Machine monitoring as a SmartFarming concept tool.

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Abstract.
Current development trends are associated with the digitization of production processes and the interconnection of individual information layers from multiple sources into common databases, contexts and functionalities. In order to automatic data collection of machine operating data, the farm tractors were equipped with monitoring units ITineris for continuous collection and transmission of information from tractors CAN Bus. All data sets are completed with GPS location data. Acreage of farm is 2,800 ha and a total of 26 monitoring units were installed since 2015. Data collection takes place continuously from switching-on to the switching-off of the tractor switchbox. Based on machine position information, it is possible to model the machine trajectory. The obtained data provides an overview of the time use of the tractors. These data are then compared with calculated models of optimal trajectory trajectories, based on the shape of the plot. A very small change in direction can be a significant reduction in riding length. With the changing of the azimuth by 1° the total length of rides was shorter about 577 m. An analysis of trajectories also reveals the locations of higher frequency and the accumulation of passes. During the season, some areas of the field are exposed to extreme loads. In terms of control data, there are important data about the working mode of the tractor and the level of the operator. During machine operation, the fuel consumption, working speed and engine speed were monitored. The recording of the working mode reflects the variability of the environment and reveals the variability of the work which was done at the same time.

Keywords. *Fuel consumption, CAN Bus, monitoring, trajectories, data collection*

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Introduction

The current vision of the succession of autonomous systems, requirements for the collection and processing of large volumes of data, control of inputs, all supported by the rapid take-up of computer technology, sensors and mobile phones fit conceptually into the development direction, generally referred to as Industry 4.0. Digitization has an important effect on the agricultural sector for quite some time now (Schönfeld et al. 2018). The advanced technologies are applied to the agriculture (Suprem et al. 2013). In this context, the term Agriculture 4.0 was presented. According to (Sundmaeker et al. 2016) the industrialization of agriculture has expanded a lot in the previous decades. Support for decision-making that arises from development and research activities is a prerequisite for efficient and environmentally friendly farming. Automated process-data acquisition can be the basis for information-steered agricultural production. In this moment, the mobile farm machines are equipped with sensors, which could be used for data collecting during the work (Steinberger et al. 2009). Wireless Sensor Networks (WSNs) could be widely applied in various agricultural application and WSNs presents a new direction of research in agricultural and farming domain (Ojha et al. 2017). The change in the nature of industry, agriculture, energy, trade, logistics and other parts of the economy relies on the discipline already used, but also on completely new concepts. It is possible to see that Big Data are beginning to be adopted in and the food and agricultural sector (Sonka 2016). In connection with data collection, it refers to the concept Internet of Things (IoT) very often (Madakam et al. 2015). The Internet of Things development, wirelessly connecting all kind of objects and devices in farming and the supply chain, is producing many new data that are real-time accessible (Wolfert et al. 2017). Sundmaeker et al. (2016) also define differences between Smart Farming and Precision agriculture, when the Smart Farming goes beyond precision farming because managements tasks not only on location but also on data, enhanced by context and situation awareness, triggered by real-time events. According to (Schönfeld et al. 2018) Smart Farming integrates agronomy, human resource management, personnel deployment, purchases, risk management, warehousing, logistics, maintenance, marketing and yield calculation into a single system.

Regarding the measurement of field variability, sensors on agricultural machines can deliver the best accessible spatial and temporal information (Heege, 2013). Deployment of geophysical instruments or implementation of sensors equipment to commonly used machines will enable an overall reduction in costs of data collection, sampling network optimization, time savings and reduce demands on workers. The quality of soil monitoring improves the combination of sensor outputs (Mahmood et al. 2012). Information products, like the TalkingFields maps, allow the farmer to more accurately react with site-specific farming techniques. More accuracy means lower production costs, as resources such as water, seeds and fertilizer are not wasted (Bach and Mauser 2018).

This paper presents and discusses the outputs of the machine data recordings, which were recorded and stored during machine operation. The data may show a different approach to the technological discipline of the operator, but also the effect of the different working conditions which are given by land sizes and field conditions.

Material and methods

Length In order to automatic data collection of machine operating data, the farm tractors were equipped with monitoring units ITineris for continuous collection and transmission of information from tractors CAN Bus. All data sets are completed with GPS location data. Acreage of farm is 2,800 ha and a total of 26 monitoring units were installed since 2015. Data collection takes place continuously from switching-on to the switching-off of the tractor switchbox. In this paper, a selection of applications is presented.

