Evaluation of Harvesting Driving Modes from Environmental Point of View †

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† Presented at the 1st International Electronic Conference on Agronomy, 3–17 May 2021; Available online: https://sciforum.net/conference/IECAG2021.

Abstract: Numerous automatic technological processes control systems are implemented in modern agriculture equipment. Automation facilitates technological processes. These control systems help customers to save fertilizer and crop protection products as well as fuel. Machinery performance data is collected and stored via the Telemetry system can be sent to a customer’s computer for overview and decision-making for the following years. However, a significant quantity of data is not automatically processed by the Telemetry system. Currently, the final decisions are done on the customer’s feelings. Farmers want to be sure that the equipment they use will not only depend on the technological process but also reduce the negative impact on the environment. The aim of this study is to analyze the combine harvester data collected in the Telemetry system during harvesting at manual and auto-steering modes. The study compares the influence of combine harvester steering modes on GHG emissions and diesel fuel consumption using the Life Cycle Assessment (LCA) modules. The results show that global warming emission, using automatic steering mode, was reduced by 2.45% as compared to the manual driving mode. The diesel fuel consumption at automatic steering mode was reduced by 9.45% compared to manual driving. The working time analysis has shown a more rational and more accurate technological operation during linear steering mode. In summary, the analysis of the structure work process provides detailed information that can increase the overall productivity of the machine and optimize the work process.

Keywords: telemetry; auto-steering; GHG emission; combine harvester; environment

1. Introduction

The constant introduction of the latest technology and innovation helps to achieve greater efficiency in the precision agriculture. Research shows that farm machinery can be efficiently managed by the automatic control of operational procedures [1]. At the same time, precision farming technologies can reduce time and fuel consumption, save seeds, fertilizers, and plant protection products [2].

The use of automatic navigation systems for agricultural processes enables the selection of appropriate driving strategies and the required precision of machine control, avoiding overlaps or uncultivated areas. Accurate driving of harvesting techniques is one of the more complex operations and key factors influencing the quality of work performed [3]. Operator fatigue during the working day reduces not only driving accuracy but also the selection of the most appropriate harvest quality parameters [1]. Automatic steering is essential to make the easier, not monotonous, and frustrating drive for the agricultural machinery operator [4].

An automatic steering system typically consists of a GNSS (Global Navigation Satellite System) receiver, a control terminal, a navigation computer, wheel angle sensors, an
The manual steering, electrically operated steering wheel, and hydraulic steering (intelligent) are the most commonly used steering systems in the agricultural sector [5].

Correction signals in addition increase the accuracy and reliability of the satellite navigation system. For the automatic driving of agricultural machinery, manufacturers use E-DIF, EGNOS (European Geostationary Navigation Overlay Service), OMNISTAR HP/XP, BASELINE HD, RTK NET, RTK (Real-Time Kinematic) correction signals. The accuracy of the automatic steering system depends on the correction signal used. The most accurate driving is achieved using the RTK correction signal since every inch is important for sowing and harvesting. Fixed reference stations via the internet may send a correction signal to an unlimited number of GPS automatic steering systems to a 15 km radius of working machines. RTK NET extends the operating distance in regions where access to the base station is limited. RTK and RTK NET use dual-frequency receivers. This means that atmospheric disturbances of the first order (propagation delays within the ionosphere) can be corrected [5,6]. The Global Positioning System (GPS) can be used to navigate a tractor and implement along a pre-determined path with 1–2 cm level relative precision [7].

The automatic steering system can follow the straight sowing technological lines during winter wheat harvesting. The RTK correction signal lines used during sowing can be transferred to the combine’s automatic steering system and used for straight-line automatic steering during harvesting [8].

The pursuit of higher productivity should not overshadow the aspects of sustainable agricultural production. Research has substantiated the impact of automatic driving in reducing the environmental pollution. Combines using automatic steering systems have shown efficient use of fuel. Efficient fuel use reduced the combine’s emissions by an average of 0.6 tons per year. It was found that the data collected in the telemetry system can be effectively used for the machinery working process assessment and for making decisions on the optimization of combine harvesters and prevention of environmental pollution [9].

Using the analysis by implementing the LCA methodology to quantify the environmental impact of harvesting can be evaluated. For the assessment of the environmental impact, a modelling software SimaPro 9.1 is used.

The aim of this study is to analyze the combine harvester data collected in the Telemetry system during harvesting at manual and auto-steering mode for monitoring GHG emissions and abiotic fossil fuels depletion using LCA models environmental impact.

The novelty of this paper is to use the data from different perspectives. It is not only the performance analysis of the combine harvester. Provided data can help to calculate the soil compaction level by equipment, exhaust emission footprint, and more other parameters which are not seen and evaluated by customers, but it makes a big influence on sustainable agriculture.

2. Materials and Methods

For the research analysis, four Claas combine harvesters Lexion 770 TT (Terra Trac) with a crawler chassis were selected. Combine harvesters worked in different farms in Lithuania. Technical characteristics of Lexion 770 TT combine harvesters: OM502 LA engine power—405 kW, cutter bars model V1050—effective cutting width 10.67 m [10].

