# EVALUATION OF COMBINE HARVESTER PERFORMANCE TELEMETRY DATA

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**Abstract.** At present, such smart systems like automatic steering, telemetry and automation of technological processes based on artificial intelligence are widely used in precision agriculture. The biggest challenge for agriculture is how to make optimal use of agricultural machinery and manage the work of the staff. The entire management of a farm can be simplified and facilitated by a telemetry system, otherwise known as a remote monitoring system, for a machine or implement. The analysis of the data obtained by this system provides an opportunity to optimize the business processes. Studies have shown that the use of automatic navigation systems allows the choice of appropriate driving strategies and the avoidance of tillage overlaps or uncultivated areas. Based on the experience of agricultural professionals, the processing of data recorded and stored in the telemetry system is encountered. The main question is how to correctly interpret, analyse and in the future use the information obtained from the yield, fertilization, spraying, soil agrochemical properties maps for making final decisions. For the study, the harvest data collected and stored in the telemetry system of the Claas Lexion combine were selected. The aim of the work is to analyse the winter wheat, spring barley, canola, oats, corn, and beans crop harvest data and show the combine harvester efficiency increasement possibilities. The structural analysis of the collected working time data of the combine harvester was performed by the methods of mathematical statistics. As the telemetry system shows, the grain unloading takes in average 2 minutes. According to these data it could be said that a grain tank unloading during combine run for a 2 min, with average yield of 7 t ha-1 could increase the combine performance by 15%. At the same time, the 2 min drive during grain tank unloading would increase the harvested area by 3.4%.

**Keywords:** combine harvester, telemetry, data, remote monitoring.

## Introduction

Interest in intelligent systems such as automatic driving systems, telemetry and artificial intelligence in agriculture is constantly growing. The benefits of such systems are studied in terms of environmental impact [1] or by optimizing the work activities of agricultural machinery [2] and workers. The management of economic activities can be simplified with the help of data stored in the telemetry system of the machine or implement.

Telemetry systems are widely used in the most complex agricultural machinery, both in tractors and combine harvesters. This system implements interfaces to communicate with data providers, integrates efficient databases to transfer complex data sets [3]. The analysis of the data collected by this system provides an opportunity to optimize work processes. In growing competitive environment farms can survive only when well managed [4]. However, farm management is a challenging and time-consuming task [5]. Online field data monitoring, collection and management requires additional competences and proper technologies, which recently have even entered the Big Data sector [6]. Studies show that the use of automatic navigation systems allows for the choice of appropriate driving strategies and the avoidance of tillage overlaps or fallow areas [7]. Based on the experience of agricultural specialists, there is a problem with the processing of data recorded and stored in the telemetry system and their purposeful use. It is important for many farmers how to correctly interpret, analyse and use as much as possible the information obtained from the maps of yield, fertilization, spraying, soil agrochemical properties [8].

Automatic steering and telemetry are important components of precision agriculture. Studies have shown that farmers using automatic steering systems increase the work efficiency by 6.04% and reduce fuel consumption by 6.32% [9; 10]. Over 60 combine harvesters performance was analysed in the Don State Technical University, where the collected results showed only 34% of harvesting performance efficiency [11].

The researchers say that the analysis of telematics data could help reduce emissions by optimizing the idle and transport modes of the combine in terms of Global Warming Potential (GWP) of 1.3 $t \cdot year^{-1}$ per machine [12].

The aim of the work is to analyse the winter wheat, spring barley, canola, oats, corn, and beans crop harvest data and show the combine harvester efficiency development possibilities.

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## Materials and methods

Data from one harvest year of one combine harvester for different types of crops: winter wheat (204.9 ha), spring barley (232.7 ha), canola (85.9 ha), oats (169.2 ha), corn (117.4 ha) and beans (89.1 ha) were used for the research. The harvested field size varied from 25 to 45 ha. Majority of the winter wheat crop field was standing crop with 16.5 to 18% of grain moisture. A CLAAS Lexion 770 TT combine was selected for the study, and the harvest data were recorded and stored in a telemetry system. The combine technical data: crawler combine with a front axle track width of 735 mm, with an installed Mercedes-Benz engine of 585 HP, telematic system, full automatic control system for harvesting machines. The telematic system served for monitoring, recording and saving of the machinery parameters for further combine-harvester optimisation, work hour analysis, diesel consumption and performance analysis, performance comparison and daily report analysis. The combine was also equipped with an automatic steering system controlled by GPS.

