

Michael Klaas
Stefan Pischinger
Wolfgang Schröder *Editors*

Fuels From Biomass: An Interdisciplinary Approach

A collection of papers presented at the Winter School 2011 of the North Rhine Westphalia Research School "Fuel production based on renewable resources" associated with the Cluster of Excellence "Tailor-Made Fuels from Biomass", Aachen, Germany, 2011

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Wolfgang Schröder, Lehrstuhl für Strömungslehre und Aerodynamisches Institut,
Aachen, Germany
e-mail: office@aia.rwth-aachen.de

Bendiks Jan Boersma, Delft University of Technology, CA Delft, The Netherlands
e-mail: b.j.boersma@tudelft.nl

Kozo Fujii, The Institute of Space and Astronautical Science, Kanagawa, Japan
e-mail: fujii@flab.eng.isas.jaxa.jp

Werner Haase, Neubiberg, Germany
e-mail: whac@haa.se

Ernst Heinrich Hirschel, Zorneding, Germany
e-mail: e.h.hirschel@t-online.de

Michael A. Leschziner, Imperial College of Science Technology and Medicine,
London, UK
e-mail: mike.leschziner@imperial.ac.uk

Jacques Periaux, Paris, France
e-mail: jperiaux@free.fr

Sergio Pirozzoli, Università di Roma “La Sapienza”, Roma, Italy
e-mail: sergio.pirozzoli@uniroma1.it

Arthur Rizzi, KTH Royal Institute of Technology, Stockholm, Sweden
e-mail: rizzi@aero.kth.se

Bernard Roux, Technopole de Chateau-Gombert, Marseille Cedex, France
e-mail: broux@13m.univ-mrs.fr

Yurii I. Shokin, Siberian Branch of the Russian Academy of Sciences,
Novosibirsk, Russia
e-mail: shokin@ict.nsc.ru

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Editors

Michael Klaas
Chair of Fluid Mechanics and Institute
of Aerodynamics
RWTH Aachen University
Aachen
Germany

Wolfgang Schröder
Chair of Fluid Mechanics and Institute
of Aerodynamics
RWTH Aachen University
Aachen
Germany

Stefan Pischinger
Institute for Combustion Engines
RWTH Aachen University
Aachen
Germany

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Preface

In 2008, the Ministry of Innovation, Science, and Research of the German state North Rhine-Westphalia launched the “NRW Research Schools” which offer the possibility of studying for a PhD/doctorate within a structured doctoral program for PhD candidates with superior academic track records. Currently, 17 Research Schools are funded by this initiative.

The international NRW Research School “Energy Generation Based on Renewable Energy Resources” (BrenaRo) is a joint initiative of more than 15 institutes from RWTH Aachen University. Based on an interdisciplinary PhD program, the main long-term objective of this research school is to train highly qualified experts in the field of energy generation with a special focus on renewable energy resources.

This interdisciplinary approach combines the research fields of Biology, Chemistry, and Engineering. The close cooperation of the Research School with the cluster of excellence “Tailor-Made Fuels from Biomass” and the DFG Collaborative Research Centre “Model based control of homogenized low-temperature combustion” provides the opportunity to work in an interdisciplinary scientific environment.

This volume contains the papers presented at the “BrenaRo Winterschool 2011” held at the “Erholungs-Gesellschaft Aachen 1837” in Aachen, Germany on November 21–22, 2011. The symposium was organized by the Institute Cluster IMA/ZLW & IfU and the Institute of Aerodynamics of RWTH Aachen University, Germany.

In the name of all scientists involved in the NRW Research School BrenaRo, the speaker of the program, Wolfgang Schröder (RWTH Aachen University, Aachen Germany), would like to express gratitude to all the participating scientists for their contributions.

The present monograph is a snapshot of the state of the art of the joint initiative of biology, chemistry, and engineering to develop new fuels. The volume gives a broad overview of the ongoing work in this field in Germany. The order of the papers in this book corresponds closely to that of the sessions of the Symposium.

The editors are grateful to Prof. Dr. W. Schröder as the General Editor of the “Notes on Numerical Fluid Mechanics and Multidisciplinary Design” and to the Springer-Verlag for the opportunity to publish the results of the Symposium.

Aachen, December 2011

Michael Klaas
Stefan Pischinger
Wolfgang Schröder

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Spray Phenomena of Surrogate Fuels and Oxygenated Blends in a High Pressure Chamber

M.M. Aye, J. Beeckmann, N. Peters and H. Pitsch

Abstract In this study, we investigate oxygenated blends and Diesel surrogate fuels under engine-like conditions in a high-pressure chamber. The investigated surrogate fuels are composed of n-decane and alpha-methylnaphthalene with different compositions according to the reference cetane numbers (CN) 53, 45, 38 and 23. In addition to the two-component surrogate fuel mixtures, we examine a three-component mixtures composed of n-decane, alpha-methylnaphthalene, and di-n-butyl ether with a reference cetane number of 53 to highlight the influence of adding di-n-butyl ether to the surrogate fuel at constant cetane number. Further, four blends with DNBE contents of 0, 10, 20 and 100 % in EN590 Diesel and corresponding cetane numbers of 53, 57.7, 62.4, and 100 were studied. We examine fuel spray characteristics in the liquid and vapor phases and the relationship between ignition quality and lift-off length. Vapor pressure is observed to significantly affect spray characteristics in the liquid phase. Vapor penetration lengths of the different fuels with the same injection pressure are found to be similar, because the differences of fuel density and viscosity in the vapor phase are too small to considerably affect the momentum flux. However, changing the injection pressures affects the vapor penetration lengths. Results show that CN is a good indicator for ignition delay. Furthermore, we discuss the fuel overlap number (OL) to indicate the separation between the liquid spray core and the reaction zone in engine-like conditions. It is found for the surrogate mixtures that OL generally increases with decreasing CN, while for the DNBE/Diesel mixtures, the opposite trend is observed. The OL number is found to be caused by a combination of cetane number and vapor pressure effects, where CN has the stronger effect for the surrogate mixtures, while the vapor pressure effect is dominant for the DNBE/Diesel blends. In the latter case, the high vapor pressure leads to short liquid penetration length and thereby larger OL number.

M.M. Aye (✉) · J. Beeckmann · N. Peters · H. Pitsch
Institute for Combustion Technology, RWTH Aachen University, Aachen, Germany
e-mail: mmaye@itv.rwth-aachen.de

1 Introduction

Compression Ignition (CI) engines are known to have particularly high thermal efficiencies. Further, it is possible to use various non-petroleum-based fuels in CI engines. Nowadays, Diesel engines occupy a vital role in the automobile market due to their many advantages such as high performance, long life, and high reliability among others. However, the Diesel process can lead to high emissions of soot and NO_x , caused by locally fuel rich incomplete combustion of hydrocarbons and large regions of high temperature, respectively.

