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НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

Монография в 5 томах

Том IV Оптимизация сельскохозяйственных ландшафтов

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INTRODUCTION

The sizes and total weights of agricultural machinery have increased steadily over the last decades. This has primarily been for economic and process-efficiency reasons. Highly specialized machinery requires high operating levels. Under adverse conditions, considerable negative changes in soil structure and in multiple soil functions can occur. Therefore, an adaption of soil load by agricultural machinery to the susceptibility of soil to compaction must be realized to reach the target of a sustainable and soil conserving traffic on arable land. Here, it must be ensured that the relevant key factors and parameters of
soil, machine and field management are taken into account. Furthermore, different technology options should be comparable, to adapt the machinery specifications and to derive recommendations for a soil conserving traffic on arable soil. For this purpose, a concept for the ‘adaption of load input by agricultural machines to the susceptibility of soil to compaction’ was developed [1].

KEY FACTORS AND PARAMETERS OF SOIL COMPACTION PROCESSES

Basic factors for describing soil compaction processes can be divided into soil, machine and field management parameters. The susceptibility of soil to compaction, among others, is mainly controlled by soil texture and soil moisture. In Fig.1 the susceptibility of soil to compaction, depending on soil texture and soil moisture, is displayed [1]. The values are increasing with increasing soil moisture and clay content. However, the influence of soil moisture is dominating. Results of field measurements [2] showed, that a single passage of a sugar beet harvester leads to an increase in dry bulk density (3.5 – 5.0 %) on a wet soil (~ pF 2.0, stagnic Luvisol, Ut3-4) for all soil depths, whereas there is nearly no change in dry bulk density for dry soil conditions (~ pF 3,5).

![Figure 1 – Susceptibility of soil to compaction depending on soil texture and soil moisture [1]](image)

The main machine parameters affecting soil compaction processes are wheel load, tire inflation pressure, contact area, contact area pressure and the number of passages (number of axles and machines within the processing chain). The effects of changing wheel loads by soil deformation for a single passage of a sugar beet harvester with empty (~ 5-6 t wheel load) and full bunker (~ 10-12 t wheel load) were measured under wet soil conditions [2]. Although the wheel load has doubled, the plastic soil deformation with full bunker (7,0 mm in 30 cm soil depth) is nearly 3 times higher than with empty bunker (2,5 mm). The comparison of mean contact area for various harvesters, tractors and transport vehicles [1] (with data of [2], [3], [4], [5]) show, that the mean contact area increases with increasing wheel loads. On average, the increase of harvesters and tractors is nearly the same. This is not the case for transport vehicles. Generally, the values are on a lower level and only increase to a smaller extent. That means higher contact area pressures and soil loads. So, the transport on the field, e.g. at silage maize harvest, with unadjusted tire inflation pressure is an area of concern in the context of soil conserving traffic and there is an increased need of further optimization.

The effects of tire inflation pressure and the number of wheel passages on soil pressure and soil deformation are shown in Fig. 2 by the example of several passages of a tractor on a sandy soil. The tractor with higher tire inflation pressure (2.1 bar) causes soil pressures of 1.3-1.6 bar in 20 cm soil depth. With adjusted tire inflation pressure of 0.8 bar the soil pressure can be reduced to 0.8-1.1 bar. In...
consequence, with adjusted tire inflation pressure the soil deformation after ten wheel-passages can be reduced by half, from 15 mm to 7.5 mm. Furthermore, soil deformation, in contrast to soil pressure, shows the effects of multiple passages. The first passage leads to the largest deformation, but every further passage leads to further deformation.

The major **field parameters** affecting soil compaction processes are **field length** and **soil tillage**. The respective agricultural processing chain has to match the field length, e.g., at silage maize or sugar beet harvest, so that unnecessary field traffic can be avoided. The loosening of the top soil during ploughing affects the pressure propagation in soil and the resulting soil deformation. Up to 40 cm soil depth, the soil pressure under a sugar beet harvester on a ploughed soil is consistently higher than at a conservationally tilled soil [2]. The soil deformation in 30 cm soil depth of a tractor with slurry tank on a ploughed soil is appreciably higher (10 mm) than on a soil with conservation tillage (1 mm) [1].

