populated rural areas. Partly the distances to be covered within a BBSR-Kreistyp 2009 differ greatly between the different federal states. So, quite noticeable are the comparably great distances in Brandenburg in “highly populated districts in agglomerations” or in “rural districts in agglomerations” in North Rhine-Westphalia.

As a consequence of the concentration processes in the food retail sale sector, today, no supermarket exists in approximately 57 % of the communities. In approximately 53 % of the communities neither a supermarket nor a discounter exists. Especially rural communities are affected by this development. In this regard it is quite evident that the grid of supermarket and discounter locations is comparably wide-meshed in the federal states Schleswig-Holstein, Mecklenburg-Western Pomerania, Rhineland Palatinate as well as in great parts of rural Brandenburg, Thuringia and Bayern (see Figure 3). This pattern is also reflected when considering the accessibility of supermarkets and discounters per

Table 3

Average distances to the next supermarket or discounter, supermarket, discounter within federal states and BBSR district types

supermarket or discounter										
federal state	average federal state	BBSR district type 2009								
		urban district types					rural district types			
		1	2	3	5	6	4	7	8	9
		average distance to the next supermarket or discounter in m								
Schleswig-Holstein	3,941	2,026	3,073	3,748	1,751	3,839	4,027	4,261	4,000	4,410
Hamburg	1,961	1,959	918	3,300						
Lower Saxony	3,455	892	2,064	3,246	1,686	3,135	3,826	3,970	3,711	4,363
Bremen	2,061	2,137			1,713		817			
North Rhine-Westphalia	2,549	1,477	2,391	3,092	1,965	2,954	6,505	3,666		
Hesse	2,663	1,285	2,196	2,925	1,219	2,546		3,409	2,946	
Rhineland-Palatinate	3,989	1,300	1,768	3,044	1,793	3,681		5,111		
Baden-Württemberg	3,147	1,368	2,087		1,620	3,315	3,823	4,164	5,821	
Bavaria	3,313	1,131	2,264	2,922	1,370	3,054	3,273	3,601	3,346	3,911
Saarland	2,509	1,881	2,375	3,147		6,220				
Berlin	1,107	1,106					3,730			
Brandenburg	5,052	2,489		8,025	3,135		4,679	4,645	2,161	6,811
Mecklenburg-Western Pomerania	5,701	1,484			1,782			5,462	5,223	5,955
Saxony	3,194			3,503	1,560	3,193	3,197	3,614	3,558	4,551
Saxony-Anhalt	3,833				1,459	3,034	6,234	3,725	3,295	4,952
Thuringia	3,574				2,223	3,475		4,057	3,286	3,988
Gesamt	3,412	1,487	2,299	3,194	1,750	3,190	4,194	4,083	3,510	4,984

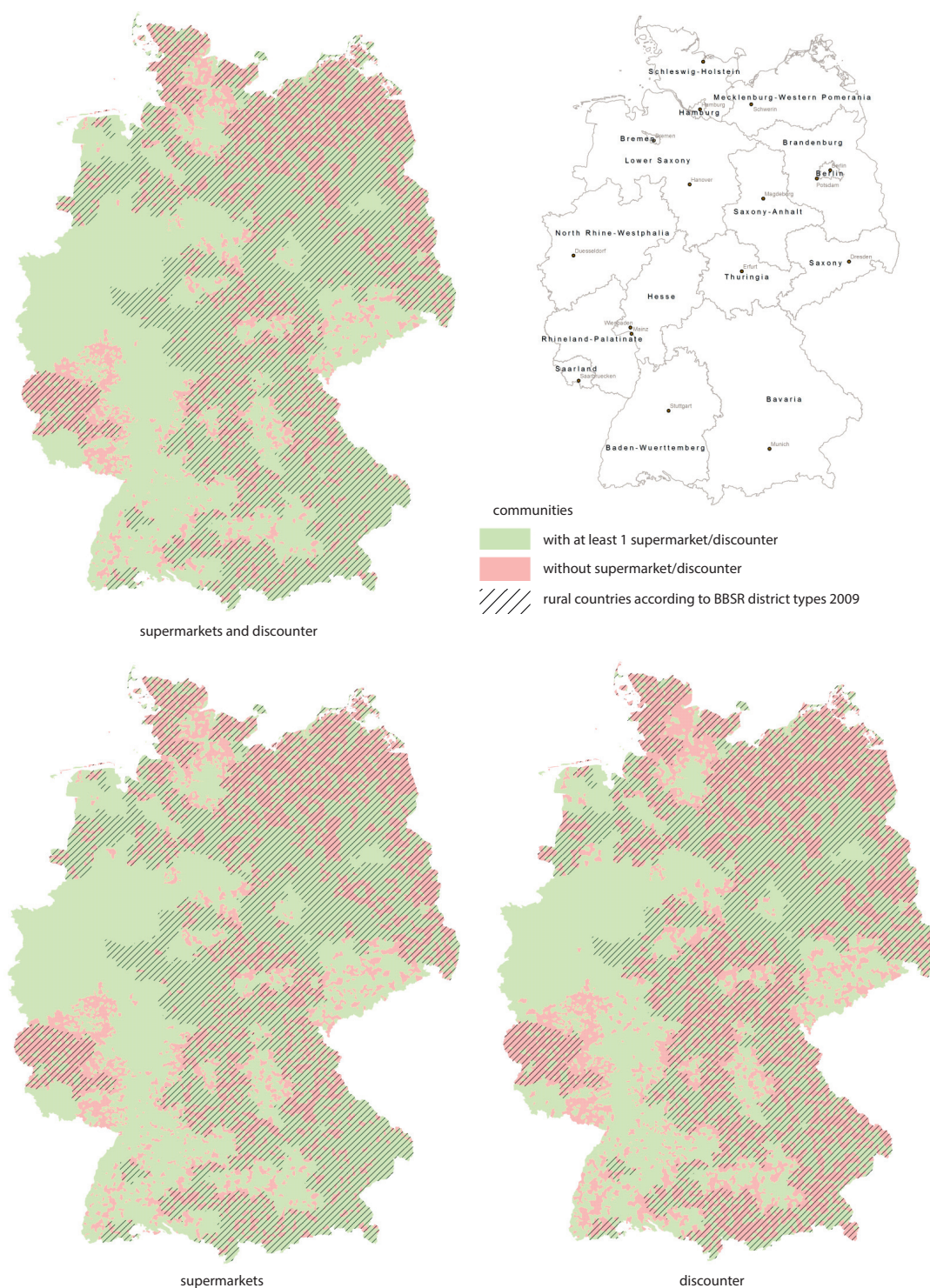


Figure 3
Communities with and without supermarket/discounter. (Sources: Administrative boundaries: Bundesamt für Kartographie und Geodäsie, 2010; BBSR district types: BBSR; Own calculations).

community average (see Figure 4). Nevertheless considering the accessibility by car (Table 4), in 99.2 % of the communities, a supermarket or discounter can on average be reached within 15 minutes driving time (60 km/h). Considering community averages, a supermarket is reachable in this time in 99 % of the communities and a discounter in 97.9 % of the

communities. In contrast, by foot, based on a 1000 m distance often used in policy, supermarkets and discounters are only reachable in 1.3 % of the communities, supermarkets in 0.8 % and discounter in 0.2 % of the communities. Supposing a slow walking speed of 1.3 m/s, supermarkets and discounters can be reached in 15 minutes (this corresponds to a

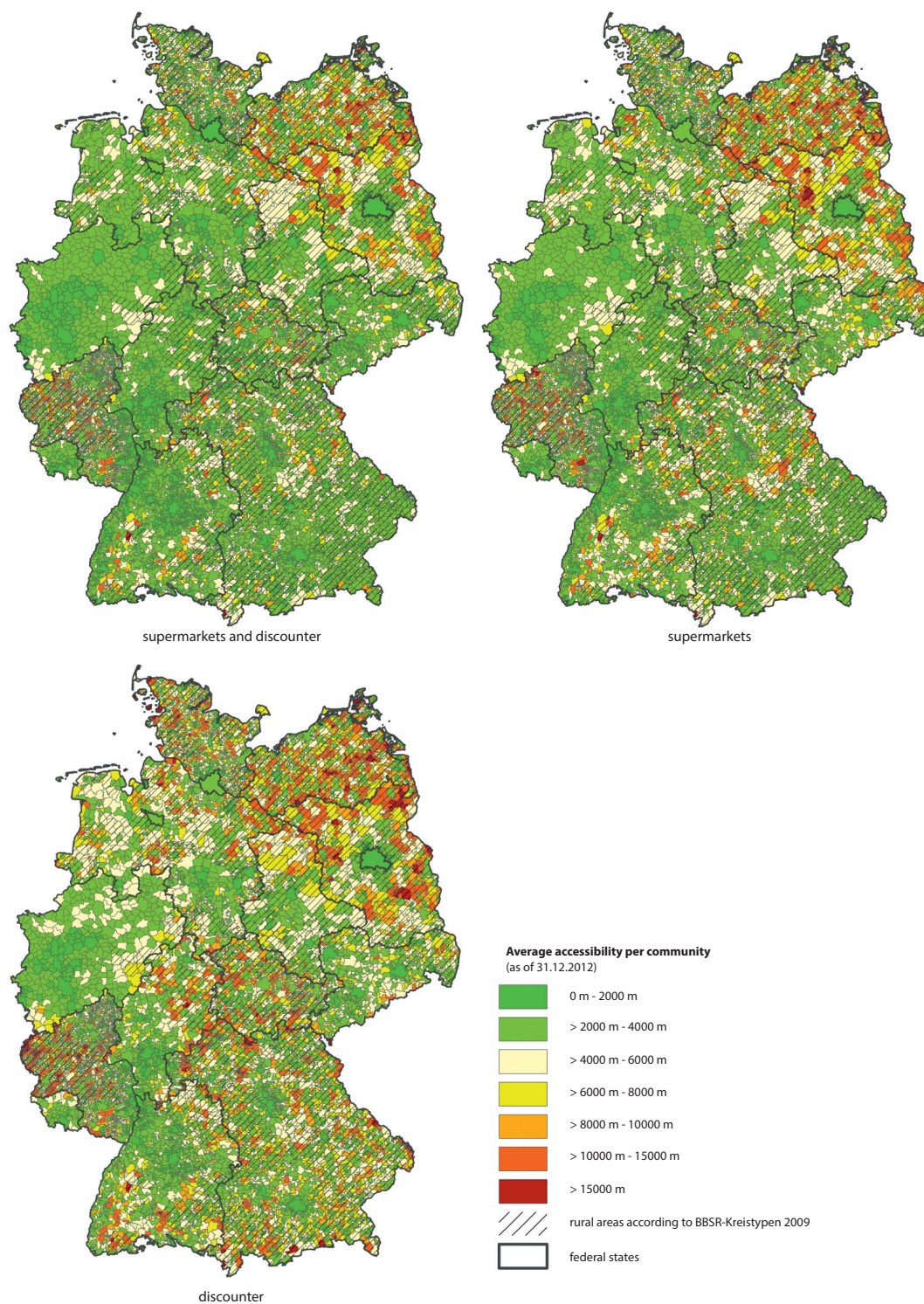


Figure 4

Average accessibility of supermarkets/discounters per community. (Sources: Administrative boundaries: Bundesamt für Kartographie und Geodäsie, 2010; BBSR district types: BBSR; Own calculations).

distance of $\leq 1,305$ m) in 3.2 % of the communities, supermarkets in 2 % and discounters in 0.9 %.

Thereby considering accessibility by foot (1.3 m/s, 15 minutes) on community averages it is quite noticeable that the accessibility decreases from the "core cities in agglomerations" to the "sparsely populated rural areas".

Although these figures give a first comprehensive summary of supermarket and discounter accessibility within different types of regions, they say nothing about existing intra-regional differences. But this information is necessary to fully assess the accessibility situation. Such information can be taken from Figures 5 and 6 showing spatially inclusive and

Table 4

Average distances to the next supermarket/discounter within communities and BBSR district types

BBSR district types 2009	distance in meters								
	0 to ≤ 1,000 (political context)			0 to ≤ 1,170 (accessible up to 15 minutes by foot [1.3 m/s])			0 to ≤ 15,000 (accessible by car up to 15 minutes [60 km/h])		
	super- market and discounter	super- market	discounter	super- market and discounter	super- market	discounter	super- market and discounter	super- market	discounter
	% of communities								
Germany	1.3	0.8	0.2	3.2	2.0	0.9	99.2	99.0	97.9
no allocation possible*	9.1	9.1	0.0	9.1	9.1	0.0	36.4	90.9	81.8
1: Core cities in agglomerations	2.0	0.0	0.0	17.6	2.0	2.0	100.0	100.0	100.0
2: Densely populated districts in agglomerations	2.5	0.8	0.5	9.8	4.5	3.4	99.7	99.7	99.7
3: Highly populated districts in agglomerations	1.3	0.3	0.1	3.1	1.8	1.1	99.4	99.3	99.3
4: Rural districts in agglomerations	1.1	0.5	0.3	1.9	1.6	0.6	99.8	99.2	98.4
5: Core cities in urbanised areas	3.3	3.3	0.0	10.0	3.3	0.0	100.0	100.0	100.0
6: Densely populated areas in urbanised areas	1.8	1.1	0.5	3.7	2.4	1.1	99.2	99.0	98.6
7: Rural districts in urbanised areas	0.9	0.6	0.1	2.4	1.7	0.7	99.6	99.6	97.4
8: Densely populated rural areas	1.0	0.7	0.1	2.1	1.6	0.2	99.2	99.2	99.0
9: Sparsely populated rural areas	0.7	0.6	0.0	1.7	1.2	0.5	97.9	97.3	94.5

* this are areas that could because of inconsistencies in the official datasets not be allocated to the BBSR-2009 Kreistypen.

comprehensive heat maps¹¹ of the modeling results for accessibility by car (60 km/h) and foot (1.3 m/s). The above described accessibility patterns are also mirrored in the maps based on the accessibility values attributed to the single raster cells of the analysis raster. All in all, it can be concluded that within the commonly accepted time of 15 minutes to reach a basic service, a supermarket and discounter, supermarket or discounter can be accessed by car with only a few exceptions (mainly in rural Mecklenburg-Western Pomerania, Brandenburg and north-east Saxony-Anhalt) nationwide in urban as well as in rural areas. In contrast, disadvantageous supermarket/discounter as well as supermarket or discounter accessibilities by foot can be registered outside cities and major settlements, so that especially in rural areas they are less accessible for people without a car.

This might to some extent be compensated by the fact that the share of households without cars is lowest in rural areas (see BMVBS, 2009; 2009a) and the willingness to cover greater distances to reach basic services is greater (see Higgs and White, 1997).

But in summary, drawing on findings due to mobility in rural areas, it can be reasoned that especially retired persons

and young adults are most affected by disadvantageous accessibility situations, as these have been identified as the two major groups of people with no car available (see BMVBS, 2009; 2009a). In many rural areas the lack of a car cannot be easily compensated by using public transport as in such areas often only rudimentary public transport exists, or suboptimal station times prevail. The reason is that in rural areas the public transport is often mainly oriented to the requirements of school transport (see Steinrück and Küpper, 2010). So, in short, especially for less mobile people, supermarket and discounter accessibility proves to be comparably disadvantageous in rural areas throughout the country.