The harvesters selected for the analysis and research of the work were equipped with a remote monitoring system of the machine parameters. Harvest parameters such as harvested area, fuel consumption, operating hours, and other parameters were collected from a database stored in the Telemetry system. All the harvesting information of each individual combine harvester is recorded and stored in the Telematic system, and can easily be extracted even after some years. The harvesting data recorded and collected from a variety of sensors installed on the harvester. It is stored in Electronic Control Units (ECU’s) and after downloading to cloud storage, the data is saved. The combines were equipped with automatic steering systems and driven by RTK (Real Time Kinematic) correction signal [11]. This signal ensures the driving accuracy of ±2 cm.
The objective of this study was to compare the influences of different combine harvester steering modes on GHG emissions and abiotic fossil fuels depletion using LCA models. The LCA models used in this study were “gate to gate” systems, including cereals harvesting processes.

The analysis was performed by implementing the LCA methodology to quantify the environmental impact of harvesting performed with two combine harvesters of the same models, one of which is driven manually, and the other uses an auto-steering mode. The environmental impact assessment was conducted with SimaPro 9.1 process modelling software [12]. The data on biomass cultivation, transportation, biofuels production, and equipment was used from Ecoinvent v3 database [13]). Based on CML-I calculation, methodology determined the resulting impact of the processes. Global warming and abiotic fossil fuel depletion are chosen as impact categories. Global warming emission has been calculated by the percentage difference between manual and automatic steering Global warming potential (GWP) emission results.

The considered functional unit (FU) of the LCA is the “harvesting of 1 ha of winter wheat”. The system boundary includes all the inputs and outputs associated with the harvesting operation. Inputs include the mass and energy necessary to complete the process, which takes into consideration the production and use of fuel, lubricants, the manufacture of the harvester, maintenance, and repair. Outputs include all emissions into the environment, which encompasses the emissions into the soil and water due to metals depletion and tire abrasion, and the emissions into the air due to exhaust gas emissions caused by fuel combustion.

This LCA accounts for the harvesting process without considering the other field cultivation processes, transportation of harvested crops, or other field applications. The harvester is allocated between the process considered and other usages using the information on weight, operation time, and a lifetime of the machinery. The weight of machinery (AM) needed for a specific process was calculated by multiplying the weight of the machinery by the operation time and driving the result by the lifetime of the machinery [14,15].

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\[ AM = m \times \frac{T}{L} \]  

where AM is the weight of combine harvester (kg/ha), m is the mass of machinery (kg), T is the operation time for 1 FU (h/ha), L is the machinery lifetime (h).

3. Results and Discussion

The Telematics system offers different kinds of analysis tools [16]. Data provided by the following categories: work hour analysis, diesel fuel consumption, performance analysis, comparison, harvest report, combine league, export data, and daily reports.

Machine performance analysis (Figure 1) provides a graphical analysis of the machine performance. It is possible to select up to 6 parameters for the analysis. To do that, the machine type and data must be selected. Then, six parameters can be selected at the discretion of the farmer. In a parameter selection list, for the combine harvester, the farmer could find chopper engagement status, concave position, engine load and speed, fuel consumption and grain moisture content, sieve losses, machine throughput, yield, and other parameters out of 45 combine harvester parameter list.
Figure 1. Graphic of combine harvester performance [17].

Figure 1 shows the combine harvester performance at a selected date. For the presentation, the 6 combine harvester parameters like autopilot status, grain yield, machine throughput, grain moisture content, engine, and fuel consumption which shown in Y axis were selected. The X-axis shows the default work time of combine harvester.

In a harvest report area, it is possible to retrieve reports and create new reports about key performance indicators of your machine according to the crop type. This report includes a work hour analysis of the machine (Table 1). For the data report analysis, the desirable machine must be selected, as well as campaign starting and ending date.

Table 1. Harvest report data [17].

| Parameters                        | Average          |
|----------------------------------|------------------|
| Engine hours                     | 246:19 h         |
| Total working hours              | 152:55 h         |
| Crop yield                       | 2747.82 t        |
| Area                             | 520.08 ha        |
| Total distance traveled in field | 880.81 km        |
| Fuel consumption, field          | 6666.5 L         |
| Average yield                    | 5.28 t/ha        |
| Throughput per hour              | 17.97 t/h        |
| Fuel consumption per weight      | 2.43 L/t         |
| Fuel consumption per area        | 12.82 L/ha       |
| Fuel consumption per working hour| 43.59 L/h        |
| Fuel consumption per transport   | 494.5 L          |
| Fuel consumption, total          | 7161 L           |

The harvest report provides the most important key performance indicators of the selected machine. The presented report in Table 1 displays the total performance at selected campaign data. It consists of several performance components related to different crop types harvested. As shown in Table 1, the total combine harvester performance consists of canola, beans, oats, peas, and wheat harvest at defined data. Besides harvest report data, the Telemetry collects the working hour distribution report. Work hour analysis provides information about the efficiency of the machine within a specific time range. For the analysis, a certain machine has to be selected and then define a period of analysis you are interested in. The different time types are displayed in absolute form and in percentage.
The provided data depends on the machine type. The customer could analyze time spent for turn around, travel, unloading while in idle, idle time due to full grain tank, idle, process time, engine off, and other time components.

