Agronomy Research Biosystem Engineering Special Issue 1, 63-67, 2011

Energy saving in farming field operations

T. Jokiniemi and J. Ahokas

University of Helsinki, Department of Agricultural Sciences, Agrotechnology, PL 28, 00014 University of Helsinki, Finland; e-mail: tapani.jokiniemi@helsinki.fi

Abstract. Limited fossil energy resources and greenhouse gases emerging from burning the fossil fuels have resulted in energy saving objectives in agriculture. It is most favourable to start the savings from processes which are least affected. In arable farming these are the direct energy inputs in field operations. The operation method of the field machinery has great influence on fuel consumption. In order to guide the driver to optimal operation, a way to show fuel consumption per l ha^{-1} is needed. A simple and cost effective way to do this was tested at the Helsinki University experimental farm at Viikki. Fuel consumption was measured with the voltage signal from the tractor's own fuel level sensor. The movements and location of the machine were recorded with a simple personal GPS tracker. Results showed that this was a useful method for large field plots and continuous working periods. For guiding purposes the fuel consumption should be displayed in real time. A CAN-based measuring system for fuel consumption measurement is now being designed.

Key words: Energy saving, farming, fuel consumption per hectare, tractor specific fuel consumption, tractor operating method.

INTRODUCTION

Limited fossil energy resources and greenhouse gases emerging from burning of fossil fuels have made energy use in farming an object of critical inspection. While the demand for food and feed increases due to the growing world population and changing diet, agriculture has a challenging task to sustain or even increase its production and reduce the use of energy at the same time.

In arable farming the greatest energy inputs are the nitrogen fertilizers, representing some 50–70% of the total energy use. The yield response to the fertilizing, on the other hand, is good, which indicates that plants use the applied energy effectively (Mikkola & Ahokas, 2009). It is favourable to start energy reduction from the processes which are least affected. In arable farming these are the direct energy inputs in field operations and, especially in Finnish climate conditions, in grain drying. Considering the possible savings one must bear in mind, that the share of energy use in field operations is roughly one fourth of farming total energy use (Mikkola & Ahokas, 2009). Therefore, the saving possibilities in these operations may not be remarkable in general level. However, they can also help to improve the viability and competitiveness of a single farm considerably. This can be used to motivate the farmers to deploy new methods, ideas, and attitudes.

Most of the direct energy inputs in arable farming consist of diesel fuel (or light fuel oil), which is the principal fuel for field machinery as well as for grain drying. The fuel consumption of the field operations is affected by several factors, for example working methods, technology used, weather conditions, adjustments and the condition of the implements, and the operators' driving method. Some systematic savings in fuel consumption can be achieved by using no-till farming or reduced tillage, since the number of work phases can be cut out (Mikkola et al., 2011).

The most common power sources in farming are tractors, which are almost without exceptions powered by diesel engines. Recently the new diesel technology has entered also farm tractors, mainly due to the new emission regulations. Technologies like variable geometry turbochargers, intercooling and electronic common-rail fuel systems have improved the efficiency of the tractor engines. At the same time tractors have become more sophisticated increasing fuel consumption. However, the efficiency of a tractor as a whole depends only partially on the engine. The key factor considering the fuel consumption is to adapt the engine load to the most favourable area in the engine load and speed map. The specific fuel consumption is usually at its lowest when the engine load is close to the highest load and the engine speed is close to the speed equivalent to the highest torque (Liljedahl et. al., 1996; Labeckas & Slavinskas, 2006). To achieve these conditions, the size of the implement has to be correctly adjusted to the size of the tractor, the transmission has to have sufficient amount of gear ratios and the driver must have the knowledge how to drive the tractor properly.

Because of the engine behaviour, the increase in driving speed for example, which in principle increases the fuel consumption, may have an opposite effect because the engine now works with more favourable area of fuel consumption. To guide the driver in finding the optimum engine and driving speeds, a way to denote the fuel consumption per hectare should be found. For this purpose the information of the tractor speed, implement width, and fuel consumption ($l\ h^{-1}$) are needed.