4.3 Estimation of the portion of population affected from different supermarket and discounter accessibilities

Identifying regions with good, respectively disadvantageous, supermarket and discounter accessibility draws a comprehensive image of supermarket and discounter provision in Germany, but this does not suffice to comprehensively assess the situation. This requires an assessment of the portion of the population affected by specific accessibility conditions. Based on the disaggregated population data of the EWZ250, it is possible to estimate the share of population affected by a certain supermarket/discounter accessibility. First of all it is not surprising that a weak negative correlation of $r = 0.29$ ¹²

¹¹ For representative purposes not the actual raster of reference is depicted, but a so-called heat map computed by applying a majority filter (considering the nine neighbouring cells of the cell under consideration) to the result raster. This representation has the advantage that spatial trends are visually enhanced and can therefore be interpreted more easily, but, as with every method of generalisation, at the cost of a certain loss in accuracy (see Meyer, 2006; Fina, 2012).

¹² Pearson product-moment correlation coefficient.

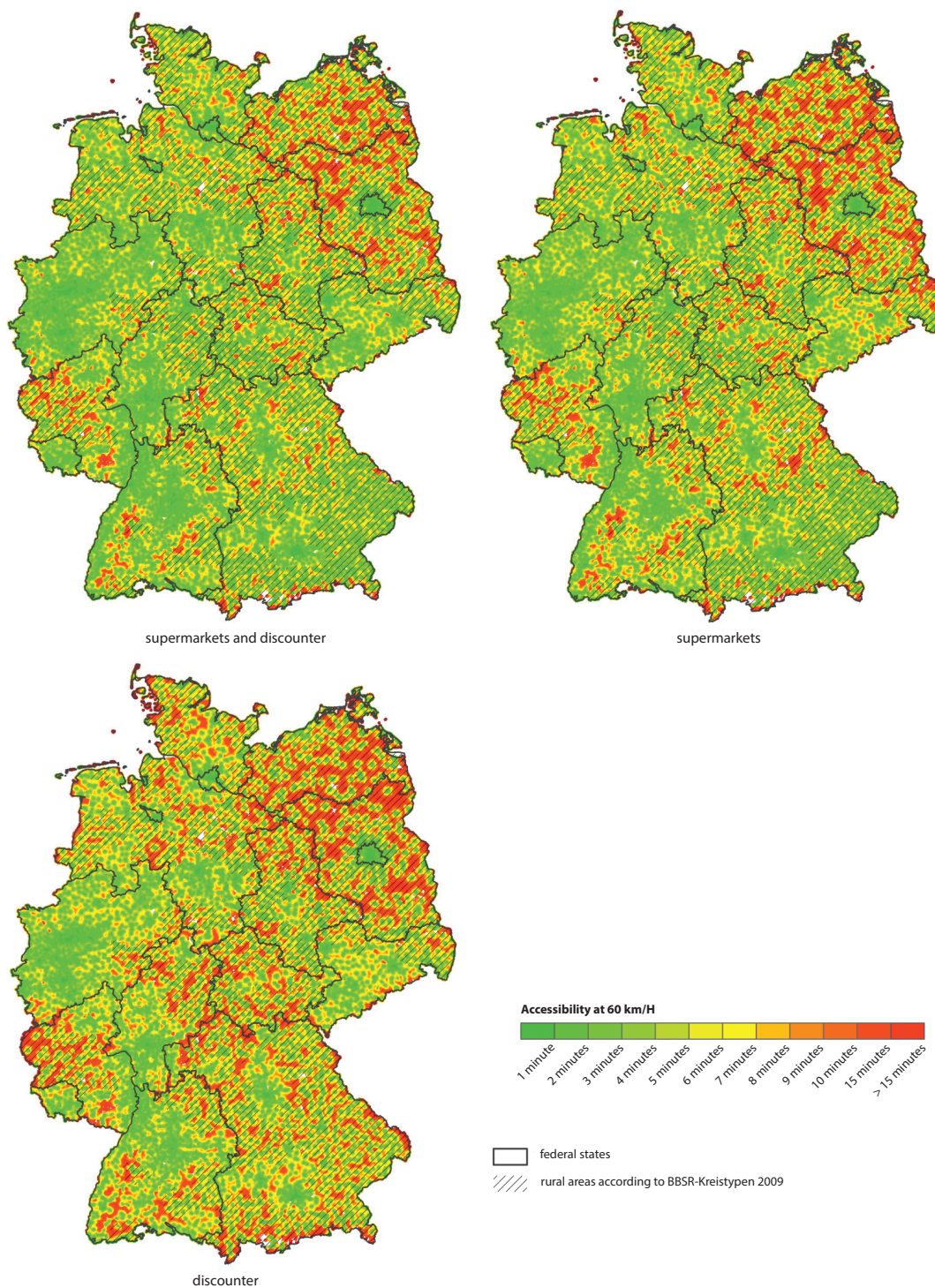


Figure 5

Heat map accessibility of supermarkets/discounter by car. (Administrative boundaries: Bundesamt für Kartographie und Geodäsie, 2012; BBSR district types: BBSR; Data: Own calculations).

exists between the distances to be covered to reach the next supermarket and discounter, respectively supermarket, and population of a raster cell of the EWZ250. Between the accessibility of a discounter and the population a moderate negative correlation of $r = -0.3$ exists. Together with the modeling results this allows the conclusion that in tendency the distances to be covered increase with a decreasing population

density. This finding is first evidence that disadvantageous supermarket/discounter accessibilities can be mainly found in areas with a low population density, respectively few potential customers.

Nevertheless, as can be seen in Table 5, summarizing the population affected by selected distances, all in all 99.9 % of Germany's population is able to reach the next supermarket

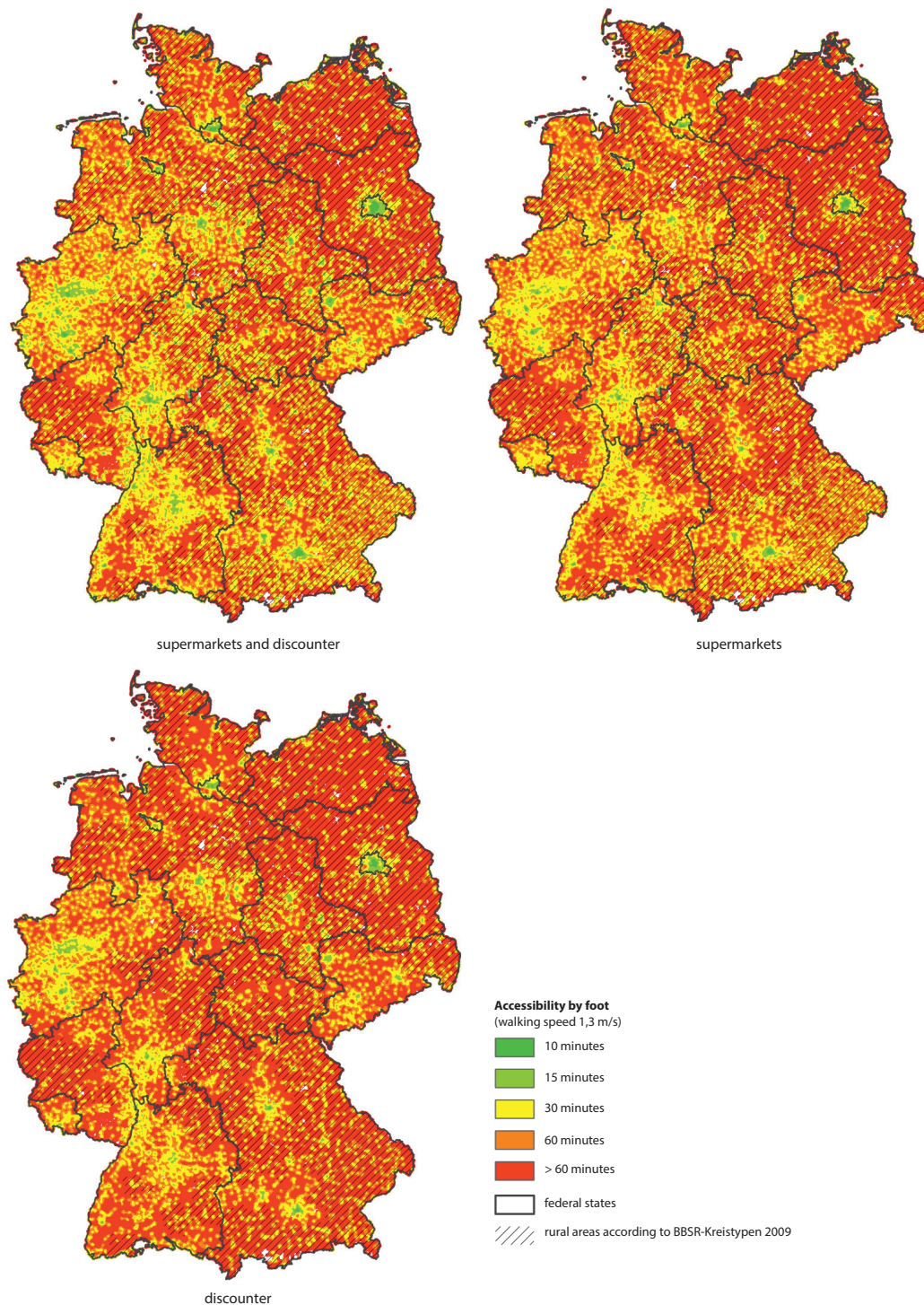


Figure 6

Heat map accessibility of supermarkets/discounter by foot. (Administrative boundaries: Bundesamt für Kartographie und Geodäsie, 2012; BBSR district types: BBSR; Data: Own calculations).

or discounter and supermarket to their home by car (60 km/h) within 15 minutes. 99.7 % reach the next discounter to their home within 15 minutes. In contrast, as can be seen quite obviously, the share of population that is able to reach the next supermarket or discounter by foot (1.3 m/s) in 15 minutes (~ 1,170 m) is 58.1 %, those who reach the next supermarket in the same time is 48.5 % and those who reach

the next discounter is 45.5 %. A look at the different BBSR district types reveals that most of the people that are able to walk to the next supermarket or discounter within 15 minutes live in urban areas.

In summary, by car only 0.1 % of Germany's population is affected by a comparatively disadvantageous supermarket and discounter, as well as supermarket accessibility, 0.3 % by

Table 5

Average distances to the next supermarket/discounter by population and BBSR district types

BBSR district types 2009	population according to EWZ205		distance in meters								
			0 to ≤ 1,000 (political context)			0 to ≤ 1,170 (accessible up to 15 minutes by foot [1.3 m/s])			0 to ≤ 15,000 (accessible by car up to 15 minutes [60 km/h])		
	total	in %	super-market and discounter	super-market	discounter	super-market and discounter	super-market	discounter	super-market and discounter	super-market	discounter
% of population according to EWZ250											
Germany	82,154,373	100.0	51.7	41.4	38.4	58.1	48.5	45.2	99.9	99.9	99.7
1: Core cities in agglomerations	18,920,862	23.0	17.3	14.6	14.5	18.8	16.6	16.5	23.0	23.0	23.0
2: Densely populated districts in agglomerations	14,127,619	17.2	9.3	7.1	6.5	10.7	8.6	7.9	17.2	17.2	17.2
3: Highly populated districts in agglomerations	6,252,935	7.6	2.9	2.3	2.0	3.4	2.8	2.4	7.6	7.6	7.6
4: Rural districts in agglomerations	2,961,253	3.6	1.3	0.9	1.0	1.5	1.1	1.2	3.6	3.6	3.6
5: Core cities in urbanised areas	4,844,255	5.9	4.1	3.4	3.4	4.5	3.9	3.9	5.9	5.9	5.9
6: Densely populated areas in urbanised areas	15,995,065	19.5	8.2	6.5	5.4	9.5	7.8	6.5	19.5	19.5	19.4
7: Rural districts in urbanised areas	8,476,885	10.3	3.3	2.6	2.3	3.8	3.0	2.7	10.3	10.3	10.2
8: Densely populated rural areas	6,921,942	8.4	3.6	2.9	2.3	4.1	3.4	2.8	8.4	8.4	8.4
9: Sparsely populated rural areas	3,653,556	4.4	1.6	1.2	1.1	1.8	1.4	1.3	4.4	4.4	4.4

a disadvantageous discounter accessibility. In contrast by foot (1.3 m/s) 41.9 % of Germany's population has to walk longer than 15 minutes to reach the next supermarket or discounter as well as supermarket, 54.8 % to reach the next discounter. Again, considering population and accessibility it becomes obvious that mainly people living in rural areas are affected by a comparatively disadvantageous accessibility situation.

4.4 Proposal for an accessibility typology of supermarkets and discounters

One way to approach a comprehensive abridged overview of supermarket and discounter accessibility, breaking down the complexity contained in the accessibility data set, is to construct a typology. We did this on the basis of the single raster cells of the EWZ250 by choosing a simple, easily understandable disaggregative approach using a cross tabulation. We took the kind of shop (supermarket or discounter) next to the place of residence into account [3 region types: next market is supermarket/ next market is discounter/ both markets at same distance] as well as whether or not this shop can be reached by foot (1.3 m/s) or car (60 km/h) within 15 minutes [3 distance types: by foot/by car/not in

15 minutes)]. This led to following proposal for a typology for the 250 m raster cells of our base raster (Figure 7). For example, in the blue regions (55 % of the raster cells) the next market reachable is a supermarket. As can be seen, outside the cities there are only a few regions (12 %) where a supermarket can be reached by foot (walking speed 1.3 m/s) in 15 minutes (dark blue). In 42 % of the regions a supermarket can be reached within a maximum driving time (60 km/h) of 15 minutes (medium blue). Only in 0.12 % this supermarket cannot be reached by car within a driving time of 15 minutes (60 km/h) (light blue).

It can be assumed that the accessibility of a market of daily needs is best for people living in the dark and medium purple regions as here both a supermarket and discounter can be reached within 15 minutes either by car or by foot. People living in the dark and medium green regions have access to a supermarket with its large assortment of goods. In contrast, people living in the dark and medium green regions only have access to a discounter with its limited assortment of goods within the accepted walking or driving time of 15 minutes.

