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Soil under Pressure

Lowered Tyre Inflation Pressure Constrains Soil Load

In the interest of agriculture and to fulfil legal requirements, land cultivation in farming must be precautionary and protective. According to § 17 of the Federal Soil Conservation Law (BBodschG), maintaining the productive functions (crop yield; costs), the regulative functions (gas exchange, infiltration) and soil habitat functions (soil organisms) are the basis of the best practice management. Hence soil compaction, especially in the subsoil, must be prevented. Three differing concepts for quantitative action recommended are discussed.

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Keywords

Soil compaction, soil protection, tyre inflation pressure

Literature

Literature references can be called up under LT 05318 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

The capacity of tractors, harvesters and transport vehicles has increased and brings advantages: saving of time and costs, and using machines with regard of soil protection, as well. On the other hand the wheel loads of today's machinery impose higher risks in deeper soil horizons, when wheeling takes place under wet soil conditions.

The task is to provide indicators in order to improve the effectiveness of prevention measures against soil compaction [4].

Against this background three concepts are under discussion, which are partly put in concrete terms:

- wheel load limitation according to the concept of pre-consolidation stress
- wheel load controlled by degressive ground pressure
- limiting the load at the soil surface by using guidelines for tyre inflation pressure

Fundamental relations between soil functions and wheel load

The fundamental relations between the essential soil functions and the variables "soil pressure", "ground pressure", "tyre inflation pressure" and "maximum allowable wheel load" are shown in a nomogram (*Fig. 1*).

The quadrant A shows root growth (as part of the production function) in relation to soil pressure, information which can be found in the literature. Further indicators of soil compaction have to be considered in combination: the air capacity (threshold value in subsoils: 5 Vol.-%), the saturated water conductivity (threshold value in subsoils: 10 cm per day) and morphological soil properties [10].

Quadrant B describes the relation between soil pressure p_B and ground pressure (target parameter). Theoretical approaches and mea-

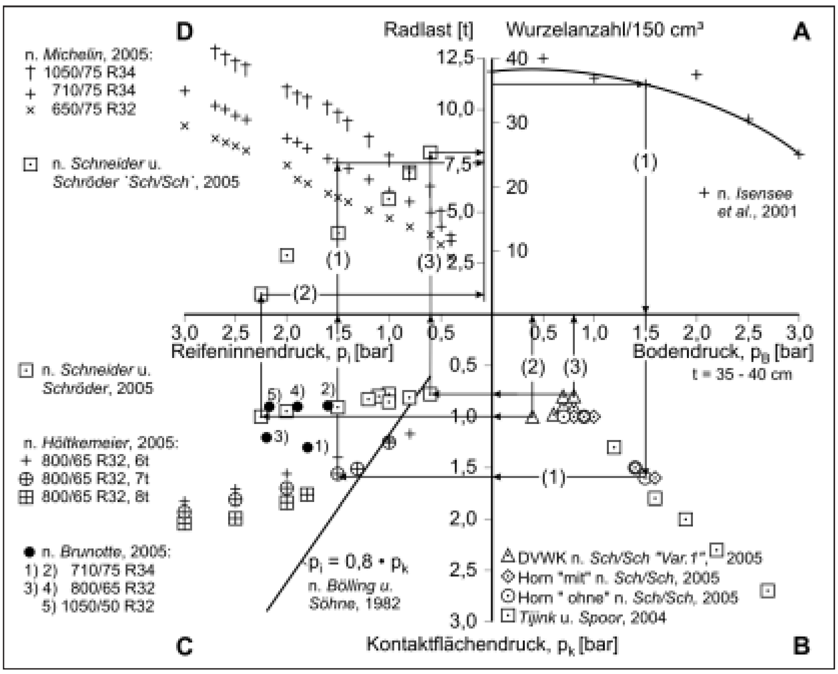

Fig. 1: Nomogram to describe the relation between soil function - tyre load

surements can be found in the literature (Fig. 1).

Quadrant C links the ground pressure p_K (determined mostly on hard surfaces) to the tyre inflation pressure. In Figure 1 p_K-measurements on fields are added for different values of tyre inflation pressure [2].

Last but not least the relationship between tyre inflation pressure with tyre properties and allowable wheel loads (target parameters) according to data books can be derived from quadrant C. "Acceptable values" by Schneider and Schröder are indicated additionally [12].

Example (1) in *Fig. 1* explains the relationship between these parameters: root growing may be reduced at 1,5 bar soil pressure, the corresponding ground pressure is 1,6 bar; the tyre inflation pressure of the tyre 710/75R34 is 1,5 bar, which allows for a maximum wheel load of 7,5 t.

Concepts to prevent soil compaction

Wheel load limitation according to the concept of pre-consolidation stress

The call of German soil scientists for "restriction of axle loads and total weights" is based on the so called "pre-consolidation stress concept" [6]. The maximum wheel load is determined by the relation between calculated soil pressure caused by agricultural machinery and pre-consolidation stress of a soil, which is measured by laboratory methods.