MATERIALS AND METHODS

A simple and cost effective way to measure the fuel consumption of farm machinery per hectare was tested at the Helsinki University experimental farm at Viikki in summer 2010. The fuel consumption was measured by the voltage of tractor's own fuel meter sensor. Speed and location were measured and recorded with a personal GPS-tracker. The measuring system was very simple, cheap and easy to install, and it did not require any modifications to the fuel system of the machine. It can also be applied to almost any farm vehicle. Manual bookkeeping was held in addition to the measurements to verify and complete the results. The measurements were carried out during different tasks, including harrowing, sowing, cutting grass, baling, harvesting grain, spreading manure, and ploughing. Fig. 1 shows the measuring system installed in a Valtra N141 tractor.

For measuring and recording the voltage output from tractor's fuel meter sensor, a Tinytag TGPR-0704 voltage datalogger was used. It was installed in a suitable place close to the fuel tank and connected to the wiring that led from the sensor to the fuel meter. Movement and location of the machine were recorded with a Globalsat BT-338 personal GPS-tracker, which was placed inside the cab of the tractor. The trace of the machine can also be displayed on a map. The logging frequency for both GPS-data and the voltage signal from the fuel sensor was 30 seconds, which enabled ca. three weeks of continuous measuring to the device memory. After each measuring period the collected data was uploaded to a computer for analysis.

Figure 1. Simple and cost-effective system for determination of the fuel consumption of farm machinery in lha^{-1}. System is installed in a Valtra N141 tractor.

To find out the corresponding voltage reading for certain amount of fuel in the tank, a calibration curve was created for each machine used in the study. This was done by pumping the tank empty and then filling it, recording the voltage reading simultaneously.

RESULTS AND DISCUSSION

The results showed that the fuel level measurement by the machine's own fuel level sensor combined with the GPS-data was a useful method for determining the fuel consumption in litres per hectare. Examples of the measurements are given in Fig. 2 and Fig. 3. Results calculated from the data are given in Table 1. The calculated area in Table 1 represents the theoretical area calculated from the driving speed and the working width. The actual area is the accurate field plot area from the farm bookkeeping. Because of the headland turns and overlapping, the actual area is smaller than the calculated area. By combining these figures, the operation efficiency of the work can be calculated as well.

Table 1. Results calculated from the measurements. Calculated area represents the theoretical area which is calculated from the driving speed. The actual area is the accurate area from the farm bookkeeping.

Fuel consumed	142	l
Speed average	4.7	$km\ h^{-1}$
Time	6.1	h
Working width	4.2	m
Calculated area	12.1	ha
Actual area	9.1	ha
Operating efficiency	75	%
Output (calculated)	2.0	$ha\ h^{-1}$
Output (actual)	1.5	$ha\ h^{-1}$
Fuel consumption	23.3	$l\ h^{-1}$
Fuel consumption	15.6	$l\ ha^{-1}$

