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Evaluation of harvesting driving modes from environmental point of view†

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Abstract: Numerous automatic technological processes control systems that are implemented in the modern agriculture equipment. Automation facilitates technological processes. These control systems helps customers to save fertilizer and crop protection products as well as fuel. Machinery performance data collected and stored via Telemetry system can be sent to 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 Telemetry system during harvesting at manual and auto-steering mode. 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 4.79% as compared to the manual driving mode. The diesel fuel consumption at automatic steering mode was reduced by 22.02% compared to the 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

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1. Introduction

Constant introduction of the latest technologies and innovations helps to achieve greater efficiency in 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 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 electronic valve control unit, and other elements. 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 increases the accuracy and reliability of the satellite navigation system. For 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 achieved using the RTK correction signal as every inch is important for sowing or harvesting. Fixed reference station via the internet may send a correction signal to an unlimited number of GPS automatic steering systems to 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 the 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 transfer 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 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 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, modeling software as SimaPro 9.1 is used.

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

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 of 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. The combines were equipped with automatic steering systems and driven by RTK (Real Time Kinematic) correction signal [11]. This signal insures 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 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 the manually driven and the other by auto-steering mode. The environmental impact assessment was conducted by SimaPro 9.1 process modeling software [12]. The data on biomass cultivation, transportation, biofuels production and equipment were used from Ecoinvent v3 database [13]). Based on CML-I calculation methodology was determined resulting impact of processes. The global warming and abiotic fossil fuels depletion are chosen as impact categories.

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, and the 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, the emissions into the air due to exhaust gas emissions caused from fuel combustion.

This LCA accounts for the harvesting process without considering the other field cultivation processes, transportation of harvested crops or other filed application. The harvester is allocated between the process considered and other usages using information on weight, operation time and 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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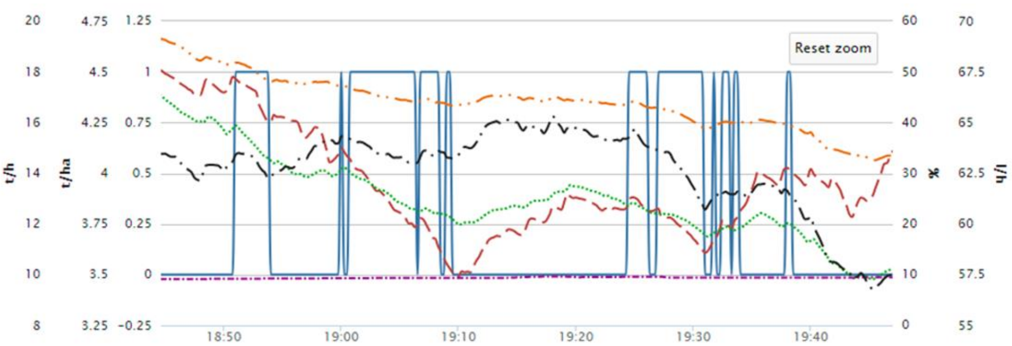
$$AM = m^*(T/L), \tag{1}$$

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

Telematics system can offer different kind of analysis tool [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 (Fig. 1) – provides with 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 6 parameters can be selected at the discretion of the farmer. In a parameters selection list, for the combine harvester, 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 parameters list.



— Autopilot status, ON/OFF; — Grain yield, t/ha; ···· Throughput, t/h; -·- Grain moisture content, %; — Engine load, %; — Fuel consumption, l/h

Figure 1. Graphic of combine harvester performance [17].

The Figure 1 shows the combine harvester performance at 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 crop type. This report includes 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 data.

Table 1. Harvest report data [17]

Total Canola Edible beans Oats Peas Wheat	
Total	**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, transport	494.5 l
Fuel consumption, total	7161 l

The harvest report provides with the most important key performance indicators of the selected machine. Presented report in Table 1 displays the total performance at selected campaign data. This total data consists of the several performance components related to different crop type harvest. As shown in Table 1, the total combine harvester performance consists of canola, beans, oats, peas and wheat harvest at defined data. Beside harvest report data, the telemetry collects the working hour distribution report. Work hour analysis – provides information about efficiency of the machine within specific time range. For the analysis, the certain machine has to be selected and then defined a period of analysis you are interested in. The different time types displayed in an absolute form and in percent. The provided data depends on the machine type. The customer could analyse 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 shown in Figure 2. According to this figure at all categories the environmental impact of manual driving is more than that of automatic steering.

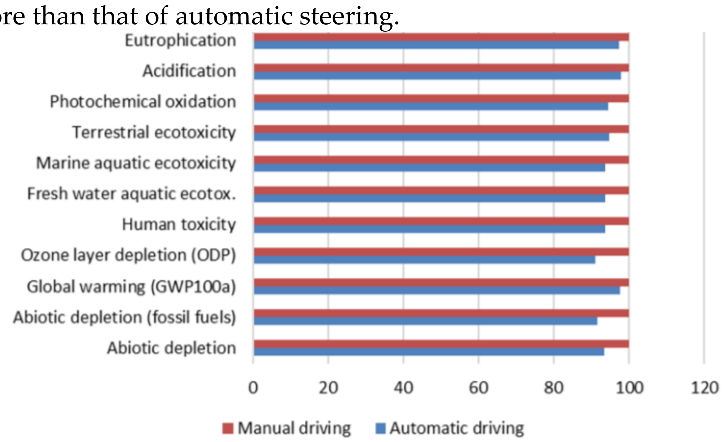


Figure 2. Environmental impact assessment diagrams for two compared systems.

The y-axis shows the impact categories and the percentage of 100% impact for the process that generates the greatest impact within each category. Reduction of acidification potential using automatic steering function is 2.11 % compared to manual driving mode (Fig. 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 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	1.1906	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 on manual mode shown higher airborne emission compare to automatic driving mode. On average, calculated emissions were by 4.22 % less at automatic steering mode, than manual driving (Table 2).

The main inventory data 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 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	12800	12800
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 auto-steering harvester is 504.4 MJ/ha and in manual driving mode – 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 machine, so a longer machine lifetime is expected. This leads to reduced embodied energy of machinery [18].

3. Conclusions

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

For environmental impact analysis of the comparative manual and auto-steering modes were carried out by using data collected in telematics.

The LCA analysis has shown, that use of automatic steering mode global warming emission reduced by 4.79 % compared to manual steering mode. Accordingly, the diesel fuel consumption at automatic steering mode was reduced by 22.02 %.

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

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