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Spatially-specific yield measurement with sugar beet

Precision farming with based on factorial differences of small field areas requires spatial yield mapping. Direct and indirect throughput recording systems for beet harvesters were investigated for construction and recording efficiency. An indirect method based on volume flow measurement with laser scan profilometer applied for site specific yield mapping was used in practical farm application. Following error analyses and practical trials this is suitable for yield mapping. On field areas of 467 m² over a trial area of 3.18 ha the yield varied between 54 and 97 t/ha.

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An environmentally-supportable and sustainable high standard of sugar beet production with increasing exploitation of yield potential and simultaneous protection of biotic and abiotic soil potential must take account of the factorial differences such as topography, regional weather, soil type and fertility and, with those, the influence of the location, technology and farm inputs on yield creation and quality.

In economical terms the target tends to concentrate in decreasing production costs, reducing losses and increasing quality. Here, however, the efficiency level and direction of the individual factors must be related to area, e.g. known for a particular strip or field portion. The size of the portion is according to the differences on the strip or the size of the strip.

Typical examples of precision farming are the optimised and therefore spatially-specific application of mineral fertiliser and plant protection sprays. Requirement for applying this form of farming is the measurability of the influencing factors, e.g. the spatial yield potential and the availability of cost efficient reliable measurement systems and sensor technology, as well as knowledge of the associated functions cause and effect , e.g., in form of prognosis models for yield, plant nutrition availability and the development of damage-causing organism populations.

One of the most important measurement tasks is thus site-specific yield mapping. For this, the crop throughflow of the beet harvester in real time must be linked with location (GPS geo-reference) and produced as information data (field map, GIS).

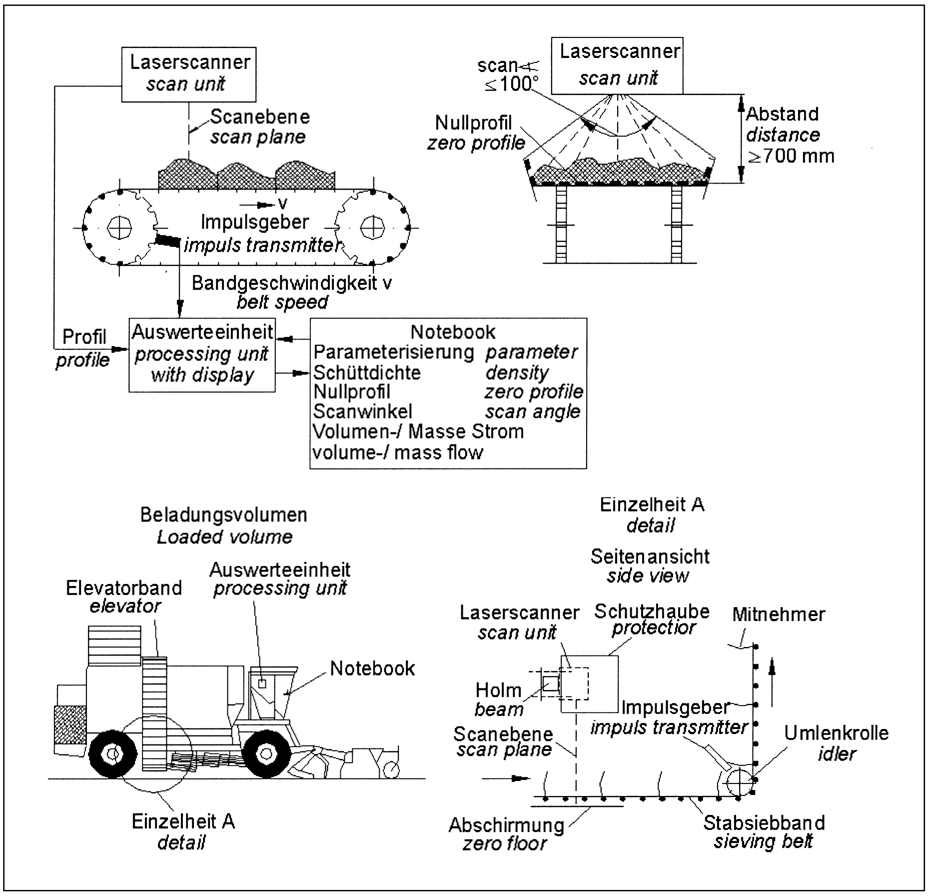

Fig. 1: Scheme of the volume-flow measuring device

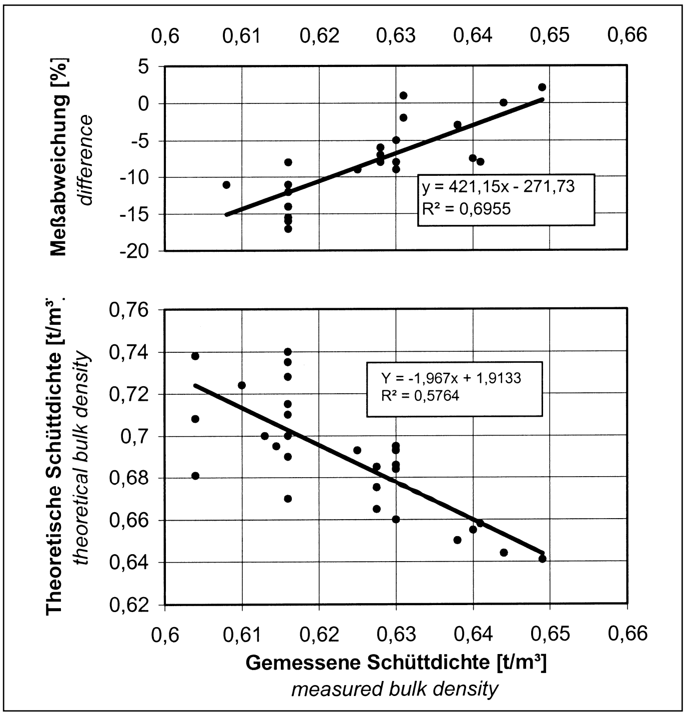

Fig. 2: Measurement difference vs. bulk density and regression (measured and theoretical bulk density)

