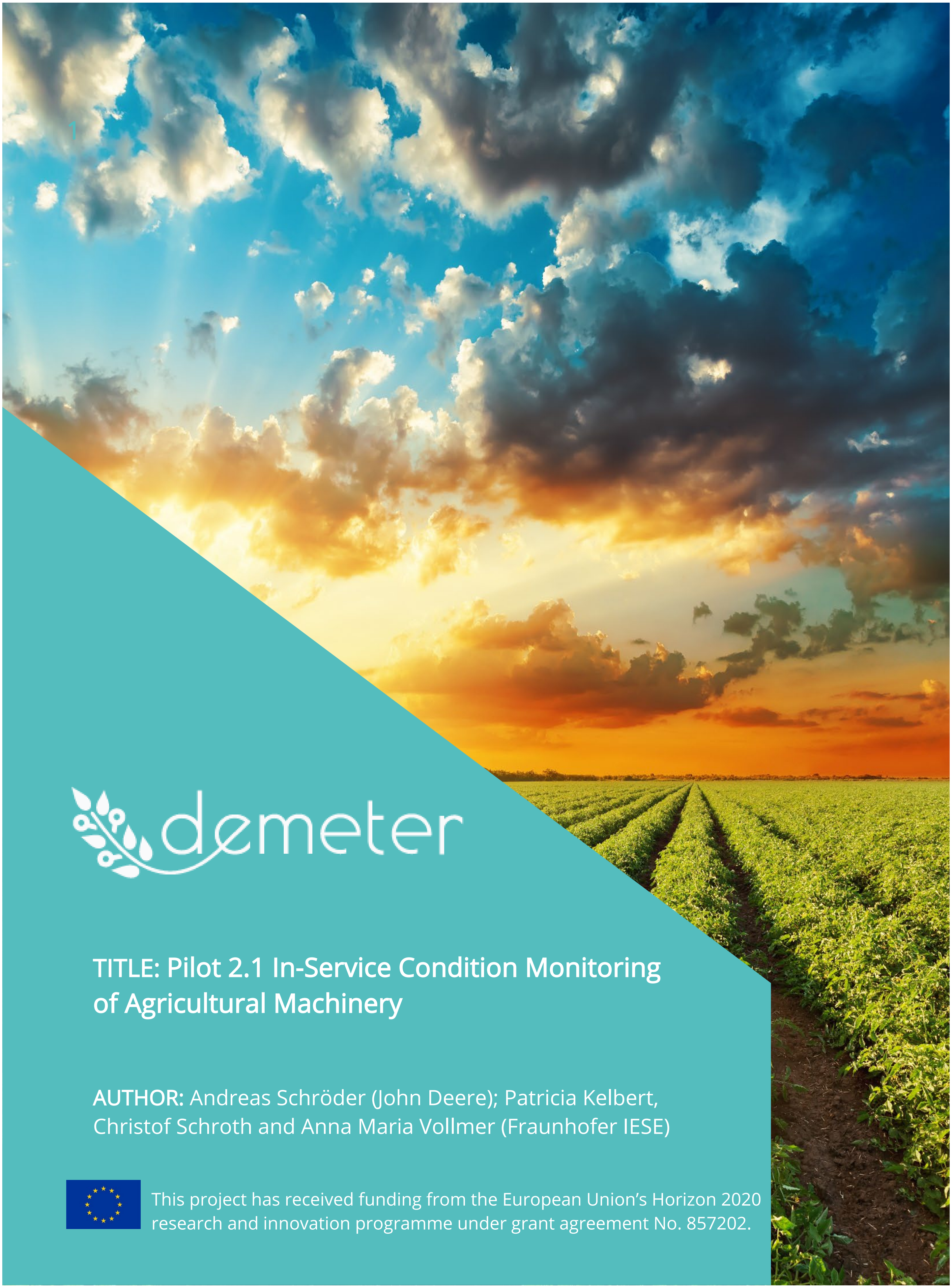

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TITLE: Pilot 2.1 In-Service Condition Monitoring of Agricultural Machinery

