TRAFFIC INTENSITY IN FIELDS AND TECHNICAL POSSIBILITIES FOR REDUCTION OF MACHINERY PASSES

Jiri Masek, Milan Kroulik, Jan Chyba, Petr Novak, Frantisek Kumhala
Czech University of Life Sciences Prague
masekj@tf.czu.cz

Abstract. Machinery traffic monitoring and detailed analysis of machine passes across a field can be a tool for the field area determination which is excessively loaded with tire contacts. Excessive traffic is connected with soil compaction phenomena and its unfavourable effects. Also passes arrangement in fields is usually without any system and therefore random and GPS with a particular traffic system can help soil protection. A very simple equipment to monitor the vehicle trajectory was placed into every machine which entered the selected fields during one cropping season. Further, together with the data obtained and the tyre widths, the total area wheeled by the machinery was counted. The following facts were found out during our research. The system with ploughing showed up to 86.14 % of the total area covered with wheel passes, the conservation tillage system showed 63.75 % of the area affected by wheeling. To sum up the results, enormous intensity of agriculture machinery passes, when talking about random traffic in fields, was revealed. The results from our measurements on the CTF experimental plots using conservation tillage are as follows. Three systems with different machinery working widths were observed. Intensity of the wheeled area decreased when using a 4 m CTF system up to 37 % of the total run-over area. With 6 m machinery working width system the wheeled area was 33 % and when using 8 m system the wheeled area was only 31 %.

Key words: traffic intensity, reduction of passes, soil compaction, GPS, CTF.

Introduction

Soil compaction is one of the major problems facing modern agriculture and is a well-recognised problem in many parts of the world. Soil compaction is defined as: "the process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing the bulk density". Intensity of trafficking (number of passes) plays an important role in soil compaction as well, because deformations can increase with the number of passes [1-3]. Experimental findings have shown that higher number of passes on the same tramline with a light tractor can do even greater damage than fewer passes with a heavier tractor. However, the first pass of a wheel is known to cause a major portion of the total soil compaction [1]. The soil compaction can be reduced by a certain passes arrangement system. Major changes in the traffic regime (on-land ploughing or minimum/ploughless tillage instead of conventional ploughing, no passage of heavy machinery) are recommended immediately after a field has been subsoiled, otherwise recompaction cannot be avoided [4].

It seems that one possible tool for machinery traffic reduction and therefore soil compaction reduction could be the Controlled traffic farming system (CTF). The greatest benefits from a CTF system are obtained when all machinery including the harvester are matched to the same wheel base. The technical solution to having the same tyre or belt spacing on all machines used in the field could be the main obstacle for common utilization of CTF. On the other hand, it is possible to use the CTF system without strictly following these conditions. When using CTF, time savings as well as material input savings can be up to 10 % or even 20 % [5]. On the other hand, contour farming, controlled traffic and sub-surface drip-irrigation are technologies where centimetre accuracy is essential for commercial application and it requires expensive equipment. However, the high investment into the technology is clearly justified by the percentage of savings [2].

This work evaluates the percentage of the wheeled area and repeated passes in fields when using conventional tillage with ploughing and conservation tillage with randomly organized traffic. And also the same parameters were monitored in fields when fixed machinery tracks were used.

Materials and Methods

Evaluation of the number and frequency of agricultural machinery passes across a field was done by means of DGPS receivers with a position recorder and with a logging time of 2 s.

All field operations and all other machinery and vehicle passes across the selected fields were monitored during one year. Also different tillage systems were evaluated, namely, conventional tillage with ploughing and conservation tillage. The trajectories for every machine run in the field were defined from the data sets received from a GPS position recorder placed in the machine. Then the area covered by the machine tyres was calculated from the tyre type, tyre width and wheel spacing. For better evaluation and comparison between different tillage systems, 1 ha of a particular field was chosen as a representative square with one 100 m long side. In addition, the number of passes and the area covered by machine tyres were calculated separately for headlands (25 m wide zones round the field). The area on headlands is expected to be more loaded by machinery passes due to U-turns and traffic and we wanted to quantify this effect. In addition, the evaluation of the number and frequency of agricultural machinery passes across a field with a fixed track system for machinery traffic (CTF) was carried out for three machinery units with the working widths 4, 6 and 8 m.