![Figure 2 – Soil pressure (upper lines) and soil deformation (lower lines) during repeated wheeling by a tractor with different tire inflation pressure (2.1 bar, red lines and 0.8 bar, blue lines)](image)

For the implementation of a soil conserving traffic on arable land, all the above-mentioned factors have to be taken into account. In consequence, the machine parameters and the processing chain (load input) have to be optimized and adapted to the prevailing soil condition (susceptibility to compaction). For this purpose, a concept for the ‘adaption of load input by agricultural machines to the susceptibility of soil to compacting’ was developed, taking all the above-mentioned parameters into account [1].

**ADAPTION OF LOAD INPUT BY AGRICULTURAL MACHINES TO THE SUSCEPTIBILITY OF SOIL TO COMPACTION**

Assessments of the susceptibility of soil to compaction are based mainly on expert based approaches (e.g. [6], [7]) or physical measurands, e.g. soil pressure (e.g. [8], [9]). For the presented assessment of the susceptibility of soil to compaction, depending on soil texture and soil moisture, an expert based approach was chosen. Based on long-term experience of an expert group of scientists and consultants from the fields of soil, crop science and agricultural engineering, as well as experienced farmers, the susceptibility of soil to compaction was assessed in a multi-stage procedure (see Fig. 1). This was compared to the mechanical load of agricultural machines (see Fig. 3). Therefore, the machine parameters (y-axis) for a huge variety of machines and combinations were weighted, depending on their influence on the mechanical soil load [1]. Thus, the mechanical load of agricultural machines can be compared to the susceptibility of soil to compaction. Fig. 3 shows the resulting grid form by the example of three technology options at silage maize harvest. From the grid form (decision matrix) you can see, whether or not a soil conserving traffic with the respective machine on the respective soil is possible. If
the intersection of mechanical load (y-axis) and susceptibility to compaction (x-axis) is below the diagonal line (green to yellow sector) a soil conserving traffic can be assumed. If the intersection is above the diagonal line (yellow to red sector), there is a risk of harmful soil compaction and negative changes in soil functions.

The concept was applied for nine sites in Germany, representing different soil textures and climate regions [1]. To calculate the soil moisture in different soil depths over the year on a daily basis, high resolution climate data of about 500 climate stations of the German Weather Service (DWD) were processed in the AMBAV model [10]. In combination with the technology options, e.g. at silage maize harvest, days of trafficability for mean time spans of field work can be derived (see Tab. 1).

For calculating the days of trafficability for silage maize harvest, three technology options were compared (see Fig. 3). 1. Maize harvester with silage trailer and direct transport to the silo. High tire inflation pressure (> 3 bar) and six wheel-passages lead to a high mechanical load. 2. Maize harvester with silage trailer and transfer onto a truck at the field edge. By separating field and road transport, the tire inflation pressure can be reduced (< 1.5 bar). That leads to a medium mechanical load. 3. Maize harvester with own bunker and direct transfer onto a truck at the field edge. Without a silage trailer and with wider tires, reduced tire inflation pressure and crap-steering, the number of wheel passages can be reduced. That leads to a low mechanical load.

The days of trafficability varies between the sites and machines or processing chains. In the following the two sites Griesheim and Eggenfelden are compared (see Tab. 1). On the site near Griesheim (~ 670 mm mean annual precipitation), the technology option 1 leads to 52 days of trafficability during the period 01.09.-31.10. (in total 61 days), on the moister site Eggenfelden (~850 mm mean annual precipitation) to 39 days. By separating field and road transport (option 2), the days of trafficability increase to 61 in Griesheim and 47 in Eggenfelden. That means additional eight days for harvest on the site in Eggenfelden compared to technology option 1. With the most soil conserving technology option 3, you have almost as many days of trafficability (58) as on the dryer site Griesheim (61).
Table 1 – Days of trafficability for two exemplary sites in Germany and three technology options

