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Using draught and torque measurements for soil mapping

For site-specific fertilising and cultivations, and for more information in computer-supported farming knowledge of spatial distribution of soil properties is required. Normal methods such as soil sampling are very expensive and require a lot of time. For this reason Hohenheim has mapped differences in soil through measuring draught and torque forces required during cultivations By linking this with the precise positioning of a RTK (Real Time Kinematics) GPS receiver, the production of draught and torque maps reflecting distribution of soil parameters over the respective areas is possible.

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Keywords

Soil mapping, draught force measurement, GPS, GIS, tillage

Literature details are available from the publishers under LT 01103 or via Internet at http://www.landwirtschaftsverlag.com/landtech/local/fliteratur.htm

Computer-support in agriculture is becoming increasing important for the sector. The development of site-specific methods of recording crop yields, weed populations, soil fertility and ground characteristics has strongly increased in recent years. For site specific working operations such as fertilising, cultivations or sowing it is important to know the exact spatial distribution of soil properties. Soil sampling is a standard method for obtaining information about the distribution of nutrients and soil characteristics within cultivated areas. However, the required investment in time and money means that only a wide gridding of sampling can be achieved. For this reason it is necessary to develop a sampling method for ground properties that enables an economical and dependable, as well as time-saving, overall sampling [1 to 7].

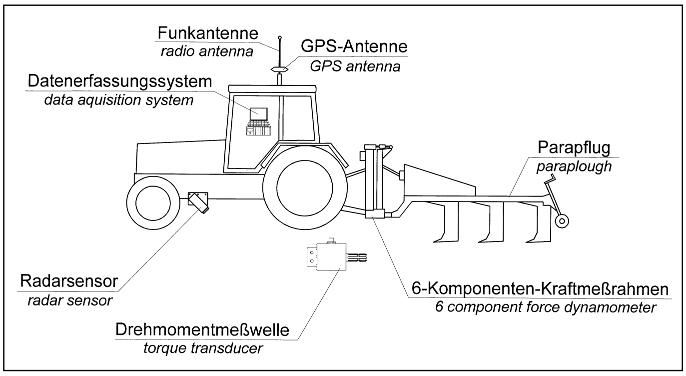

Fig. 1: Experimental design for draught force and torque mapping

Experiment structure

At the Institute for Agricultural Engineering, Hohenheim University, a method was investigated for measuring draught requirements between tractor and cultivating implement and pto torque requirements during powered cultivations. From the data thus collected conclusions were drawn regarding soil properties. The experimental structure comprised a force and torque measurement system between tractor and attached cultivation implements, extended through a position and speed recording capability. The main elements of the measurement instruments comprise a 6-component force measurement frame, a torque measurement shaft, a RTK GPS unit and a data recording system (*fig. 1*).

The 6-component force measurement frames were fitted between tractor and cultivation implement. This comprised two frame elements linked to each other through six force-measurement connectors. Three recorders collect the longitudinal forces, two the vertical and one recorder the lateral force. Maximum loading of the individual measurement connectors equalled 100 kN, so that the measurement capacity was sufficient for all soil cultivation procedures including ploughing and deep-loosening.

For power cultivation implements, a torque measurement shaft was also used. This had a measurement capacity of 4 kNm maximum. This is sufficient for normal working depths with working widths of three metres in medium-heavy soil. The measured forces, torque and pto speed were transferred to a notebook PC over a measurement amplifier. The data was stored in the PC.

The actual position of the measuring equipment is assessed by very accurate RTK GPS. With the help of a reference station and carrier wavelength analysis the position of the measuring vehicle could be determined within a few centimetres. Speed was measured by radar sensor. Both information areas – position and speed – were recorded by the notebook along with force and torque data. Measurement rate for all recorded values was 5 Hz.

The GPS antennae was mounted on the tractor cabin roof. For the measurement of forces and moments at the working implements, position data in longitudinal and vertical directions had to be processed as ap-

