UTILIZATION OF GPS GUIDANCE SYSTEMS IN CONTROLLED TRAFFIC FARMING

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Abstract. Soil compaction by machinery traffic in agriculture is a well recognised problem in many parts of the world. Subsoil compaction has been acknowledged by the European Union as a serious form of soil degradation, which is estimated to be responsible for degradation of an area of 33 million ha in Europe. The sequence and frequency of field operations corresponded with real farm conditions and depended only on the farmer decision and common practice. As a result of this fact, soil is exposed very often to repeat passages and thus irreversible structural changes connected with soil compaction. Soil compaction phenomenon is connected with the number of machinery passes and also with time exposure of the soil surface to contact pressure. The soil compaction caused by traffic reduces soil infiltrability, hydraulic conductivity, porosity, aeration and increases bulk density and impedance for root exploration. In relation to the soil protection against erosion and compaction other possibilities are locked for guidance systems utilization in this time. In field experiments different soil tillage technologies and different organization of machine tracks on the field were compared. Reducing the tillage intensity (by different soil tillage) leads to reducing of machinery passes. The minimalized tillage technologies dropped the intensity of passes around 36 %. There is more than 60 % reducing of run over the soil surface by using controlled traffic farming (permanent tram lines on field) compared to random traffic farming. The GPS guidance systems are used almost in all field operations.

Keywords: GPS, CTF, soil compaction.

Introduction

Controlled traffic farming (CTF) is all about managing soil compaction – confining it to narrow strips across the land and maximizing the remaining undamaged soil area for cropping. In practice it means matching the machinery tracks so that they take up the least possible area. Although this is made simpler by satellite guidance, it can be achieved with conventional marking systems. Farm conversion to CTF in the first instance means adopting a CTF "mindset" – the belief that separating wheels and crops is a key method of reducing costs and increasing returns. From here on it is simply a matter of good planning and timely investment that ensures a minimum 15% return on capital, an increase in crop returns and a substantial reduction in costs [1].

The agricultural land resources represented 53.7 % of the total area of the Czech Republic (7,867 thousand hectares), i.e., 4,234 thousand hectares. The area of the arable land was 3,532 thousand hectares, which represents 72 %. Around 42 % of the arable soil stands in danger of soil erosion.

The global problems connected with soil conditions are soil erosion (still increasing worldwide) and soil compaction (particularly in developed countries using big heavy machinery in fields). Soil erosion and compaction by machinery traffic is one of the major problems facing modern agriculture and it is a well-recognised problem worldwide [2].

With today's emphasis on intelligent and sustainable farming methods, satellite navigation for agricultural machinery is essential. Machinery manufacturers, mainly tractor and harvester producers, offer several variants for automatic steering and navigation. Current issues are of intensive management and its influence on agricultural land and remedial measures. Soil compaction is primarily most frequently associated with the field operations of heavy machines.

Controlled traffic farming cuts fuel, labour and machinery costs by dramatically reducing soil damage. This makes farming simpler, more reliable and less time consuming. It also delivers environmental benefits, such as reduced water run-off and soil erosion, improved fertilizer use efficiency, less risk of nitrous oxide and methane emissions and improved carbon sequestration. Overall, with reduced fuel, energy and machinery inputs and fewer greenhouse gas emissions, the carbon footprint of CTF is likely to be the lowest of all farming systems.

CTF is a simple way of dramatically reducing the input costs (time, fuel & machinery) – and at the same time increasing the crop yields – both of which are done sustainably and both of which increase the farm profit. CTF is a whole farm approach to the separation of crops and wheels; it is a system that avoids the extensive soil damage and costs imposed by normal methods. Controlled traffic is not rocket science – it simply involves confining all field vehicles to the least possible area of permanent traffic lanes. Appropriate agronomy and management is used to maximize the potential of both the cropped and wheeled areas for their specific purposes. In practice it means repeated use of the same wheel tracks for every operation, and it is ideal for all machines to have the same wheel track and for all implements to have a particular span (Fig. 1).

The soil compaction phenomenon is connected with the number of machinery passes but also with time exposure of the soil surface to contact pressure.