Trajectories modelling

Based on machine position information, it is possible to model the machine trajectory. The obtained data provides an overview of the time use of the tractors. These data are then compared

with calculated models of optimal trajectories, based on the shape of the plot. For the evaluation of the movement of machine on field, two fields with different shape and acreage were selected. The acreage of fields were 14.68 ha and 42.64 ha. From the record of values, real trajectories of motion were obtained. The choice of trajectory was always based on the experience of the operator or the tradition of cultivation. Trajectories were recorded during the sowing of winter wheat. The working with of sowing machine was 8 m. The OptiTrail (LeadingFarmers, joint-stock company, Czech Republic) program was used for modelling of the optimal driving direction with regard to the shape of the plot.
For the trajectory calculation, the model needs four inputs and parameters, shape of field, which is described by shapefile, working width of machines, number of rides at headlands and minimum turning radius. For each plot, a total of 180 driving directions were determined with a step of 1°. For the each individual trajectories direction, the lengths of working and non-working rides, length of transport distance, the number of turns and the length of the rides at the headland were calculated. In this moment, only A-B lines were modelled. The most appropriate line presented with shortest distances was selected for comparison.

Passes intensity monitoring

An analysis of trajectories also reveals the locations of higher frequency and the accumulation of passes. For the passes intensity determination, the field was divided by square grid with the cell 8x8 m and map maps were created from the sum of machinery position records in time at a particular place. It means, the more times a machine entered each square the more records for the square and also the more time a machine spent in the square the more records there as well (dependence on working speed and/or even machine stops).

Monitoring of operational data

The data from the monitoring units was further used for evaluation of the operational indicators. Engine speed, working speed and fuel consumption were evaluated. A time series of values was obtained with a record interval of 1 s. Data filtering was performed before processing. Values larger or less than three times of the standard deviation from the mean value were excluded from the initial data set. The time series were smoothened during the subsequent modification. A simple running average method was applied to smooth the time series of all measurements using following equation:

$$\hat{Y}_t = \frac{1}{3}(Y_{t-1} + Y_t + Y_{t+1}) \tag{1}$$

where: Y are original values at time t.

Smothed data were evaluated by geostatistical methods and presented as amaps. Software ArcGIS 10.4.1 (ESRI, Red lands, USA), tools GS+ for Windows (Gamma Design Software, LLC, Michigan, USA), and Microsoft office (Microsoft Corporation, Redmond, USA) were used. limits for papers:

Results and discussion

Automated data acquisition about machine operating modes can be the basis for information-based agricultural production. Figure 1 shows a view of the movement of the machine from the moment when the tractor's switch box if turned on. In this case, record was transferred to the GIS (Geographic Information System) environment.