Assessment: The validation of the DVWK-calculations in the field is not completed yet. It would be easy to determine the wheel load by dividing total weight through the number of wheels. However, the effects of wheeling depend on the actual soil moisture as well as on the contact area of the tyres. This concept of "restriction of axle loads and total weights" does not take into account both factors explicitly. Considerable misinterpretation regarding the risks of soil compaction could be possible by establishing general limits of wheel load [16]. In consequence such regulations don't allow practicable solutions relevant to soil protection regarding the problem of soil compaction.

Wheel load controlled by degressive ground pressure

Schneider and Schröder suggest "wheel load controlled by degressive ground pressure" on the basis of literature references [12]: wet soils (pF 2) with moderate or low ability to support loads can be loaded up to a maximum of 1 bar at the soil surface. An additional proposal for protecting the soil is to reduce the tyre inflation pressure with increasing wheel load (see quadrant D in *Fig. 1*, examples (2) and (3)).

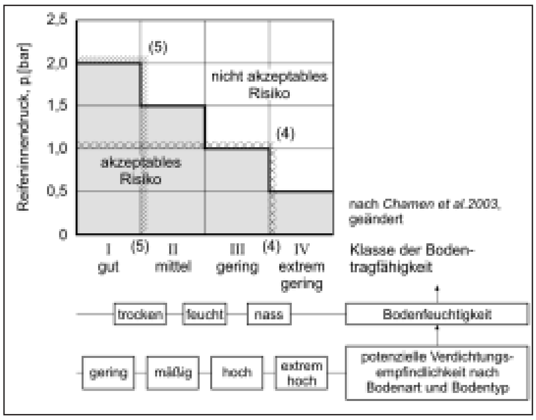

Fig. 2: Scheme for the relation between tyre inflation pressure and soil bearing capacity

Assessment: First of all the question from the practical point of view is, why a tyre, which should carry 7,8 t with 0,6 tyre inflation pressure (example (3) in quadrant D), should have higher inflation pressure, when wheel load is smaller than 7,8 t (example (2) in quadrant D)?

The idea of this concept is the "overproportional reduction of ground pressure when wheel load increases". Indeed, the contact area is an important parameter due to soil protecting gear; however, it is not possible to determine the contact area in-situ and online, as well. From that it can be concluded that in practice this concept is not a useful solution, because the target parameter cannot be determined on the field.

Limiting the load at the soil surface by using guidelines of tyre inflation pressure

There is a considerable evidence to suggest accurate indicators; as mentioned above, wheel load and ground pressure don't belong to this category. A comparison between wheel load and inflation pressure has shown that the inflation pressure is the better indicator for mechanical impacts on soil [13]. In comparison to older tyres, modern tyres are allowed to use very low tyre inflation pressure.

The latter has been proposed for a long time [15]. Mechanical impacts on soil can be influenced by lowering the tyre inflation pressure in two directions (Fig. 1): the ground pressure decreases (see quadrant C) and the soil pressure (see quadrant B) at the same time as well the maximum allowable wheel load is limited (see quadrant D). The last point may be the bridge to the other concepts mentioned above.

Certainly the concept "tyre inflation pressure controlled wheel load" intends to adapt the tyre inflation pressure to the sensitivity of the soil to compaction. It is necessary to achieve the lowest possible inflation pressure referring to a given soil moisture status. An EU working group suggested to estimate the soil vulnerability classified into four soil susceptibility classes corrected according to the actual soil moisture status [5].

Those classes of soil susceptibility are roughly related to four classes of tyre inflation pressure ≤2 bar to separate acceptable from not acceptable situations (*Fig. 2*).

The maximum value of 2 bar requires the use of conservation tillage or onland-ploughing in practice.

If it is not possible to assess the potential sensitivity of a soil to compaction the following guidelines for acceptable tyre inflation pressure are suggested [9]: <1 bar (see example (4) in Fig. 2) on loosened topsoil and wet subsoil (springtime) and <2 bar (see example (5) in Fig. 2) on settled topsoil and dry subsoil (summer/autumn).

Conclusion and outlook

From the practice point of view the concept "tyre inflation pressure controlled wheel load" is preferable compared to the other two concepts. Limiting the allowable wheel load doesn't meet the requirements of both practical agriculture and soil protection; the control of wheel load by target values for ground pressure fails in that it offers no possibility to determine the size of the contact area tyre/soil in the field.

Guidelines for tyre inflation pressure adapted to soil trafficability (<1 bar and <2 bar, respectively) challenge engineers and farmers. The choice of tyre inflation pressure as target parameter has several advantages: easy to control, adjustable by tyre inflation systems, correlated with the tyre load-bearing capacity, relevant for soil protection and finally even economically profitable (higher driving force, less fuel consumption).

The graph of the fundamental relations (Fig. 1) is to be improved regarding the quantification of the target values and the relationships between the parameters.

A future vision is the development of a trafficability sensor.