In order to solve this problem, it is necessary to understand the fundamental issues such as fuel spray formation and the effect of different fuels on the combustion behavior. The spray characteristics affect spray formation and air-fuel mixing processes inside the engine, which have a major influence on ignition, the combustion process, and the formation of emissions.

Ignition delay of fuel in air is one of the most important characteristics for combustion in compression ignition (CI) engine. The cetane number is a rating to indicate how quickly a fuel will ignite in a CI engine [1]. A fuel with a longer ignition delay allows longer mixing time for fuel and air before combustion [2]. Fuel mixtures with different ignition quality can be obtained with a combination of good and poor ignition quality fuels in different proportions.

In terms of combustion and spray formation, it has been widely discussed in the past, which surrogate fuel is best suited to replace Diesel fuel in fundamental theoretical and computational studies [3]. The reference IDEA fuel, composed of 70 % n-decane and 30 % alpha-methylnaphthalene (AMNL) was found to be a good surrogate for diesel in conventional Diesel combustion mode [4]. In the present study, there will be a focus on oxygenated fuels. The oxygen content in the fuel strongly influences particulate emissions. A higher percentage of oxygen in fuel blends contributes to greater overall reduction in particulate emissions [5]. Liota et al. [6] found the oxygen content in ethers to be more effective than the oxygen content in alcohols and more details on the effect of different oxygen groups in the fuel were given by Pepiot-Desjardins et al. [7].

The fuel spray characteristics have been examined in a high-pressure chamber for different variables such as injector-type, nozzle-type, injection-pressure, energizing-time, ambient pressure and temperature in the high pressure chamber, for instance by Kim et al. [8].

To study the influence of the fuel properties on the spray characteristics, different single component fuels and fuel mixtures are investigated here for given injection system and ambient conditions. AMNL is used as a cetane reducer to control the cetane number in the present study. Di-n-butyl ether (DNBE) has been found to be a cetane enhancer for Diesel fuels [9].

2 Experimental Apparatus

2.1 Pressurized Spray Chamber

In order to study fuel spray characteristics and combustion details, a constant volume, constant flow-rate, high-pressure chamber was used that was built at the Institute for Combustion Technology (ITV) at RWTH Aachen University.

Experiments were performed using Mie scattering imaging technique for the liquid phase and shadowgraphy imaging technique for the vapor-phase to detect spray penetration and spray cone angle. Furthermore, OH* chemiluminescence was used for characterization of lift-off length (LOL) and ignition probabilities of the injected fuels.

A schematic picture of the spray chamber, its dimensions, and the cross sectional views of the measurement area are shown in Fig. 1. The principle of the set-up has been described in detail by Spieckermann et al. [10]. Essentially, the chamber has a constant high pressure and high temperature air through-flow, where pressure and temperature can be adjusted independently up to 50 bars and 800 K. The design of the chamber enables three-sided optical access through quartz-glass windows, which are orientated perpendicularly (90°) to each other.

Compressed air is sent through micro filters to the chamber by means of an external compressor. The air then enters the heater, which has a maximum power of 24 kW, where it is heated to the desired temperature. Following the heating, the hot air passes through the bottom flange into the measuring area of the chamber. For these conditions, at 17.42 kg/m³ and 800 K, the hot air velocity in the chamber is 0.12 m/s. This is very small in comparison to the spray tip velocity during fuel injection.

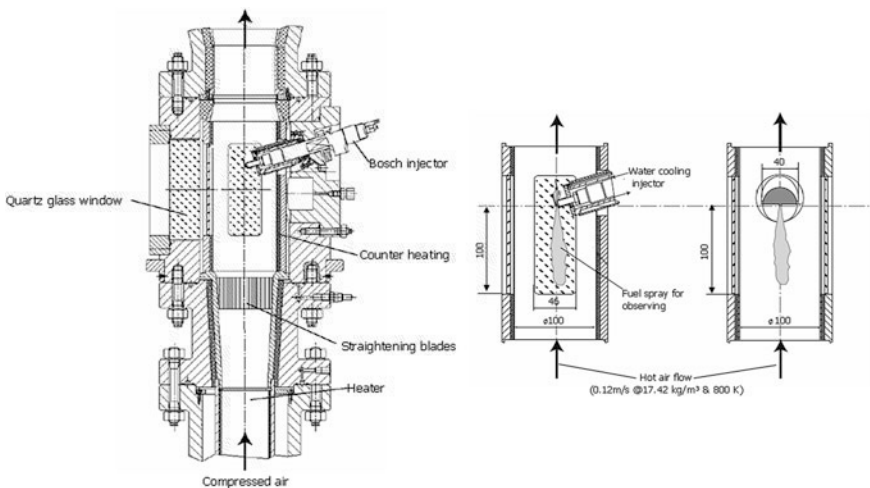


Fig. 1 Constant flow spray chamber and *cross sectional* view of observing section

Hot pressurized air passing through the chamber in the time between the end of combustion and the next injection process helps to remove the combustion residue and unburned hydrocarbons. This is then cooled down in a water-cooled external heat exchanger and throttled to ambient pressure using a Degussa air-flow controller with a constant flow rate of 60 kg/h.

2.2 Injection System

The principle of the injection system has been described in detail by Aye et al. [2]. A Bosch solenoid injector with a three hole nozzle specifically designed for research is used. This nozzle is similar to a sample injector nozzle 0 433 171 838 (Bosch), but it has a cone angle of 148° and 3 spray holes, and the spray hole diameter is 0.141 mm. Measurements have been conducted with an energizing time of 700 μs and rail pressure of 600 bar for surrogates and an energizing time of 1,000 μs and rail pressures of 700, 1,000, and 1,300 bar for oxygenated blends.

2.3 Mie and Shadow Imaging Technique

The optical set-up for the simultaneous measurements using Mie, shadowgraphy, and OH* imaging techniques is shown in Fig. 2. An optically simultaneous Mie and shadowgraphy imaging technique is used for the investigation of liquid and vapor penetration of the investigated sprays. The optical set-up and all specifications have been described by Aye et al. [2]. For the image-data acquisition, a Davis LaVision image acquisition system is used.

2.4 OH-Measurement Technique

The isolation of the OH signal is achieved by applying a filter combination with a transmission range of 290–325 nm and a maximum at around 313 nm. The principle of the optical set-up for measuring the OH* is described in detail by Pauls et al. [9]. The OH* spectral range is from 275 to 350 nm [11]. Soot luminosity also emits broadband emission with significant emission at around 310 nm, but OH* dominates in the LOL region, where soot has not been formed yet [12]. The OH chemiluminescence image in Fig. 3 shows that probable soot luminosity (red color) occurs only in the downstream part of the flame. The measuring procedure in this paper therefore is consistent with the LOL measurement from [13]. The LOL of the flame and the probability of ignition delay are extracted from time series images of OH*.