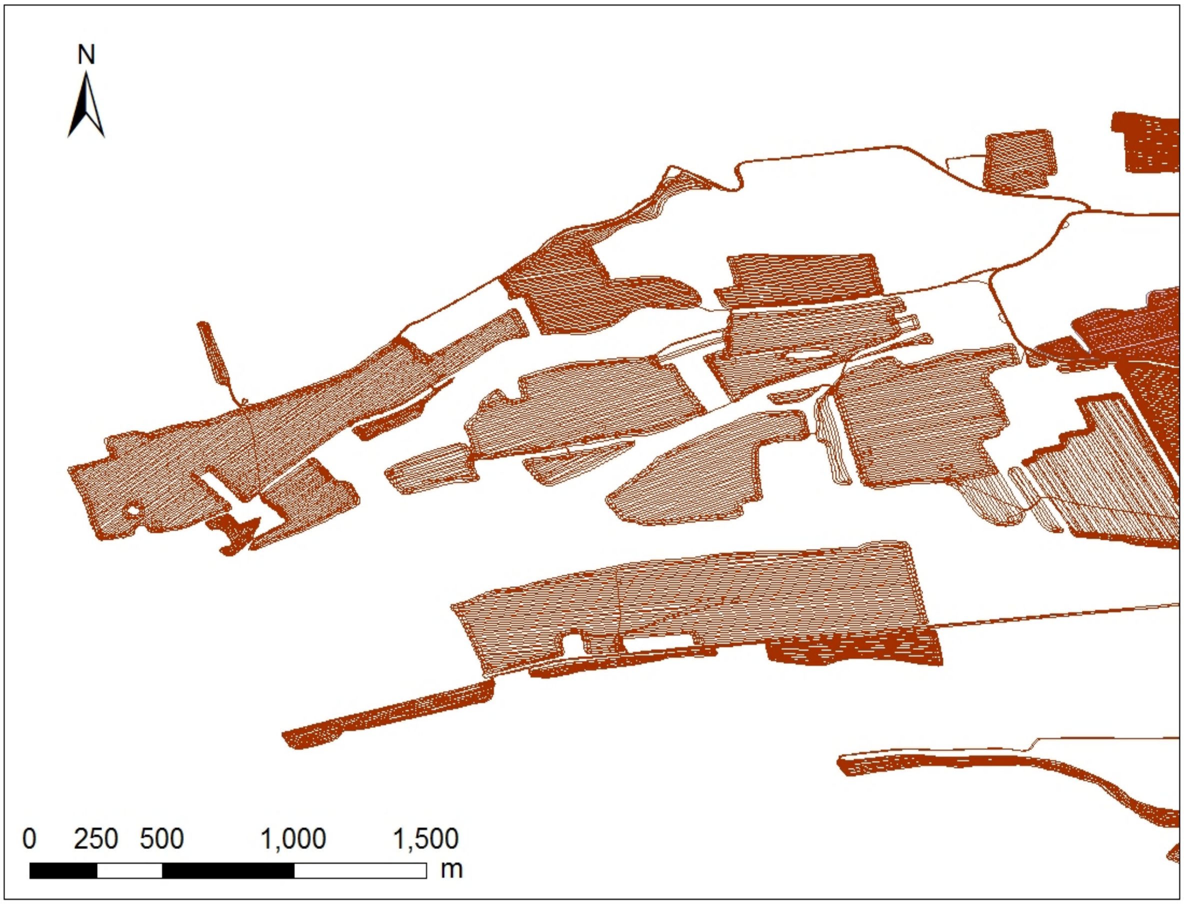

Fig. 1 Record of the machine moving, which was taken by the monitoring unit.

Real-time data capture brought an image of the motion of the tractors across the fields. For the performance, two plots were selected (Figure 2). The acreage of the field A was 14.68 hectares. 6,764 points were recorded on this field. Total length of rides was 24,097.8 m. From this, 14,512.3 m is the main working ride, which represents a working ride especially in the middle of the field. 9,585.5 m represents a turns and a rides length on the headlands. The total number of recorded turns was 84. The azimuth of the line relative to the vertical axis was approximately 165 °. A trajectory model with the same azimuth was calculated for comparison with real values. The trajectory model showed lower values compared to reality. The difference is mainly due to the length and the number of turns. Optimal trajectories with regard to the shape of the field were also modelled. Based on the model, a trajectory azimuth 45 ° was recommended. The values of the rides lengths are given in Table 1.

The acreage of the field B was 42.64 hectares. 16,823 points were recorded on this field. Total length of rides was 62,833.7 m. From this, 45,604.4 m is the main working ride. 17,229.3 m represents a turns and a rides length on the headlands. The total number of recorded turns was 130. The azimuth of the line relative to the vertical axis was approximately 73 °. The significant difference in the length of rides compared to the model is given by the higher number of turns and the significant non-working crossings within the fields that have been observed. The same procedure as for the field A was for determination of the lengths of individual trajectories was used. Based on the model, azimuth 72 ° for optimal trajectory was recommended. The values of the lengths of the rides are also given in Table 1.

Table 1. Model values of travel lengths based on the real azimuth of the rides and lengths of passes modelled for optimal trajectories.

Field	Azimuth	Total length of rides [m]	Length of working rides [m]	Length of turns [m]	Number of turns	Length of headland rides [m]	Transport [m]	Working and nonworking rides ratio [%]
A Model of real trajectory	165°	21,561.24	15,800.06	2,402.14	73	3,359.04	0.00	11.2
A Model of optimal trajectory	45°	20,817.41	15,845.98	1,612.39	49	3,359.04	0,00	10.2
B Model of real trajectory	72°	58,723.93	48,532.71	2,895.73	88	6,368.83	926.66	6.5
B Model of optimal trajectory	73°	58,146.10	48,474.97	2,961.54	90	6,368.83	340.76	5.7