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Pilot 2.1 – In-Service Condition Monitoring of Agricultural Machinery

1 Introduction

DEMETER aims to lead the Digital Transformation of the European agrifood sector based on the rapid adoption of advanced technologies, such as Internet of Things, Artificial Intelligence, Big Data, Decision Support (DSS), Benchmarking, Earth Observation, etc., to increase performance in multiple aspects of farming operations, as well as to assure the viability and sustainability of the sector in the long term. It aims to put these digital technologies at the service of farmers using a human-in-the-loop approach that constantly focuses on mixing human knowledge and expertise with digital information. DEMETER focuses on interoperability as the main digital enabler, extending the coverage of interoperability across data, platforms, services, applications, and online intelligence, as well as human knowledge, and the implementation of interoperability by connecting farmers and advisors with providers of ICT solutions and machinery.

DEMETER focuses on the deployment of farmer-centric, interoperable smart farming-IoT (Internet of Things) based platforms, to support the digital transformation of Europe's agri-food sector through the rapid adoption of advanced IoT technologies, data science and smart farming, ensuring its long-term viability and sustainability.

Twenty real-world pilot projects, grouped into five pilot clusters, are running within DEMETER to demonstrate and evaluate how agricultural innovations and extended capabilities benefit farmers, technology providers, and society. The topics, scope and size of the pilots are diverse, from saving resources, such as water and energy, to a more environmentally compatible crop management with reduced application of fertilisers and pesticides, to improved animal welfare and the tracing of complete supply chains.

This white paper describes the pilot 2.1, "In-Service Condition Monitoring of Agricultural Machinery", which aims at demonstrating the potential application of onboard sensors for in-service condition monitoring.

2 Importance of digital agriculture

Digitalization in agriculture uses technologies like data analysis, automation, and sensor data, to improve various aspects of farming operations. The adoption of digitalization in agriculture has the potential to increase efficiency, reduce costs, and improve crop yields. One of the key impacts of digitalization in agriculture is through precision farming. Precision farming utilizes technology such as GPS and sensor-based data to gather information about soil conditions, weather patterns, and crop growth. This information can then be used to make more informed decisions about planting, fertilization, and pest management. This allows farmers to use resources more efficiently and leads to increased crop yields.

Another important aspect is the use of automation. It can be used to perform tasks such as planting, harvesting and even milking cows. This can help to reduce costs and improve the overall safety of farming operations.

Regarding the traceability of food products, digitalization is a key factor. Technologies like barcodes or RFID tagging of products from farmer to consumer help to improve food safety, reduce waste and increase the consumers' confidence in the food supply.

Furthermore, digitalization in agriculture can also provide a wide range of data that can be used to improve the sustainability of farming operations. For example, it can be used to monitor and reduce the use of water, fertilizer, and other resources. This can help to decrease the environmental impact of agriculture and improve the overall sustainability of farming operations.

Another example of data processing is machine monitoring. It involves the use of sensors to collect data on the performance of farm equipment. This data can then be analyzed to identify any issues or inefficiencies, allowing farmers to proactively maintain and repair their equipment. One of the key benefits of machine monitoring is that it allows farmers to detect and fix problems early before they become more serious and costlier to repair. This can help to extend the lifespan of farm equipment and reduce downtime. Additionally, machine monitoring can provide information on data like fuel consumption, which can be used to optimize machine performance and reduce operating costs. Regarding the safety of farming operations, machine monitoring can help to prevent damages and injuries by showing alerts in case of malfunctions or even predicting potential failures before they occur. It is expected that emission monitoring will be mandatory with upcoming European Stage VI non-road emission standards. The only way to satisfy this requirement without intensively attaching additional and costly hardware or even performing specific tests in lab environmental settings is the digitalization of sensor data and in conclusion the monitoring of machines during operation.