<table>
<thead>
<tr>
<th>exemplary sites in Germany</th>
<th>Days of trafficability for different mechanical soil load</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>(1.) maize harvester + silage trailer, direct transport to silo</td>
</tr>
<tr>
<td></td>
<td>(01.09. - 31.10.)</td>
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<tr>
<td></td>
<td>topsoil</td>
</tr>
<tr>
<td>1. Griesheim</td>
<td>52 (±2)</td>
</tr>
<tr>
<td>2. Eggenfelden</td>
<td>39 (±2)</td>
</tr>
<tr>
<td>1. Griesheim</td>
<td>61</td>
</tr>
<tr>
<td>2. Eggenfelden</td>
<td>39 (±2)</td>
</tr>
</tbody>
</table>

The decision matrix and the derived mean regional days of trafficability are a planning tool, that helps the farmer in the planning of new investments and operating levels of machines. Especially on sites with high soil moisture during important time spans, the choice of a suitable technology option is becoming increasingly more important. In such cases, the days of soil conserving trafficability are limited. Therefore, the annual operating levels and work loads of machinery have to be adapted and reduced, to get time spans for a rest period of harvesters after heavy rainfalls. A detailed description of the concept, the methods and results for a variety of machines and crops can be found at [1].

CONCLUSIONS
1. Measures and recommendations for soil conserving traffic on arable land and the prevention of soil compaction are:
   - Prevention of high wheel loads under adverse/wet soil conditions.
   - Optimizing the mechanical load of agricultural machinery e.g. by adapt the tire inflation pressure to the wheel load (tire pressure control system, large tire valves).
   - Reduction of the number of passages by optimizing the field traffic, e.g. prevention of unnecessary field traffic, implementation of a field traffic management and integration into the operating procedures.
   - Optimizing/Reduction of operating levels of machinery and campaign performance to be able to use time spans with more favourable soil conditions.
2. Within the presented concept the soil load of agricultural machinery can be compared to the susceptibility of soil to compaction to assess the options of a soil conserving traffic.
3. Different machines and processing chains can be compared regarding their soil load and adapt machinery specifications to the prevailing soil conditions for a soil-conserving traffic.
4. Average days of trafficability of agricultural soil for main time spans of field work can be derived, depending on mechanical load of machinery and agricultural technique.
5. The information on days of trafficability for main time spans of field work helps the farmer to plan new investments and operating levels of machinery.

REFERENCES
Глава IV/21: АДАПТАЦИЯ ОБРАБОТОК ПОЧВЫ К ОСОБЕННОСТЯМ АГРОЛАНДШАФТА
Chapter IV/21: Adaptation of Soil Tillage to the Characteristics of the Agrolandscape

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РЕЗЮМЕ. Обработки почвы – один из самых затратных и разрушающих почву приёмов в агrotechnологиях производства сельскохозяйственных культур. Актуальным направлением снижения затрат на выполнение обработок и одновременно минимизации техногенной деградации почвы является адаптация их видов к исходному состоянию почвы в агроландшафте. Характеризуется оно плотностью, засорённостью и обеспеченностью почвы питательными веществами. Проведена дискретизация состояния почвы, позволившая поставить в соответствие механизированные способы обработок каждому из дискретных состояний. Содержание обработок для каждого из выделенных состояний ограничивается технологической потребностью, что позволяет экономно расходовать ресурсы и меньше подвергать почву техногенному воздействию. Тестовыми расчётами установлено снижение прямых эксплуатационных затрат и техногенной нагрузки на почву при выполнении адаптивных обработок.

Abstract. Soil tillage is one of the most costly and destructive methods in the agrotechnology of crop production. Current trends of reducing the costs at performing tillage and simultaneously minimizing human-made soil degradation are the adaptation of tillage operations to the initial state of the soil in the agrolandscape. It is characterized by density, admixtures and provision of soil with nutrients. A discretization of the soil state was carried out, which made it possible to match the mechanized methods of processing to each of the discrete states. The content of tillage for each of the isolated states is limited by the technological need, which allows to economize resources and less to subject the soil to human-made impact. Test calculations showed a reduction in direct operating costs and anthropogenic load on the soil when performing adaptive tillage.

КЛЮЧЕВЫЕ СЛОВА: агроландшафт, обработка почвы, плотность, засорённость, питательные вещества.