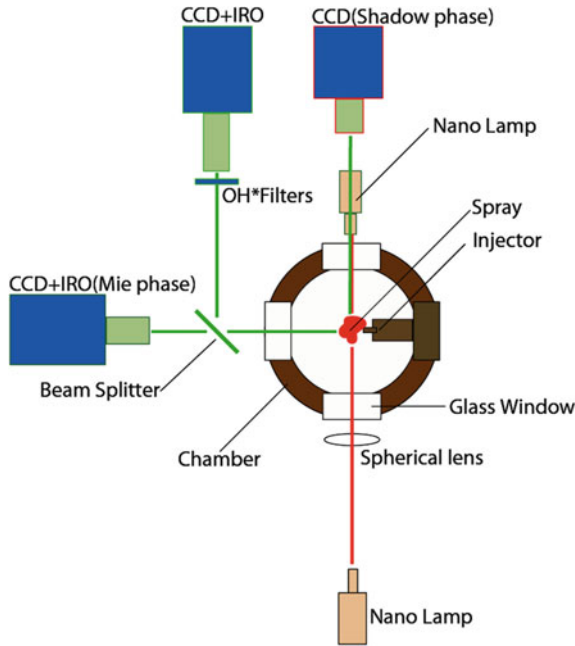


Fig. 2 Sketch of imaging set-up

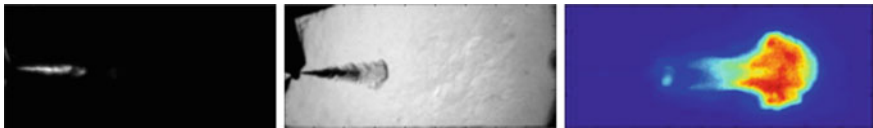


Fig. 3 Measured liquid, liquid + vapor, and OH* signals (from left to right)

3 Definition of Spray Characteristic

For the image processing, a Matlab code was developed. The procedures of the code have been described in previous work [2]. The spray penetration length S for liquid and vapor is defined as the distance between the nozzle tip and the final pixel of spray along the axial line of the nozzle for Mie and Shadowgraphy images, respectively. The spray cone angle β is calculated from the upstream half of the spray area assuming a triangle for Mie and shadow images. LOL is defined as the distance between the nozzle tip and the first pixel in a vertical profile of OH*. Spray penetration length, spray cone angle, and LOL are shown in Fig. 4. The formulation for spray cone angle is as follow:



Fig. 4 Definition of spray characteristics (S = Penetration Length, LOL = flame lift-off, β = spray angle)

$$\tan\left(\frac{\beta}{2}\right) = \frac{Area_{s/2}}{\left(\frac{S}{2}\right)^2}$$

and can be evaluated for both the liquid and vapor phase.

4 Fuel Properties

Thermodynamic and fluid properties of the tested fuels are shown in Fig. 5 and Table 1. These data help to understand the characteristics of the formation of spray, its dynamics, and the behavior of the vapor phase. The order of vapor pressure of the considered fuels is $DNBE > n\text{-Decane} > AMNL$. Figure 5 shows that densities and viscosities at 1 atm. differ among the fuels in the liquid phase, but are similar in the gas phase. Density and viscosity of n-decane, DNBE, and AMNL show a discontinuity caused by the phase change at 450, 410, and 515 K (respective boiling temperatures at 1 atm.).

5 Fuel Blends Preparation

The investigated fuels and fuel blends along with the respective cetane numbers are shown in Table 2. The formulation to determine the cetane numbers of the mixtures used here is described in Ref. [2]. European standard EN 590, which has low sulphur content and is oxygen-free, was used as reference Diesel fuel (CN = 53). The fuel was obtained from Haltermann Products and complies with the CEC reference fuel standard, RF-06-99 [14]. To obtain the required cetane numbers for the blends, AMNL and n-decane were mixed in different proportions.

Additionally, the oxygenated fuel DNBE is added in one of the mixtures to highlight differences of CN = 53 surrogate fuels. For further oxygenated blends, DNBE was mixed in different proportions with Diesel.

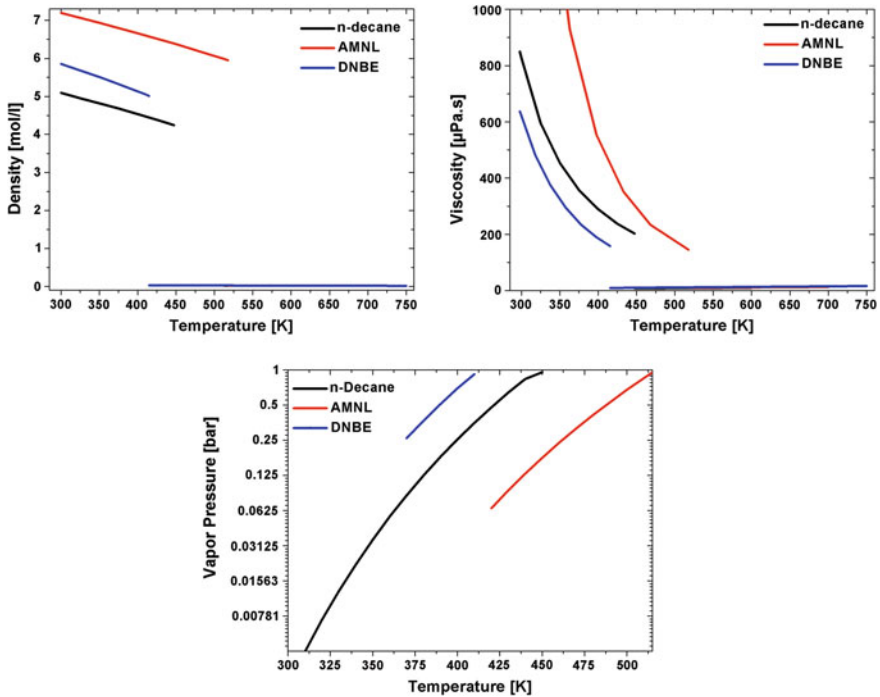


Fig. 5 Fuel properties

Table 1 Fuels properties [14, 20]

	Diesel	n-Decane	AMNL	DNBE
Density @ 15 °C kg/m ³	833.8	734 @ STP	1001 @ STP	771.3
Viscosity	2.892	0.969	3.436 @ 25 °C	0.7198
Vapor pressure @ 40 °C	–	0.255	0.03	0.692
FBP °C	359.3	174	241	142
Dist. 50 % BP °C	275.5	–	–	–
Dist. 95 % BP °C	346.1	–	–	–
Cetane number	53	76	0	100

6 Results and Discussion for Fuel Spray Process

This section is divided into three parts. In the first part, the mixture formation of Diesel, DNBE, and the oxygenated fuel blends are discussed. Mixture formation of surrogate fuels is then examined in the second part. The parameters that influence mixture formation of the oxygenated fuel blends and surrogate fuels are also analyzed. In the final part, we will discuss the flame lift-off and ignition of all tested fuels. Further, we will examine fuel overlap to estimate emissions for all tested fuels.

