Sensors connection for yield determination on round balers with variable chamber

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Abstract

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The main aim of this article is to present a technical solution for straw and forage yield mapping when using round balers with variable chamber for harvest. The yield measurement is based on monitoring of instantaneous position of a tension roller mechanism for press chamber circular belt. Wheat straw was harvested – baled, during our trial measurements. The acreage of the trial field was 12 ha. Calibration of the measuring system showed a strong dependence of the tension roller position on the amount of pressed straw (R^2 = 0.99). Geostatistical evaluation confirms a spatial relationship of measured data sets with a moderate spatial dependence. Finally, yield map of straw was created.

Keywords: forage crops; straw; throughtput; yield; yield mapping; round baler

Yield mapping is one of the basic elements of precision agriculture system. Different sensors and systems which are mounted directly on harvesters are commonly used for yield mapping nowadays. Concretely for straw and forage yield mapping, the sensors are placed on mowing machines or forage choppers. Another possibility could be weighing of the whole harvester or transport machine such as pick-up balers or wagons. This idea is very simple but the practical application brings together technical and organisational problems. Wheeler et al. (1997) described basic yield measuring system requirements for crops yield mapping which was based on continuous weighing of wagons.

Goodwin et al. (1999) continued in this research which was based on continuous weighing of wagons together with GPS (Global Positioning System) – wagon position monitoring. Another idea for yield mapping during forage crops harvest is based on the similar principle but it is adapted for pick-up balers. Behme et al. (1997) and Wild and Aurenhammer (1997, 1999) developed this measuring system. The system was based on load measurement of the machine axle by means of strain gauges. The whole system could be completed with GPS receiver in order to create yield maps. Weighing during the time when the machine was stationary was very precise, but in the case of working and moving across a field, the

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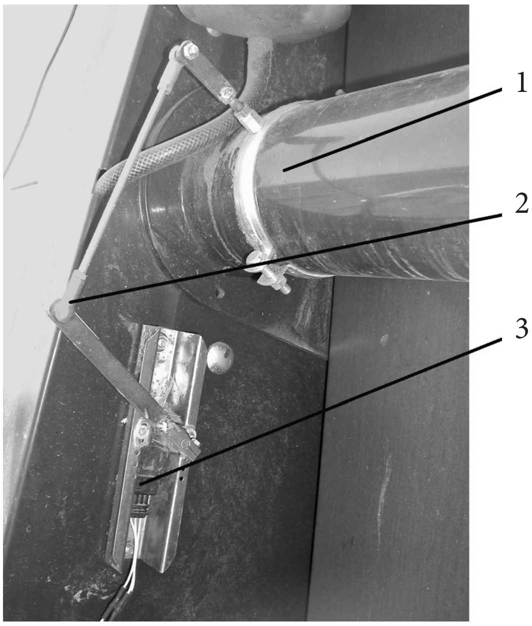

Fig. 1. Technical description of potentiometer position
1 – belt tension roller mechanism, 2 – connecting rod, 3 – potentiometer

system showed an error greater than 20%. Shocks and impulses caused by machine passing across terrain irregularities had a negative influence on the accuracy of the measurement.

The main aim of this article is to present a technical solution for straw and forage yield mapping when using round baler with variable chamber for harvest. The principle is based on monitoring of instantaneous position of tension roller in the press chamber.

MATERIAL AND METHODS

The technical solution for forage and straw yield measurement consists of a simple arrangement of a position sensor – potentiometer, connecting rod and connecting collar mounted on the belt tension roller on a chosen round pick-up baler with variable chamber. Rotary baler with variable chamber VICON RV1601 OPTICUT (Kverneland Group, Norway) was used for the experiments. Wheat straw was pressed during trial measurements. Position of the belt tension roller was monitored by the potentiometer. Potentiometer placement is shown in Fig. 1. Detailed description brings utility model No. CZ 19754 U1 (Kroulík et al. 2009).

A specially designed electrical circuit was connected with the potentiometer and DGPS receiver (Garmin GPS 18 PC). The data from the potentiometer and DGPS receiver were saved into a processing unit. Output signal from the potentiometer were pulses which were recorded each 2 s in our case.

Calibration procedure of the system was done in the following way. The discontinuous row (10 m straw row, 10 m break without straw) with several repetitions was created manually before the calibration of the system. Straw sections of this row were weighed first to obtain the real weight value and the precise position of each section was recorded by GPS receiver. Later on, the complete discontinuous row was pressed by the baler. The potentiometer pulses were recorded during baler work. The number of measured pulses corresponded with the position of measuring belt tension roller during the chamber filling.

From the obtained data sets it was possible to determine material throughput and finally create yield maps.