Two aspects are quite interesting. First the east-west distinction identifiable in Berlin, where in the western part the

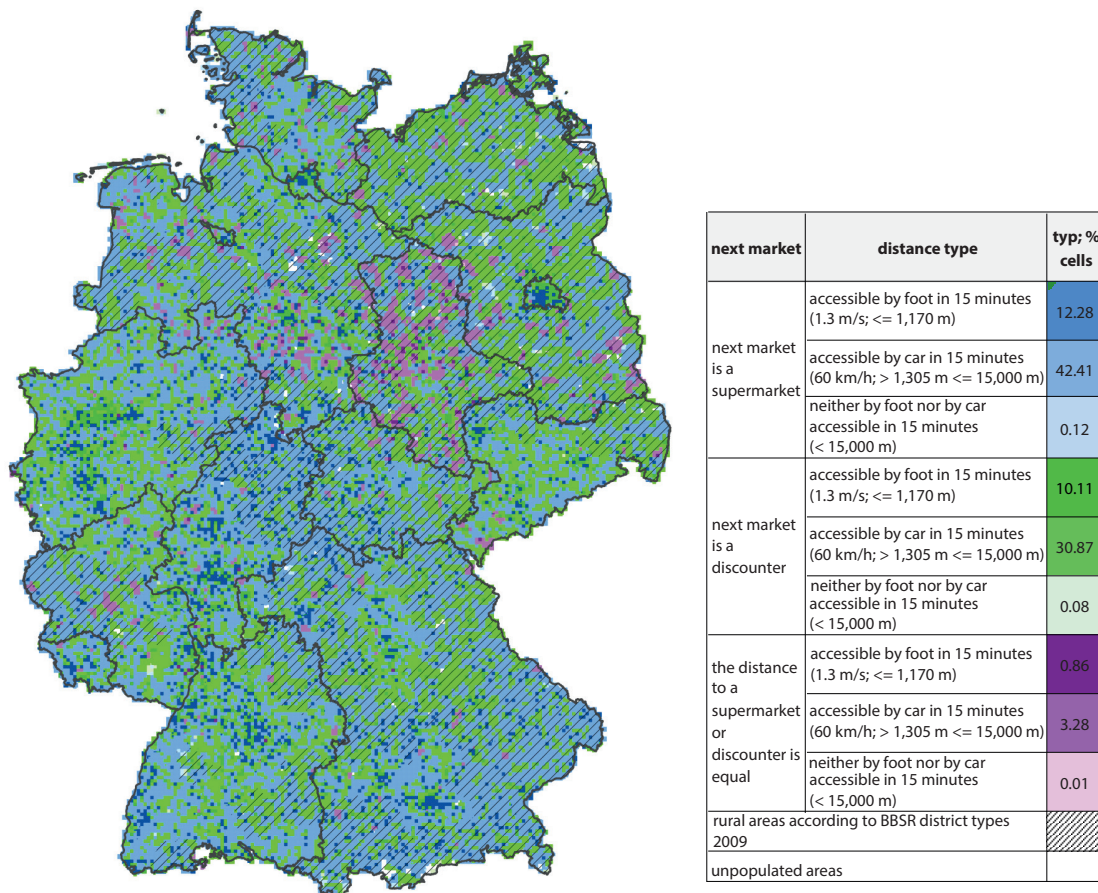


Figure 7

Typology supermarket/discounter accessibility. (Raster-cell-map has been visually enhanced by applying a 6 x 6 moving window majority filter to the original raster data). (Administrative boundaries: Bundesamt für Kartographie und Geodäsie, 2012; BBSR district types: BBSR; Data: Own calculations).

next markets are mainly supermarkets and in the eastern part the next markets are mainly discounters. Second, in Saxony-Anhalt, but also in some parts of Brandenburg and Saxony, there are comparably more cells where the next supermarket or discounter is at an equal distance. One reason for this phenomenon could be that here supermarkets and discounters are comparably often located in shopping centers at the outskirts of settlements.

5 Conclusion

Altogether the modeling results suggest that at present in Germany supermarkets and discounters are well accessible nationwide for people with a car available. Nevertheless, compared to the agglomerations in rural areas the driving times are comparably long. But this is relativized by the fact that regions with longer distances to reach the next supermarket/discounter are mainly sparsely populated. In contrast, by foot, only a comparably small amount of the population is able to reach the next supermarket or discounter within a maximal walking time of 15 minutes (supermarket or discounter: 58 %; supermarket: 49 %; discounter: 46 %). A clear urban-rural divide can

be registered due to this aspect. That is, the share of the population able to walk to the next supermarket/discounter decreases by increasing rurality. In this regard it is particularly noticeable that a comparably disadvantageous accessibility can mainly be found in the federal states Mecklenburg-Western Pomerania, Brandenburg and the northeast of Saxony-Anhalt. So, especially for less mobile people, in rural areas supermarkets and discounter are quite poorly accessible. Drawing on findings of other studies (see BMVBS, 2009; 2009a) it can be assumed that in rural areas especially elderly people and young adults are affected by the comparably poor supermarket and discounter accessibility. The reason is that members of those two groups have been identified as the people least likely to have a car available. For certain small immobile groups of people and a few sparsely populated rural areas a disadvantageous supermarket and discounter accessibility can be registered. But, against the background that at present the main means of transport for shopping purposes is the car (vgl. BMVBS, 2011; Lein, 2012; Handelsverband Deutschland, 2013), and the fact that people in cities as well as rural areas still seem to be happy with the local retail situation (vgl. Ellger, 2000; Heinritz et al., 2003; Born, 2009; Handelsverband Deutschland, 2013), no urgent need for intervention can be identified at present.

Nevertheless, one should be aware that people living in regions with a comparatively disadvantageous accessibility situation might judge this differently based on their subjective local experience. Here, it can be advised to take such voices seriously and critically assess the specific local situation based on real-life field data, as modeling results cannot mirror the reality of a specific local place in all of its facets.

In conclusion, it has to be noted that a GIS-based accessibility analysis allows a quantitative assessment of the accessibility situation of basic services, provides first indications for potentially disadvantageous accessibility situations, and helps identify potential deficits. As such it can help to identify: a) potential case study regions and b) basic services with disadvantageous accessibility worth being considered in more depth. Although a more technical analysis is an essential precondition to gain important insights in accessibility situations of specific basic services, it says nothing about how people judge and deal with specific disadvantageous accessibility situations. But to fully assess the situation such information is needed in addition to the quantitative data. In this sense, to come to a comprehensive image of the retail situation and to be able to deduce policy recommendations in addition to the quantitative analysis we conducted, further in-depth research, building on detailed case studies of the more qualitative aspects of supermarket and discounter accessibility must be done. The study at hand can help to identify regions qualifying for such in-depth research.

Furthermore, to come to a comprehensive overview and reliable assessment of the situation of basic service provision, the analysis of one single kind of basic service, like for example supermarkets and discounters, is not enough. That is, if we want to identify regions disadvantaged with regard to basic services accessibility we should examine if and in which regions several important services are missing or poorly accessible (see for example (Neumeier, 2013) for the accessibility of street petrol stations or (Neumeier, 2012) for the accessibility of public pharmacies).

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Animal Welfare Reporting in der EU – (was) kann Deutschland von seinen Nachbarn lernen?

Sonia Starosta und Angela Bergschmidt *

Zusammenfassung

Die Haltung, der Transport und die Schlachtung von Nutztieren stehen in Deutschland in der Kritik, nicht tiergerecht zu sein. Repräsentative Daten und Fakten, die dies belegen oder widerlegen, werden jedoch nur vereinzelt veröffentlicht. Ein umfassender Monitoring-Bericht zur Tiergerechtigkeit der landwirtschaftlichen Nutztierhaltung mit wissenschaftlich fundierten Indikatoren könnte diese Wissenslücke schließen und die aktuelle Debatte versachlichen. Solch einen Bericht, der die Aspekte Gesundheit, Verhalten und Emotionen der Nutztiere abdeckt, gibt es in Deutschland bisher noch nicht. Der vorliegende Beitrag dokumentiert, inwiefern *Animal-welfare*-Berichte von anderen europäischen Staaten geeignete Indikatoren enthalten. Dokumente aus Dänemark, Finnland, Großbritannien, Österreich und der Schweiz wurden für die Untersuchung ausgewählt, bei der das aus dem Umweltbereich stammende *Driving-Force-Pressure-State-Impact-Response*-Konzept angewendet wurde. Der deutsche Tierschutzbericht wurde ebenfalls in die Untersuchung einbezogen. Die Analyse ergab, dass in den Berichten vorrangig über staatlich ergriffene Maßnahmen, wie Tierschutzkontrollen und Sanktionen, berichtet wird. Eine Blaupause für einen deutschen Prototypen eines Tiergerechtheits-Monitoring konnte somit zwar nicht identifiziert werden, die Berichte enthalten aber Anregungen für die Verwendung einzelner Indikatoren. Finnland gibt z. B. den Anteil verworfener Tiere an, die am Schlachthof angeliefert werden, sich aber nicht für eine Weiterverarbeitung eignen. Dänemark nennt den Anteil der Mastgeflügelbestände mit hohen Prävalenzen von Fußballenerkrankungen. Informationen, wie der Anteil kontrollierter tierhaltender Betriebe, werden von verschiedenen Ländern als Indikator für staatliche Bemühungen, das Tierschutzgesetz durchzusetzen, präsentiert. Sie sind aber schwer zu interpretieren und daher nicht ohne zusätzliche Informationen verwendbar.

Schlüsselwörter: Tiergerechtigkeit, Informationstransfer, Monitoring, Tierwohl, Tierschutzberichterstattung

Abstract

Farm animal welfare reporting in Germany: what can we learn from our neighbours?

Animal husbandry, the transport and the slaughter of farm animals in Germany are criticized for compromising animal welfare. Representative facts and figures which prove or disprove these statements are rare. A comprehensive monitoring report on animal welfare with scientifically sound indicators could close this knowledge gap and objectify the debate. Such a report, covering the main aspects of animal health, behavior and emotional status, does not exist yet. This article examines the extent to which other European countries have published animal welfare reports, whether they contain relevant animal welfare indicators and may serve as a model for a German report. Five publications from Denmark, Finland, the United Kingdom, Austria and Switzerland were selected for the study, in which the *Driving-Force-Pressure-State-Impact-Response*-concept, developed for environmental indicators, was applied. The German animal protection report was included as well. The analysis showed that the reports primarily provide information on government measures, such as animal welfare inspections. While the reports therefore cannot serve as a blueprint for a German prototype, they do contain some suitable and applicable indicators. Finland for example, reports on the proportion of animals proportion of rejected animals for slaughter. Denmark indicates the proportion of broiler flocks with a high prevalence of foot pad dermatitis. Information on the proportion of controlled farms is presented by several countries as an indicator for the government's efforts to enforce the animal protection law. Interpretation of this evidence is problematic and therefore these indicators are not applicable without additional information.

Keywords: Animal welfare, transfer of information, animal welfare reporting, animal protection reporting

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1 Einleitung

Problemstellung

Das Thema Tierschutz wird derzeit in der Wissenschaft und Öffentlichkeit intensiv diskutiert. Insbesondere die Haltungsbedingungen von landwirtschaftlichen Nutztieren, deren Transport und die Bedingungen bei der Schlachtung werden kritisiert. Die Ergebnisse einer 2007 durchgeführten europäischen Umfrage belegen, dass die Tiergerechtigkeit der landwirtschaftlichen Nutztierhaltung für die Bevölkerung ein wichtiges Thema ist. Auf einer Skala von 1 (keine Bedeutung) bis 10 (sehr hohe Bedeutung) erlangte das Thema Tiergerechtigkeit im Durchschnitt die Wertung 7,8 (European Commission, 2007).

In der deutschen Debatte fällt auf, dass der Status quo der Tiergerechtigkeit von verschiedenen Akteuren unterschiedlich eingeschätzt wird. Während Verbraucher/-innen das Wohlbefinden der Nutztiere gefährdet sehen (Deimel et al., 2010), schätzen Landwirte und deren Vertreterorganisationen den Gesundheitszustand ihrer Tiere besser denn je ein (Deutscher Bauernverband, 2014). Die tatsächliche Faktenlage ist dabei jedoch lückenhaft. Für eine Beurteilung des Status quo gibt es im Vergleich zu anderen Sektoren, wie dem Umweltbereich¹, weder repräsentative Daten, ein allgemein anerkanntes Indikatoren-Set, noch eine Darstellung in Berichtsform. Dadurch fehlt eine belastbare Informationsbasis für Entscheidungen von Politik und BürgerInnen.

Zielstellung

Das Thema der tiergerechten Haltung gewinnt innerhalb Europas zunehmend an Bedeutung. Daher ist es denkbar, dass in einigen europäischen Ländern entsprechende Daten erfasst, zusammengetragen, aufbereitet und in Berichten veröffentlicht werden. Vor diesem Hintergrund erfolgt eine Sondierung einschlägiger Berichte auf europäischer Ebene. Hierbei wird geprüft, ob andere EU-Mitgliedstaaten bereits routinemäßig ein *Animal welfare* Monitoring durchführen bzw. Berichte hierzu veröffentlichen und ob Deutschland von seinen Nachbarn lernen kann. Zudem wird analysiert, ob aufbereitete Informationen aus dem deutschen Tierschutzbericht in einem Monitoring-Bericht Tiergerechtigkeit verwendet werden können.

Die Berichtsanalyse ist ein erster Arbeitsschritt des Projektes „Erstellung eines Prototypen für einen nationalen Monitoring-Bericht Tiergerechtigkeit“ am Thünen-Institut für Betriebswirtschaft.

Vorgehensweise

Im vorliegenden Beitrag wird, nach einer kurzen Begriffsdefinition und einer Beschreibung des Standes der Indikatorenentwicklung (Abschnitt 2), zunächst der Auswahlprozess für die in die Untersuchung einbezogenen *Animal welfare*-Berichte erläutert und das Untersuchungsmaterial beschrieben (Abschnitt 3.1). Anschließend wird das gewählte Analyseraster für die Inhaltsanalyse dargestellt (Abschnitt 3.2) und Bewertungskriterien genannt, die die inhaltliche Qualität der Berichtsinformationen einschätzen (Abschnitt 3.3). Der Ergebnisteil (Abschnitt 4) gibt einen Überblick über die Indikatoren, die anschließend im Hinblick auf ihre Eignung für ein deutsches Monitoring Tiergerechtigkeit diskutiert werden (Abschnitt 5).

2 Begriffsdefinitionen und Stand der Forschung

Tierwohl bzw. Tierwohlergehen wird als direkte Übersetzung des englischen *animal welfare* verstanden. Im Gegensatz zu Tierschutz (*animal protection*), der sich auf Aktivitäten des Menschen bezieht, ist Tierwohl auf die Wahrnehmung des einzelnen Tieres bezogen (Blokhuis et al., 2003; Ingenbleek et al., 2012). Der Begriff Tiergerechtigkeit wird für die Messung und Bewertung von Tierwohl im Zusammenhang mit Verfahren (z. B. Haltungsverfahren, Schlachtfverfahren) und Management verwendet. Tierwohl und Tiergerechtigkeit sind multidimensionale Konzepte, die nur umfassend beurteilt werden können, wenn folgende Aspekte berücksichtigt werden: die Tiergesundheit (*animal health*), die Ausführbarkeit von natürlichen Verhaltensweisen (*natural behaviour*) und das emotionale Befinden (*emotional state*) eines Tieres (Fraser et al., 1997). Vielfach wird zur Definition von Tierwohl und Tiergerechtigkeit auch das Konzept der fünf Freiheiten des britischen Farm Animal Welfare Council, 2009 herangezogen.² Für die Beurteilung werden ressourcen-, management- und tierbezogene Indikatoren herangezogen (Schrader, 2013).

Indikatoren werden als Anzeiger definiert, die einen Sachverhalt näherungsweise beschreiben bzw. auf einfache Weise komplexe Prozesse und Zusammenhänge operationalisieren (Siemer et al., 2006). In der Wissenschaft besteht Einigkeit darüber, dass für eine Beurteilung des Status quo der Tiergerechtigkeit, tierbezogene Parameter notwendig sind (Hartung, 2012; Averós et al., 2013). Daten, die direkt am Tier bzw. auf dem Betrieb erhoben werden können, sind z. B. Verletzungen,

¹ Die nationale Strategie zur biologischen Vielfalt (BMU, 2007) legt konkrete Ziele fest und formuliert Indikatoren, mithilfe derer eine Zielerreichung in Rechenschaftsberichten überprüft wird (BMU, 2013). Im Rahmen der 2002 begonnenen nationalen Nachhaltigkeitsstrategie wurden ebenfalls Indikatoren bestimmt (Statistisches Bundesamt, 2014) und regelmäßig Fortschrittsberichte veröffentlicht. Darüber hinaus werden vom Bundesumweltamt „Daten zur Umwelt“ teils als Broschüre, teils als Datenangebot im Internet für eine „fundierte Diskussion über mehr Umweltschutz“ bereitgestellt (Umweltbundesamt, 2011).