Table 2 Fuel compositions

Fuels	CN	Remark
Diesel	53	EU-fuel EN 590
30 % AMNL + 70 % n-decane	53	Surrogate
34 % AMNL + 46 % n-decane + 20 % DNBE	53	Surrogate
40 % AMNL + 60 % n-decane	46	Surrogate
50 % AMNL + 50 % n-decane	38	Surrogate
70 % AMNL + 30 % n-decane	23	Surrogate
DNBE	100	Ether group (O ₂ 12.29 %wt)
20 % DNBE + 80 % diesel	62.4	Oxygenated blend (O ₂ 2.31 %wt)
10 % DNBE + 90 % diesel	57.7	Oxygenated blend (O ₂ 1.15 %wt)

6.1 Spray Formation of DNBE and Oxygenated Blends

We investigated DNBE in mixtures of 0, 10, 20, and 100 % (by liquid volume) with EN590 Diesel for different injection pressures, to illuminate the influence of the fuel properties and injection pressure on fuel spray.

The average spray penetration lengths of DNBE, Diesel, and their blends of both liquid and vapor phases are shown in Fig. 6, which clearly indicates that the fuels with higher DNBE content have smaller penetration lengths in the liquid phase. The figure indicates for instance a difference between liquid penetration lengths of Diesel and DNBE by more than a factor of two.

Here, it may be noted that DNBE has a substantially higher value of vapor pressure. Figure 6 shows that vapor penetration lengths of all tested fuels are similar even though they are of different fuel compositions. It is clear from Fig. 5, that most of the fluid properties of the vapor phases for given conditions are not very different. This means that, for a given injection pressure, the overall spray lengths for all test fuels are similar.

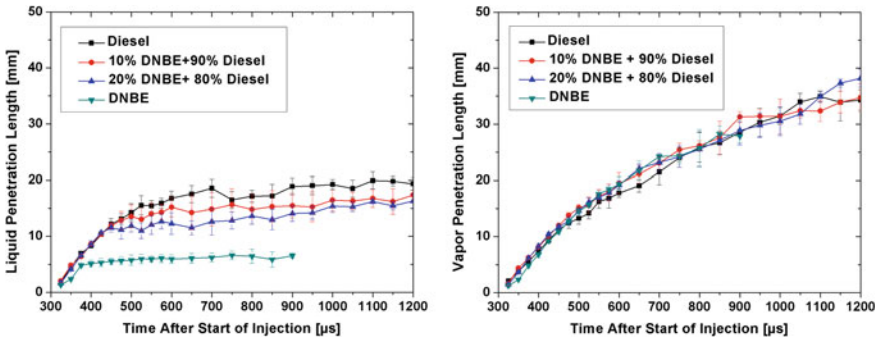


Fig. 6 Penetration length of oxygenated blends ($T_{\text{cham}} = 800$ K, $P_{\text{cham}} = 50$ bar, $P_{\text{inj}} = 700$ bar)

However, differences can be observed in the vapor phase volume (or area in the two-dimensional images). Figures 7, 8 and 9 show exemplarily instantaneous images of the liquid phase (dark color) and vapor phase (grey color) for Diesel, DNBE, and 20 % DNBE in Diesel. It is observed that a fuel with a higher DNBE content provides for better mixture formation as indicated by the larger vapor phase area compared to a fuel with lower DNBE content. This can be observed, for instance, at 575 μs after start of injection (ASOI). Note that in Fig. 8 there is no DNBE image at 1,000 μs ASOI, since by this time the spray has already ignited.

Instantaneous images of 20 % DNBE and averaged penetration lengths for both liquid and vapor phases of DNBE are shown for varying injection pressures in Figs. 10 and 11, respectively. The results show that liquid spray penetration lengths of DNBE with different injection pressures are almost the same. This is interesting, since the higher pressure injection leads to higher injection velocities, which in turn would suggest higher liquid penetration length. But the high vapor pressure of DNBE seems to lead to fast vaporization soon after droplets are formed. Therefore,

Fig. 7 Diesel spray formation

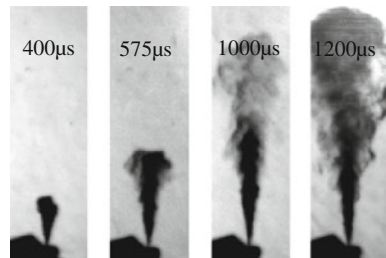


Fig. 8 DNBE spray formation

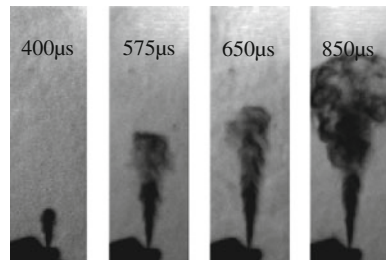
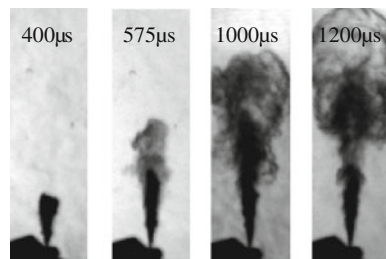


Fig. 9 20 % DNBE spray formation



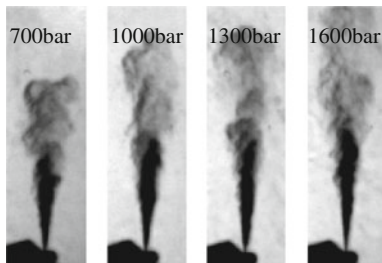


Fig. 10 20 % DNBE spray for varying injection pressures @ ASOI 800 μ s

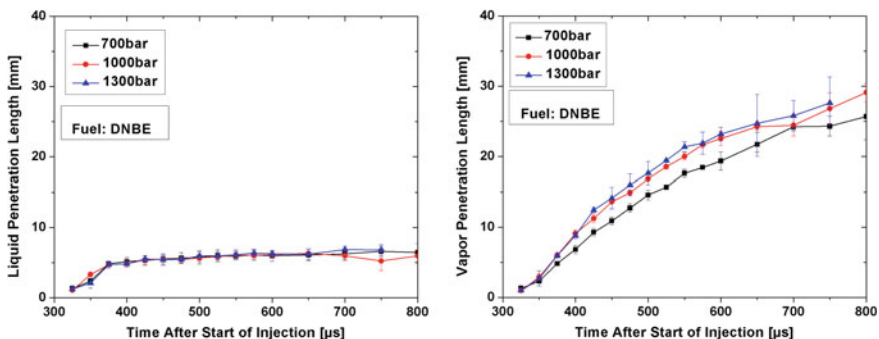


Fig. 11 Spray penetration lengths of DNBE ($T_{cham.} = 800$ K, $P_{cham.} = 50$ bar)

in this case, it is noted that vapor pressure is more influential for mixture formation than the injection pressure. However, it is clear that due to momentum conservation, the total injection pressure affects the overall fuel penetration length, which is shown in Fig. 11 (right).

