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Development of Mechanical Soil Stress by Combine Harvesters

Modern combine harvesters receive hefty criticism for the potential soil damage from their vehicle mass. To analyze this problem, seven typical combines built between 1946 and 2004 were evaluated on their vehicles mass and average ground contact pressure. Although the vehicle mass has increased considerably within the last 50 years, the average ground contact pressure of the combine tyres has been reduced.

In the last decades agricultural engineering is characterized by the use of more and more powerful and heavier working machines due to the general economic conditions.

The mechanical loading which comes along with these machines is seen as the main reason for subsoil compaction in grain production. It results from a combination of exogenous and endogenous load factors.

With the development of combine harvesters as example, the evolution of selected load relevant parameters, which are relevant for detrimental soil compaction will be pointed out.

Material and Methods

To demonstrate the development of subsoil compaction caused by combine harvesters, seven types of combine harvesters of the construction years between 1946 and 2004 were compared (*Table 1*). All the examined machines are self-propelled combine harvesters, except the Claas-Super. The Super is a pulled combine harvester which needs a tractor. A Hanomag R40 was used for the calculation of the subsoil compaction, as a typical model for his time.

Results

In the last five decades the net weight of the examined combine harvesters has quadruplicated. The capacity of the grain tank has an increasing share in the total weight which depends on the type of crop. Therefore it can be observed that the development of the total weight has an exponential progression (*Fig. 1*).

To make a statement about the influences on the soil the average ground contact pressure has to be determined. Therefore the mathematical models of McKeyes and TASC and the determination of the inflation pressure of the tyre is used

In the model of McKeyes the contact area is determined by multiplying the tyre width with the tyre calibre and dividing the product by four. This formula is based on the assumption that the topsoil is solid. The TASC model [3] calculates the average ground contact pressure with the help of the wheel load and the contact area between the tyres and elastic soil based on practical tests.

A further method to calculate the ground contact pressure is based on the fact that especially in modern radial ply tyres the inflation pressure of the tyre bears most of the wheel load so that the following rule of thumb can be used: inflation pressure of the tyre ≈ ground contact pressure [4].

The three methods lead to different statements about the average ground contact pressure at the main combine harvester's axle. The model of McKeyes calculates a higher value then the TASC model, due to the assumption that the ground is solid, whereas the TASC model calculates with an elastic soil.

Table 1: Data regarding subsoil compaction of the combine harvesters examined

model	start of construction	working width [m]	capacity [t/h]	front axle	rear axle
Super	1946	2,2	1,5	100/80-12	-
Herkules	1953	3	2,2	14.9-26	5,5-16
Matador	1962	3	3,3	14.9-30	11.5-15
Dominator	1974	3,6	12	18.4-30	12.5/80
Lexion 450	1995	6	22	650/75 R 32	14.9 R 24
Lexion 570	2003	7,5	33	800/65 R 32	700/50-26.5
Lexion 570	2003	7,5	33	650/75 R 32	700/50-26.5
double tyres				18.4 R 38	

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Keywords

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Literatur

Literaturhinweise sind unter LT 06517über Internet http://www.landwirtschaftsverlag.com/ landtech/local/fliteratur.htm abrufbar.