² Die fünf Freiheiten sind: (1) Freiheit von Hunger und Durst: Tiere haben Zugang zu frischem Wasser und gesundem und gehaltvollem Futter. (2) Freiheit von haltungsbedingten Beschwerden: Tiere haben eine geeignete Unterbringung (z. B. einen Unterstand auf der Weide), adäquate Liegeflächen etc. (3) Freiheit von Schmerz, Verletzungen und Krankheiten: Die Tiere werden durch vorbeugende Maßnahmen bzw. schnelle Diagnose und Behandlung, Verzicht auf Amputationen (bzw. Betäubung) versorgt. (4) Freiheit von Angst und Stress: Durch Verfahren und Management werden Angst und Stress vermieden z. B. durch Verzicht auf Treibhilfen. (5) Freiheit zum Ausleben normaler Verhaltensmuster: Die Tiere haben die Möglichkeit das Normalverhalten auszuüben (z. B. durch ausreichendes Platzangebot, Gruppenhaltung etc.).

Gangbildveränderungen und Sterberaten. Auch Schlachthofbefunde können als wichtige Informationsquelle für die Ex-post-Bewertung des Tierwohlergehens während der Haltung und beim Transport gelten (Böckel, 2008; EFSA panel for Animal Health and Animal Welfare, 2012; Kremer, 2013; Schleicher et al., 2013). Darüber hinaus werden ressourcenbezogene Messgrößen wie Stalleinrichtung, Weidegang und das Flächenangebot pro Tier für die Bewertung der Ausführbarkeit des Normalverhaltens genutzt. Beispiele für managementbezogene Parameter, die Rückschlüsse über das Auftreten von Schmerzen und negativen Emotionen erlauben, sind die Durchführung von Eingriffen an den Tieren (Kastration und Schwanzkupieren bei Schweinen etc.).

Im Rahmen von verschiedenen Forschungsprojekten wird der Frage nach einer Einschätzung des Wohlergehens von Nutztieren nachgegangen. Dabei konnten bereits zahlreiche Indikatoren zur Messung und Bewertung der Tiergerechtigkeit entwickelt, weiterentwickelt und systematisiert werden. Das von der Europäischen Union geförderte Welfare-Quality (WQ®)-Projekt erarbeitete z. B. Methoden und Protokolle mit Indikatoren für Rind, Schwein und Geflügel, mithilfe derer eine Beurteilung von Tiergerechtigkeit auf dem Betrieb durchgeführt werden kann. Die EFSA hat auf Anfrage der Europäischen Kommission eine Liste geeigneter Indikatoren herausgegeben, in der die Indikatoren des WQ®-Projekts enthalten sind (EFSA Panel on Animal Health and Welfare, 2012a; 2012b; 2012c). Diese Beurteilungsschemata finden in der Praxis von Landwirtschaft und Lebensmittelverarbeitung noch keine direkte Anwendung. Vielmehr werden die WQ®-Protokolle und Vorschläge der EFSA als *Toolbox* verstanden und fließen zu Teilen beispielsweise in die Kriterienlisten von Produktlabels ein („Tierschutz-kontrolliert“ – Vier Pfoten, „Tierschutzlabel“ – deutscher Tierschutzbund). Sie schlagen sich allerdings nicht in Form von nationalen Berichten und Status quo-Beschreibungen in Deutschland nieder.

Auch wenn in Deutschland keine umfassenden Berichte über Tiergerechtigkeit vorliegen, werden einzelne Aspekte in einer Reihe von offiziellen Berichten adressiert:

- Der nationale Tierschutzbericht ist ein Rechenschaftsbericht, den das BMEL an den Bundestag zu richten hat. Er informiert über die Aktivitäten zur Einhaltung und Verbesserung des Tierschutzes (BMELV, 2011).
- Der jährlich erscheinende Tiergesundheitsbericht des Friedrich-Loeffler-Instituts (FLI) gibt Rechenschaft über die Verbreitung von Tierseuchen und Infektionskrankheiten innerhalb Deutschlands und beschreibt deren Bedeutung für den Menschen (Friedrich-Loeffler-Institut, 2012). Zwar werden Prävalenzen einzelner Krankheiten angegeben, nicht aber deren Wirkung auf das Tierwohlbefinden.³

- Auf europäischer Ebene gibt es gesetzliche Berichtspflichten, denen Deutschland nachzukommen hat. Alle EU-Mitgliedstaaten sind verpflichtet, sowohl einen Bericht über die durchgeführten Tiertransportkontrollen (EU, 2005, Artikel 27) als auch einen Jahresbericht (Kontrollplan) über die Umsetzung von verschiedenen Kontrollen, u. a. im Lebensmittel- und Tierschutzbereich, an die Europäische Kommission weiterzuleiten (EU 2006/778/EG, Art. 8; EU, 2004 Nr. 882/2004, Art. 44). In Letzterem werden die Anzahl kontrollierter landwirtschaftlicher Betriebe angegeben sowie der Anteil der Betriebe mit Beanstandungen (BMELV, 2011a). Sowohl der Tiertransportbericht als auch die mehrjährigen Kontrollpläne der Mitgliedstaaten sind im Internet schwer auffindbar und nicht an die Öffentlichkeit adressiert, sondern an die Europäische Kommission.

3 Methode

3.1 Auswahl und Charakterisierung des Textmaterials

Das Untersuchungsmaterial dieser Arbeit sind offizielle, öffentlich zugängliche Berichte europäischer Staaten, die sich mit dem Thema Tiergerechtigkeit auf nationaler Ebene befassen. Da es sich hierbei um Textmaterial, d. h. um *fixierte Kommunikation* handelt, wird die Methode der qualitativen Inhaltsanalyse (Mayring, 2000) angewendet.

Die Suche nach Berichten zu Tiergerechtigkeit fand in zwei Schritten statt. Über eine Internetrecherche wurden Berichte in englischer, deutscher und französischer Sprache gesammelt. Ausschlaggebend für die Berichtsauswahl waren folgende Aspekte: Die Berichte europäischer Staaten enthalten Informationen, die Rückschlüsse auf das Wohlergehen der Nutztiere zulassen, sind für die Öffentlichkeit zugänglich und liegen in elektronischer und/oder gedruckter Form vor. Ein weiteres Kriterium war die Art der Publikation der Berichte. Diese sollten durch nationale Einrichtungen in einem regelmäßigen Turnus veröffentlicht werden, da im deutschen Kontext ebenfalls ein solcher Rahmen angestrebt wird.⁴ Aus diesem Grund sind primär offizielle Internetseiten staatlicher Institutionen, wie Ministerien oder Fachbehörden, durchsucht worden. Von der Recherche ausgeschlossen sind aufgrund ihrer schweren Zugänglichkeit offizielle Rechenschaftsberichte der europäischen Mitgliedstaaten an die Europäische Kommission. Sie können zudem keine Vorbildfunktion erfüllen, da Deutschland bereits jetzt, wie alle anderen Mitgliedstaaten, dazu verpflichtet ist, die entsprechenden Angaben zu Tierrechtsverstößen zu machen.

Zusätzlich wurden die Landwirtschafts-, Gesundheits- oder Verbraucherministerien aller 28 Mitgliedstaaten per E-Mail angeschrieben und um die Zusendung der nationalen

³ Der Zusammenhang zwischen anzeigespflichtigen Tierseuchen und Tierwohlbefinden wird je nach Krankheit unterschiedlich eingeschätzt. Das *Farm Animal Welfare Committee* (FAWC) fasst hierzu in einem Bericht Expert/-innenmeinungen zusammen. Befragte wurden gebeten, die Schmerzintensität und -dauer einzelner Tierkrankheiten zu bewerten. Das im FLI-Bericht auftauchende Bovine Virusdiarrhoe ist neben Salmonellose die einzige Infektionskrankheit, die in genanntem FAWC-Bericht auftaucht und von Expert/-innen als stark Schmerzen verursachende Krankheit eingestuft wird (Farm Animal Welfare Committee, 2012).

⁴ Ein umfassender Monitoring-Bericht *The welfare state: five years measuring animal welfare in the UK, 2005 bis 2009* der Tierschutz-Organisation *Royal Society for the Prevention of Cruelty to Animals* (RSPCA) wurde nicht berücksichtigt, da er nur einmalig erschienen und von einer Nichtregierungsorganisation publiziert wurde.

Tabelle 1

Ausgewählte nationale Berichte

Land	Berichtstitel	Herausgeber	Turnus der Veröffentlichung
Deutschland (DE)	Tierschutzbericht der Bundesregierung 2011	Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz	Alle vier Jahre
Finnland (FIN)	Animal welfare in Finland - National Report on Animal Welfare 2013	EHK - Finnish Center for Animal Welfare (gefördert durch das Agrarministerium)	Alle drei Jahre
Dänemark (DK)	Animal welfare in Denmark 2010	Kooperationsprojekt (DCAW): Danish Veterinary and Food Administration, Ministry of Food, Agriculture and Fishery	Jährlich (in dänischer Sprache)
Österreich (AT)	Tierschutzbericht an den Nationalrat 2011/2012	Bundesministerium für Gesundheit	Alle zwei Jahre
Schweiz (CH)	Tierschutzbericht 2011	Bundesamt für Veterinärwesen BVET	Seit 2010 alle drei Jahre
Großbritannien (GB)	Progress through partnership: The UK Chief Veterinary Officer's 2009 report on animal health and welfare	Dep. of Agric. and Rural Development, of Environment Food and Rural Affairs (DEFRA); Welsh Assembly Gov.; Scottish Government	Erscheint nicht mehr in diesem Format

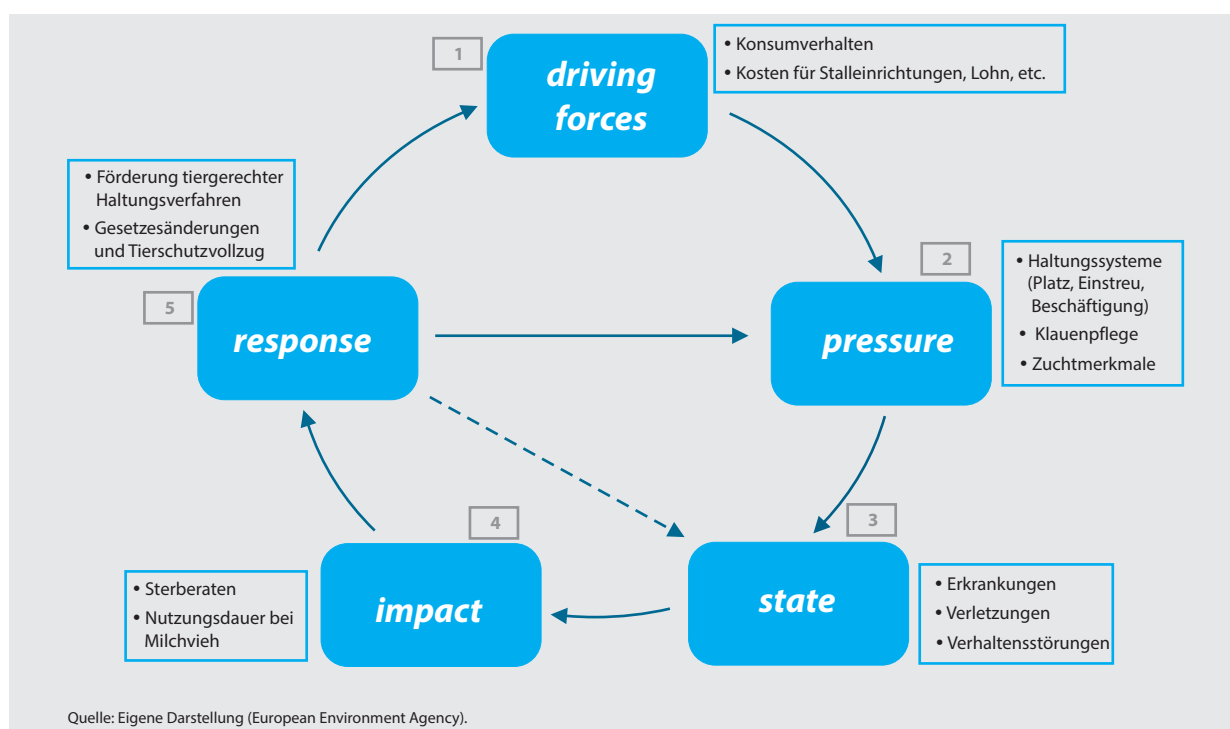
Quelle: Eigene Darstellung.

Animal-welfare- oder *Animal-health-*Berichte gebeten. In einem Zeitraum von zwei Monaten lag der Rücklauf der E-Mail-Anfrage bei insgesamt vier Berichten, wobei keine zusätzlichen Informationen zu bereits im Internet verfügbaren Berichten generiert werden konnten.

Letztlich führte die Recherche zu einer Auswahl von sechs durch offizielle Stellen (Ministerien, Fachbehörden u. Ä.) veröffentlichter Berichte aus Deutschland, Großbritannien, Dänemark, Finnland, Österreich und der Schweiz. Die Informationen über Berichtstitel, Herausgeber und Turnus der Veröffentlichung sind in Tabelle 1 zusammengefasst.

3.2 Analyseraster für eine Strukturierung des Textmaterials – Kategorien aus dem Umweltbereich

Der Zustand der Tiergesundheit, des Tierverhaltens und emotionalen Befindens kann am besten über tierbezogene und ggf. ressourcen- oder managementbezogene Indikatoren gemessen werden. Nicht immer stehen Daten für entsprechende Indikatoren zur Verfügung. In Ergänzung können daher (weiche) Einflussfaktoren, wie beispielsweise politische Maßnahmen (Tierschutzvollzug) und das gesellschaftliche Engagement mit einbezogen werden. Dieses

**Abbildung 1**

Das DPSIR-Modell aus dem Umweltbereich mit Beispielen aus dem Tierwohlbereich

Vorgehen ist im Umweltbereich üblich und hat zur Entwicklung einer Indikatorenstruktur geführt, die eine Einbeziehung von Einflüssen, Zuständen und Reaktionen ermöglichen soll.

Um möglichst viele relevante Informationen aus den ausgewählten Berichten extrahieren zu können, wurden Hauptanalysekategorien definiert (Kuckartz, 2012), die einer solchen Systematisierung aus dem Umweltbereich entstammen. Das Umweltmodell in Abbildung 1 umfasst fünf Indikatorengruppen: *driving forces* (Antriebsindikatoren), *pressure* (Belastungsindikatoren), *state* (Zustandsindikatoren), *impact* (Auswirkungsindikatoren) und *responses* (Maßnahmenindikatoren) (DPSIR). Das DPSIR-Modell ist eine Erweiterung des *Pressure-State-Response*-Modells der OECD (Gabrielsen und Bosch, 2003). Es verdeutlicht die Position und Interaktion der Indikatoren (Smeets und Weterings, 1999).