The following figures illustrate the influence of the fuel’s vapor pressure and the injection pressure on the atomization characteristics more clearly. Figures 12 and 13 show the penetration lengths of 20 and 10 % DNBE in the fuel, respectively, for various injection pressures. Both liquid and vapor penetration gradually increase with increasing injection pressure for these fuels. This shows that reducing the percentage of DNBE content (reducing vapor pressure) in the fuel leads to an increasing influence of injection pressure on the liquid penetration.

6.2 Spray Formation of Surrogate Fuels

The surrogate fuels are investigated under the same chamber conditions. The comparison of liquid penetration lengths in Fig. 14 clearly shows that the tested surrogate fuels have markedly different spray phenomena. For the tested surrogate

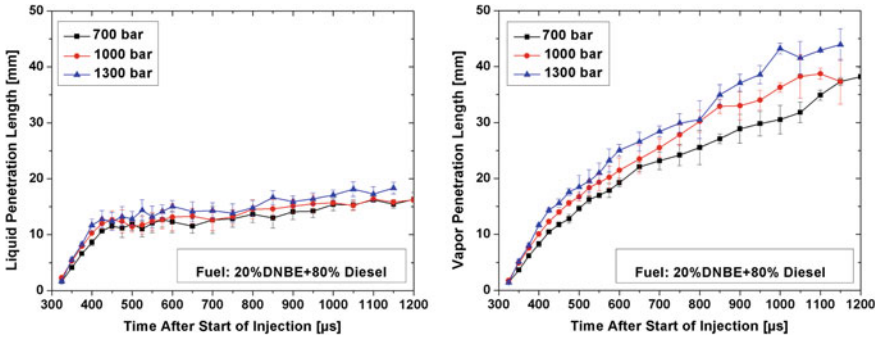


Fig. 12 Penetration length of 20 % DNBE blend ($T_{\text{cham}} = 800 \text{ K}$, $P_{\text{cham}} = 50 \text{ bar}$)

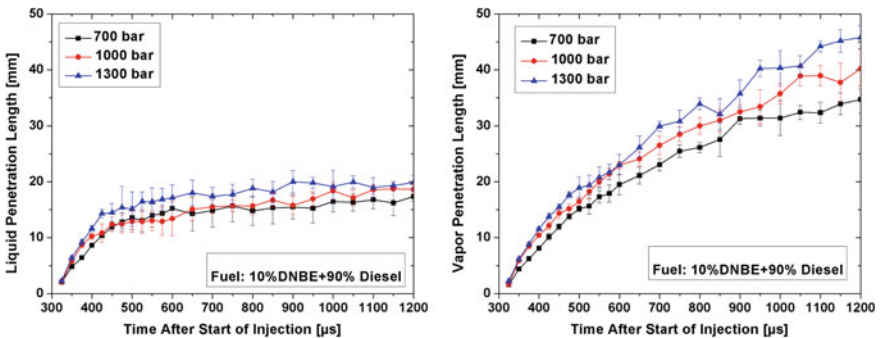


Fig. 13 Penetration length of 10 % DNBE blend ($T_{\text{cham}} = 800 \text{ K}$, $P_{\text{cham}} = 50 \text{ bar}$)

fuels, higher AMNL (reduced vapor pressure) content in the fuel gradually increases the penetration length in the liquid phase (Fig. 14, left). This shows that vapor pressure under Diesel conditions is one of the most important fuel properties for spray development and subsequent mixing for both oxygenated or non-oxygenated fuels. The right panel of Fig. 14 showing liquid penetration for different fuel compositions at the same cetane number demonstrates that this effect does not necessarily correlate with cetane number, because liquid penetration lengths of the same CN fuels are substantially different.

Figure 15 (left) shows that all tested surrogate fuels with varying AMNL contents have similar vapor penetration lengths before ignition takes place. The start of ignition is visible in Fig. 15 (left) by the plateauing vapor penetration, and is at around 975, 1125, and 1275 μs for the 30 % AMNL in the fuel, 40 % AMNL in the fuel, and 50 % AMNL in the fuel mixtures, respectively. Ignition was not seen in the observation area for the 70 % AMNL in the fuel mixture. After start of ignition, the exact value of vapor penetration length cannot be measured accurately anymore and should therefore not be further discussed.

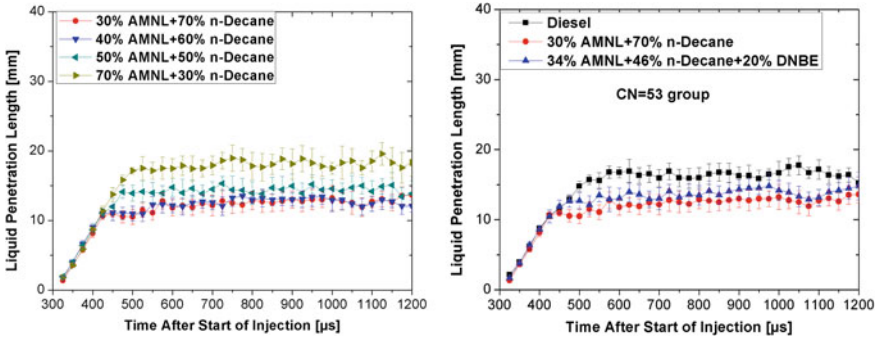


Fig. 14 Liquid penetration lengths of surrogates ($T_{\text{cham}} = 800 \text{ K}$, $P_{\text{cham}} = 40 \text{ bar}$, $P_{\text{inj}} = 600 \text{ bar}$)

The right panel of Fig. 15 shows the overall spray cone angle, which is an indication for the vapor phase area. This quantity has a local peak for all tested fuels at 450 μs after start of injection, which is at the instance of full injector opening, at which the droplet cloud is struck with a higher velocity jet of following droplets [15]. As for the oxygenated blends, fuels with higher AMNL content, and therefore lower vapor pressure, have a smaller vapor phase area, while the vapor penetration length for all surrogates is nearly equal.

In conclusion, a better mixture preparation, indicated here by a larger vapor phase area can be realized by increasing the DNBE content in the oxygenated blends and decreasing the AMNL content in the surrogate fuels at the same injection pressure.