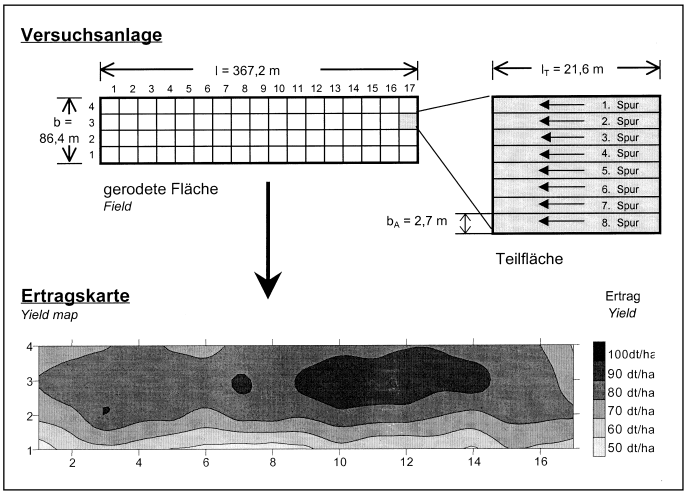

Fig. 3: Trail and site specific yield

Functional requirements and conception

According to construction-methodical procedure, a requirement list was created with function, working, interface, and other requirements and these classified according to already established or desired priority. Regarded as biotechnological requirement is a yield of 30 to 75 t/ha pure beets and thus 1.4 to 3.5 kg/running m and row. With a soil tare of 5 to 20% and lifting speed of 4.5 to 8 km/h the calculated throughflow was 8 kg/s and row.

- Material flow as time-integral of specific gravity

$$\dot{m} = \frac{dm}{dt} = \frac{dV}{dt} \cdot \varsigma = \frac{dA}{dt} \cdot v \cdot \varsigma \quad \varsigma = const.$$

with ζ = bulk density; v = flow speed; A = material flow cross section

- Material flow as time-integral of impulse forces

$$\dot{m} = \frac{d}{dt} \sum m_i = \frac{1}{v_2 - v_1} \sum dF_i$$

with m_i = impulse mass; v_2 - v_1 = velocity difference; F_1 = impact impulse

- Material flow as algorithm of biotechnological parameters or energy requirement

$\dot{m} = f(d_{max})$ $\quad$ $\dot{m} = f(M_d)$

with d_{max}= maximum root diameter; M_d = drive moment of the conveying element.

For the measurement in real time of the harvester-related material flow the difference must be determined between *direct measurement procedure* (the immediate relationship of material flow and physical parameters such as weight, power impulse, remaining energy), and *indirect measurement procedures* (linking functions of mass flow and biotechnological and physical-technical parameters, e.g., volume flow • bulk density).

From a calculation point of view, the four direct measurement procedures – conveyor belt weigher (66.7%), impulse belt weigher (44.4%), deflection plate (47.2%) radiation absorption (58.3%) – and the four indirect measurement procedures – profile mechanical (25%), profile laser impulse running time/laser scan (91.7%), profile pulse radar (83.3%), profile ultrasonic (80.6%) – were compared with the values given in ( ). For the measurement-technical realisation the laser impulse time system (bulk scan system Sick LMS 210) was thus chosen (*fig. 1*). Given as distance measurement precision was ± 50 mm in the range from 0.7 to 30 m with a radial vision of 100° and a light pulse gap of 0.25°. As a result of the profile classification in 50 mm gaps, a systematic measurement uncertainty of 7.14% resulted.

Trail method

The measurement system was tested in a beet cleaner/loader with test parameters measurement deviation, soil tare, load measurement and bulk density.

Mobile testing of the system took place in a commercially available 6-row harvester bunker (*fig. 2*) with the test parameters spatially-based harvested material weight, bulk density, soil tare and speed of travel. The test facilities in long strips enabled the spatially-specific harvesting of 467 m² (*fig. 3*).

Trial results

In the stationary trial no association was found in the investigation of the parameter influences between on the measurement deviations of load measurement and the soil tare. The bulk density was negatively correlated and the error therefore increased with increasing bulk density (B=69.6%). For the actual value, a theoretical bulk density was calculated and compared with the bulk density determined in a sample container (1m³), whereby a relationship with a coefficient of determination of B=57% existed. The observed error forced a review of the different porosity for shaken and unshaken bodies. The correction of the systematic error based on the difference in bulk density gave a cleaned measurement error of 1 to 4%.

The results of the mobile test indicated in the same way a negative measurement deviation by only a limited scatter of 1.158, according to this relative yield differences were able to be reliably measured. A dependency of measurement deviation on load measurement, travelling speed and bulk density could not be established reliably because of the limited number of repetitions. A correction of bulk density because of the results of the stationary trials reduced the measurement error to 1% so that the measurement results could be used in mapping actual yields (fig. 3). According to these, the yield varied on field parts from 21.6•21.6 = 467 m² of a strip of 3.18 ha between 54 and 97 t/ha. The results comply with those of English trial results whereby in field sizes of over 7 ha yield variations of over 100% appeared. The association of volume flow measurement system, harvester information system and GIS produced a site-specific yield mapping system suitable for computer-supported farm management.