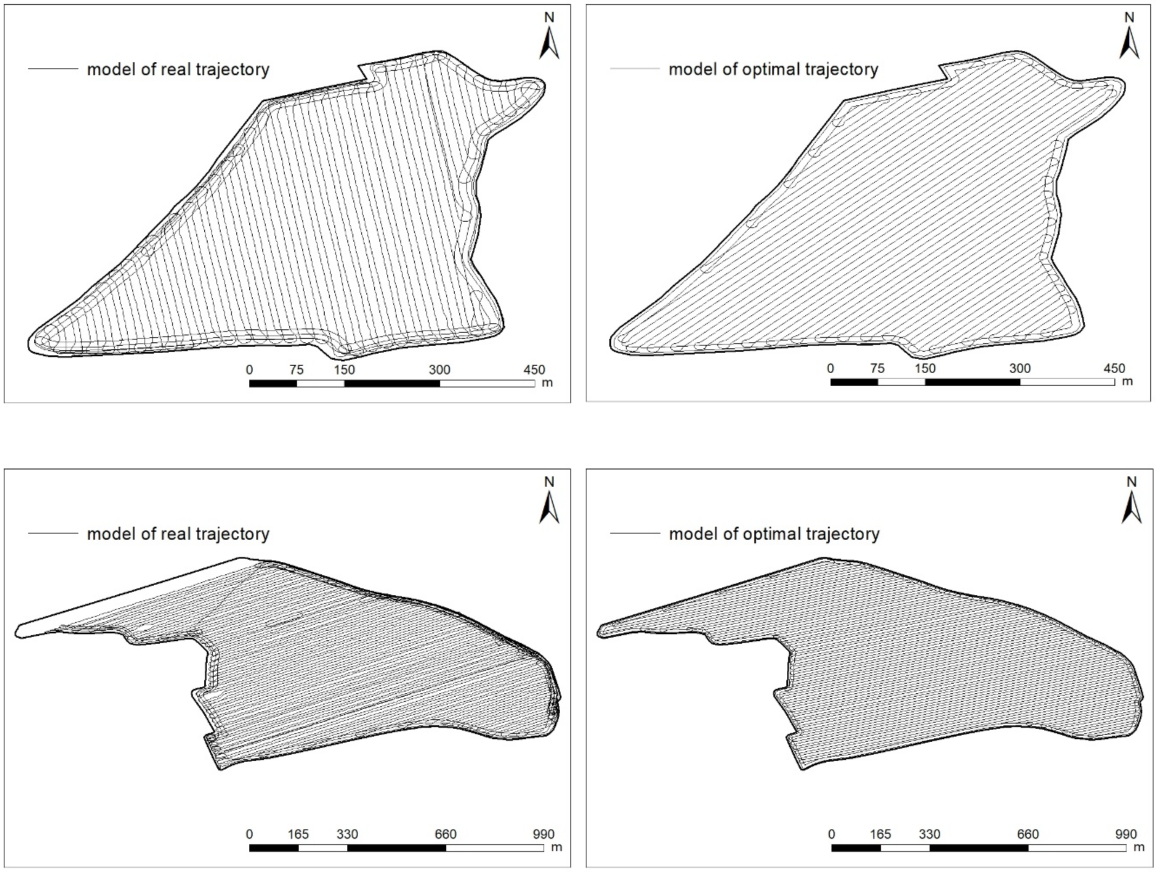

Fig 2. Selected fields with recorded real direction of machine work trajectories and modelled trajectories for two selected fields. Field A is shown above, field B is shown below.

In both scenarios, the shorter lengths of total length of rides associated with route optimization were noted. The ratio between working and non-operating rides ranges from 5.7 to 11.2%. The ratio of working and non-working rides has a decrease with acreage increasing of the field. This is consistent with the work of Wagner (2001). He states that the field acreage increasing is associated with a positive effect on reducing the working time per unit area due to a decrease of the time of machine turning. Trajectory optimization will have a more significant effect, especially on smaller areas. Fechner (2014) has determined the positive effect of optimizing trajectory of work passes to save time when measured on real soil blocks. The most significant time savings resulted from the optimization of trajectories on fields ranging between 10 and 40 ha. On fields with a larger area, the time savings were below 10 % compared to the current work rides. Edwards et al. (2017) also describe a reduction in total journey time when optimizing routes compared to the operator. In our case the length of the rides was the main measure. As illustrated in the graphs and Figures 3 and 4, turns and non-working driving are most involved in the overall length of the rides, while the length of the main work rides is similar. On the other hand, the model trajectories did not respect the slope of the land, which may also be an important step in the trajectory proposals (Jin and Tang 2011, Hameed et al., 2013, Hameed 2014).