Of course, there are also challenges for farmers regarding digitalization. The adoption of digitalization does come with some risks, including costs and data privacy. One of the main risks is the cost of implementing and maintaining digital technology. Regarding the return of investment, farmers can be hesitant to invest in digital technologies which also include training and educating employees on how to use these technologies effectively.

Another risk is data privacy. As farmers adopt digital technologies, they are generating large amounts of data about their operations. This data can be extremely valuable, but it also raises concerns about who has access to this data and how it is being used. Hence, farmers but also providers of digital solutions have to protect the analysed data as well as the information which is gathered directly from machines or in the field.

All in all, the benefits can predominate and by adopting digital technologies in the right way, farming can be more efficient, safer, and even more environmentally friendly while costs can be reduced.

3 Pilot Overview

This pilot monitors and analyses machine data of onboard sensors, so the proper function of the engine and after-treatment can be checked. The visual feedback of machine function helps farmers to maintain the engine and after-treatment or even to avoid possible failures. It is expected that emission monitoring will be mandatory with upcoming European Stage VI non-road emission standards. Hence, we started with the first steps of automated machine monitoring to ease the farmer's daily work by offering one place where the data and conditions of all machines can be monitored.

(1) Firstly, we needed to collect relevant data from the machinery: The engine and after-treatment data are logged from the CAN-Bus. Different parameters are defined and the corresponding messages from the bus are recorded. This offers the flexibility to add additional parameters which can be monitored in the future. At first, we tested this approach by storing the corresponding data on a SD-card. To further proceed with the collected data, it first had to be extracted manually from this SD-card in a frequent manner. Obviously, it is not convenient and contemporary to work with SD-card to get the data because it is not suitable in practical settings with farmers that the technician can physically be at the machine at every time. Additionally, this would also be time-consuming for the technician itself. Therefore, after the first round of "manual" data gathering, we used a new version of loggers.

These new loggers are able to save the data directly on an internal John Deere server, which is an important improvement in terms of connectivity and timesaving. Sensor data from the machines are logged with 10 Hz to ensure that evaluations are accurate while keeping the files in a manageable size. Logging 60 parameters for one hour leads to a file of around 20 MB in size. Parameters which are used for the analysis of the machine condition are for example exhaust gas temperatures, engine oil and coolant temperatures as well as pressures.

(2) Secondly, the data needed to be checked initially to enable and ensure correct processing: Data is exported in .csv format, including time stamps and parameter values of the sensors. Afterward, we checked on the quality of the data, i.e., performed boundary-checks to investigate if the data is compliant with the given boundaries and if the engine and after-treatment are working correctly. Potential tests of legislators with PEMS (Portable Emission Measurement System) might become mandatory: thus, checking if the engine and after-treatment systems are working correctly is highly relevant. By continuously monitoring and analysing their machines' data, farmers have the advantage of knowing that their machines are working properly and can react promptly in case of a malfunction, which also reduces maintenance costs.

(3) Our third step focused on the additional usage and analysis facilities of the data to get more insights and new knowledge: the previously mentioned initial check of the data already allowed us to better understand the machinery conditions and the collected data. This consequently enabled us to identify additional possibilities to make use of the data, e.g., we executed a DEMETER decision support component to perform an analysis related to the driving behaviour of the machinery because the driving of the machinery itself has also an impact on the produced emissions.

The pilot is deployed on two sites in Germany. One is the Hofgut Neumühle and the other one is the Bayrische Landesanstalt für Landwirtschaft – location Grub. The monitoring of machine conditions is done by adding a reprogrammed John Deere Modular Telematics Gateway (MTG) which is used as a datalogger (see Picture 2). The involved partners in this pilot are John Deere and Fraunhofer IESE. John Deere is responsible for the data acquisition and expert knowledge about machine data. Fraunhofer IESE is in charge of the data processing, data analysis, as well as the data quality assessment.

Picture 1: John Deere 6R 230 in operation on the field.