Driving forces beschreiben allgemein soziale und ökonomische Entwicklungen sowie Lebensweisen und Konsumniveaus in einer Gesellschaft (Smeets und Weterings, 1999). Bei dem Versuch, *driving forces* auf den Tierbereich zu übertragen, kommt die Erfassung des Nachfrageverhaltens und der Zahlungsbereitschaft, bezogen auf tierische Produkte, infrage. Hintergrund ist die Annahme, dass eine starke Nachfrage nach tiergerecht erzeugten Produkten zu Veränderungen in der Produktion führt. Das Konsumverhalten wird wiederum dadurch geprägt, wie informiert und aufgeklärt eine Gesellschaft über die Produktionsbedingungen ist. Daher werden Berichtsinhalte, die Auskunft über den Wissensstand einer Gesellschaft geben, mit berücksichtigt. Auch Lohnkosten, die Kosten für Stalleinrichtungen, Einstreu oder Weidemanagement können als „Rahmenbedingungen“ *driving forces* für die Entscheidungen der Landwirte für oder gegen ein bestimmtes Haltungs- und/oder Managementverfahren sein.

Pressure-Indikatoren beschreiben die Belastung, die durch menschliches Handeln ausgeübt wird. Im Umweltbereich ist dies etwa die Flächennutzungsintensität (Linster, 2003). Übertragen auf den Bereich Nutztierhaltung könnten *Pressure*-Indikatoren beispielsweise ressourcen- und managementbezogene Indikatoren sein, wie der Anteil an Kühen mit und ohne Weidegang, die Besatzdichte (EFSA Panel on Animal Health and Welfare, 2012a) und der Anteil an Betrieben mit spezieller Ausstattung, wie Stroheinstreu oder besonderem Beschäftigungsmaterial für Schweine (EFSA Panel on Animal Health and Welfare, 2012c). Letztere geben Aufschluss über die Möglichkeiten der Tiere, ihr Nahrungsaufnahme-, Erkundungs- und Spielverhalten auszuleben. Flächenangebot und Zugang zu Auslauf lassen Rückschlüsse auf die Bewegungsmöglichkeiten bzw. -einschränkungen der Tiere zu. Aus diesem Grund wurden Tiertransporte ebenfalls der Kategorie *pressure* zugeordnet. Die Transportdauer und Anzahl transportierter Tiere geben Auskunft über die Zeitspanne, in der die Bewegungsfreiheit eines Tieres stark eingeschränkt war. Mögliche managementbezogene *Pressure*-Indikatoren sind die Häufigkeit und Regelmäßigkeit der Klauenpflege (Schrader, 2013) oder die Enthornungspraxis (mit oder ohne Anästhesie, Beruhigungs- und Schmerzmittel). Auch der Themenkomplex Tierzucht fällt in

die *Pressure*-Kategorie. Indikatoren könnten hier z. B. der Anteil an Gesundheitsmerkmalen bei der aktuellen Zuchtwertschätzung sein.

State-Indikatoren beschreiben einen Zustand und sind im Bereich Biodiversität z. B. die Anzahl bedrohter Tierarten oder die Konzentration von CO₂ in der Luft. Für den Tierbereich sind das Auftreten von Erkrankungen, Verletzungen und Verhaltensstörungen gängige Zustandsbeschreibungen. Pathologische Parameter geben Auskunft über den gesundheitlichen Zustand der Tiere. Verletzungen bei Schweinen, beispielsweise am Ohr oder am Schwanz, können Anzeichen von Kannibalismus sein und lassen Rückschlüsse auf gestörtes Verhalten zu (Deimel et al., 2010). Darüber hinaus gibt es die Möglichkeit, über Verhaltensbeobachtungen im Stall direkte Aussagen über Verhaltensweisen der Tiere zu treffen.

Impact-Indikatoren drücken Veränderungen aus, die *Pressure*- und *State*-Indikatoren zugeordnet werden können. Eine mögliche Kausalkette aus dem Umweltbereich ist die Wirkung der Zunahme von Siedlungs- und Verkehrsflächen (*pressure*) und einer damit einhergehenden Beeinträchtigung der Pflanzenvielfalt (*state*). Diese wiederum kann die Zahl bedrohter Tierarten negativ beeinflussen (*impact*). Übertragen auf den Tierbereich kann z. B. die Sterberate in einem Geflügelstall oder bei der Ferkelaufzucht als *Impact*-Indikator beschrieben werden (Dickhaus, 2010; The Welfare Quality® Consortium, 2009). Diese korreliert mit der Besatzdichte (*pressure*) und Krankheitshäufigkeit (*state*) in einer Herde. Die geringe Nutzungsdauer bei Milchvieh ist ebenfalls ein Auswirkungsindikator, verursacht u. a. durch mangelhafte Boxen- und Klauenpflege (*pressure*), damit einhergehender Euter- oder Klauenerkrankung (*state*) und vorzeitigem (krankheitsbedingtem) Abgang (The Welfare Quality® Consortium, 2009a).

Response-Indikatoren drücken politische und gesellschaftliche Bestrebungen aus, Problemen vorzubeugen und ungewollte Zustände zu verbessern (Gabrielsen und Bosch, 2003). Im Tierbereich erfolgt die staatliche Einflussnahme beispielsweise über die Ausgestaltung von Gesetzen und die Überwachung von deren Einhaltung (Matthews und Hemsworth, 2012). Gesetzliche Vorgaben und Tierschutzkontrollen sind allerdings unter anderem von der Ausstattung der ausführenden Behörden abhängig. Daher kann ein weiteres Indiz für staatliches Engagement beispielsweise die personelle und materielle Ausstattung der zuständigen Veterinärämter sein. Tierschutz-Bildungsarbeit in Schulen und im Rahmen von Workshops und Seminaren kann ebenfalls als Reaktion auf Wissensdefizite bezüglich der Haltung und des Schutzes von Nutztieren angesehen und daher der Kategorie *responses* zugeordnet werden. Durch Bildungsarbeit können SchülerInnen und VerbraucherInnen für den Nutztierbereich sensibilisiert werden. Darüber hinaus ist die Förderung tiergerechter Haltungssysteme (z. B. über die Investitionsförderung im Rahmen der Entwicklungsprogramme für den ländlichen Raum) als Indikator für das förderpolitische Engagement anzusehen. Das gesellschaftliche bzw. sektorale Engagement, Veränderungsprozesse anzustoßen, könnte gegebenenfalls über die Anzahl und

Entwicklung entsprechender Interessenvertretungen, Vereine, Aufklärungsprojekte, Medienberichterstattung, die Schaffung von Tierschutzlabeln etc. dokumentiert werden.

Die oben genannten fünf Kategorien lassen sich nicht immer klar voneinander abgrenzen. Treibende Kräfte von Entwicklungen (*driving forces*) und initiierte Maßnahmen, um Zustände zu verändern (*responses*), können sehr nahe beieinander liegen. Gleiches gilt für die Zuordnung verschiedener tierbasierter Indikatoren zu den Kategorien *state* und *impact*. Je nach Einschätzung können Prävalenzen, wie Schwanz- und Ohrenbeißen bei Mastschweinen, als Reaktion (*impact*) auf Verhaltensstörungen (*state*) und zu wenig Platz und Beschäftigungsmaterial (*pressure*) angesehen werden oder als Zustand an sich (*state*). Die Bestimmung, welche Indikatoren welcher Kategorie angehören, ist daher nicht immer eindeutig. Trotz dieser Einschränkungen wurde das Modell als Grundlage für die Textanalyse gewählt, da es gegenüber der „klassischen“ Einteilung in tier-, management-, und ressourcenbezogene Indikatoren den Vorteil bietet, Ursachen-Wirkungs-Zusammenhänge explizit darzustellen.

3.3 Bewertungskriterien für die in den Berichten verwendeten Indikatoren

Monitoring-Indikatoren sollten möglichst spezifische Informationen liefern und im Zeitverlauf Veränderungen abbilden können (Siemer et al., 2006). Nach der inhaltlichen Strukturierung der Textinformationen werden die verwendeten Indikatoren daher auf diesbezügliche Aussagemöglichkeiten hin untersucht. Hierzu wurden entsprechende Kriterien bestimmt. So sind beispielsweise Angaben über die Anzahl und den Anteil ökologisch wirtschaftender Betriebe (*Pressure*-Indikator) besser interpretierbar, wenn zusätzlich die Information bereitgestellt wird, welche Tierarten und wie viele Tiere ökologisch gehalten werden. Von einer hohen Aussagekraft wird daher gesprochen, wenn konkrete Hinweise über

- die Anzahl betroffener Tiere,
- die Tierart (Rind, Schwein oder Geflügel) gegeben werden und

- die Darstellung von Informationen einen Zeitraum von mehreren Jahren abdeckt.

Die Nennung von konkreten Fördersummen für tiergerechtere Haltungssysteme, die Anzahl durchgeführter Tierschutzkontrollen, die Höhe des Konsumniveaus tierischer Produkte in einer Gesellschaft sind Beispiele und für eine mögliche Quantifizierung und Konkretisierung von Berichtsinhalten die der Kategorie *driving forces* und *response* zugeordnet werden.

4 Ergebnisse

Die in den Berichten enthaltenen Indikatoren wurden den verschiedenen Kategorien (*driving forces*, *pressure*, *state*, *impact* und *response*) zugeordnet und beschrieben. Dabei konnten die Kategorien *pressure*, *state* und *impact* zusammengefasst werden, da hier nur wenige Nennungen zu verzeichnen sind.

4.1 Driving forces

Driving-force-Indikatoren werden ausschließlich im finnischen *Animal-welfare*-Bericht verwendet, und zwar für die Bereiche Bildung und Konsumverhalten. Der Bericht betont in einem Abschnitt beispielsweise, dass keine *Animal-welfare*-Inhalte im Curriculum der Grund- und weiterführenden Schulen zu finden sind. In der veterinärmedizinischen Fakultät, im Fachbereich Agrarwissenschaften und im Rahmen des Biologiestudiums werden vereinzelt Kurse zu dieser Thematik angeboten (Finnish Centre for Animal Welfare, 2013). Die mangelnde fachliche Schwerpunktsetzung im Bildungsbereich kann die Entwicklung eines Verständnisses von Tiergerechtigkeit behindern und dadurch gesellschaftsinduzierte Veränderungsprozesse verlangsamen. Bezüglich des Konsumverhaltens enthält der Bericht Informationen u. a. über den jährlichen Fleischkonsum pro Kopf, der in einem Zeitraum von vier Jahren angegeben wird (Finnish Centre for Animal Welfare, 2013). Außerdem wird die Nachfrage nach „Bioprodukten“ (Milch, Eier, Fleisch) in Form von

Tabelle 2

Identifizierte Indikatoren der Kategorie *driving forces*

Land	Bereiche	driving forces (Antriebsindikatoren)	Spezifizierte Informationen
FIN	Bildung	Fehlender schulischer und akademischer Schwerpunkt	
FIN	Konsum	Fleischkonsum	- in Kilogramm pro Person - 2007 bis 2010 - Fleisch von Rind, Schwein, Geflügel
FIN	Konsum	Eier-, Milch- und Fischkonsum	- 2010
FIN	Konsum	Nachfrage nach ökologisch erwirtschafteten Produkten	- Marktanteile und Konsumanteile
FIN	Konsum	Anteil VegetarierInnen	- Unterscheidung zwischen Semi-VegetarierInnen, PescetarierInnen und Ovo-Lacto-VegetarierInnen

Quelle: Eigene Darstellung; FIN= Finnland.

Marktanteilen dargestellt. Neben dem Konsum wird auch der Verzicht auf tierische Produkte als relevante Information angesehen. Der Anteil an VegetarierInnen wird hier als Indiz für einen hohen Grad an Sensibilisierung für das Tierschutzthema interpretiert (Finnish Centre for Animal Welfare, 2013). Die ausgewählten *Driving-force*-Indikatoren des finnischen Berichts sind in Tabelle 2 zusammengefasst.

4.2 Pressure, state, impact

Eine Darstellung von *Pressure*-Indikatoren erfolgt im finnischen und deutschen Bericht. Bezüglich der Art des Haltungssystems nennt Finnland die Zahl ökologisch wirtschaftender Betriebe und gehaltener Tiere. Dabei wird unterschieden zwischen Rindern, Schweinen, Legehennen und weiteren Nutztiergruppen (Finnish Centre for Animal Welfare, 2013). Der deutsche Tierschutzbericht gibt Auskunft über Hennenhaltungsplätze in Boden-, Käfig- und Freilandhaltungssystemen (BMELV, 2011). Finnland dokumentiert zudem die Dauer von Schlachthof- und Transitttransporten, die im Jahr 2008 stattfanden. Dabei wird zwischen Transporten unter neun, über zwölf und über vierzehn Stunden unterschieden (Finnish Centre for Animal Welfare, 2013). Informationen zur betroffenen Tierart oder Anzahl der transportierten Tiere sind nicht aufgeführt.

Von der Vielzahl vorhandener *State*-Indikatoren (Lahmheit, Schwanzspitzennekrosen, Mastitis etc.) ist die Dokumentation der Fußballengesundheit bei Mastgeflügel im dänischen Bericht der einzige Indikator dieser Kategorie, der aus den sechs untersuchten Berichten extrahiert werden konnte. Dänemark berichtet für 2010 über den Anteil der Geflügelbestände, bei denen bei einer stichprobenhaften Erfassung⁵ Fußballendermatitis, eine schmerzhafte Erkrankung der Fußballen, festgestellt wurde (Danish Center for Animal Welfare, 2011). Angaben über die Größe der

betroffenen Herden fehlen, was die Interpretierbarkeit der Angaben einschränkt.

Informationen der Kategorie *impact*, wie beispielsweise die Nutzungsdauer von Milchvieh oder die Mortalität bei der Ferkelaufzucht, sind in den Berichten nicht enthalten. Nur im finnischen Bericht wird ein *Impact*-Indikator erwähnt. Für den Zeitraum 2007 bis 2010 wird der Anteil der Tiere genannt, die auf Schlachthöfen ankommen und dann verworfen, also nicht für den menschlichen Verzehr verwendet werden. Die Angaben gelten u. a. für Mastschweine, Sauen und Rinder. Finnland folgert, dass der festgestellte Aufwärtstrend verworfener Schlachttiere starke gesundheitliche Probleme bei den angelieferten Tieren vermuten lässt (Finnish Centre for Animal Welfare, 2013).

Die Ergebnisse der Berichtsanalyse für die drei Kategorien *pressure*, *state* und *impact* sind in Tabelle 3 zusammengefasst. Insgesamt konnten fünf Indikatoren identifiziert werden. Nur im finnischen und deutschen Bericht wurden Zeitreihen dargestellt. Die Anzahl betroffener Tiere wird im finnischen Bericht im Zusammenhang mit der ökologischen Tierhaltung und im deutschen Bericht durch die Anzahl Haltungsplätze bei Legehennen quantifiziert. Finnland ist das einzige Land, das in seinem Bericht Informationen aus den Bereichen Transport und Schlachtung veröffentlicht. Allerdings fehlen bei den Schlachtdaten Angaben zur Anzahl betroffener Tiere und bei Tiertransporten Angaben zu den Tierarten.