RESULTS AND DISCUSSION

Trial measurements were carried out in the selected field and started by pressing arranged discontinuous row as it was explained above. This step was taken as a calibration procedure. Calibration data were processed and put into a chart. Fig. 2 shows the course of the data record (number

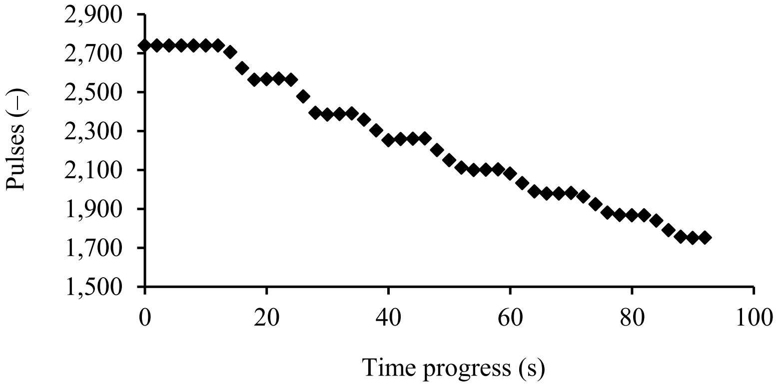

Fig. 2. Course of data record during discontinuous straw row pressing

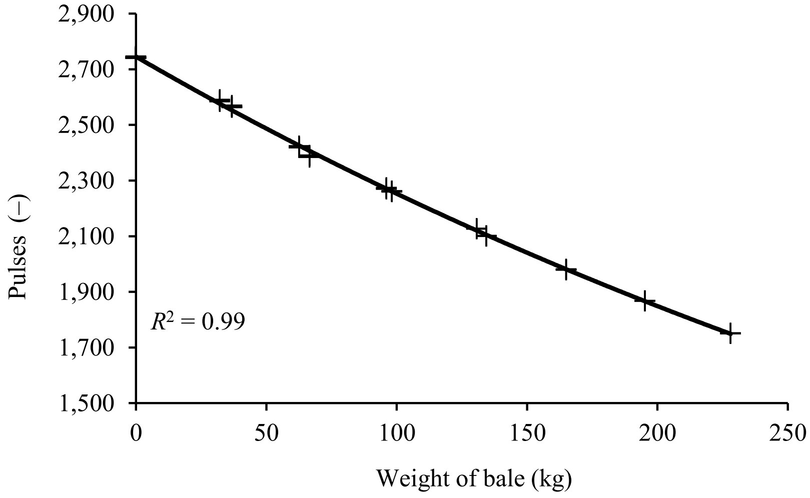

Fig. 3. Dependence of pulses count on weight increment of a bale

of potentiometer pulses) during the calibration. Regular change in pulses count was observed during additional material input – material rolling in a press chamber. It means, to be more precise, we observed a dependence of the sensor output signal on the size of a bale. Further, the recounting procedure was carried out from the bale size to the bale weight and thus it was possible to determine the calibration curve.

The dependence of the potentiometer pulses count on the bale weight increment was the best described by an exponential curve with the equation $y = 2{,}745 \times 1e^{-0.002x}$. The calibration curve course is shown in Fig. 3.

A balanced compression of bales was achieved during pressing and that is why the increase of the bale volume was clearly in correlation with its weight increment. As a result of this fact we reached a really good coefficient of determination $R^2 = 0.99$ for the calibration curve, it means the sensor output signal dependence on the bale weight. The part of data logging brings Fig. 4.

Small modifications were done with the initial data sets prior to their processing and evaluation. It means for example, that the values that did not describe precisely the factor measured were removed from the initial data set, e.g. errors possibly occurring on headland or when the belt tension-mechanism went back after discharge phase of the press chamber. Values larger than double of the average were also excluded from the initial data sets. The values obtained during wrapping phase were excluded as well. The last step was to count the real straw yield in t/ha. The range of yield values was from max 7.3 t/ha to min 1.5 t/ha. The average value of the yield was 4.4 t/ha.

Modified data were processed using geostatistical methods. Experimental variograms were calculated for all values. Spherical model with a residual variance (nugget) were used for interleaving the experimental variogram (Fig. 5). Creation of the model variogram was done on the basis of R-squared values. This coefficient evaluates the accuracy of a fitted model as the sum of residual squares RSS (Residual Sums of Squares). It is clear from Fig. 5 that it is possible to model the variograms for evaluated file and to calculate basic parameters of the variogram. These parameters are

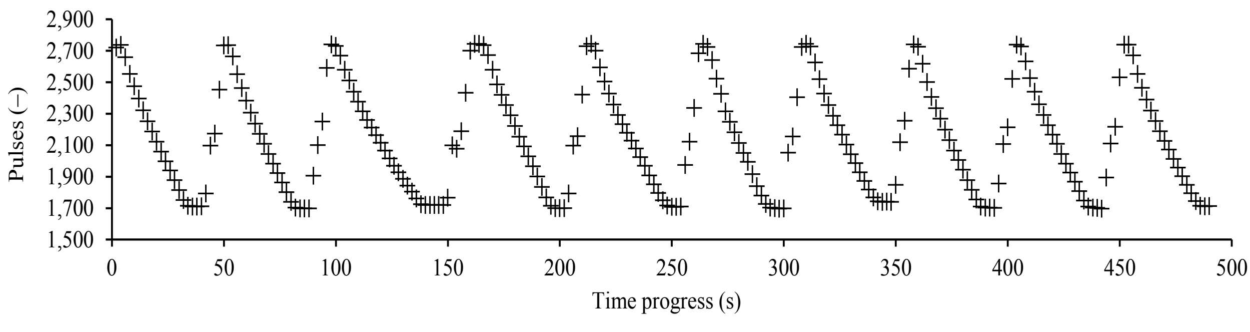

Fig. 4. Adapted measured values – number of pulses in time (during real harvest)