Image 2: John Deere MTG used as a datalogger on the machine.

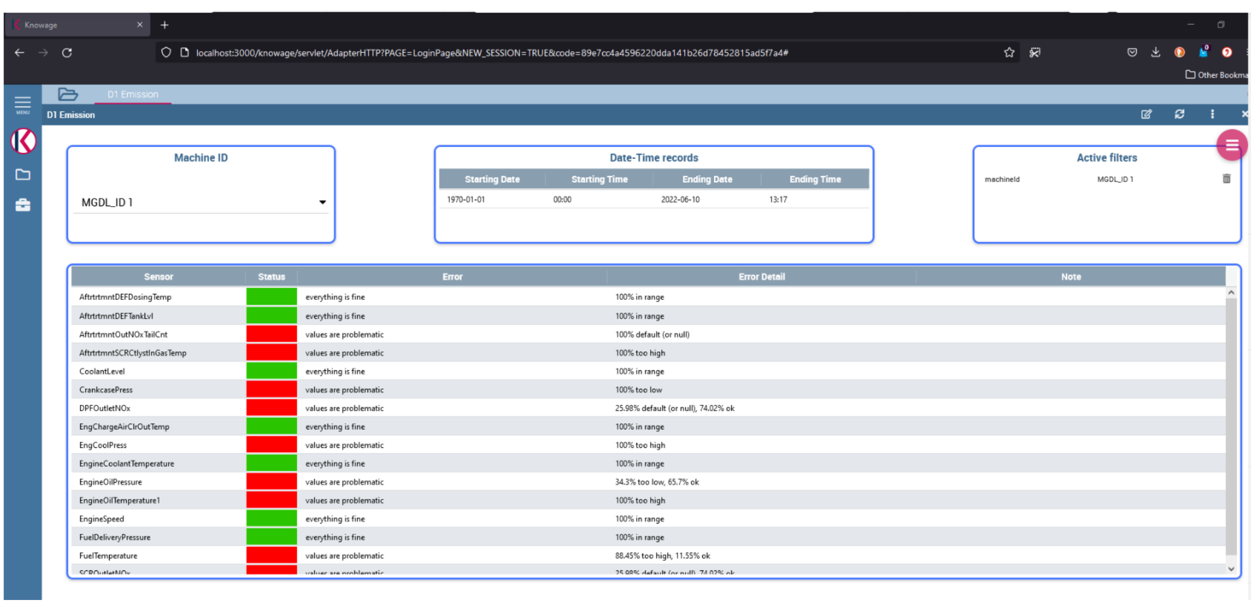
4 DEMETER Integration

The pilot contributes and makes use of different DEMETER components (often also called DEMETER enablers) such as 2.C.1 Data Quality Assessment (DQA), Agricultural Information Model (AIM), 4.D.1 Emission DSS 1 & DSS 2 including the DEMETER Adaptive Visualization Framework, and DEMETER Enabler Hub (DEH) & Client.

<u>DEMETER enablers and other technologies</u>

Within step 2, the **data quality assessment (DQA)** enabler is integrated into the data pipeline to ensure adequate quality of the gathered and monitored data before the actual analysis starts. The DQA tool has been adjusted to the pilot-specific data: it can take as input csv files and is highly configurable. So far, 13 out of 17 available metrics have been selected in pilot 2.1 to assess the quality of the structured data gathered. For each metric, the percentage of occurrence of problematic values is determined. In addition, a detailed list of suspicious data can be generated.