Results and Discussion

Two different tillage systems were evaluated with regard to the intensity of machinery passes across the fields when using random machinery traffic. Tyre tracks and the area run over by the tyres were observed in the selected fields. All machinery entries and movements in the evaluated field during one year were included into the analysis (Table 1). The sequence and frequency of field operations corresponded with the real farm conditions and depended only on the farmer decision and common practice.

The results showed that 86.13 % of the total field area was run over with a machine at least once a year, when using conventional tillage, and 63.75 % of the total field area was run-over when using conservation tillage.

Table 1

Frequency of agricultural machinery passes across a field (random traffic)

Conventional system with ploughing	**Width of tyres, mm**	**Working Width, m**	**Run-over area, %**	**Conservation tillage**	**Width of tyres, mm**	**Working width, m**	**Run-over area, %**
Stubble break.	580	6	18.9	Stubble break.	800	8	23.0
Ploughing	710	3.5	44.6	Desiccation	465	36	2.67
Presowing preparation	580	10	32.0	Shallow tillage	800	8	21.4
Seeding	580	6	19.2	Seeding	800	8	20.2
Protection, fertilization (spraying rows)	300	24	2.5	Protection, fertilization (spraying rows)	300	36	2.81
Harvest	800	7.5	21.7	Harvest	900	9	25.2
Grain disposal	580	–	3.9	Grain disposal	710		0.9
Straw ballers press	480	–	13.5	–	–	–	–
Straw bales disposal	460	–	3.9	–	–	–	–
Repeatedly run-over area, %							
1x	–	–	33.26	–	–	–	39.26
2x	–	–	31.06	–	–	–	19.56
3x	–	–	15.60	–	–	–	4.41
4x	–	–	5.03	–	–	–	0.51
5x	–	–	1.04	–	–	–	0.01
6x	–	–	0.14	–	–	–	–
Run-over (total), %			86.13	Run-over (total), %			63.75

Further, detailed evaluation of ones and repeatedly run-over areas was carried out. The details are in Table 1. Figure 1 shows one example of a position record of a machine collecting bales from the field surface. Figure 2 interprets the statement: "Soil compaction phenomenon is connected with the number of machinery passes but also with time exposure of the soil surface to contact pressure" [1]. Figure 2 shows places with different traffic intensity and also with different time exposure of soil to the machinery load. The map in Figure 2 was created from the sum of machinery position records in time at a particular place – in the selected squares 6x6 m (the field was divided by square grid with the cell 6x6 m). It means, the more times a machine entered each square, the more records for the square and also the more time a machine spent in the square the more records there as well (dependence on the working speed and/or even machine stops).