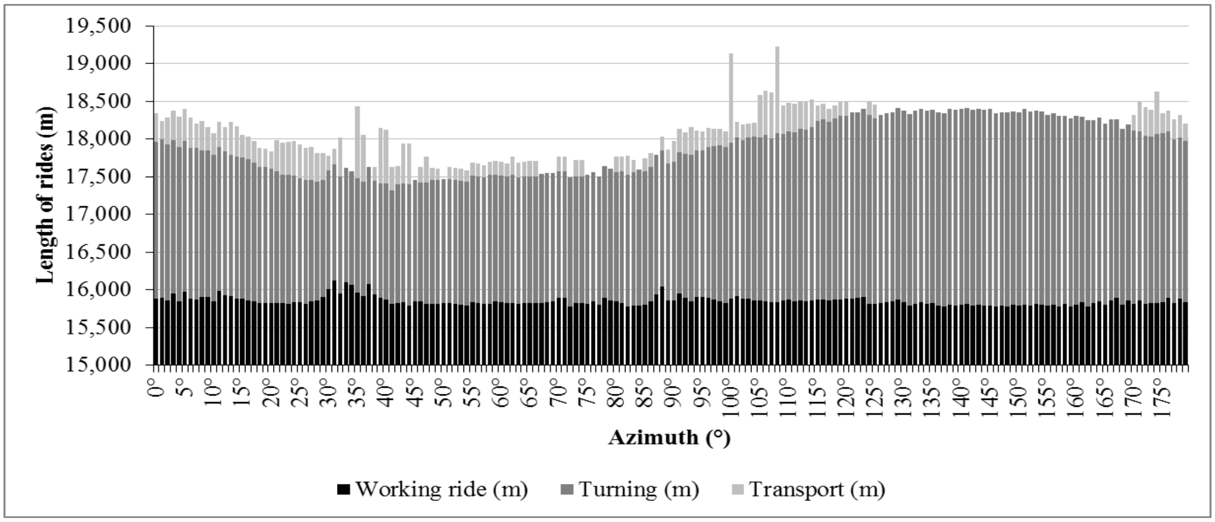

Fig 3. The lengths of working and non-working rides determined for each trajectory azimuth on field A.

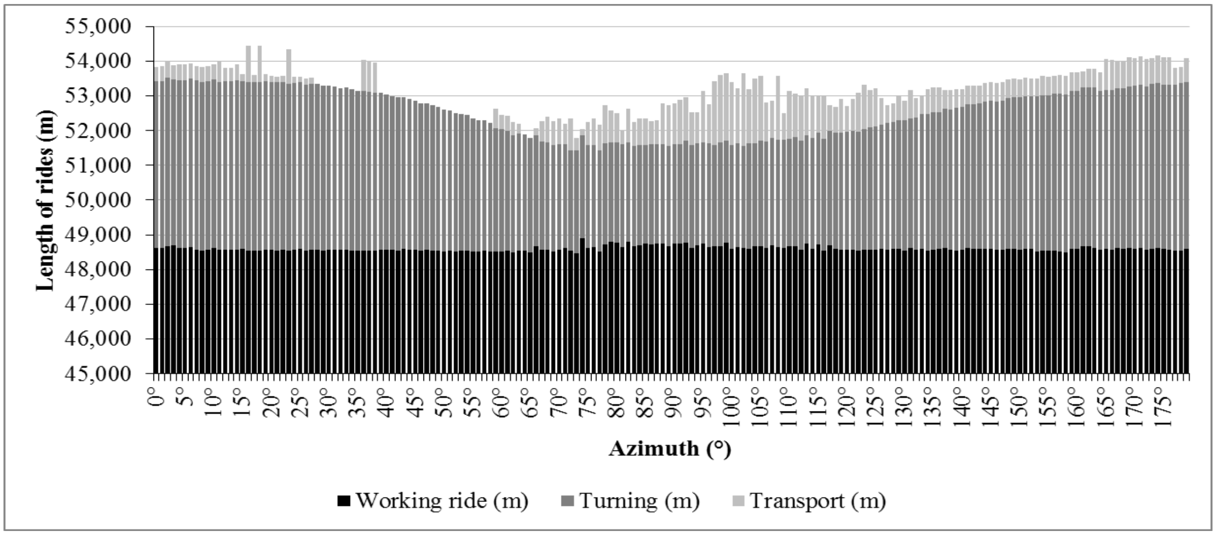

Fig 4. The lengths of working and non-working rides determined for each trajectory azimuth on field B.

