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Geo-coded Measurements of Draught Force during Tillage

Soil parameter variability is the main reason for introducing site specific farming. One method of attaining information about this variability is the continuous measurement of draught forces during conventional tillage. In this paper draught force maps of various fields were drawn during cultivating and ploughing. These maps are used to determine the influence of different process-related and location-related parameters on the variation of draught force.

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The studies were supported by the companies of John Deere and Lemken.

Keywords

Tillage, draught force mapping, precision agriculture, soil characteristics

Common methods to obtain information about the variability of soils are soil sampling, the use of existing soil maps, interpretation of yield maps or other existing field maps. One approach to obtain this information during normal tillage operations is the mapping of draught forces. The required draught force for tillage implements is related to process-related parameters like kind of used implement, working width, working depth and working speed. A second area of influencing parameters are the location-related factors. The most important of these factors are type of soil, soil density, soil moisture and the topography of the field. In research it could be proved, that the location-related parameters have got a significant influence on draught forces and that this influence can be shown in draught force maps. These results were obtained with experimental force-measuring devices as well as with the commercial draught force sensors in tractors [2]. These sensors are usually used for the electronic hitch control.

In this work at the University of Hohenheim draught forces and the accompanying important parameters were measured on different fields over several years. The results are used to standardise measured draught forces within fields and between different fields and conditions. Furthermore a second low-cost measuring system was tested which is more practically orientated. This second measuring system uses the signals of the standard fitted hitch control draught sensors and is equipped with an own GPS-Receiver and antenna. The low-cost system should help to determine the practicability of draught force mapping in agricultural practice.

Draught force mapping and methods

The draught force mapping on a high accuracy level is done with a six-component draught measurement frame which is integrated between tractor and tillage implement. Forces and torques within this frame are measured with load cells in three directions with a maximum load of 100 kN. In addition the values of the standard fitted draught sensor in the lower links are recorded. For positioning a real time kinematic GPS (RTK-GPS) receiver with a high positioning accuracy and own reference station is used (*Fig. 1*).

Hitch position, engine speed, wheel speed and transmission rate are received from the