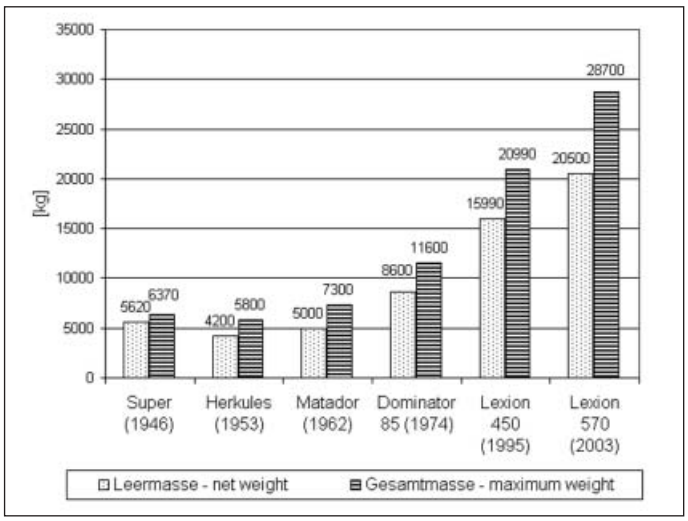

Fig. 1: Development of net and total weight

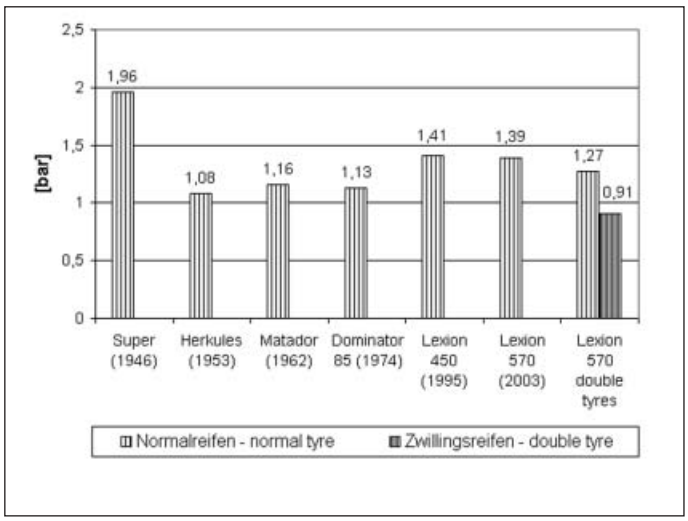

Fig. 2: Average ground contact area pressure at the main axle of the models by full loading calculated by TASC

For modern tyres the TASC and the air pressure model lead to similar values. Observing older tyres with a higher carcass stiffness, the air pressure model becomes inaccurate, because here loads are assumed which were not experimentally determined for all types of the examined tyres. Therefore for the further examinations the TASC model is used, because it demonstrates the different types of tyres the best and near to the practice.

The examination shows that due to the development of the chassis of the SP-combine harvesters that the average ground contact pressure remains on a similar level (*Fig. 2*). At this point of time, the lower average ground contact pressure is restricted by the statutory machine width and the technology of the chassis [5].

The examination has shown further that in the discussion about a possible subsoil compression mainly the front axle of the combine harvester is observed, because 75 % of the weight are located there. Which average ground contact pressure, despite the lower weight is located at the rear axle, is shown in *Table 2*. Only for new combine harvesters this risk could be eliminated with bigger tyres.

Besides the average ground contact pressure the duration of the load has influences on the subsoil compaction. The longer the load affects the ground, the better air and water could be displaced out of the pores and the pores could be compressed. Due to the capacity increase, of the combine harvesters and the increased driving speed, a decrease of the duration of the load can be observed. The average ground contact area pressure of the Matador e. g. effected for 0.73 seconds on the ground while today the Lexion 570 has a load duration of only 0.54 seconds.

Further the cruised parts of the area during harvest are determined. The biggest part has to be cruised with the pulled combine harvester (~ 43 %) while the new automotive combine harvesters cruise only 25 to 30 %.

Discussion

The examination shows that the parameters for soil compaction have not changed in a way like it could be expected because of the enormous increase in vehicle weight.

The net and total weight of the vehicles has enormously increased during the period of the examination. The total weight has nearly quintupled and amounts to 28.7 tons for the biggest model.

Much more decisive for a possible subsoil compaction is the average ground contact area pressure. The highest values in this examination were shown the tractor pulled model, the Super. The values for the SP-combine harvesters range in a comparable level with a slightly increasing tendency for the newer models for both the front and the rear axle.

model	start of construction	front axle [bar]	rear axle [bar]
Herkules	1953	1,08	2,11
Matador	1962	1,16	1,05
Dominator	1974	1,13	1,06
Lexion 450	1995	1,41	1,64
Lexion 570	2003	1,39	0,93

Table 2: Average ground contact area pressure for front and rear axle according to TASC

The duration of the subsoil compaction could be lowered through the increased speed despite the bigger tyres.

The part of the cruised area decreases with an increasing working width of the combine harvesters.

In summary the examination has shown that the for economic aspects necessary use of powerful combine harvesters is compliant with the requirements for avoiding a sustainable subsoil compression if the ground has a sufficient stability. As about this stability no comprehensive knowledge exists it is still unknown how fare adoptions of the chassis to the requirements of soil protection are necessary or rather still be sufficient.

If the stability of the ground during harvest lies in the area of the momentarily exercised ground contact pressures the use of modern powerful combine harvesters is more soil protective than the use of elderly models.

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