Feed rate measurement technique and yield maps creating in fodder plant harvesting

P. Miklenda, F. Kumhála, V. Prošek

Department of Agricultural Machines, Technical Faculty, Czech University of Agriculture in Prague, Prague, Czech Republic

Abstract: The main aim of this article is to evaluate the possibility of forage yield maps creating based on mowing machine's conditioner power input measurement. Strong spatial dependence was observed for conditioner power input data. For the data file from material feed rate measurement the medium spatial dependence was calculated. Relatively low value of variograms range is possible to explain by the type of chosen exponential model. Visual displaying of data distribution is done by the maps. These maps were plotted under kriging method. It is possible to observe distributions of higher and smaller values of conditioner power input and material feed rate measurement by this way. Plotted maps are shown in Figures. The correlation coefficients were calculated 0.419 for filtered data. It follows from this evaluation that conditioner power input measurement can be used for the determination of mowing machine material feed rate.

Keywords: material feed rate; yield map; moving machine; conditioner; torque meter

A forage crop yield sensor can be useful in several applications of precision farming. Information about immediate yield of forage can support management decision with the aim of local field cultivation. Maybe the information about forage yield can be sometimes most accurate then information about yield of combinable crops.

Feed rate measurement techniques of forage harvesters are known and tested by different authors already. The feed rate measurement can be based on many different principles, for example harvester's blower or basics unit power input measurement (Vansichen & De Baerdemaeker 1993), distance between feeder rolls measurements (Auernhammer *et al.* 1994; Ehlert & Schmidt 1995; Martel & Savoie 1999; Schmittmann *et al.* 2001; Diekhans 2002), crop impact force in the spout measurement (Missotten *et al.* 1997; Martel & Savoie 1999; Schmittmann *et al.* 2001), crop layer thickness in the spout measurement (Schmittmann *et al.* 2001), electric capacitance in the spout measurement (Martel & Savoie 1999) etc.

Site specific measurement of biomass in growing crops is known as well (Ehlert *et al.* 2002). The principle of this measurement is based on moving pendulum.

Feed rate measurement technique for mowing machines is not so developed at this time. Demmel *et al.* (2002) used the principle based on the belt weighing technology for the measurement of the mowing machine material feed rate. This system is suitable for the mowing machines equipped with row conveyor.

The main aim of this article is to evaluate the possibility of forage yields maps creating based on mowing machine's conditioner power input measurement.

EQUIPMENT AND EXPERIMENTAL METHOD

A mowing machine ŽTR 216 H (Agrostroj Pelhřimov, Co., Czech Republic) was used for the measurements. This machine consists of two working drums and a finger conditioner. Working width of the machine is 2.15 m. The mowing machine was equipped with an electronic measuring unit developed in our laboratory. The mowing machine conditioner shaft was supplied with a torque-meter based on resistant strain gauges and with a RPM optical sensor measuring number of conditioner shaft revolutions.

Beside the torque-meter the mowing machine was equipped with DGPS receiver and front wheel

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 604607905.

PTO counter. Signals about the position of mowing machine from DGPS receiver and signals from torque and optical PTO sensors were recorded every five seconds. All signals were processed in one chip microcomputer ATMEL 89C2051. Data from microcomputer were transferred into a notebook by communication port RS 232. The average values of torque sensors and PTO of conditioner shaft were saved into a computer file every five seconds. That is why was later possible to calculate conditioner power input and working speed of the machine. Electronic equipment used for these measurements enabled to calculate machine location and corresponding condition power input.

Every moment of DGPS signal interception was marked on harvested row by card. Every section of harvested row between cards was manually weighted after each overpass of the machine. It was assured that the data obtained from electronic measurement unit corresponds to the data obtained by weighting. It was possible to evaluate the dependence of conditioner's power input on material feed rate later.

RESULTS AND DISCUSSION

As it was discussed above the data obtained from electronic measured unit are corresponding with the data obtained by weighting. These data are comparable in that case. Statistical treatment of obtained data was performed using MS Excel and Statgraphic for Windows. Geostatistical analyses were conducted using ArcGIS 8, Geostatistical Analyst and GS++, version 5.1.1.

The field with about 0.34 ha acreage was harvested during our measurements. The number of achieved data allowed using geostatistical data analysis procedure for data evaluation. The overview of statistical indicators concerning to power input and feed rate values is given in Table 1.

It is possible to derive from maximum and minimum values as well as from the variation coefficient value that the variability of tested files is relatively high in both cases. According to skew value it is possible to decide if the measured data are from normal distribution or not. Because the skew values are between –2 and 1 in both cases it is possible to presume that measured data comes from normal distribution. It is not necessary to use any type of data transformation in this case.