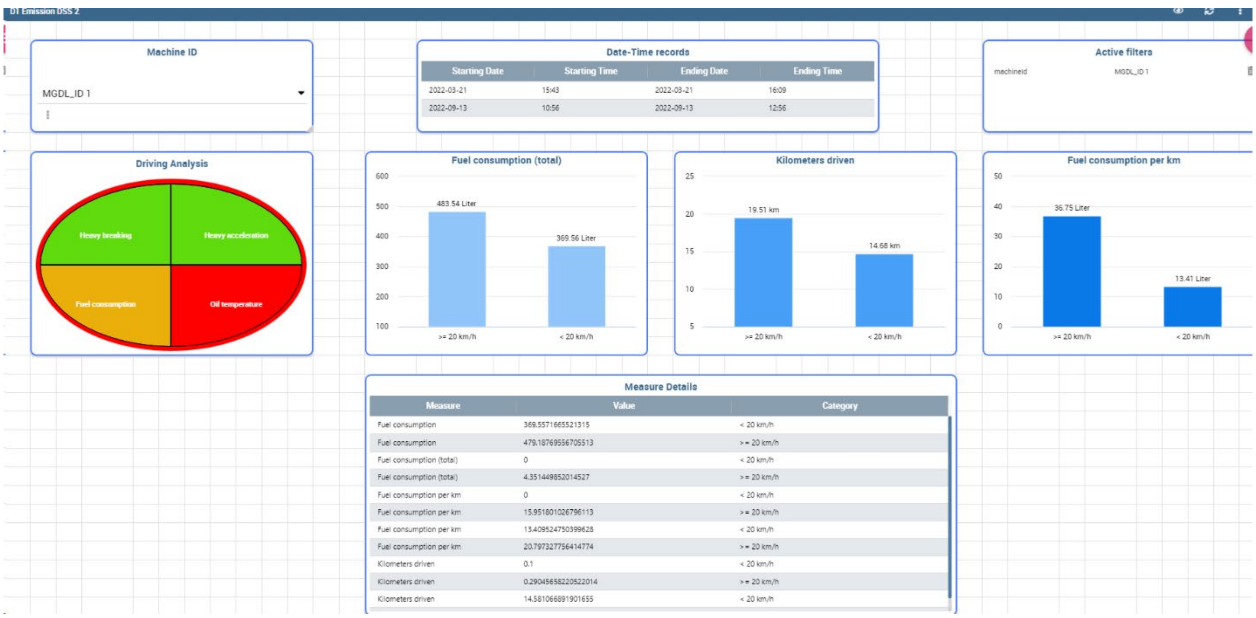
A second DEMETER component, the **DEMETER 4.D.1 Emission DSS 1** assesses the criticality of “problematic” data, scaling the data quality analysis results for more than 15 of our collected parameters into 3 levels (good, medium, and bad). By means of the **DEMETER AIM**, this assessment is integrated into the **DEMETER Adaptive Visualization Framework** to have a visualized dashboard based on Knowage (see Picture 3).



Picture 3: Visualization of assessed machine data on KNOWAGE.

Within step 3, another decision support component, the **DEMETER 4.D.1 Emission DSS 2**, has been developed collaboratively across DEMETER work packages and is used on the gathered data for performing a driving analysis on road sections. For this purpose, the logged data is checked for heavy breaking or heavy acceleration events. Additionally, driving behaviour for engine warm-up and fuel consumption are analysed. A general assessment of the driving quality is also given based on the previous weighted analyses. Also, by the means of **DEMETER AIM**, this driving analysis enabler is integrated into the **DEMETER Adaptive Visualization Framework** (see Picture 4).

We collaborated with partners from the DEMETER work packages 2 and 4 during the two pilot phases (i.e., Round 1 and Round 2), in order to ensure that the generated outputs are both AIM compliant and integrable into Knowage.



Picture 4: Visualization of the assessment of the driving quality.

To ease the usage and management of DEMETER enablers, the **DEMETER DEH** should be used. But since the integration of DEMETER DEH is not possible in the preferred way (i.e., publicly accessible server) due to data privacy reasons, we made use of an alternative method. Indeed, the raw sensor data must remain at John Deere premises and cannot be uploaded to another system. Nevertheless, the **DEMETER DEH Client** can be installed locally to gather DEMETER enabler usage information related to this pilot which will be shared in a non-automatic way by us manually to ensure the data privacy constraints.