Harvest data for all of the above plant species were selected for the study. Thus, different sizes and different weather conditions were used during the harvest. The total sizes of cereals harvested during the study, depending on the plant species, ranged from 86 ha of spring barley to 205 ha of maize field area. Although the combine was equipped with an automatic propulsion system, harvesting was also performed while driving manually. In the study, in the automatic driving mode, the combine harvested between 3 and 12% of different crops.

The data of the harvested field and the parameters of the combine work efficiency were recorded and stored in the microprocessor of the combine telemetry system. The remote monitoring (telemetry) system records and stores a wide range of data, including the coordinates of the machine location, the date and exact time of the work, the efficiency of the machine, the time and nature of downtime, the machine operating parameters and other important information related to the day’s work. The data collected in the telemetry system were saved in Excel format and transferred to a personal computer for further data analysis. The following parameters of the combine were monitored and recorded for data analysis: fuel consumption per hectare, grain tons and the proportion of efficient combine work with unproductive work.

## Results and discussion

During the research, the same combine was used for harvesting different types of crops. The combine data were collected in telemetry platform database by harvesting winter wheat, spring barley, canola, oats, corn, and beans. During the harvest, the focus was on the combine parameters and the data collection, such as the unloading portion during travel, unloading portion while idle, turnaround time portion, process time portion, idle time portion, travel time portion and idle time with full grain tank portion. The distribution of combine harvester utilization in different working modes was recalculated and distributed according to the price of different crop grains. The distribution of the price of one ton of grain in the stages of the combine operation is presented in Table 1. The grain prices were taken from official pages of grain elevator grain purchasing pricelists.

Table 1

**Grain cost distribution per different grain processing time portions**

| Combine harvester process time distribution | Wheat | Spring barley | Canola | Oats | Maize | Field beans |
|---|---|---|---|---|---|---|
| Unloading portion during travel, EUR | 5.46 | 4.54 | 6 | 4.8 | 4.98 | 3 |
| Unloading portion while idle, EUR | 5.46 | 4.54 | 12 | 3.2 | 17.43 | 6 |
| Turnaround time portion, EUR | 24.57 | 22.7 | 54 | 14.4 | 24.9 | 33 |
| Process time portion, EUR | 117.39 | 99.88 | 294 | 102.4 | 124.5 | 180 |
| Idle time portion, EUR | 73.71 | 45.4 | 156 | 17.6 | 52.29 | 51 |
| Travel time portion, EUR | 38.22 | 40.86 | 72 | 14.4 | 14.94 | 27 |
| Idle time with full grain tank portion, EUR | 8.19 | 9.08 | 6 | 3.2 | 9.96 | 0 |
| Grain price, EUR | 273 | 227 | 600 | 160 | 249 | 300 |

The grain harvesting stages in the table are grouped into two sections. One of the harvesting components is useful work for harvesting. This section includes the useful portion of work for harvesting such as, the unloading portion during travel, unloading portion while idle, turnaround time portion, process time portion which were monitored and measured. The second component of the harvest time is useless or inefficient work of the combine harvester. This is the time spent on non-harvesting work and reducing the combine productivity and efficiency. The following components of the combine harvester were indicated as inefficient work: the idle time portion, travel time portion and idle time with full grain tank portion. The part of the grain price was deducted for each of the grouped work components of the combine. The distribution of the price of grain according to the components of the useful and unprofitable use of the combine harvester, harvesting different plant species, presented in Fig. 1.