4.3 Response

Aussagen zu *Response*-Indikatoren finden sich in allen untersuchten Berichten. Bei der Berichtsanalyse wird vor allem der staatliche Wille, Tierschutzgesetze umzusetzen, als wiederkehrender Berichtsinhalt identifiziert. Folgende Aspekte sind hierbei von Bedeutung:

1. Anzahl/Anteil⁶ kontrollierter Betriebe (Kontrolldichte), ggf. nach Tierarten

Tabelle 3

Identifizierte Indikatoren der Kategorie *pressure*, *state* und *impact*

Land	Monitoring-Daten/Informationen	Daten nach Tierart aufgeschlüsselt	Nennung von Anzahl betroffener Tiere	Zeitangabe	Kategorie
FIN	Ökologisch wirtschaftende Betriebe und gehaltene Tiere	ja	ja (nur Kühe)	2008 bis 2010	P
DE	Legehennen: Anteil und Anzahl Tiere in Käfig-, Boden-, Freiland- und ökologischer Haltung	ja	ja	2008 bis 2010	P
FIN	Transportdauer (kurz, mittel, lang)	nein	nein	2008	P
DK	Mastgeflügel: betroffene Herden/Betriebe nach Fußballen-Screening	ja	nein	2010	S
FIN	Verworfen Schlachtkörper (Anteil von allen angelieferten Schlachttieren in %)	ja	nein	2007 bis 2010	I

Quelle: Eigene Darstellung; FIN = Finnland, DE = Deutschland, DK = Dänemark; S=state, P=pressure, I=impact.

⁵ Aus jeder am Schlachthof angelieferten Herde müssen 100 Tiere untersucht werden. Anhand eines festgelegten Untersuchungsprotokolls werden Fußballen als gesund oder entzündet kategorisiert.

⁶ Die jährliche Gesamtzahl durchgeführter Tierschutzkontrollen wird besser interpretierbar, wenn sie in das Verhältnis zu allen kontrollpflichtigen Betrieben gesetzt wird (Kontrolldichte). So werden strukturelle Entwicklungen (z. B. Rückgang an landwirtschaftlichen Betrieben) berücksichtigt und intertemporale sowie regionale Vergleiche möglich.

Tabelle 4Identifizierte Indikatoren der Kategorie *response*: Tierschutzkontrollen

Land	Anzahl kontrollierter Bestände/ Betriebe	Anteil kontrollierte Bestände/Betriebe	Spezifizierte Informationen - Zeitspanne - Tierart
DE	–	–	–
FIN	✓	– Lediglich Angabe von Zielwerten (1,5 % Kühe, 2 bis 8 % Schweine, 7 bis 15 % Legehennen)	✓ Angaben für 2006 bis 2010 ✓ Kälber, Legehennen, Schweine, Rinder
AT	✓	✓ Angabe der Anzahl kontrollpflichtiger Betriebe und tatsächlich kontrollierter Betriebe (Anlehnung an EU-Vorlage 2006/788/EG); keine Zielwertangabe	✓ Angaben für 2011 bis 2012 ✓ Kälber, Schweine, Legehennen, Rinder, Mastgeflügel
DK	✓	– Lediglich Angabe von Zielwert (5 %)	✓ Angaben für 2010 ✓ Schweine, Rind, Mastgeflügel, Legehennen
GB	✓	–	✓ Angabe für 2009 ✓ Kälber, Rinder, Milchvieh, Schweine, Legehennen, Mastgeflügel
CH	–	– Lediglich Angabe von Zielwert (25 %)	–

Quelle: Eigene Darstellung, FIN = Finnland, DE = Deutschland, DK = Dänemark, GB = Großbritannien, CH = Schweiz, AT = Österreich.

2. Anzahl/Anteil festgestellter Verstöße bei den kontrollierten Betrieben, ggf. nach Tierarten
3. Anzahl/Anteil Sanktionsmaßnahmen bei festgestellten Verstößen

Tabelle 4 gibt einen Überblick über die von den Ländern bereitgestellten Informationen zu **Anzahlen und Anteilen kontrollierter Betriebe**: Finnland und Österreich stellen am meisten Informationen zur Verfügung, die Schweiz und Großbritannien am wenigsten. Im deutschen Bericht werden hierzu keine Angaben gemacht. Österreich orientiert sich an der Vorgabe der Europäischen Union (EU, 2006/778/EG) und gibt die Anzahl der kontrollierten und kontrollpflichtigen Betriebe für einen Zeitraum von zwei Jahren an (Österreich/Bundesministerium Gesundheit, 2013). Finnland nennt zwar über einen längeren Zeitraum (2006 bis 2010) die Anzahl von kälber-, schweine-, legehennen- und rinderhaltenden Betrieben, die kontrolliert wurden, führt aber nicht aus, welchem Anteil der Betriebe dies entspricht (Finnish Centre for Animal Welfare, 2013). Angaben zur Kontrolldichte werden hier, ebenso wie im schweizerischen und dänischen Bericht, nur als Zielgröße angegeben. Es gibt keine Hinweise darauf, ob die gesetzte Zielmarke erreicht wurde.

Zur Feststellung von **Verstößen** findet man in allen untersuchten Berichten Informationen (BMELV, 2011; Danish Center for Animal Welfare, 2011; Finnish Centre for Animal Welfare, 2013; Österreich/Bundesministerium Gesundheit, 2013; Schweizer Bundesamt für Veterinärwesen, 2010; Oguntunde et al., 2010). Über **Sanktionsmaßnahmen** berichten hingegen nur der österreichische und dänische Bericht. Abmahnungen, Bußgeldbescheide, Strafanzeigen o. Ä. werden in diesen Berichten tabellarisch dargestellt (Danish Center for Animal Welfare, 2011; Österreich/Bundesministerium Gesundheit, 2013).

Finnland geht zudem auf die Personalausstattungen der Veterinärämter ein und quantifiziert Neueinstellungen über die Kommunen (Finnish Centre for Animal Welfare, 2013). Im Rahmen der Professionalisierung des Veterinärwesens gibt der Tierschutzbericht der Schweiz an, wie viele Kurse angeboten und wie viele Amtstierärztinnen und Amtstierärzte an Fortbildungskursen teilgenommen haben (Schweizer Bundesamt für Veterinärwesen, 2010).

Bezüglich der Durchsetzung höherer Tierschutzstandards im Vergleich zum europäischen Regelwerk führt Finnland aus, dass das Schwanzkupieren bei Mastschweinen und Schnabelkürzen bei Legehennen bereits verboten ist (Finnish Centre for Animal Welfare, 2013), während die EU diese Praktiken durch Ausnahmeregelungen immer noch gewährt (EU 2008/120/EG, Anhang 1, Kapitel 1). Deutschland nennt den vorzeitigen Ausstieg aus der konventionellen Käfighaltung zwei Jahre vor dem offiziellen europaweiten Verbot (BMELV, 2011).

Ein weiterer relevanter Aspekt von *response*, die Umsetzung nationaler Fördermaßnahmen (Finanzierung über Landes- und EU-Mittel), wird im finnischen und deutschen Bericht angesprochen. Finnland nennt geförderte (Öko-) Betriebe, die Anzahl der auf diesen Betrieben gehaltenen Tiere und die im Jahr 2010 ausgezahlte Fördersumme, sowie Betriebe, die von 2006 bis 2009 an Agrarinvestitionsförderungsprogrammen teilnahmen (Finnish Centre for Animal Welfare, 2013). Deutschland listet Investitionsfördersummen für Stallbauten auf, die den Anforderungen an eine „besonders tiergerechte Haltung“ gerecht werden (BMELV, 2011). Das nichtstaatliche Engagement bringt der österreichische Bericht zum Ausdruck, indem er die erfolgreiche Umsetzung eines Tierschutz-Bildungsprogrammes betont und dabei die Anzahl ausgebildeter TierschutzreferentInnen benennt, sowie die Anzahl bestellter „Tierschutz-macht-Schule“-

Tabelle 5

Weitere Response-Indikatoren

Land	Maßnahmenindikatoren	Spezifizierte Informationen
FIN	Hoher gesetzlicher Mindeststandard, vorzeitige Umsetzung von EU-Bestimmungen	- Schwänze kupieren, Schnäbel kürzen nicht gestattet (deskriptiv)
DE	Hoher gesetzlicher Mindeststandard, vorzeitige Umsetzung von EU-Bestimmungen	- Konventionelle Käfighaltung ist bereits seit 2010 verboten
FIN	Fördermaßnahmen	- Tierschutzprämie im Öko-Landbau: Anzahl teilnehmender Betriebe, Tierzahlen (nicht nach Tierart differenziert), Gesamtfördersumme für 2010 - Prämien für tiergerechte Haltungsverfahren: Anzahl Betriebe nach Produktionsrichtung (Milchvieh, Schwein), Gesamtfördersumme für den Zeitraum 2007 bis 2010
DE	Fördermaßnahmen	- Agrarinvestitionsförderprogramm: Anzahl geförderter Ställe (Um- und Neubauten), gezahlte Fördersummen, 2007 bis 2009 - Stroh- und Weideförderung: Anzahl abgeschlossener Verträge und Fördersummen, 2007 bis 2009
FIN	Ausstattung der Veterinärbehörden	- Anzahl zusätzlich eingestellter Veterinärinnen und Veterinäre
CH	Weiterbildungsangebot für VeterinärInnen	- Anzahl weitergebildeter Tierärztinnen und Tierärzte - Anzahl durchgeführter Kurse (Tierschutzmodule)
AT	Wissensvermittlung im Bereich Tierschutz durch „Tierschutz macht Schule“-Verein	- Anzahl ausgebildeter TierschutzreferentInnen - Anzahl bestellter Unterrichtsmaterialien

Quelle: Eigene Darstellung; FIN = Finnland, DE = Deutschland, CH = Schweiz, AT = Österreich.

Materialien (Österreich/Bundesministerium Gesundheit, 2013). Die Response-Indikatoren, die sich nicht im engeren Sinne mit den Kontrollen vom Tierschutzrecht befassen, sind in Tabelle 5 zusammengefasst.

5 Diskussion

5.1 Vorgehen und Methodenwahl

Durch die aus pragmatischen Gründen (Sprachkenntnisse, Einsparung von Übersetzungskosten) sprachlich eingegrenzte Suche nach englischen, französischen und deutschen Berichten konnte zwar ein Einblick in, aber kein vollständiger Überblick über die europäische Berichtslandschaft erreicht werden. Möglicherweise wurde interessantes Berichtsmaterial anderer europäischer Staaten nicht berücksichtigt, sodass nicht ausgeschlossen werden kann, dass eine „Blaupause“ für einen deutschen Monitoring-Bericht Tiergerechtigkeit in einem der nicht untersuchten EU-Staaten vorliegt.

Ein mögliches Problem bei der Anwendung des DPSIR-Modells für einen deutschen Bericht kann darin bestehen, dass durch die Vielzahl an möglichen Indikatoren das Hauptziel eines Monitorings-Tiergerechtigkeit – über Zustand und Entwicklung von Gesundheit, Verhalten und Emotionen von Nutztieren zu berichten – in den Hintergrund gedrängt wird und stattdessen umfangreiche Materialien zu Tierschutzkontrollen, Bildungsmaßnahmen und Konsumententwicklungen präsentiert werden. Hier sollte bei der Erstellung auf Vollständigkeit geachtet werden (siehe Abschnitt 3.2).

Eine grundsätzliche Option des Modells, die allerdings in den untersuchten Berichten nicht genutzt wurde, liegt darin, das Fehlen von geeigneten Zustandsindikatoren durch andere Indikatorenkategorien zu kompensieren. Im Umweltbereich

wird z. B. die Hoftor-Stickstoffbilanz (ein *Driving-force*-Indikator) verwendet, um Nährstoffeinträge durch die Landwirtschaft zu dokumentieren. Der Transport von Nährstoffen durch die Bodenschichten dauert lange, sodass der Zustandsindikator „Stickstoffbelastung des Grundwassers“ erst Dekaden später festgestellt werden könnte. Im Bereich der Tiergerechtigkeit wäre beispielsweise die erfolgreiche Zucht hornloser Milchkurhassen ein *Driving-force*-Indikator, der im Zusammenhang mit der Enthornung steht.

5.2 Die Interpretation von *Driving-Force*- und *Response*-Indikatoren

Die Interpretation von *Driving-Force*- oder *Response*-Indikatoren im Hinblick auf ihre Relevanz für eine Veränderung der Tierwohlsituation ist oft schwierig. Das soll am Bsp. der Tierschutzgesetzkontrollen erläutert werden.

Zwar sind „angemessene“ Kontrollindikatoren eine Voraussetzung für die Durchsetzung von Gesetzen, letztendlich sind sie aber nur dann ein wirksames Instrument zur Einhaltung der Tierschutzgesetze, wenn die Kontrollen sorgfältig durchgeführt werden und festgestellte Verstöße tatsächlich geahndet werden.

Eine im Zeitverlauf ansteigenden Zahl festgestellter Verstöße kann z. B. sowohl auf einen höheren Anteil an tatsächlichen Verstößen als auch auf eine verbesserte risikobasierte Auswahl und verstärkte Inspektion auffälliger Betriebe zurückgeführt werden (Thüringer Ministerium für Soziales, 2005).

Neben dem angewandten Überwachungssystem, wie der risikoorientierten Betriebskontrolle, sind weitere Faktoren für den Erfolg des Tierschutzvollzuges entscheidend.

Die personelle und materielle Ausstattung der Veterinärbehörden (Österreich/Bundesministerium Gesundheit, 2011)

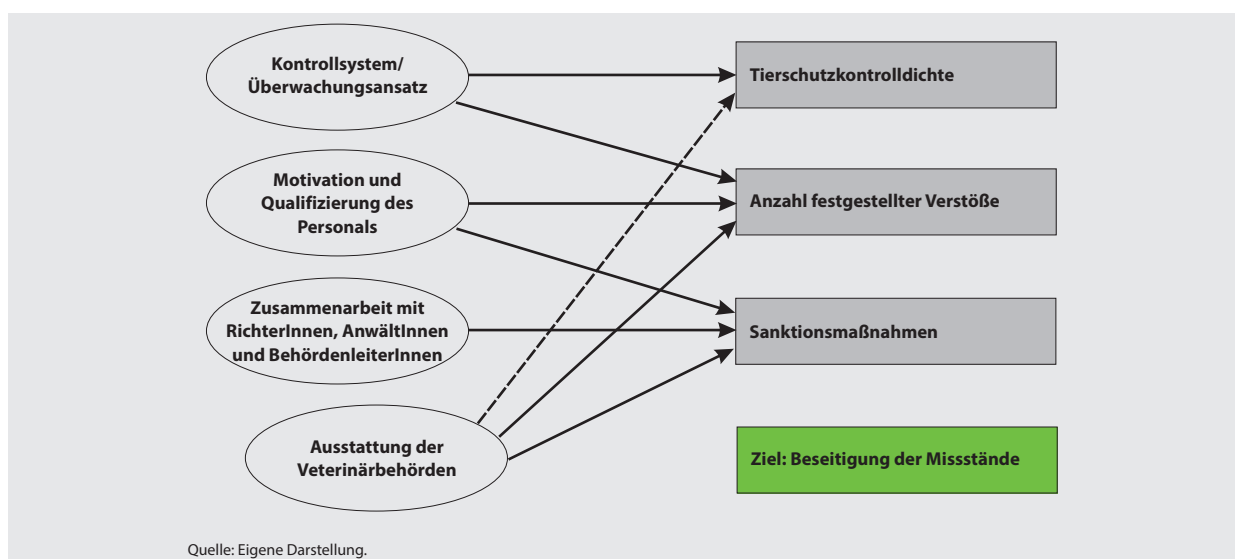


Abbildung 2
Einflussfaktoren auf den erfolgreichen Tierschutzvollzug (Auswahl)

sowie die Motivation und Qualifikation des Personals sind ebenso von Bedeutung wie die Zusammenarbeit der Veterinärbehörden, der Staatsanwaltschaft und der Gerichte. Abbildung 2 fasst wesentliche Einflussfaktoren auf tierschutzbezogene Informationen, wie Verstöße und Maßnahmen, zusammen.