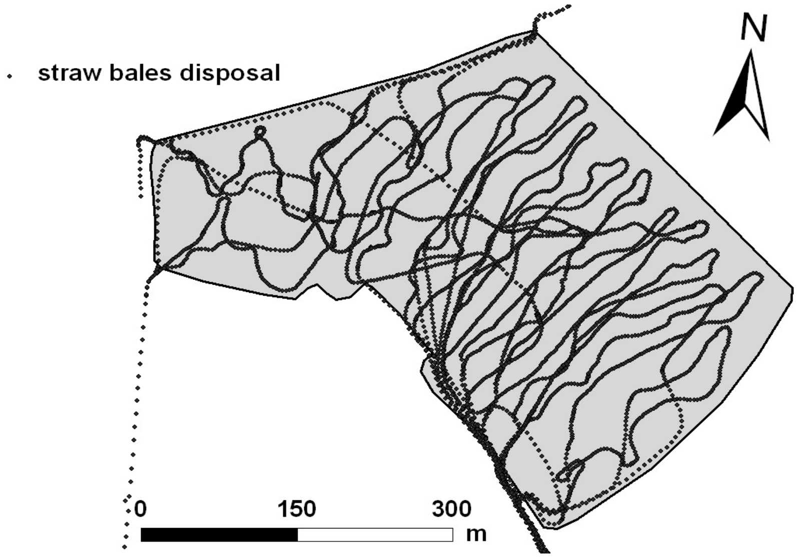

Fig. 1. **Tractor trajectories from bales disposal – position record**

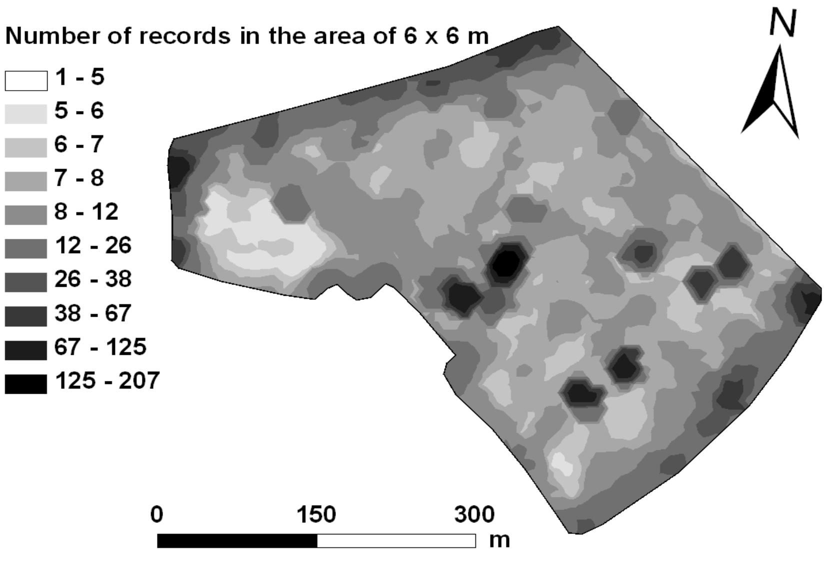

Fig. 2. **Map characterising intensity of traffic and time spent at a certain area**

Also headlands of the field were evaluated concerning the repeated passes and the results in Table 2 show very intensive traffic and tyre contacts with soil at these places, mainly due to machinery turns. The wheeled area on headlands was always higher than 80 %.

The results show that the less intensity of field operations, the less loading of soil with machinery passes. Table 2 also shows the percentage of the area wheeled by repeated passes which cause even worse effect on soil. Despite the fact that the intensity of machinery passes decreased when using conservation tillage, the loading on the soil profile caused by machine tyres was still quite high.

The results from the fixed track system for machinery traffic (CTF) measurements on the experimental plots (only conservation tillage) are as follows. The intensity of the wheeled area decreased when using a 4 m system up to 37 % total run-over area. With the 4 m machinery working width system, it was possible to concentrate all tyre passes into two permanent tracks due to almost the same machine wheel spacing. Generally, the wheel spacing could be the major obstacle for CTF application because there are no standards for agriculture machinery manufacturers. Therefore, there are usually different machines and implements with different tyre spacing on farms. On the other hand, it is possible to use CTF despite not having all machines with the same wheel spacing. Then more than two (usually three) tyre tracks are used when using significantly wide or narrow wheel-spaced machines. This exception is usually a harvester with much wider wheel spacing than tractors and tools.

Table 2

Frequency of agricultural machinery passes on headlands (headland width 25 m)

Conventional system with ploughing,		Conservation tillage	
Number of passes repetitions	Run-over area, %	Number of passes repetitions	Run-over area, %
1x	17.09	1x	30.23
2x	25.70	2x	31.16
3x	23.99	3x	15.86
4x	15.08	4x	4.05
5x	8.50	5x	0.46
6x and more	3.83	6x	0.01
Run-over area (total), %	86.14	Run-over area (total), %	81.76

The experimental arrangement with 8 m machinery working width was exactly this case. All machine tracks were concentrated into two lanes except the combine harvester. Therefore, the combine harvester passes were organized in the way that one wheel of the harvester ran on the existing fixed lane/track and the second wheel made an additional third track. Finally, three track systems resulted from this case. The intensity of the wheeled area decreased when using the 8 m system with three tracks up to 31 % total run-over area. This value is not too much different from the value of the total run-over area for a 4 m system (37.38 %) when taking into account half the number of passes for the 8 m system. This was caused by the third track made by the combine harvester with wide tyres. With 6 m machinery working width system the wheeled area was 33 %.