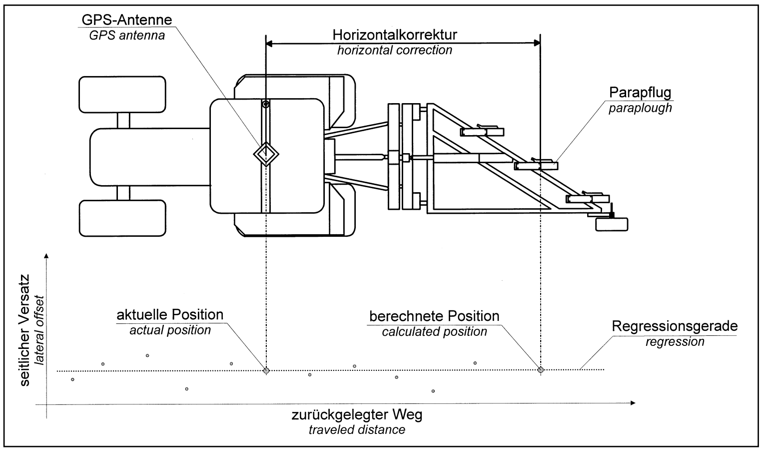

Fig. 2: Determination of real implement position

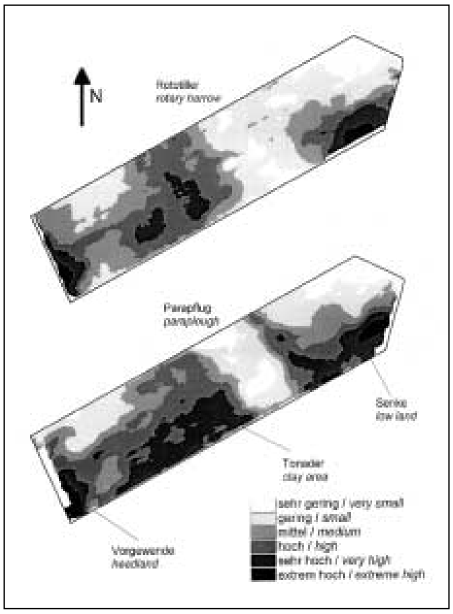

Fig. 4: Maps of draught force for tillage with rotary harrow and paraplough

propriate after the field investigation (post processing). For this purpose, with regard to direction of travel and a pre-established correction amount (*fig. 2*), the actual position was calculated with the help a of regression straight-line through the five most-recently measured and five next positions. The measured topographical altitude was reduced to the height of the antennae (GPS) above the field surface. To even out false information caused by machinery vibration and other interference, the average values according to the speed of travel over five to 10 measurements were calculated. A GIS software was used for graphic presentation of the data.

Results and discussion

Many different parameters have influence of the forces and moments during soil cultivation. On one hand, the implements themselves, on the other also working depth, working width, operational speed and naturally different soil parameters such as type of soil, moisture content and degree of compaction.

Many trials were carried out at the Hohenheim University station. The area of the field involved was around 3 ha. Seasonal operations carried out for the investigations were stubble cultivations with winged share grubber, rototiller and disc harrows as well as deep soil loosening with a Paraplough.

Figure 3 indicates the development of draught and vertical forces and torque for a stubble cultivation bout with the rototiller after harvested peas. Over a wide sector, the three curves have a similar form. Within the individual curve lines there are differences in the respective force and torque requirements to be seen. Very large variations are evident at the beginning and end of the curves which are related in the main to soil compaction, uneven field surfaces and irregular driving speeds. The difference in the forms of the curves in total were caused by the differences in type of soil, soil compaction and wet zones.

Further trials have shown that the use of draught power delivers the best results. In *figure 4* two draught maps are presented for the same strip of field. The upper map shows the distribution of draught forces measured with the rototiller whilst the lower indicates the same forces required during deep loosening of soil with the Paraplough (three months later).

Both maps show the same spatial distribution of draught force requirements. Identifiable differences between the maps are associated with different working depths for the two implements. Intense compaction can be identified on the field headlands caused through turning manoeuvres. To the west of the strip middle a seam of clay across the trial field. In this area, too, a higher draught requirement is noticeable. A topographical hollow lies in the south east corner of the field where, because of lying floodwater, more intense compaction had occurred and higher draught forces were required.

The results presented here support the possible mapping of force and torque moment differences during soil cultivation. The data thus collected can be processed and interpreted in many ways. There are, however, many factors of influence acting upon the measured data which make more difficult a precise specification of the reasons for the different forces and moments. These include surface unevenness, the influence of operational speed, uneven working depths, soil moisture, oscillations within the total measurement equipment, as well as vibrations caused by the implements.

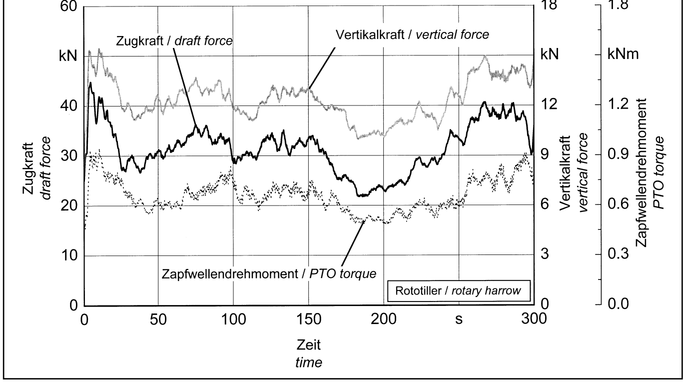

Fig. 3: Draught force, vertical force and torque vs. time for one pass

Outlook

With the measurement equipment presented here it is possible to record forces and torque moments directly during soil cultivations and through this, in combination with highly accurate positioning data from an RTK GPS unit, to map the spatial distribution of such force and torque moment values. These maps reflect the spatial variations of soil properties. Such a mapping method must, however, take account of a large number of influencing factors which have to be considered in future developments so that the recorded values can be standardised. In order to reduce the cost of the procedure, and to simplify the system, it will be necessary to use the integrated draught force sensors (EHR) and CAN-Bus facilities which are already available in tractors nowadays.

Literature

[1] *Paul, W.*: Zugkraftmessung zur Teilschlagkartierung. Landtechnik 47 (1992), H. 2, S. 490-491
[2] *Van Bergeijk, J.*: Soil tillage resistance as tool to map soil type differences. Third International Conference on Precision Agriculture, Minesota USA (1996), conference proceedings, pp. 605-616
[3] *Domsch, H.* and *R. Kuhn*: Use of GPS to determine field loading by transport vehicles. Proceedings of EurAgEng International Workshop Agricultural Transport 1999, Universität Gießen, pp. 39-49
[4] *Weißbach, M.*: Flächenbonitur mit dem Horizontalpenetrometer. Landtechnik 53 (1998), H. 2, S. 68-69
[5] *Stewart, C.*: Soil mapping using conductivity measurement. Leading Edge 2 (1998), H. 2, pp. 18-20
[6] *Banton, O., M.-K. Seguin* and *M.-A. Cimon*: Mapping Field-Scale Physical Properties of Soil with Electrical Resistivity. Soil Sci. Soc. Am J. 61 (1997), pp. 1010-1017
[7] *Mönnicke, S.* und *G. Bernhardt*: Sensoren zur teilflächenspezifischen Messung der Feuchte im Boden. Tagung Landtechnik 1998, VDI-Verlag, S. 235-240