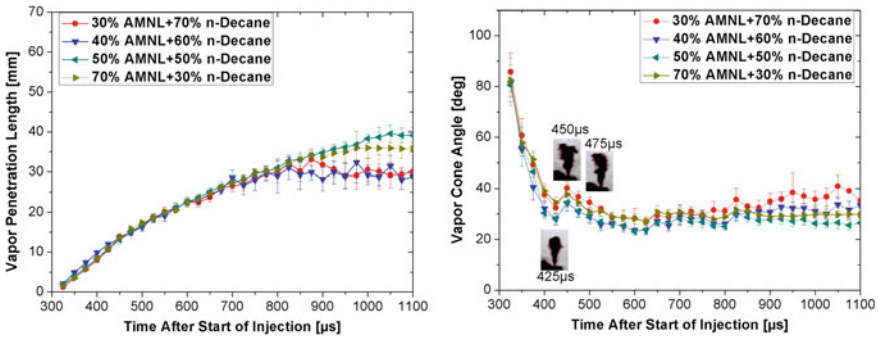


Fig. 15 Vapor characteristics of surrogates ($T_{\text{cham}} = 800 \text{ K}$, $P_{\text{cham}} = 40 \text{ bar}$, $P_{\text{inj}} = 600 \text{ bar}$)

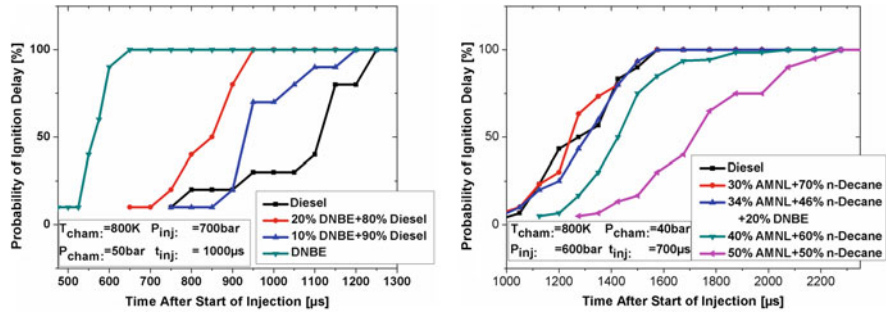


Fig. 16 Ignition qualities of oxygenated fuels and surrogate fuels

6.3 Spray Combustion

6.3.1 Probability of Ignition Delay

The definition of ignition probability has been described in [2]. The ignition quality could not be compared between the surrogates and oxygenated fuels due to the different injection and chamber pressure conditions. However, in the results for both fuel groups, the ignition delay increases with decreasing CN. In Fig. 16 (left), the transition time of 0–100 % ignition probability is 150 µs for DNBE and is increased up to 500 µs for Diesel. The oxygenated blends show a significant reduction in the transition time for increasing oxygen ratio in the blend. The interesting observation in Fig. 16 (right) is that the fuels with the same cetane number of CN = 53 have a similar trend for the ignition probability. The fuel containing 40 and 50 % AMNL have increased ignition delay by factor of 1.1 and 1.4 compared with the fuels with CN = 53 (30 % AMNL, 20 % DNBE, and Diesel), respectively. It follows that CN is a good indicator for ignition delay for both oxygenated blends and surrogates.

6.3.2 Flame Lift-Off Length

The flame lift-off length (LOL) is an important characteristic in spray combustion. A high LOL can lead to reduced soot emissions, since a high lift-off leads to increased time for mixing before combustion. The flame LOLs of oxygenated blends and surrogate fuels are shown in Fig. 17.

The left panel of Fig. 17 shows the influence of the injection pressure on LOL. It is observed that the fuels with higher oxygen content have a smaller LOL dependence on pressure than fuels with lower oxygen content. There is also generally a reduction in LOL with increasing oxygen content in the fuel. It is also well known that under Diesel engine combustion conditions, particulate emissions are typically significantly reduced using oxygenated fuels [16]. In Fig. 17 (right), LOL increases with increasing AMNL content in the mixture. Higher CN fuels produce a shorter

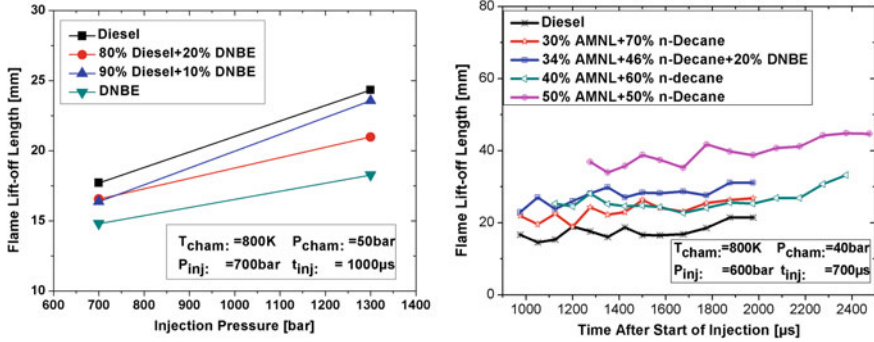


Fig. 17 Flame lift-off lengths

LOL [17]. But Fig. 17 (right) shows that even different fuels with the same CN have different LOL depending on their composition. Therefore, ignition quality expressed by CN and LOL, does not necessarily correlate. It is interesting to see that the fuels, which are rich in oxygen have shorter LOL and those rich in aromatic compounds have longer LOL.

6.3.3 Overlap Number

The OL number is defined in Ref. [18] as the difference between LOL and liquid penetration length (LPL) divided by LOL

$$OL = \frac{(LOL - LPL)}{LOL}.$$

A higher OL number can therefore be caused by the attenuation of the reactivity of the fuel leading to a larger LOL, and it leads due to the increased separation of liquid spray and reaction zone to reduced burning under very rich conditions. As shown in [18], the OL number correlates with the tendency of the fuel to form soot, such that a higher OL number was found to result in less soot. The definition of the OL number is similar in its meaning to the percentage of stoichiometric air (ζ_{st}) introduced by Siebers and Higgins [19] that expresses the trend of soot formation as function of the LOL and a characteristic length of the spray that represents the liquid penetration length. This quantity ζ_{st} is the average percentage amount of air at the lift-off location to stoichiometrically burn the evaporated fuel. Therefore, the higher the entrainment of air mixing upstream of the lift-off location, the higher is its value. Interestingly, the authors give an analytical expression, which has only the LOL as an unknown. The authors point out that the oxygen in the entrained air reacts with the fuel in a rich reaction zone in the central region of the spray just downstream of the LOL. The products of this rich reaction zone are ideal for forming soot, suggesting a strong link between soot formation and the amount of air

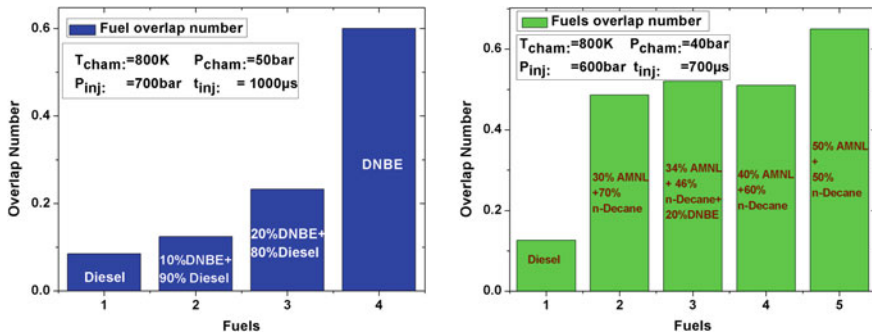


Fig. 18 Fuel overlap number

entrainment that occurs upstream of location of LOL. Figure 18 provides the OL numbers for the different fuels considered here. It should be noted here that the OL numbers cannot be compared among the two fuel groups examined here, because the experiments for both were performed with different ambient conditions and injection pressures.