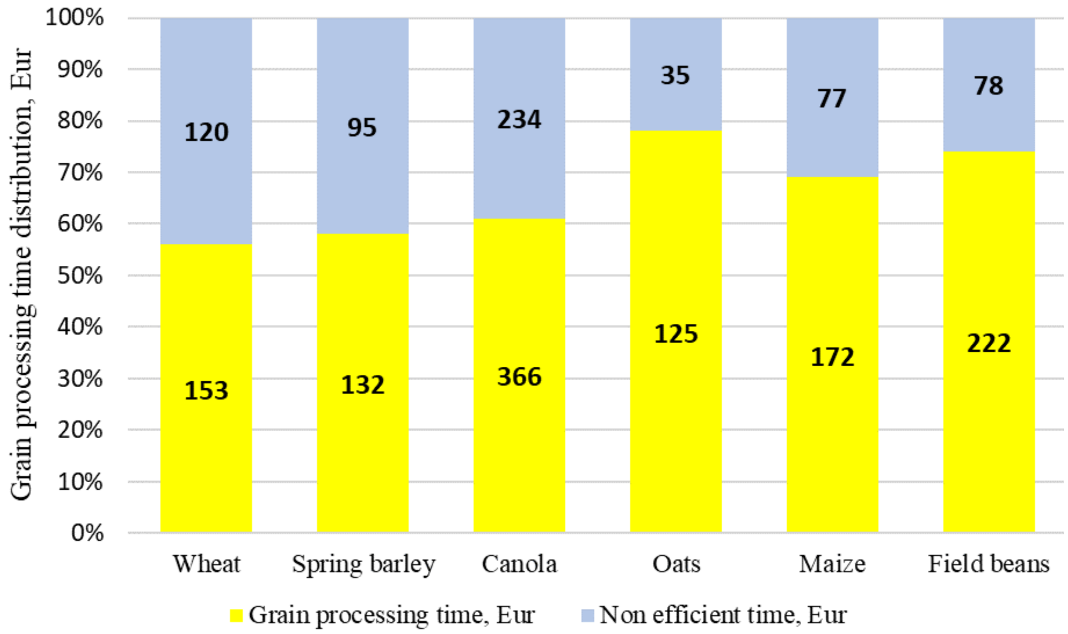


Fig. 1. **Grain price distribution for grain processing and non-efficient time**

As can be seen from Fig. 1, the smallest part of the grain price component of unprofitable work went to the oat harvest. The share of unprofitable work was 21.9% of the oat grain price, which in financial terms amounted to 35 EUR. This relatively small component of the unprofitable work could be explained by the fact that oats, as a plant, have a low resistance to bedding, and the mass of oat straw and threshing of oat seeds do not require significant energy resources. A completely different picture is seen in the wheat harvest graph (Fig. 1). Here, the share of the wheat grain price for unprofitable work amounted to 120 EUR, or 43.9% of total unprofitable work. This means that almost half of the wheat grain price is for non-direct harvesting operations of the combine harvester.

Analysis of the data collected in the telemetry system shows that the share of inefficient combine harvesting in rapeseed harvest is the largest in financial terms. Although in percentage terms it is only 39% of total unprofitable work, in terms of costs it is even 234 EUR of the canola price. A number of factors could be attributed to the unprofitable operation of a combine harvester. Unlike oats, wheat has a higher amount of straw, which can cause clogging of the combine cutterbar, feederhouse, or even the threshing mechanism. As a result, it is necessary to stop the combine and perform cleaning work. It takes time, in other words, time is not used for harvest. Another efficiency consuming factor in unprofitable harvesting may be the lying down crop. After growing a large yield of wheat, the crop tends to fall down due to wind or heavy rain. To harvest the fallen crop, the cutterbar is lowered as low as possible to collect as much of the crop as possible. Lowering the cuttebar causes clogging, the possibility to break the cutting knives or stones entering the cuttebar or combine itself. All these failures slow down the operation of the combine and thus contribute to the reduction of the combine performance, downtime during repair or maintenance.

So, which factors of inefficient combine utilization have the biggest impact on the combine productivity decline? Fig. 2 analyzes the three main factors that reduce the combine performance, these are the idle time portion, travel time portion and idle time with full grain tank portion. As it can be seen from Fig. 2, in the case of all harvested crops controlled during the research, idle time is the largest factor in the utilization of all inefficient working time. This means that during harvesting the harvesters idle for a large part of the time for different reasons.