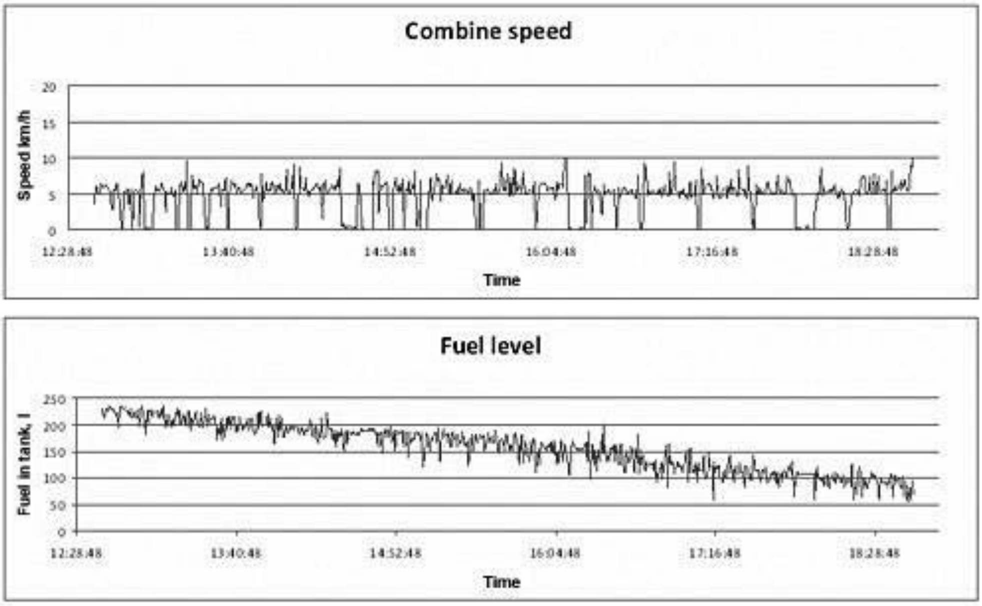

Figure 2. Combine speed and fuel level in treshing. Data measured 13 August 2010.

Figure 3. Combine movements in the fields 13 August 2010.
Total harvested area 9.08ha.

The accuracy of the system is adequate for this purpose with a few conditions. The measuring period has to be quite long, preferably several hours, and the engine load relatively high to generate a measurable difference in tank fuel level and thus in the voltage signal of the sensor. Also the work during the measurement should be quite continuous, since the break periods are difficult to eliminate from the results. At the Viikki experimental farm there are both arable and forage farming and also research plots, which causes small and scattered field plots. This made the data analysis more difficult. Analyzing and processing the data requires also a lot of manual work. All data processing was made in Excel spreadsheet program. Using more advanced programs could make the analysis easier and could also help to eliminate break and road transport periods.

CONCLUSIONS AND FURTHER RESEARCH

Measuring the fuel level with tractor's own fuel level sensor combined with the GPS-data proved to be a useful method with certain prerequisites. To achieve adequate accuracy, the field plots should be quite big and continuous working periods quite long. Besides energy use also the operating efficiency is easy to determine with the system. More advanced data processing methods would improve the feasibility of the system.

To guide the driver during the work, fuel consumption should be displayed in real time. Most of the modern tractors are equipped with a CAN-bus (Controller Area Network) to manage data traffic between several controller units of the machine. Using the fuel consumption data from tractor's CAN-bus would enable the real time display of the fuel consumption. It would also supply some additional data, for example the draught force from the three point hitch sensors. Basically all the data in the CAN-bus could be recorded. For example Schutte et al. (2004) collected fuel consumption and draught force data from the CAN-bus successfully. CAN-based measuring system is now being designed for the summer 2011.

ACKNOWLEDGEMENT: This study was made within the ENPOS-project (Energy Positive Farm) financed by the Central Baltic Interreg IV A programme 2007–2013.

REFERENCES

Ahokas, J & Mikkola, H. 1986. Factors influencing the fuel consumption of a tractor. (In Finnish). *Vakolan tutkimusselostus 43*.

Labeckas, G. & Slavinskas, S. 2006. The effect of rapeseed oil methyl ester on direct injection Diesel engine performance and exhaust emissions. *Energy Conversion and Management*, 47, 1954–1967.

Liljedahl, J., Turnquist, P., Smith, D. & Hoki, M. 1996. *Tractors and their power units*. ASAE Textbook No. 801P0196. 463 p.

Mikkola, H., Pahkala, K. & Ahokas, J. 2011. Energy consumption in barley and turnip rape cultivation for bioethanol and biodiesel (RME) production. *Biomass and bioenergy*, **35**, 505–515.

Mikkola, H. & Ahokas, J. 2009. Energy ratios in Finnish agricultural production. *Agricultural and food science*, **18**, 332–346.

Neunaber, M. & Wilmer, H. Tractor test: Massey Ferguson 8690 SCR. *Profi International* 2/2010, 12–17.

Schutte, B., Herrmann, L., Schreiber, M. & Kutzbach, H. D. 2004. Mapping fuel consumption. Landtechnik **59**, 152–153.