Bei der Betrachtung von Tierschutzkontrollen als *Response*-Indikator für eine Durchsetzung des Tierschutzgesetzes muss bedacht werden, dass Kontrollen nur dort wirksam sein können, wo die gesetzlichen Rahmenbedingungen hinreichend präzisiert wurden, was z. B. für Milchkühe in Deutschland nicht der Fall ist. Eine Voraussetzung für die Einordnung der Kontrollinformationen ist daher ein Überblick über die rechtlichen Rahmenbedingungen.

5.3 Vollständigkeit der Berichte

Für eine vollständige Messung der Tiergerechtigkeit müssten die Berichte die Aspekte Tiergesundheit, Tierverhalten und das emotionale Befinden mit Daten unterlegen. Es müssten ferner für alle relevanten Nutztierarten (Rind, Schwein und Geflügel) die Bereiche Haltung, Transport und Schlachtung abgedeckt werden. Diese Kriterien erfüllen die untersuchten Berichte nicht.

Der Aspekt Tiergesundheit wird nur im dänischen Bericht anhand des Indikators „Fußballennekrosen“ bei Mastgeflügel dokumentiert. Informationen über die Ausführbarkeit des Normalverhaltens können in begrenztem Umfang über die ressourcenbezogenen Angaben zu den nach den Richtlinien des ökologischen Landbaus gehaltenen Tieren (Finnland) und des Anteils an Legehennen mit Zugang zu Auslauf (Deutschland) entnommen werden. Indikatoren zum emotionalen Zustand, welche beispielsweise über den Anteil an Tieren mit kupierten Schwänzen oder gekürzten Schnäbeln darstellbar wären, werden in keinem der Berichte direkt genannt. Allerdings geht die Nennung der über EU-Vorgaben

hinausgehenden Verbote des Schwanz- und Schnabelkupierens in Finnland indirekt auf diesen Aspekt ein.

Die untersuchten Berichte sind im Hinblick auf die Erfassung aller relevanten Nutztierarten unvollständig. Angaben zur Haltung im ökologischen Landbau werden beispielsweise nur für Mastschweine, Legehennen und Milchvieh spezifiziert, nicht aber für Mastgeflügel und Mastrinder. Im Hinblick auf den Gesundheitszustand der Tiere liegen sogar nur für Mastgeflügel Informationen vor (Fußballennekrosen).

Aus den für die Tiergerechtigkeit wichtigen Bereichen Haltung, Transport und Schlachtung werden in den Berichten nur zu den ersten beiden Handlungsfeldern Informationen bereitgestellt. Für die Schlachtung relevante Indikatoren, wie beispielsweise Wartezeiten am Schlachthof oder die Art und Effektivität der Betäubung, fehlen ausnahmslos.

6 Schlussfolgerungen und Ausblick

Die Untersuchung der Berichte hat gezeigt, dass nicht nur in Deutschland, sondern auch in den betrachteten Ländern für die Nutztierhaltung noch kein Monitoring Tiergerechtigkeit existiert. Die Berichtsanalyse brachte keine *Blaupause* für einen deutschen Bericht hervor, zeigte aber einige Optionen auf.

Die Anwendung des *Driving-Force-Pressure-State-Impact-Response*-Ansatzes auf den Bereich Tiergerechtigkeit hat den Blickwinkel auf die in den Berichten enthaltenen Informationen zu Einflussfaktoren (*driving forces*) und Reaktionsmöglichkeiten (*responses*) gelenkt und so die „klassische“ eng auf die Aspekte Tiergesundheit, Tierverhalten, emotionaler Zustand ausgerichtete Perspektive geweitet. Hierdurch konnten aus den untersuchten Berichten europäischer Staaten einige auch für eine deutsche Berichterstattung interessante Indikatoren identifiziert werden.

Für viele der genannten *Driving-force*- und *Response*-Indikatoren liegen die Daten für eine Beschreibung der

deutschen Situation bereits vor. In manchen Fällen können diese direkt aus existierenden, zu anderen Zwecken veröffentlichten Dokumenten entnommen werden. Angaben zu Fördermaßnahmen werden beispielsweise in den jährlich erscheinenden Monitoring-Berichten der Entwicklungsprogramme für den ländlichen Raum veröffentlicht (European Network for Rural Development, 2014). Weitere in Deutschland verfügbare Datensätze sind die Ergebnisse der halbjährlich und jährlich veröffentlichten Schlachttier- und Fleischuntersuchung des Statistischen Bundesamtes (Destatis). Hier liegen, wie im finnischen Bericht tabellarisch dargestellt, Informationen zu verworfenen Schlachttieren und andere Daten über Organverwürfe vor. Verwurfszahlen können daher ebenfalls ohne großen Zusatzaufwand für einen deutschen Bericht im Zeitverlauf dargestellt werden.

Die Kontrollen zur Durchsetzung der Tierschutzgesetze müssen alle Mitgliedstaaten aufgrund der Verpflichtungen für die europäische Berichterstattung bereits jetzt einheitlich dokumentieren. Da hierbei über die Anzahl und Ergebnisse der Kontrollen auf landwirtschaftlichen Betrieben sowie beim Transport berichtet wird, ist die „Kontrolldichte“ als *Response*-Indikator für einen deutschen Bericht problemlos umsetzbar, ebenso wie eine Zusammenfassung der Beanstandungsgründe. Ein weiterer in den untersuchten Berichten enthaltener Aspekt ist die nationale Tierschutzgesetzgebung (Finnland). Eine übersichtliche und transparente Darstellung der über den verpflichtenden EU-Mindeststandard hinausgehenden Gesetze, aber auch der bislang noch nicht gesetzlich geregelten Bereiche kann für den deutschen Kontext geleistet werden. Teilweise sind diese Informationen bereits im deutschen Tierschutzbericht enthalten.

In einigen relevanten Bereichen liegen zwar Daten vor, befinden sich aber in privatem Eigentum und/oder werden nicht einheitlich erfasst. Das von Dänemark bereits im Bericht verwendete Fußballen-Monitoring bei Mastgeflügel setzt sich zwar auch in Deutschland mehr und mehr durch und wird in einigen Bundesländern bei allen Tieren bereits automatisiert oder „manuell“ stichprobenhaft aufgenommen (ML, 2011). Die Verwendbarkeit für einen nationalen Bericht ist aber trotz einer guten Eignung des Indikators (wissenschaftlich anerkannt, relevantes Tierschutzproblem) aufgrund des schwierigen Zugangs und der uneinheitlichen Erfassung dieser Daten nicht absehbar. Auch Informationen über Weiterbildungsangebote für amtliche Veterinäre, wie sie die Schweiz bereitstellt, und über die im finnischen Bericht beschriebene personelle Ausstattung der Ämter, könnten relevant für einen deutschen Bericht sein. Diese Daten müssten aber auf Ebene der Bundesländer abgerufen werden, sodass die Informationsbeschaffung mit einem hohen Aufwand verbunden wäre.

Welche der in den untersuchten Berichten verwendeten Indikatoren letztendlich in eine deutsche Berichterstattung aufgenommen werden, hängt allerdings nicht nur von Fragen der Datenverfügbarkeit ab. Die Indikatoren müssen zuallererst den Kriterien, nach richtungssicherer Interpretierbarkeit, wissenschaftlicher Validität und Reliabilität entsprechen. Über die Anregungen aus den Berichten benachbarter Staaten hinaus, bedarf es zudem Überlegungen und einer

Entscheidung darüber, welche weiteren Tiergerechtigkeitsindikatoren sich für ein aussagekräftiges nationales Monitoring eignen. Eine Vielzahl wissenschaftlich fundierter Indikatoren gibt es bereits. Für diese muss einerseits geprüft werden, welche für den Zweck einer nationalen Berichterstattung am bestgeeignetsten sind. Zudem kann es notwendig sein, aus der Vielzahl der Indikatoren eine Auswahl zu treffen, um die Berichterstattung nicht zu überfrachten. Diese Auswahl sowie die Prüfung, ob sich bereits vorliegende Monitoring-Daten für eine Indikatorenentwicklung eignen, oder mit welchem Aufwand sich die noch nicht vorliegenden Informationen erheben lassen, sind Kernstück des Forschungsvorhabens „Erstellung eines Prototypen für einen nationalen Monitoring-Bericht Tiergerechtigkeit“ am Thünen-Institut für Betriebswirtschaft in Braunschweig.

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Organic goat meat production in less favoured areas of Romania

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Abstract

More than 1.2 million goats are currently being reared in Romania today, with the numbers rapidly increasing. Moreover, the country holds 4.9 million hectares of pastures, mostly situated in regions listed as less favoured areas (LFA's). A comparative study showing production performances of two pasture types (organic vs. conventional), and of two kids genotypes (Carpatina vs. F₁ Boer x Carpatina) was implemented. The annual pasture yields were 26.4 t/ha (5.3 t/ha/a DM) in the conventional pasture and of 30.6 t/ha (6.1 t/ha/a DM) in the organic managed pasture, respectively. The average carrying capacity was 1.89 livestock units (LU; one LU is equal to 500 kg liveweight) for the conventional pasture, and 2.18 LU for the organic pasture, respectively. The conventional pasture had an estimated potential of production ranging from 114 to 163 kg of kid meat/ha, while the estimated production for the organic pasture was between 149 and 252 kg of kid meat/ha. Result have proved to be encouraging regarding the potential of the LFA's in Romania to produce goat meat under organic rearing systems with purebreed genetics. Of the technical solutions identified, those regarding pasture management could be applicable to current commercial farming practices in order to improve goat farming profitability while at the same time tackling socio-ecological issues such as nature conservation and animal welfare.

Keywords: goat meat, organic production, Romania, extensive grazing systems, crossbreeding, Boer goats, Carpatina goats

Zusammenfassung

Ökologische Ziegenfleischproduktion in benachteiligten Regionen in Rumänien

In Rumänien werden mehr als 1,2 Millionen Ziegen gehalten, Tendenz steigend. Weiterhin gibt es rund 4,9 Millionen Hektar Weideland, das meiste liegt in benachteiligten Regionen. Es wurde eine vergleichende Studie auf zwei unterschiedlichen Weidequalitäten (ökologisch und konventionell) mit zwei unterschiedlichen Genotypen (reinrassige lokal verbreitete Doppelnutzungsrasse der Karpatenziege sowie ein Kreuzung dieser Rasse mit der Fleisch betonten Burenziege) durchgeführt. Die Tragfähigkeit wurde mit 1,89 Grossvieheinheiten (GV; eine GV entspricht 500 kg Lebendmasse) für die konventionellen Flächen und 2,18 GV festgestellt. Pro Hektar konnten auf den konventionellen Flächen zwischen 114 und 163 kg und auf den ökologischen Flächen 149 bis 252 kg Ziegenfleisch pro Jahr produziert werden. Die Kreuzungslämmer erreichen mit rund 154 g fast 40 Gramm höhere Tageszunahme als die reinrassigen Karpaten-Ziegenlämmer (117 g/d). Damit zeigte sich, dass es ökonomisch sinnvoll ist, die Flächen ökologisch zertifiziert mit Kreuzungsziegenlämmern zu nutzen, wenn es einen Markt für Prämiumqualitäten (Öko-Zertifikat) gibt. Damit wird nicht nur die Wirtschaftlichkeit sondern auch der Umweltschutz und das Tierwohl verbessert.

Schlüsselwörter: Ziegenfleisch, Ökologischer Landbau, Rumänien, extensive Weidewirtschaft, Kreuzungszucht, Burenziege, Karpatenziege

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1 Introduction

The organic farming sector in the EU has been rapidly developing during the past decades. In 2011 a total area of 9.6 million ha were cultivated as organic, compared to 5.7 million ha in 2002 (Eurostat, 2014). During the last decade, organic area in the EU improved by about 500,000 ha per year, with the whole organic area representing 5.4 % of total utilized agricultural area in Europe (DG-AGRI, 2013).

The organic goat sector within the EU accounts for 0.4 million heads, concentrated geographically in Greece (4.1 % of goats reared in Greece) and Italy (7.5 % of the national flock), with the farmers essentially focused on organic cheeses production (DG-AGRI, 2013).

In Eastern and Southern Europe, the majority (over 85 %) of the sheep and goats flocks 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).

Currently, Romania has a national flock of 9.5 million sheep and 1.2 million goats (MADR, 2014), with numbers increasing by 5 to 8 % each year for both species in the last 5 years. Moreover, the country has a pasture surface of 4.9 millions ha, which could sustain a flock of up to 16 million sheep and goats (Dragomir, 2009). Sheep and goats are being reared in Romania almost exclusively under extensive low-input production systems, with the breed structure being dominated by indigenous rustic breeds, such as the Turcana (52.4 %) and Tsigai (24.3 %) in sheep (Ilisiu et al., 2013) and Carpatina (over 80 %) in goats (Pascal et al., 2011). With the goat production being orientated primarily towards the milk production, while the kid meat is regarded as a marginal product. The Carpatina goat is regarded as low performing, however the breed has a remarkable organic resistance and adaptation. Reports concerning performance of Carpatina breed have shown modest production levels, with milk yields estimates of 240 to 260 kg/lactation (Padeanu, 2001) and growth rates in kids as low as 94 g/day (Voia et al., 2010).

Although Romania holds around 10 % of the goat flocks reared in the EU, with the industry representing an important sector of the agriculture at national level, research on organic goats production systems is lagging behind, compared to that from other states. Up-to-date, the importance of organic farming in Romania has remained limited, especially in the animal production sectors (dairy, meat and eggs), with significant progress being made for crops and horticulture in the last five years. Given the high production potential (large surface of natural pastures, the increasing numbers of sheep and goats, great number of LFAs, consolidated foreign markets), in the European Agricultural Fund for Rural Development (EAFRD) programs for Romania, the organic farming was set-out as a priority for local development, with several measures and types of funding's addressing investments in the organic animal production sector and being available for the 2014 to 2020 period. Moreover, the Romanian goat breeders could take advantage of the EU developed

schemes such as PDO (protected designation of origin), PGI (protected geographical indication) and TSG (traditional speciality guaranteed), having in mind that the government and the EU are subsidizing up to 50 % the market-placement activities of such products, starting 2012 according to Council Regulation EC 3/2008 and translating national law and regulation in place. Thus, traditional products such as the goat meat 'virşli' sausages, could be promoted and protected, bringing added value into the sector, and creating premises for further development.

However, the low purchasing power of the local consumers and the consideration of the general public that the small ruminants production systems are environmental- and animal-friendly, are the two main constraints for the future development of the organic goat meat production in Romania in particularly, and Eastern and Southern Europe in general.

Starting year 2011, the Research and Development Station for Sheep and Goats from Caransebes of the Romanian Academy for Agricultural and Forestry Sciences began implementing a research programme on organic sheep and goats farming. The main objective of the project was to explore and identify technical solutions to the specific constraints of organic sheep and goats farming linked to reproduction performances, feeding strategies and management, animal health and welfare.