Figure 18 shows that both fuel groups with higher oxygen content and higher aromatic content show an increase in OL number. Although LOL of DNBE is short, the separation between liquid core and reaction zone is enough to result in a higher overlap number due to its very short liquid penetration length. It is also found that an increase in AMNL, and therefore in aromatic content, leads to an increase in OL number which indicates a reduction in soot formation. This is an interesting trend, since higher aromatic content, especially of naphthalene, is known to increase soot in basic kinetic experiments. Here, however, higher AMNL content also reduces the reactivity of the fuel. This is evident in Fig. 17 (right), where an increase in LOL is observed with increasing AMNL in the fuel. For increased LOL, combustion takes place in a region where the liquid phase is mostly or completely evaporated and fuel and air are already well mixed.

7 Conclusions

In this paper we investigated the spray phenomena of oxygenated fuel mixtures, surrogate fuels, and Diesel. For the liquid penetration length it is found that lower vapor pressure of the fuel leads to higher maximum values in all fuel groups. The vapor penetration lengths of either blends with oxygenates or aromatic compounds are not influenced by fuel properties.

The vapor penetration lengths of both fuel groups increase with increasing injection pressures. By investigating the pure DNBE, 10 % DNBE in the fuel and 20 % DNBE in the fuel with different injection pressures, it is also found that vapor pressure is more influential for mixture preparation than injection pressure. The

results demonstrate that vapor pressure is a very important fuel property irrespective of the fuels containing oxygenated or aromatic compounds.

The results show that CN is a good indicator of ignition delay for both oxygenated blends and surrogates because fuels with the same CN have similar trends in ignition probability and fuels with different CN show that their ignition trends correlate with the value of CN. In the oxygenated blends study, LOL is increased by either decreasing oxygen content or increasing injection pressure.

The trends in ignition quality expressed by CN do not necessarily correlate with LOL, because LOLs can be substantially different for fuels with the same CN depending on their composition. Interestingly, it is found that fuels rich in DNBE have shorter LOL and those rich in aromatic compounds have longer LOL.

Oxygenated compound fuels are well known to reduce particulate emissions, and AMNL addition is expected to produce more soot due to its aromatic nature. The OL number indicates the separation between the liquid spray core and reaction zone, which provides an indication for the tendencies of the tested fuels to form soot. Higher OL number indicates less overlap between liquid spray core and reaction zone, which would lead to diminished soot formation. The experimental results show that both the fuel groups with higher oxygen content and with higher aromatic content have an increase in OL number, which indicates less soot. The reason for this trend is that higher AMNL content fuel reduces the reactivity and increases LOL, which leads to stronger separation of liquid spray core and the flame, and therefore to enhanced mixing of fuel and air before combustion.

In view of this study, vapor pressure and CN should be considered as important parameters in selecting the fuel for CI combustion. We can conclude that better spray atomization could be realized not only with modified injection systems such as nozzle, injector, pressure, etc. but also with fuel composition and fuel molecular structure.

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GIS-Based Model to Predict the Development of Biodiversity in Agrarian Habitats as a Planning Base for Different Land-Use Scenarios

M. Ernst, J. Oellers, A. Toschki, H. Hollert and M. Roß-Nickoll

Abstract Biodiversity is defined in the political sphere as an important subject of protection and the extinction of species to be listed here should not only be held in acknowledged protected areas, but rather also in areas used agriculturally. The situation in agriculture is currently strongly changing through influencing factors, such as climate change and restructuring in favour of renewable resources. Since this development on the one hand holds the risk of a loss of biodiversity, and on the other redevelopments also offer opportunities, this is indispensable for a well-founded evaluation to operably forecast the effects of land use change on organisms. Suitable methods for this are currently lacking. These loopholes should be closed by the model worked out here. Based on species collections from earlier studies, autecological organism data from the bibliography, as well as suitable map material, a Geographical Information System will be created which makes it possible to forecast biodiversity in a regional context.

1 Historic Development and Current Situation of Biodiversity in the Agricultural Landscape

Except for a few, island-like confined locations, the landscape existing in central Europe today can by no means be described as “natural”, i.e. not influenced by people. Moreover, it has already been greatly changed through anthropogenic use in pre-industrial times. Without this influence, beech forests and mixed beech forests would above all dominate in Germany on the basis of the given climatic and

M. Ernst (✉) · H. Hollert · M. Roß-Nickoll
Institute for Environment Research (Biology V), RWTH Aachen University,
Worringerweg 1, 52074 Aachen, Germany
e-mail: marit_ernst@bio5.rwth-aachen.de

J. Oellers · A. Toschki
Research Institute for Ecosystem Analysis and Evaluation E.V. (Gaiac),
Kackertstraße 10, 52072 Aachen, Germany

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edaphic conditions. Deforestation has however produced a mosaic of forest and non-forested land, over-use has led to a degradation of many regions, in which open brush-land and moorland have come into being. It is to be assumed that this increase in biotope diversity is also accompanied by a significant increase in biodiversity. This development was reversed however with industrialisation in the middle of the 19th century, which in agriculture led to mechanisation, growing farm sizes and an increase in fertilisation and use of pesticides; the biological diversity of the artificial landscape again decreased. This trend intensified in the middle of the 20th century through another drive of technology and innovation, strong growths in productivity accompanied further devastation of habitats and decreasing diversity in the agricultural landscape. It was not until the 1970s that increased efforts to protect nature and biotopes were made [6].

In spite of this, loss of biodiversity has also continued. The main cause of this is mentioned by Möckel [35] as being the change from an extensive, varied agriculture and forestry to the intensive farming of today, which levels out the landscape through land consolidation and melioration, extensive mono-cultures, ploughing up, intensive use of fertilisers, pesticides, high grazing density, drainage of wet locations, locations with marginal yields becoming fallow etc. Accordingly, the loss of biodiversity in agricultural lands is significantly larger than in areas close to nature [6, 21, 47, 49, 53].