5 Feedback from farmers

As the largest manufacturer of agricultural machinery, John Deere is always in contact with farmers, listening to their needs and developing solutions that fit their needs. Communicating frequently with the people who ultimately use the solution can ensure that the need is met, and that the solution can have a meaningful impact.

During the project, we had a constant exchange with farmers and conducted additional interviews with the sites involved in the pilot. The presentations and discussions of intermediate results helped to improve the analysis and visualization parts. For example, one of the most time-consuming but also fruitful interactions to better understand the farmers' setting and the gathered data to precisely adjust the intended analysis were our tests in the field. In cooperation with agricultural experts, driving tests were defined that included as many different driving situations as possible. In addition to the logging of sensor data of the tractor, a video of the machine with audio comments from the driver was recorded. This was useful when setting up the analysis part to ensure that the results of the analysis are correct and cover real situations. Of course, the whole data exchange throughout the project is compliant with data privacy requirements. Since the beginning of the project, we were able to record more than 300 datasets.

During the installation of the datalogger devices on the farms, there was a constant exchange of information with the farmers. For example, we proposed and discussed the location of the device on the machine several times and also on-site to understand the benefits and drawbacks of different options. By spending this effort, we wanted to ensure a smooth integration of our solution into the specific farmer's setting and increase its acceptance for the future.

6 Benefits

Using machine condition monitoring has several benefits for farmers. By monitoring the performance and sensor data of their machines, farmers can identify and address issues that can affect efficiency such as low fuel pressure or clogged filters.

Engine and after-treatment monitoring can help farmers to detect potential problems early, allowing them to act before the damage becomes more serious and costlier. This has a direct impact on the maintenance costs of the machine and therefore on the financial load.

By monitoring machines, farmers can ensure that they are operated safely and in compliance with regulations which can help to reduce the risk of accidents and injuries. Additionally, the monitoring of the after-treatment data can support

ensuring that machines are always running in compliance with given emission standards. This can help the farmer avoid fines and allows damage to be detected and repaired at an early stage, thereby reducing environmental impact. During the project, we defined four specific KPIs for the solution respectively:
(1) The time needed to check on the machine condition should be reduced by 5 percent. Besides the comfort factor, this also is a direct driver in reducing costs for the farmer. (2) The time needed for maintenance should be reduced by 5 percent through a simplified fault analysis. The recorded and visualized data can help to find sources of malfunctions faster. Since this is only one part of fixing the machine, and material as well as actual repair costs are not changed, (3) the goal is to reduce the overall costs for machine maintenance by 3 percent. (4) The last KPI is to reduce the environmental impact in case of an engine or after-treatment malfunction by 10 percent. By analysing engine and after-treatment data there is the possibility to detect a malfunction even if it is not recognisable during the farming operation.

The next steps of the pilot solution will focus on further testing and evaluating the outputs and defined benefits. Additionally, we plan to collect more data to have a broader set of working scenarios by the farmers captured, more datasets available for the parameters gathered, and to ensure that the solution works properly.

7 Conclusion

By giving farmers visual feedback on the machine conditions, the time needed to check on the machine as well as the time for maintenance can be reduced. The use of the developed solution can improve the efficiency, environmental impact of agricultural machinery, safety, and overall experience of the farmer.
To provide this service to the customer, several DEMETER solutions are used: By analysing the quality of the recorded raw data, it is ensured that the results are valid and resilient. Providing the output data in a DEMETER AIM compliant format makes it possible to visualize the results of the analysis using the DEMETER Adaptive Visualization Framework and to increase interoperability for future applications.
The DEMETER project provided a useful framework to demonstrate the usefulness of collecting and processing data gathered from onboard sensors for in-service condition monitoring. The collaboration with the partners allowed us to increase the value of collecting data in that area, i.e., the DEMETER setting significantly facilitated the elaboration on the possibilities of in-service condition monitoring and increased the value of our intended pilot.

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