Environmental impact assessment diagrams for two compared systems are shown in Figure 2. According to this figure, for all categories, the environmental impact of manual driving is greater than that of automatic steering.

Figure 2. Environmental impact assessment diagrams for two compared systems.

The y-axis shows the impact categories and the percentage of 100% impact for the process that generates the greatest impact within each category. The reduction in acidification potential using the automatic steering function is 2.11% compared to manual driving mode (Figure 2). The ozone layer depletion and fossil fuel depletion can be reduced by 8.81% and 8.30%, respectively, compared to manual driving, while other impact categories vary between 2.45 and 6.43%. The significant environmental impact of the manual harvester driving process resulted from the higher fuel consumption during operation and higher machinery wear through its lifetime.

The inventory of airborne emissions steered combine harvester at manual and automatic mode is presented in Table 2.

Table 2. Inventory of manual versus automatic steering airborne emissions.

| Emissions                          | Manual  | Auto   | Difference in %, Manual vs. Auto Steering |
|------------------------------------|---------|--------|-----------------------------------------|
| Carbon dioxide, CO₂                | 160.5   | 156.9  | 2.24                                    |
| Carbon monoxide, CO                | 1.906   | 1.135  | 4.67                                    |
| Methane, CH₄                       | 0.1806  | 0.1689 | 6.48                                    |
| Nitrogen oxides, NOX               | 1.851   | 1.84   | 0.59                                    |
| NMVOCa                             | 0.2648  | 0.2566 | 3.10                                    |
| Particulate Matter, PM10           | 0.0959  | 0.0898 | 6.36                                    |
| Sulfur dioxide, SO₂                | 0.2943  | 0.2764 | 6.08                                    |
| **Average**                        |         |        | **4.22**                                |

Combine harvester steering in manual mode has a higher airborne emission compared to the automatic driving mode. On average, calculated emissions were by 4.22% smaller at the automatic steering mode compared to the manual driving (Table 2).

The main inventory data is reported in Table 3. The corresponding total embodied energy of the combine harvester attributed to 1 ha of both operation processes (in MJ) was estimated. It should be highlighted that the mass of harvester needed for the processing of 1 ha in auto-steering mode is 7.39 kg/ha, while using manual driving it is increased to 7.90 kg/ha.
Table 3. Inventory data for the two driving modes of harvesting.

| Indicator               | Manual | Auto |
|-------------------------|--------|------|
| Mass of harvester, kg   | 12,800 | 12,800 |
| Rated power, kW         | 430    | 430  |
| Lifetime, h             | 1300   | 1300 |
| Amount of machinery, kg/FU | 7.9   | 7.39 |
| Fuel consumption per FU, kg/FU | 20.05 | 18.16 |

The embodied energy of the auto-steering harvester is 504.4 MJ/ha, and in manual driving mode, is 539.2 MJ/ha. The energy savings (8.30%) from machinery embodied energy by following the optimized automatic driving mode is demonstrated. In other words, automatic driving performs the same amount of work with less wear on the machine, so a longer machine lifetime is expected. This leads to the reduced embodied energy of machinery [18].

4. Conclusions

Work hour distribution analysis provides information about the efficiency of the machine within a specific time range. Using the harvest report, it is possible to analyze combine harvester performance and to create key performance indicator reports according to crop.

Environmental impact analysis of the comparison between manual and auto-steering modes were carried out using data collected in telematics.

The LCA analysis has shown that using the automatic steering mode global warming emissions were reduced by 2.45%. The provided value has been calculated as a percentage difference between manual and automatic steering GWP emission results. Accordingly, the diesel fuel consumption in the automatic steering mode was reduced by 9.45%.

To conclude, the analysis of the structure work process provides a detailed information of the overall increase of machine productivity and working process optimization. On another hand, it helps to manage the harmful impacts on the environment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/IECAG2021-10178/s1.

Author Contributions: Conceptualization, E.J. and A.J.; methodology, E.J.; A.J. and K.V.; software, A.J. and K.V.; validation, E.J. and A.J.; formal analysis, E.J.; A.J., and K.V.; investigation, E.J.; A.J. and K.V.; resources, E.J.; A.J. and K.V.; data curation, E.J.; A.J., and K.V.; writing—original draft preparation, E.J.; A.J., and K.V.; writing—review and editing, E.J. and A.J.; visualization, E.J. and A.J.; supervision, E.J. and A.J.; project administration, E.J. and A.J.; funding acquisition, E.J. and A.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to thank the Institute of Agricultural Engineering and Safety of Agriculture Academy of Vytautas Magnus University for the test development and support.

Conflicts of Interest: The authors declare no conflict of interest.
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