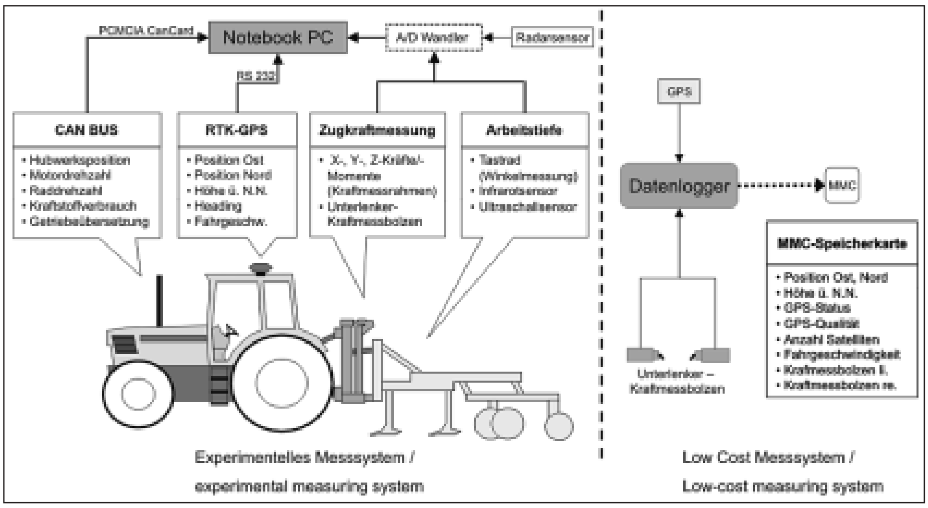

Fig. 1.: Simultaneously used measurement systems for draught force mapping

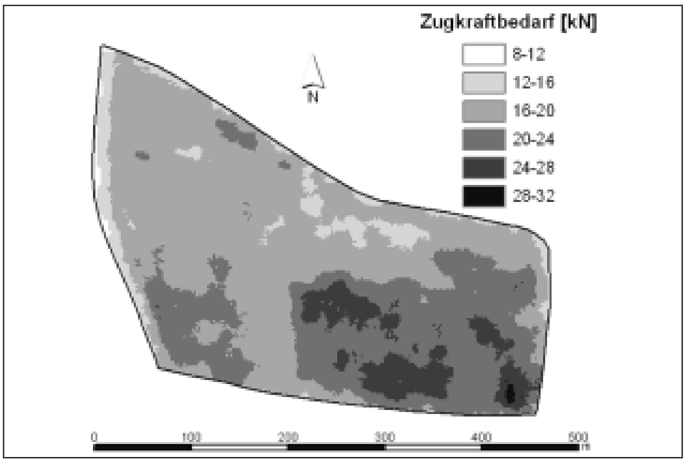

Fig. 2. Draught force map for the plot „Lammwirt" (11.0 ha), 1. 8. 2003

tractor CAN-Bus system without additional sensors. Also the fuel consumption in litre per hour is available on the CAN-Bus. This information is used instead of a complicated and very cost extensive fuel consumption measuring system. The real forward speed is measured with the RTK-GPS as well as with a tractor-mounted radar-sensor. For analogue-digital conversion an external A/D-converter is used while the measured signals are visualised and stored on a Laptop-PC. A second independent measuring system is based on a data logger that records the signals of the lower link sensors and the actual position via GPS. The GPS-data and the sensor values are stored in ASCII-format on an MMC-memory card. This card format can be read with a standard PC. Variations in the working depth have a strong influence on the draft force for tillage implements. To measure the working depth a cultivator was equipped with different sensors for online-measurement of working depth (depth wheel with potentiometer, infrared sensor, ultrasonic sensor). The sensor values of the hitch position were also used to allow a comparison between these different sensing principles for the working depth.

Several draught force mappings were executed on the research farms of the University of Hohenheim on several fields at approximately 80 ha in 1999 [3, 4] and 2003 after cereals, rape and pulse crops. Most of these experiments were carried out with a mounted cultivator (Lemken Smaragd 9/300) and a reversible four-furrow plough with hydraulic working width adjustment (Lemken VariOpal 7). A tractor John Deere 6620 with an engine power of 92 kW was used for the measurements with these implements.

From the continuously stored data of the draught force measurements, turns on the headland were filtered out in the data processing by the help of the hitch position. Using the heading-information of the GPS the difference between the position of GPS-antenna and implement is corrected in the data. Measured data was averaged over 10 values to reduce the amount of data. For averaging the sensor values, the arithmetical mean was calculated while for the position data the median of ten values was used to avoid errors in the position calculation because of averaging. The difference between averaging the positioning data with the median or the arithmetical mean is very obvious when driving bends or turns. Visualisation in maps and further geostatistical processing of the data is done with the GIS program Arc View.

Results

The map of draught force of a mounted cultivator with 3 m working width in the second stubble tillage after the pre-crop oats with an average working depth of 14 cm is shown in *Figure 2*. The working depth was relatively constant because the implement was depth-controlled through the attached tandem-roller and the average working speed was 8,9 km/h. The raster image was produced by using a kriging method for the draught force values of the draught measurement frame. Large- and small-scaled variations in draught are visible for the field "Lammwirt" in high spatial resolution. These results were also achieved on other fields and with different tillage operations. If regions of equal draft within a field are related to soil, the problem occurs that soil maps are often only available with a lower spatial resolution than the maps of draught force. Areas of different soil types for the Field "Lammwirt" have the similar extent than the regions of equal draught in this map. Nevertheless for a quantification of this relationship between draught and type of soil (clay content) an increase in the resolution of the soil maps is necessary [5]. Because of this, mappings of soil electric conductivity (ECa) will be carried out in 2004.

With the depth wheel and the hitch position sensors, a good resolution of the working depth measurement could be achieved. The sensors without mechanical contact to the soil surface (ultrasonic, infrared) measured the distance, because of variations in height of stubbles of the pre-crop was not very precise. Furthermore in the experimental measuring system a good correlation between measured draught with the draught measurement frame and the commercial sensors in the lower links could be observed. However, in some driving lanes existed differences between both sensor signals that have to be explained. Models for the prediction of draught force from the literature in combination with the results of these experiments should help to carry out a standardisation of draught force maps in the further work.

Literature

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