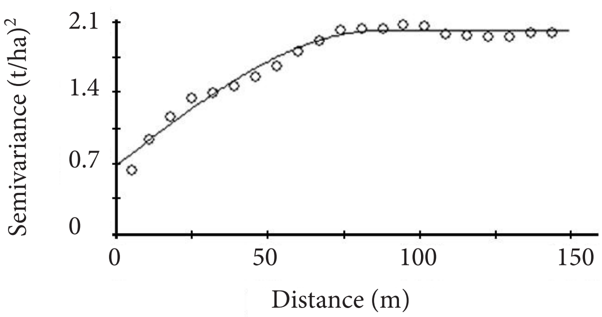

Fig. 5. Variogram of straw yield (t/ha)

Table 1. Parameters of the variogram model

Parameter	Straw yield
Nugget C_0	0.68
Sill $C_0 + C$	2.01
Range A_0 (m)	88.4
$(C_0/C_0 + C) \times 100$ (%)	34
Model	Spherical
R^2	0.98
RSS	0.08

RSS – Residual Sums of Squares

shown in Table 1. The value of spatial relationship is possible to calculate when dividing residual variance C_0 by total limit value ($C_0 + C$) and this parameter determines the strength of spatial dependence. In our case, $C_0/(C_0 + C)$ value ranges between 25% and 75% and then the spatial dependence is taken as the moderate one. It is possible to say that the spatial interrelationships exist according to variogram parameters and the distribution of yield values is not random in the selected field.

Graphical display of data distribution is expressed as yield maps. Straw yield map shown in Fig. 6 were created using the Kriging interpolation method. Validation of the model value or interpolation of data obtained is performed using the Cross-validation method. This method eliminates the original value and calculates a new value using the Kriging method for a particular point. The relevance of an estimate can also be identified by means of the correlation analysis between measured and estimated values. Coefficient of correlation R should be equal to 1 in an ideal case. Coefficient of correlation $R = 0.82$ was observed for our case. That is why we can say that the significance of variogram modeling for the subsequent interpolation was proved. Coefficients of correlation also approve the estimate accuracy obtained from the interpolation method.

Variability in crop yield is the basic source variable for the majority of operations and inputs to a field when using precision farming principles. In addition to this, the yield data provide initial information on the particular land intended to be a part of precision farming. Especially monitoring of grain yield is commonly used for this purpose nowadays. On the other hand, yield monitors are less used during forage crops harvest. Taking into account high acreage of forage crops generally, in relation to cereals acreage, yield monitoring of forage crops could be useful as well.

CONCLUSION

Position measurement of a belt tension roller on round pick-up balers with variable chamber could

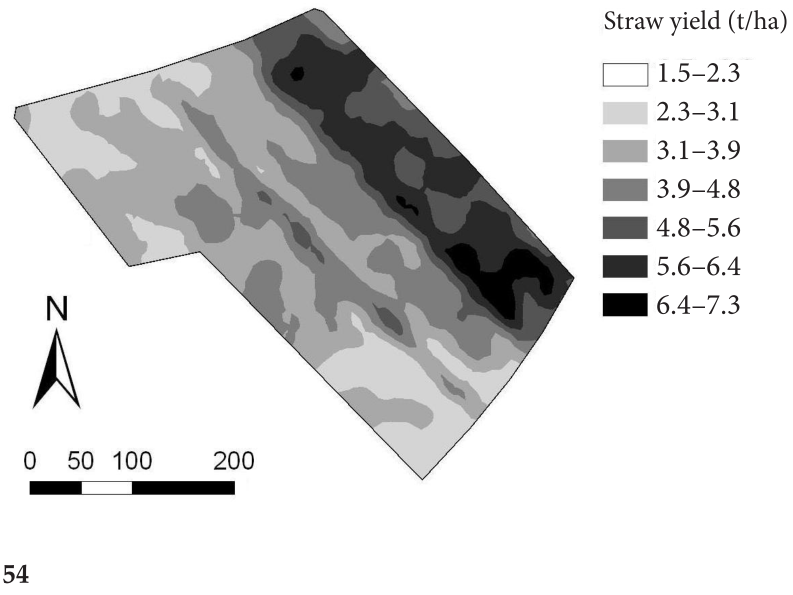

Fig. 6. Yield map of straw (t/ha)

be used for yield monitoring. Calibration of this system showed a strong dependence of the belt tension roller position on the amount of pressed straw. System design was very simple and was not sensitive to vibrations. On the other hand, the presented system is suitable only for one particular type of round bale machines – balers with variable chamber. Calibrations for different materials to be harvested are necessary as well.

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