Figure 5 interprets the statement: “Soil compaction phenomenon is connected with number of machinery passes but also with time exposure of soil surface to contact pressure” (Bakker and Davis 1995). It shows places with different traffic intensity and also with different time exposure of soil to the machinery load. The map was created using all inputs that took place between 2016 and 2017. The inputs were soil cultivation, seedbed preparation, sowing, fertilizing, plant protection, harvesting and grain deposition.

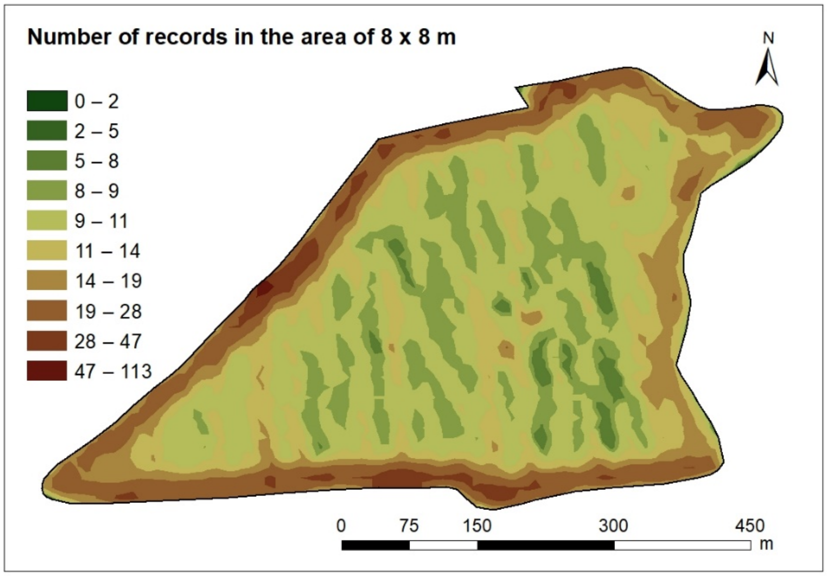

Fig. 5 Map characterising intensity of traffic and time spent at a certain area.

As a remedy against undesirable soil compaction, deep loosening is often applied. This is an extremely energy-intensive procedure. Based on the record of the frequency of passes, it is possible to identify areas with a high concentration of passes and the risk of soil compaction.

In terms of control data, interesting data are available about the working mode of the tractor itself or its engine. In this case the role of the machine operator plays an important role, his responsibility and the knowledge of the engine operating mode. We are directly connected with the economy of the operation of the kit, expressed via the consumption of fuel. Machine monitoring becomes an instrument to control and improve the situation from the perspective of the economical utilisation of work tools. Figure 6 provides a graphical record of engine speed during the ploughing of the field.

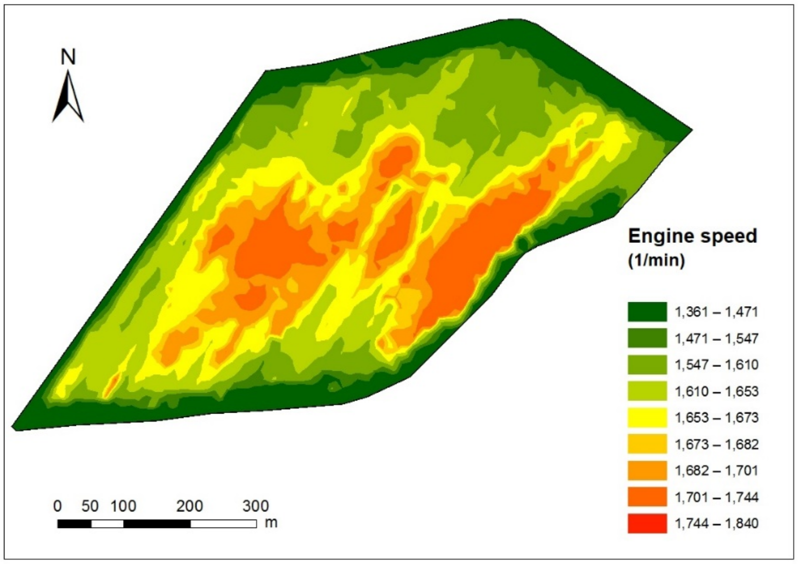

Fig. 6 Recording of the engine speed of the tractor.