On the other hand, it is obvious from the results that repeatedly run-over areas increased in comparison with random traffic. A detailed description for 4 m and 8 m working widths is in Table 3. The tyre sizes used on machines in an 8 m system are listed in Table 1. Machines in the 4 m system used tyres with the following widths: 480 mm for tillage and seeding, 600 mm for harvest and 650 mm for spraying, fertilization and transport.

Table 3

Frequency of machinery passes across a field where fixed tracks were used.

Conservation tillage 4 m working width		Conservation tillage 8 m working width	
Number of passes repetitions	Run-over area, %	Number of passes repetitions	Run-over area, %
1x	4.58	1x	10.38
2x	3.24	2x	0.00
3x	5.18	3x	8.46
4x	16.51	4x	7.65
5x	0.16	5x	1.36
6x	7.71	6x and more	3.03
Run-over area (total), %	37.38	Run-over area (total), %	30.88

Literature sources [6] and [7] stated that fixed tracks improve entry and movement across a field and also allow an earlier date for in-field operations. Fixed tracks also lead to reduction in tractor draught force for implements and better stability of machines in tracks [8]. It is also necessary to co-operate with agriculture machinery producers to design suitable wheel spacing and total machine weight for an integrated farming system in the future. It will lead to the possibility of using fixed tracks during all field operations resulting in less soil surface wheeling and less soil loading with contact pressure between tyres.

Also it has to be stated that the experiments were done under real running condition on farms with conventional machines not really suitable for CTF, especially concerning the tyres. The tyres for CTF could normally be considerably smaller than those commonly used in practice.

Conclusions

The results from the evaluation of the passes frequency across a field showed a high number of tyre contacts with soil when using conventional tillage technologies with ploughing. More than 86 % of the total field area was run over in this case. Also, a high number of repeatedly run-over areas was detected there (twice run-over area 31 %, three times run-over area 15.6 %). Conservation tillage had significantly lower number of machinery passes with a total run-over area of almost 64 %.

On the other hand, when using the system with fixed tracks for all machinery passes, the total run-over area by machinery tyres decreased significantly up to 31 % in comparison to randomized traffic in a field.

Acknowledgements

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 604 6070905 and by the Ministry of Agriculture of the Czech Republic, Project No. QH 9210

References

1. Bakker, D.M., Davis, R.J. Soil deformation observations in a Vertisol under field traffic, Aust. J. Soil Res. 33, 1995, pp. 817-832.
2. Gan-Mor, S., Clark, R. L. DGPS-Based Automatic Guidance – Implementation and Economical Analysis. Paper No. 011192, ASAE, St Joseph, MI, USA, 2001.
3. Hamza, M.A., Anderson, W.K. Soil compaction in cropping systems: A review of the nature, causes and possible solutions. Soil & Tillage Research, 82(2), 2005, pp. 121-145.
4. Schäfer-Landefeld, L., Brandhuber, R., Fenner, S., Koch, H.J., Stockfisch, N. Effects of agricultural machinery with high axle load on soil properties of normally managed fields. Soil & Tillage Research, 75(1), 2004, pp. 75-86.
5. Li, H.W., Gao, H.W., Chen, J.D., Li, W.Y., Li, R.X. Study on controlled traffic with conservative tillage. Transactions of the Chinese Society of Ag-Eng., 16, 2000, pp. 73-77. Conservation tillage on runoff and crop yield. Pap.No.041071 ASAE, St Joseph, MI, USA.
6. McPhee, J.E., Braunack, M.V., Garside, A.L., Reid, D. J. Hilton, D.J. Controlled traffic for irrigated double cropping in a semi-arid tropical environment: part 2, Tillage operations and energy use. Journal of Agricultural Engineering Research, 60, 1995, pp. 183-189.
7. Radford, B.J., Yule, D.F., McGarry, D., Playford, C. Amelioration of soil compaction can take 5 years on a Vertisol under no till in the semi-arid subtropics. Soil & Tillage Research, 97, 2007, pp. 249-255.
8. Lamers J.G., Perdock U.D., Lumkes L.M., Klouster J.J. Controlled traffic farming systems in the Netherlands. Soil & Tillage Research, 8, 1986, pp. 65-76.