The aim of the current research was to evaluate the technical efficiency and viability of introducing the organic goat meat production in less favoured areas of Romania.

2 Materials and methods

2.1 Location and animals

The trial was initiated starting autumn 2013 at the Research and Development Station for Sheep and Goats from Caransebes (45°25'N/22°13'E). Caransebes region has a typical Central European humid continental climate, with the research station being located at 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. Temperatures express seasonal patterns with summer daily means of 20.1 °C in July and winter daily means of -0.8 °C in January (Table 1).

The project herd consisted of 90 multiparous purebred Carpatina does, managed under organic rearing conditions as stipulated by the Council Regulations of the European Commission (2092/1991/EEC and 1804/1999 EEC) on standards of organic animal husbandry. Two breeding herds were set-up, with half of the does ($n = 45$), randomly selected being mated with Carpatina purebred bucks, while the second group of does were exposed to Boer bucks. Buck/doe ratio was roughly of 1:20, for two consecutive oestrous cycles (42 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 m² and 0.5 m² per doe and kid, respectively. Does

received high-quality clovers and pastures hays *ad libitum*, with an additional 200 g of concentrates in late gestation and during suckling period. All hays and concentrates were organically produced on farm. Creep feeding of kids was not practiced, they were solely reliant on the dams milk production. Kids were weaned at 60 days of age.

Table 1

Experimental design and general management conditions

Location:	45°25'N/22°13'E	Altitude of the site:	280 m
Annual precipitation:	737.2 mm	Mean annual temp.:	12.9 °C
Breeding herd:	90 Carpatina does	Buck/doe ratio:	1:20
Indoor housing:	120 days	Kids weaned at:	60 days
Pasture management:	rotational grazing	Kids /experiment:	80
Kids /group:	40 (sex ratio 1♂:1♀)	Kids genotype / group:	20 CA /20 F ₁ BC

After weaning (April, 2014), kids were divided into two groups of 40 individuals each (20 Carpatina purebreds and 20 F₁ Boer x Carpatina), 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 m²). Kids were provided on pasture with shelter and shade, and had non-restricted access to water and mineral blocks.

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

2.2 Pasture management

In order to evaluate the potential of producing organic kid meat in western Romania, under pasture-based extensive system, a comparative study between two pasture types was implemented. One managed and fertilized conventionally (CONV), and one organic managed pasture (ORG), which was subject to a conversion period of two years (2012 and 2013).

The CONV pasture was fertilized initially in two stages, first in early spring 2012 with a dose of N₁₀₀P₇₀K₇₀, and secondly, after the first harvest with a dose of N₅₀. In 2013, fertilization was made by administrating N₁₀₀ in early spring and N₅₀ after the first harvest. During both years, the pasture was used to produce bailed hay, and was not used for grazing. The following plant species were identified within the pasture: grass 59 % (*Lolium perenne*, *Festuca pratensis* and *Festuca arundinacea*), legumes 2 % (*Lotus corniculatus* and *Trifolium repens*) and other species 39 %.

The ORG pasture was fertilized in early-spring 2012 by direct grazing with the animals, at a stoking rate of 1 goat/1.5 m², 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); *Trifolium repens* 10 % (2 kg/ha). During the conversion period, the pasture was used to produce hay, and not directly grazed by animals.

Grass availability (DM/ha) was measured monthly using twelve iron-fenced net boxes (1.5 × 1.5m, 1m height), randomly placed on grazing area, according to the method described by Napolitano et al. (2011). Herbage was harvested at ground level from three 1 × 1m areas placed into boxes. The total herbage mass was weighted and sub-sampled to evaluate dry matter and chemical composition and to estimate the botanical composition.

In 2014, both conventional and organic pastures were fenced using net wire fencing of 150 cm height. With the distance between the CONV and ORG pastures being of 200 m, in order to avoid as much as possible differences in pasture yields caused by soil type and fertility.

2.3 Data collection

In Carpatina does the conception rate (%), litter size (%) and litter weight gain at 28 days of age (kg) was recorded. Conception rate was calculated as the ratio between the number of does kidding relative to the total number of the does exposed to the buck. Litter size (prolificacy) was computed as the ratio between the number of kids obtained relative to the number of does kidding. Litter weight gain at 28 days of age was calculated by subtracting the litter weight at birth from the litter weight at 28 days.

Individual kid records were made by identifying the birth type, ear-tag number, birth weight and date, dam and sire genotype, weight at 28, 60, 90, 120, 150 and 180 days. Survival rates of kids from birth to weaning (60 days of age) was recorded.

Body weight was monitored using the electronic Inscale Platform Scale EOE 150 K 100 XL equipped with an animal weighing programme, in the morning at the same hour on each day, in order to obtain the highest accurate data.

Data were statistically using MiniTab14 software and differences between groups were analyzed by non-parametric Mann-Whitney-Wilcoxon test. All decisions about the acceptance or rejection of statistical hypothesis have been made at the 0.05 level of significance.

3 Results and discussion

Carpatina does on this project were at the upper end of the range for fertility rates (estimates of 80 to 95 %) previously reported for meat goats (Malan, 2000; Rhone, 2005; Browning et al., 2011). Furthermore, the current study represents the first report of fertility rates for Carpatina does (Table 2).

Table 2

Mean ($\pm$ SEM) for does reproductive performance and kids survival rates

Conception rate (%):	92.2 $\pm$ 0.28	Litter size (%):	146.9 $\pm$ 0.57
Birth weight CA (kg):	3.67 $\pm$ 0.06 ^a	Birth weight F ₁ BC (kg):	4.24 $\pm$ 0.11 ^b
CA weight at 28 d (kg):	8.07 $\pm$ 0.11 ^a	F ₁ BC weight at 28 d (kg):	10.1 $\pm$ 0.16 ^b
ADG in un-weaned CA (g)	117.4 $\pm$ 0.01 ^a	ADG in un-weaned F ₁ BC (g)	154.0 $\pm$ 0.01 ^b
Survival rate CA (%):	91.3 $\pm$ 0.37 ^a	Survival rate F ₁ BC (%):	88.7 $\pm$ 0.40 ^a

^{a,b} Column means with different superscripts differ significantly at $p \leq 0.05$; ADG – average daily gain

Reproductive outputs is the production traits with the greatest impact on profitability in commercial meat goat farms.

Litter size of the experimental flock was lower than previous estimates and reports by Duricic et al. (2012) for does managed semi-intensively and those of Rahmann (2009) for does reared under organic production systems, respectively. However, the litter size of 146.9 % is within the limits for the breed's standard, of 130 to 160 % (Voia, 2011).

Boer-sired kids were heavier ($p \leq 0.01$) at birth compared with those produced by Carpatina sires (4.24 vs. 3.67 kg). Birth weight of the F₁ Boer x Carpatina kids was higher than previous data reported by Duricic et al. (2012) for Boer purebreds, the higher litter size of the Boer does (180 %) could have resulted in individual lower weights at birth.

Significant differences between the adult average body weights of the two breeds was a reason for concern at the beginning of the project. Given that Carpatina does weigh between 40 to 45 kg, while adult Boer bucks weight is of 110 to 120 kg. Although kids sired by the Boer bucks were heavier, no dystocia or other related birth problems were recorded during the kidding season. Worth mentioning that the breeding heard was consisting exclusively out of multiparous Carpatina does (3 to 4 parity).

Overall, reproductive performance of the Carpatina does is not suitable for the meat production. For the breed to become a potential maternal-breed to be used in future crossbreeding schemes with meat specialized bucks (e.g. Boer, Kiko), intense selection for prolificacy and milk-ability is recommended.

Genotype influenced significantly ($p \leq 0.01$) kids weight at 28 days of age, with F₁ Boer x Carpatina crossbred kids outperforming the Carpatina purebreds. Although kids dams were of the same breed, and presumably had the same milk-ability, the higher birth weight of the crossbreeds might contributed to the higher growth rates during the first 28 days.

Average daily gain of F₁ Boer x Carpatina kids was significantly ($p \leq 0.01$) higher than their counterparts, the Carpatina purebreds, with average values of 154.0 g/day and 117.4 g/day, respectively. Results are in accordance with those reported by Belay et al. (2014), on using Boer bucks as terminal sires for improving kid growth rates.

Survival rates of kids till the age of weaning was not affected ($p \geq 0.05$) by sire's genotype, although Carpatina kids outperformed slightly the crossbreeds. This indicator could prove useful for Romanian farmers which plan to use Boer bucks for crossbreeding with native breeds and populations, in order to improve growth rates and carcass quality of lambs.

Despite encouraging prospects, the application of innovative pasture cropping systems is encountering difficulties due to the lack of technical information and solutions regarding the correct management of organic pastures for the small ruminants sector (Ronchi and Nardone, 2003).

During the third year of vegetation, at the end of the conversion period, the organic managed pasture yield was of 30.6 t/ha, compared to the 26.45 t/ha crop, estimated for the conventional managed pasture (Table 3). Overall, the increase in production of 15.6 % for the organic pasture could be attributed to the legumes species incorporated in the initial over-seeding, and to the annual rain falls registered in 2014, of 900.8 mm, which are were with 30 % higher than the average annual rain falls for the region.

Table 3

Estimates on the organic and conventional pastures yields (3rd year of vegetation)

Production trait	Conventional	Organic
Pastures yields (t/ha)	26.45	30.60
Dry matter (t/ha)	5.29	6.12
Pastures crude protein production (kg/ha)	813	987
Biological nitrogen fixation (BNF), (kg/ha)	22	65
Pastures carrying capacity (animal units)	1.89	2.18

The incorporation of legumes (*Trifolium* and *Medicago* spp.) into organic managed pastures, leads to an improvement of both pasture yields and nitrogen fixation, as previously demonstrated by Caporali and Campiglia (2001). The organic pasture has yielded a crude protein production superior with 21.4 % compared to the conventional managed pasture, average estimates being of 987 kg/ha and 813 kg/ha, respectively.

Higher protein content of a pasture has a series of benefits, such as allows a higher stoking rate, has the potential to produce better quality hays, the palatability rises, and thus the selective grazing is reduced. Nitrogen fixation in soil has significant implications for both the small ruminant industry as well for the environment protection. During the current study, the biological nitrogen deposited in soil was of 22 kg/ha for the conventional pasture, while for the organic pasture, the nitrogen deposited in the soil was of 65 kg/ha, resulting a three folded quantity of nitrogen deposited in the soil per hectare. The higher pasture yield for the organic pasture, compared to the conventional managed pasture, could be attributed to the following three aspects: i) seeding and pasture plant structure, which for the organic pasture had a initial legumes proportion of 20 %, compared to the 2 % in the conventional pasture (being

- known that the white clover is self-seeding easily and invasive towards grass species), with the organic pasture being in its 3rd year of vegetation, when most cultivated pastures are reaching their production peak;
- ii) the nitrogen available in soil, which constrains significantly plants growth and thus, pasture yields, with several studies outlining that the legumes nitrogen deposited in soil has a superior plant availability and absorption rates, compared to synthetic nitrogen used in the conventional system;
- iii) in addition, the higher levels of rain falls registered during 2014 (+ 30 % than the average for the region), might have caused a significant higher growth rates of the plants, favoring the cultivated species from the organic pasture. Most-likely, all three factors mentioned above have concurred to the unexpected results concerning the two pastures yields. Giving the organic's pasture higher yield, the carrying capacity (animal units) was higher with 15.3 %, compared to the conventional pasture.

Under pasture conditions, the Carpatina kids had growth rates of 100.7 g/day and 105.2 g/day, under conventional and organic systems, respectively (Table 4). Pasture type did not influenced ($p > 0.05$) growth rates in the purebred kids. While for the F₁ Boer x Carpatina kids, the pasture type influenced significantly ($p \leq 0.05$) the growth rates, with average values of 145.2 g/day and 177.3 g/day being recorded in the conventional and organic systems, respectively.

Table 4

Data on growth rates performances and on kids

Trait	Conventional	Organic
ADG on pasture in Carpatina kids (g)	100.7 ± 0.02 ^a	105.2 ± 0.03 ^b
ADG on pasture in F1BC (g)	145.2 ± 0.02 ^a	177.3 ± 0.03 ^b
Meat production estimates in CA kids (kg/ha)	114 kg	149 kg
Meat production estimates in F ₁ BC (kg/ha)	163 kg	252 kg

Based on both kids growth rates and pastures production yields, the potential of meat production for the two genotypes and two pasture types was estimated. The conventional pasture from the current project had a potential of production of 114 kg/ha for Carpatina purebreds, and of 163 kg/ha for F₁ Boer x Carpatina crossbreed kids. While for the organic pasture, it was estimated a production potential of 149 kg of meat per ha while rearing Carpatina purebreds, and of 252 kg/ha for the Boer x Carpatina dual-breds. Current results are in accordance with reports of Mbuku et al. (2015), which found that throughout crossbreeding, the improvement of meat production rises with 18.2 kg per doe mated per year, compared to using dairy purebreds. Nutritional strategies in low cost and easy to apply in pasture based systems can improve the productive performance of goats and have the potential to lead to profitable and successful enterprises.

The technical efficiency and viability of organic and conventional meat goat production were investigated (Table 5). Overall, the production costs in the organic production system were greater, when compared with the conventional management of the pasture. With the pasture seeding costs being higher with 40.6 %, and those of price/t of pasture of 25.8 % for the organic pasture, compared to the conventional system.

Estimated production costs per kg of kid meat were higher by 12.6 % when rearing Carpatina purebreds, and by 35.3 % when F₁BC crossbreeds were concerned. Altogether, higher production costs should reflect in the economic returns (EUR/kg of sold kid), in order for the farmers to adopt the organic production systems. This could be achieved either throughout niche marketing of organic goat 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 5

Technical efficiency of organic production of goat meat

Costs categories (in EUR)	Conventional	Organic
Pasture seeding costs /ha	191.90	269.96
Production costs /t of pasture	6.97	8.77
Annual pasture maintenance costs /ha	83.23	128.23
Production costs /kg of meat CA	2.37	2.67
Production costs /kg of meat F1BC	1.16	1.57

Rahmann (2007) in his work concerning the economic returns in dairy and meat goat sectors, has shown that farm profitability differs to a great extent, with an average annual income of 163 EUR/doe raised for milk production, while the returns for meat goats was of 36 EUR/doe.

However, rearing goats for meat offers a set of advantages, when compared to dairy goats, such as: management in meat animals is less dependant on infrastructure and investments; the labour costs are being significantly reduced; no need for inveting in milking parlors and milk coolonig tanks; the possibility of using transhumance for landscape management; lower veterinary care and energy costs.

4 Conclusions

Current results have proved to be encouraging regarding the potential of the Less Favoured Areas from Romania to produce goat meat under organic rearing systems. Technical solutions identified, regarding pasture management might have applicability in current commercial farming practices, in order to improve goat farming profitability, in the same time tackling environmental issues.

Introduction and use of the South African Boer meat specialized breed into crossbreeding schemes with local unimproved goat populations has lead to a significant increase of both growth rates and kid meat production per hectare.

Taking advantage of the Boer meat producing potential, the local low-input breeds high levels of adaptation and organic resistance, and also of the heterosis effects.

However, both farmers and policy makers should be aware and keep in mind both the unconsolidated markets for organically kid meat found in Eastern Europe, as well as the volatility of the small ruminants meat markets and demand.

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