The quality of work operations, but also the energy consumption during the work, is associated with the working speed of the tractors (Figure 7). Recording of the work speed can also be used as a control tool and a document of properly conducted work with respect to the recommended working speeds of the machines.

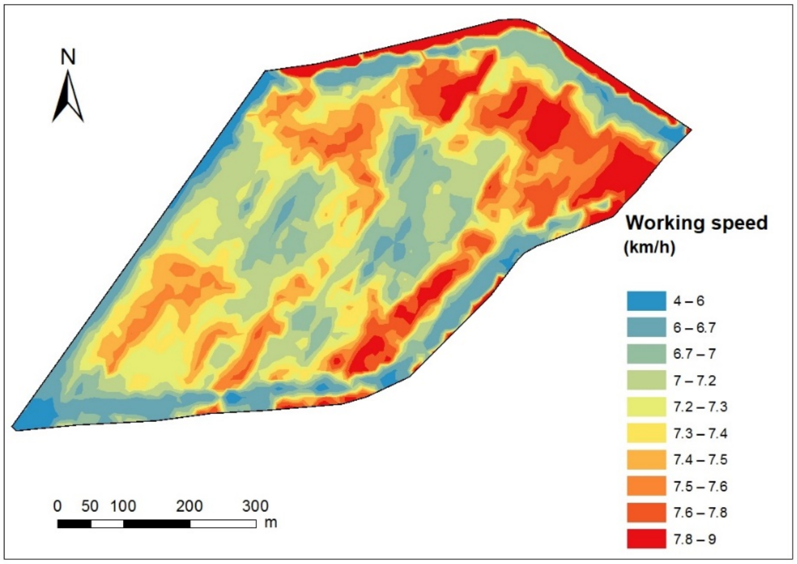

Fig. 7 Recording of the working speed of the tractor.

Significant information from the machine operation record is fuel consumption. If we add the data about fuel consumption to the other inputs during the season and the yield map, we will get a completely different view of the economics of the individual plots and their parts. The record of fuel consumption during soil preparation is shown in Figure 8.

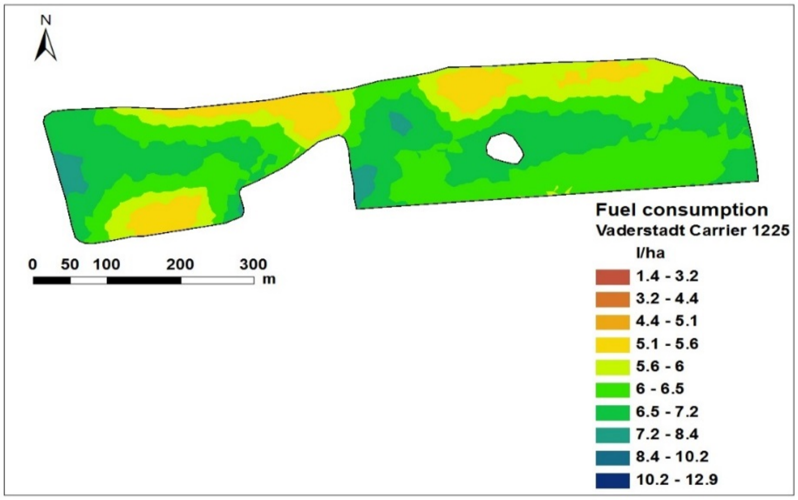

Fig. 7 Map of the fuel consumption during soil preparation.

Conclusion

With the introduction of machine monitoring, a greater control of farm management can be demonstrated, with the possibility of a very detailed assessment of inputs and outputs, including the aspect of strengths and weaknesses. Using a simple monitoring system, significant data was obtained with a minimum of additional costs.

Detailed monitoring, modelling, and timely signalling will make it possible to optimize inputs in decision processes. Information technology will also enable connections with a wide range of other disciplines. This report is only part of the volume of data that can be read from the record. IoT aims to unite everything under a shared infrastructure that will not only allow us to control the things around us but also keep us informed about the state of affairs.

Despite significant advances in data collection and evaluation, hardware and software compatibility, many manual tasks are required, specialized software, often up to scientific knowledge. It is still a limiting factor for using this data, as well as a lack of a data reuse concept. There is still much work to do in this respect. In any case, collecting data is the first significant step.

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