In an international context and also in Germany, pressure on agricultural ecosystems is currently intensifying through changed framework conditions in agriculture. Alongside changes through direct and indirect effects of global climate change (Federal Office of Environmental Protection [7]), the growing competition through globalisation, high demand for and promotion of biomass from the energy sector, obligatory laying fallow of land ceasing to apply, increasing land competition and higher competitiveness of field use, increased intensification of field and grassland use, stronger utilisation of lands set aside, as well as ploughing grass lands for field use are to be mentioned in this regard [Cf. 35, 37]. The risk of loss of biodiversity through the extension of renewable resources, which are used as energy (production of heat/cold, power, fuel) and industrial plants (fibres, chemical and pharmaceutical products) in particular is referred to many times (e.g. [13, 16, 20, (Panel of Experts for Environmental Issues) 48]). It is therefore the declared goal of the Federal Government of Germany to increase the proportion of renewable energies in gross final energy consumption to 18 % by 2020, 30 % by 2030, 45 % by 2040 and 60 % by 2050 (German Federal Ministry for Economics and Technology and German Federal Ministry for the Environment, Environmental Protection and Reactor Safety [11]). Renewable energy sources should replace the only limited fossil and nuclear energy sources and therefore make a large contribution to conservation of resources and to controlling the greenhouse effect (Federal Environmental Agency [55]). Furthermore, the addition of bio-components to fuels should be increased [11]. For this purpose, large areas will be needed for the cultivation of renewable resources. If the proportion of agricultural areas used in such a way still amounted to 11.8 % in 2005 (German Federal Ministry for Nutrition, Agriculture and User Protection [8]), forecasts assume that the proportion of the areas available

for this will increase by more than 50 % by the year 2050 (Institute for Technical Thermodynamics (German Aerospace Centre) [26]).

This current and still to be expected process of restructuring the agricultural landscape does not only bring risks, but can also bring opportunities for biodiversity, since reform and land use change also always offer scope for design [53]. Agriculture is at a crossroads in this regard, and it now depends on which direction of development will be taken, and how far insights from research on the support of ecological objectives are integrated in systematic agricultural use (e.g. increase in structure variety).

At the same time biodiversity is defined as a subject of protection in a political framework. Protection and sustainable use of biodiversity are therefore objectives of the Convention on Biological Diversity, CBD, which was negotiated by the United Nations in Rio de Janeiro in 1992, and includes the European Union as one of its signatories. The term biodiversity here includes the levels of ecosystems, species and genes. The Convention enjoins the participating states to develop their own national biodiversity strategies [56]. This was done in Germany in 2007 with the National Strategy for Biodiversity (NBS). Here the goal was stated as stopping the extinction of species by 2010 and reversing the process, which applies to the entire landscape, including intensively used areas. Up to 2020 biodiversity in agricultural ecosystems should be significantly increased [9]. In 2010 the goal of maintaining biodiversity was however unsuccessful, and since the gap between the actual and intended values was still large, the goal for 2010 can only be reached under very great efforts [10]. Alongside the agreements mentioned, biodiversity as a subject of protection or conservation of a habitat function is also anchored in numerous other laws on national and international levels, such as the Cartagena Protocol [12], Directive 91/414/EEC (EU 1991, Pest Control), Directive 2001/18/EC (EU 2001, Use of GMOs), GenTG (German law on genetic engineering [22], Use of GMOs), BBodSchG (German federal law on soil protection [2], § 1, Soil Protection), PflSchG (German law on plant protection [41], § 6, Pest Control), Natura 2000 [50], BNatSchG (German law on nature protection [4], § 1 and § 5, Nature Protection), UVPG (German law on environmental impact assessment [58], Impact Regulation), USchadG (German law on environmental damages [57], Avoidance and Remediation of Environmental Damages).

Decisions on land use are however often made on the basis of short-term, mostly economic considerations, and higher sustainability concerns often remain disregarded.

2 State of Current Research

There are currently no suitable methods to operably forecast biodiversity in agricultural landscapes, and, according to the Commission for Soil Protection at the “Umweltbundesamt” (Federal Environmental Agency [29]), there is currently no knowledge about evaluating the landscape in the case of a change in the systems of use; it is therefore recommended to investigate the development of biodiversity when

there are conversions in the relevant model regions. Evaluation of risk for biodiversity outside of authorising materials is generally based on the protection, conservation and/or development goals of nature protection law rules. Corresponding protection targets are predominantly defined for all species or respectively habitat types to be protected, but not for all species and habitat types not considered worthy of protection. The landscape in Germany is not however made up entirely of nature reserves, but rather primarily from anthropogenically used areas (for agriculture, settlements and traffic) which are not under any strict nature protection [47, 54].

Models which deal with damages to species and changes in habitats mostly only focus on climate change. In order to assess sensitivities, dynamic approaches such as bioclimatic modelling e.g. [3, 38] or vulnerability analyses e.g. [25] are used. The dynamic models currently available in science are to date still restricted to global issues, which cannot be transferred to concrete local situations [27]. In the area of practical nature protection, primarily indicator-based sensitivity analyses are carried out, which in their structure correspond to the approach of a vulnerability analysis. So, for example, the risk assessment of possible changes to FFH areas in Germany as a result of climate change follows the methodology of indicator-based sensitivity analyses [40]. Similar studies have already been carried out for individual federal states, or are currently being carried out in North Rhine-Westphalia [31]. Within the framework of these studies, the plant species of individual habitats are grouped and defined in sensitivity levels according to the proportions of hygrophytes and plants growing in cold conditions:

<10 % cold or respectively humidity indicators 1 (low sensitivity), 10–20 % cold or respectively humidity indicators 2 (medium sensitivity) and >20 % cold or respectively humidity indicators 3 (high sensitivity). Climatic changes are not however the only influence on species or habitats. Other environmental changes related to humans such as the deposition of pollutants or changes in land use are significant factors involved which are not considered within the framework of the studies described above.

In addition, the studies are mostly limited to the analysis of legally protected types of habitat, for which there are clear requirements and conservation goals. The typical habitats, predominantly less worthy of protection, of an agricultural landscape are not considered in such studies. A conceptual approach to the evaluation of biodiversity in the agricultural landscape is lacking.

Moreover, no positive development can be represented through the approaches currently available, but rather only the risk of negative consequences is forecast.

Within the framework of the national strategy for biodiversity, 19 indicators were developed which in their monitoring also cover endangered species (red list) as well as protected species within the FFH areas alongside sustainability indicators. Moreover, the states of preservation of areas with special protection status form the focus of the monitoring. As an indicator for recording sustainability, a total of 59 types of bird from six different types of habitat were brought in Achtziger et al. [1], which were determined in the course of the national sustainability strategy. For the part habitat of agricultural land, ten types of bird are representative for biodiversity in this habitat. The fact that only such a small number of species are