Frequency histograms of evaluated files are shown on Figure 1. The smallest values only were removed from measured data (start and end of working trip). The removing of these data was done by the cutting of the frequency histogram edges. The values twice exceeding the average mean value were removed as well for each file.

Next adjustment overlaid on time smoothing of measured data. According Hayhoe *et al.* (2002) the recording of measured data oscillates around the curve. The same oscillation of measured data was observed during the conditioner power input and material feed rate measurement on tested field.

The method of simple moving average was used for data smoothing. Simple moving average is arithmetic average calculated from previous measured data of time series.

Table 1. Summary statistic of the variables

	Conditioner power input (kW)	Material feed rate (kg/s)
Mean value	4.44	4.21
Median	4.36	4.20
Standard deviation	1.39	1.43
CV (%)	31.39	34.07
Sample variance	1.95	2.06
Sharpness	–0.15	–0.42
Skew	–0.15	0.25
Difference max.–min.	7.57	7.14
Minimum	0.19	1.14
Maximum	7.76	8.28
Number of logging	282	282

CV (%) – coefficient of variation

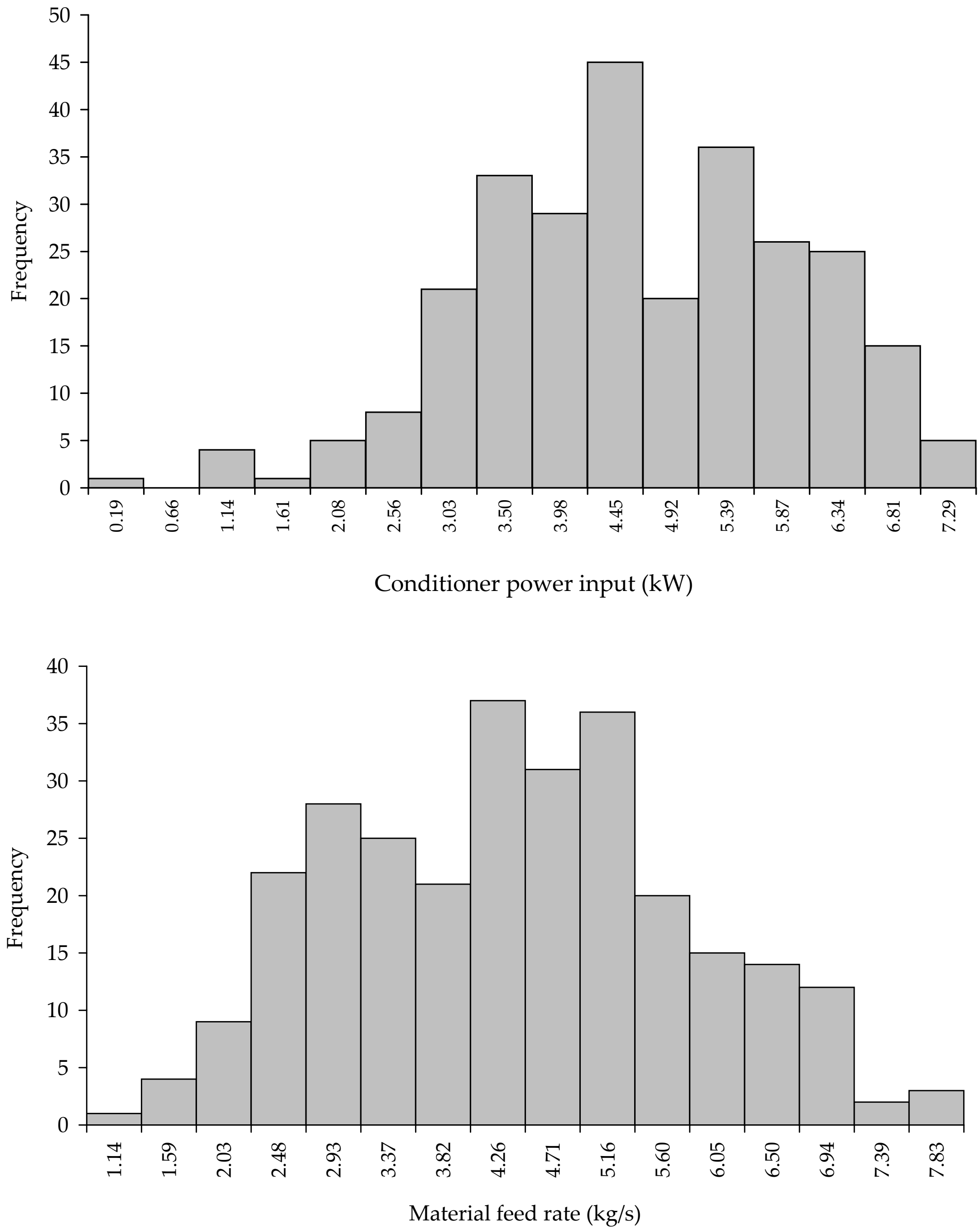

Figure 1. Histograms of the variables

The transformation of data was calculated following formula:

$$\hat{Y}_t = \frac{1}{5}\left(Y_{t-2} + Y_{t-1} + Y_t + Y_{t+1} + Y_{t+2}\right)$$

where:

Y – origin values in t time point

The smoothing of measured values is done by average from four neighbour values calculation. The smoothing in $t + 1$ time point is done by the same procedure.

Smoothed data were used for space relation evaluation of measured data. In Table 2 is calculated correlation coefficient evaluating the dependence of conditioner power input on material feed rate on 99% confidence level.

Space relationships between measures files were studied by means of variogram constructions and variogram parameters evaluation. Experimental variograms were built for all measured values. Calculated experimental variogram was substituted by

Table 2. The correlation matrix of filtered data

Variable	Material feed rate (kg/s)
Conditioner power input (kW)	0.419*

*significant dependence on the 99% confidence level

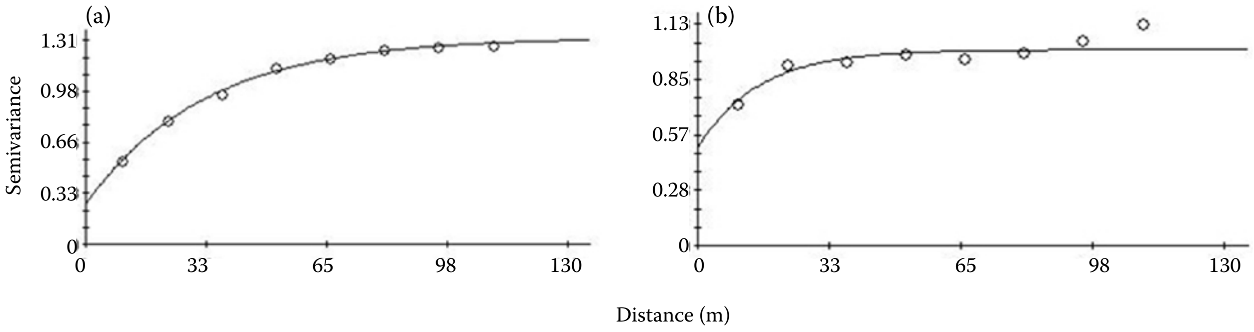

Figure 2. Variograms of (a) conditioner power input (kW) and (b) material feed rate (kg/s) (values standardized to zero mean and unit variance)

model variogram in next step. The creation of model variogram was done on the basis of R-squared values. This coefficient evaluates the accuracy of fitted model such as the sum of residual squares RSS (Residual Sums of Squares). For variogram modelling the data transformation by using simple moving average seemed to be very important. The variograms for both measured files on Figure 2.

It is clear from that figure that it was possible to model the variograms for both evaluated files and to calculate basic parameters of variograms. These parameters are shown in Table 3.

The exponential variogram model with residual variance was used in both cases. It is possible to derive from the values of R-Square and RSS that model variogram was well chosen. Smaller R-Squared value for the file from material feed rate measurement is possible to explain by iterative increase of the semi variance after acquiring first limit (see Figure 2). The area of tested field as well as the borders of that

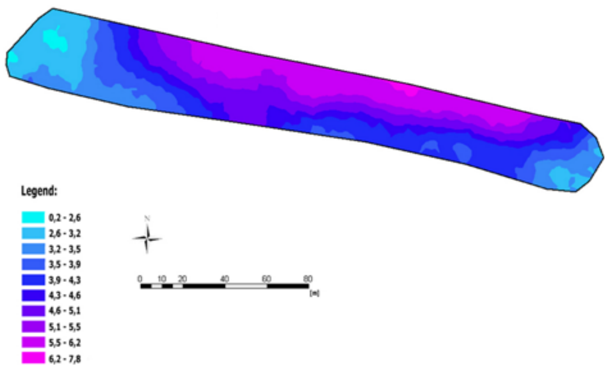

Figure 3. Map of kriged estimates of conditioner power input (kW) (values standardized to zero mean and unit of variance)