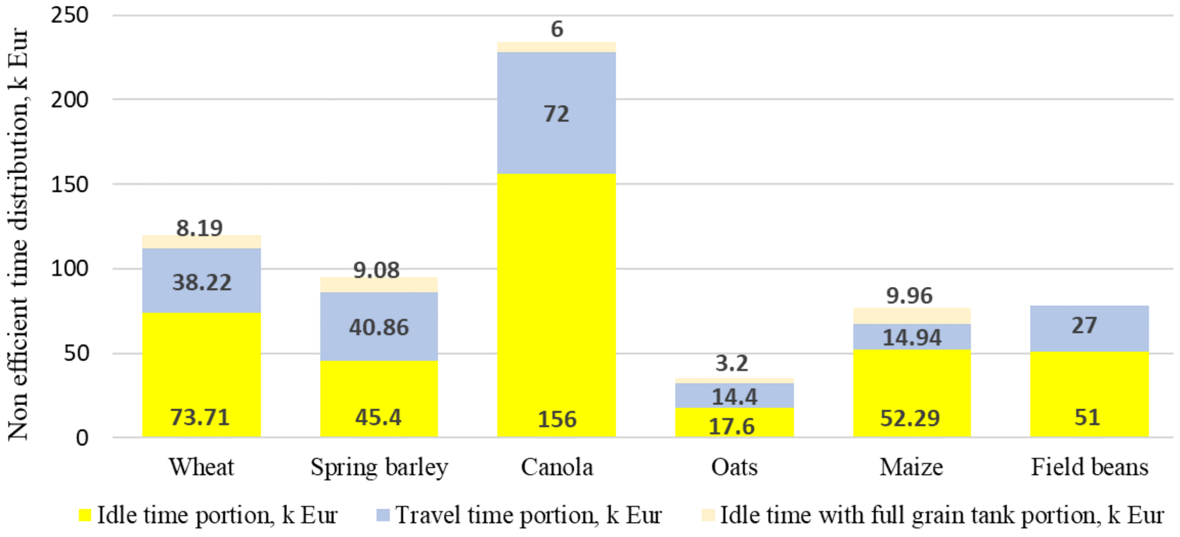


Fig. 2. **Financial losses due to non-efficient time portions**

From Fig. 2 it can be seen that as much as 156 and 73.71 EUR is accounted for by idling of the combine in harvesting canola and wheat, respectively. However, the highest unprofitable harvesting costs are when the combine is idling. They account for 68, 67, 61, and 65% of total unprofitable harvesting costs, respectively, with harvesting corn, canola, beans, and wheat, respectively. Field trips also make up a significant part of the cost of unprofitable work. However, farmers could also focus on reducing costs. In some cases, they account for as much as 43% of the total cost of unprofitable work during spring barley harvesting. The lowest cost of unprofitable work is when the combine is in idle with a full grain hopper due to congestion of trailers or logistics. These costs represent up to 13% of the total cost of harvesting maize.

In summary, the idle time portion, travel time portion, and idle time with full grain tank portion on the overall scale of unprofitable combine work yield in averaged 60, 32, and 8%, respectively. As it is shown in Fig.2, the combine harvester idling time takes quite a significant part. Combine idling time consists of the time when the combine just started and runs on idle speed. The reasons of the engine idling need to be followed. Such figures make us think about more rational working methods, proper preparation of harvesters before harvesting, better organized grain removal logistics and the possibility to sow fields with one plant species as close to each other as possible.

## Conclusions

1. The lowest part of oat grain price component of inefficient work was during oat threshing, which accounted for 21.9% and the biggest part 43.9% of unprofitable work went for wheat harvest. In average the unprofitable work of all harvested crop comprised 35% of the total harvesting process.
2. Unprofitable harvesting work portions like the idle time portion, travel time portion, and idle time with full grain tank portion on the overall scale of unprofitable combine work yield in average 60, 32, and 8%, respectively.
3. The selection of most rational working methods, combine harvester settings, better organized grain removal logistics and field sowing strategy composition definitely would save time and resources of the harvesting process.

## Author contributions

Conceptualization, A.J. and E.J; methodology, A.J. and E.J.; software, A.J.; validation, A.J. and E.J.; formal analysis, A.J., E.J. and G.J.; investigation, A.J., E.J. and G.J; data curation, A.J., E.J. and G.J; writing – original draft preparation, A.J., E.J. and G.J; writing – review and editing, A.J. and E.J.;

visualization, A.J., E.J. and G.J; project administration, E.J.; funding acquisition, G.J. All authors have read and agreed to the published version of the manuscript.

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