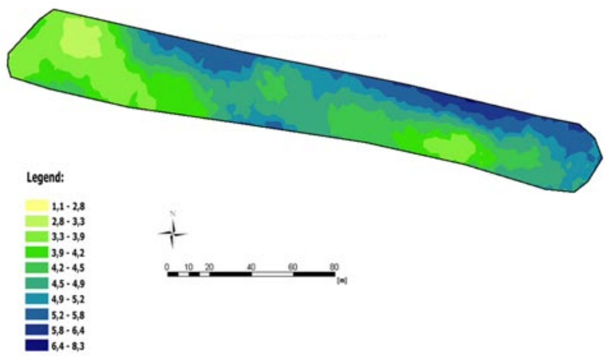

Figure 4. Map of kriged estimates of material feed rate (kg/s) (values standardized to zero mean and unit of variance)

Table 3. Parameters of the variogram models

Variable/Parameter	Conditioner power input (kW)	Material feed rate (kg/s)
Nugget C_0	0.262	0.50
Sill C_0+C	1.33	1.00
Range A_0 (m)	32.1	15.0
$C_0/(C_0+C)$	0.19	0.50
R^2	0.99	0.79
RSS	0.001	0.02
Model	exponential	exponential

field did not allow observing variogram for longer destinations. Nevertheless this was not the aim of our research.

The value of spatial relation is possible to calculate dividing residual variance C_0 by total limit value ($C_0 + C$). It is possible to divide space relations to following groups. If $C_0/(C_0 + C)$ is ≤ 25% it is to possible to use term strong spatial dependence. If $C_0/(C_0 + C)$ value range between 25% and 75% the spatial dependence is medium and if $C_0/(C_0 + C)$ is ≥ 75% the tested data are spatially independent. If the result from that formula is equal to 100% the pure nugget term is used.

According to Table 3 strong spatial dependence was observed for conditioner power input data. For the data file from material feed rate measurement the medium spatial dependence was calculated. Relatively low value of variograms range is possible to explain by the type of chosen exponential model. Visual displaying of data distribution is done by the maps. These maps were plotted under kriging method. It is possible to observe distributions of higher and smaller values of conditioner power input and material feed rate measurement by this way. Plotted maps are shown in Figure 3 and 4.

CONCLUSIONS

It can be derived from carried out measurements and evaluation that between the data from conditioner power input measurement and the data from mowing machine material feed rate measurement exists statistically significant dependence on 99% confidence level. The correlation coefficients were calculated 0.419 for filtered data. It follows from this evaluation that conditioner power input measurement can be used for the determination of mowing machine material feed rate.

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Received for publication April 11, 2006
Accepted June 6, 2006

Abstrakt

Miklenda P., Kumhála F., Prošek V. (2006): **Technika měření průchodnosti žacích strojů a tvorba výnosových map při sklizni pícnin**. Res. Agr. Eng., **52**: 123–128.

Cílem práce bylo vyvinout a ověřit funkčnost čidla použitelného pro sledování okamžitého výnosu pícnin při jejich sklizni rotačním žacím strojem. S využitím poznatků v publikovaných literárních pramenech byla navržena a vyvinuta metoda měření okamžité průchodnosti materiálu rotačním žacím strojem, která je založena na principu měření okamžitého příkonu čechrače rotačního žacího stroje pomocí torzního kardanového dynamometru. Na základě dosažených výsledků lze konstatovat, že metoda měření průchodnosti materiálu rotačním žacím strojem, založená na principu sledování příkonu čechrače pomocí torzního kardanového dynamometru, je po kalibraci dostatečně přesná pro potřeby tvorby výnosových map. Rovněž skutečnost, že pomocí tohoto principu měření lze rozlišit

průchodnost 0,5 kg/s, hovoří ve prospěch této úvahy. Např. SCHMITTMANN a kol. (2001) při měření průchodnosti materiálu sklízecí řezačkou dosahovali podobných koeficientů determinace a rozlišovaná průchodnost byla 2 kg/s. Úspěch této metody však nezáleží pouze na získání naměřených hodnot a podkladových souborů dat pro další výstupy, ale také na tom, jak dobře a jak rychle budou vytvořeny poznatky potřebné k agronomickému využívání nových technologií. Geografické informační systémy jsou pak důležitým nástrojem pro zpracování a prezentaci takto získaných prostorových dat.

Klíčová slova: průchodnost materiálu; výnosové mapy; žací stroj; čechrač; torzní kardanový dynamometr

Corresponding author:

Ing. PETR MIKLENDA, Ph.D., Česká pojišťovna, a. s., Hráského 2231, 149 00 Praha 4, Česká republika
tel.: + 420 224 553 862; fax: + 420 224 551 723, e-mail: pmiklenda@cpoj.cz, miklenda@chello.cz