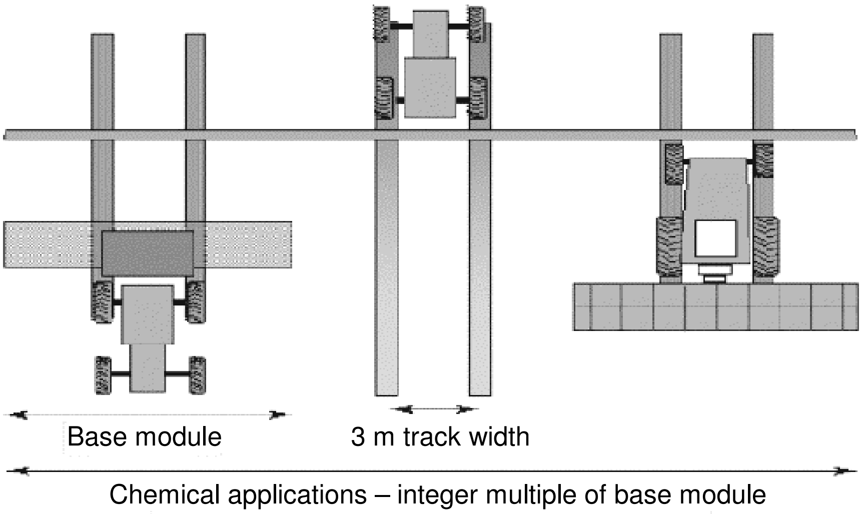

Fig. 1. **CTF system with base module of 9 m and a 3 times multiple to give 27 m for chemical applications. The wheel track width is 3 m [1]**

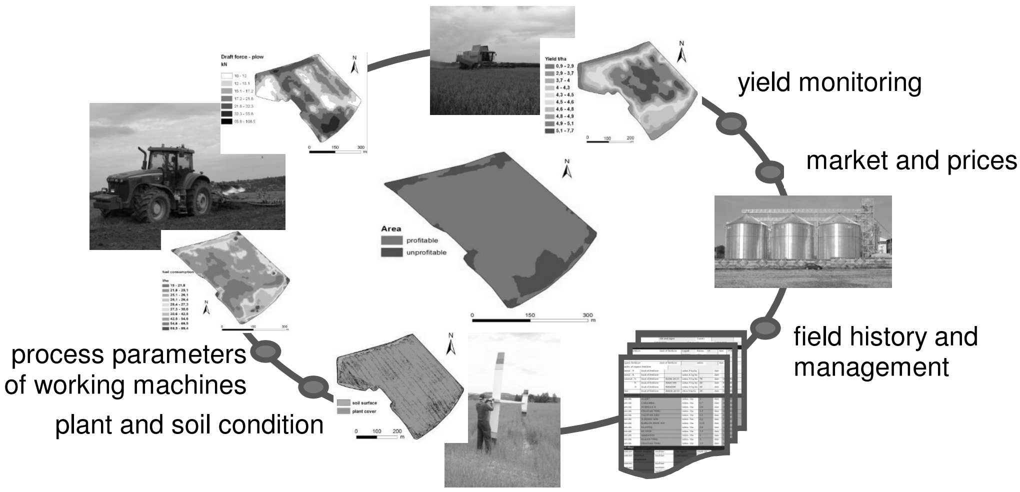

Fig. 2. **Precision farming circle**

CTF is appropriate for anyone growing crops, whether these are grass, roots, energy, legumes or cereals, on any scale and whether with manual, semi- or highly-mechanised systems. It is a system that cuts costs at their source; it creates opportunities and avoids compromises associated with wheels, rutting and poor cloddy seedbeds [3]. It should be the goal of all producers. CTF is a part of precision farming system (Fig. 2). There are many benefits associated with CTF and they all help to deliver the two most important factors in farming operations - increased profit and improved sustainability [4], [5]. These are delivered by improving the soil health, which in turn lowers the costs and increases crop returns but it also results in improved environmental conditions. Lower costs and increased returns are brought about by [1]: lower energy for cultivation and machinery investment, better seedbeds and improved soil structure, potential to retain more organic matter and soil living organisms and it could improve water storage. Monitoring of the process parameters of the working machines especially during tillage is easy due to modern tractors and electronic equipment. Crop yield monitoring is one of the most widespread applications of precision farming [6].

Materials and methods

In order to gain the enter data for further Controlled Traffic Farming systems observation, several measurements concerning the frequency and total area of machinery passages in a field were done. The experiment was prepared in real field condition by using conventional and conservation soil tillage systems. The observed field is situated in central Bohemia. There ware observed all working operations during a year from soil preparation until soil tillage after harvest. For the experiment we needed the DGPS receiver and data storage unit only. DGPS receivers were placed into a machine for monitoring of all machinery passages across the observed fields with 2s logging time for position data saving. The total area covered by machine tyres by passages was calculated according to the tyre width and their number on machines. There are three different soil tillage technologies used in the experiment - one conventional soil tillage based on ploughing and two conservation technologies based on minimum soil tillage and No Till (direct seeding).

Results and discussion

All working operation during the whole year was observed. On the field different soil tillage technologies are used. Tables 1 and 2 show the frequency of passes on the surface of the field plot in 1 ha segment. The total area covered/run-over by all machine tyres was calculated with help of the software ArcGIS 9.

Table 1

Frequency of agricultural machinery passes on a field (conventional tillage)

Conventional system with ploughing	Width of tyres, mm	Working width, m	Run-over area, %
Stubble breaking	580	6.0	18.9
Ploughing	710	3.5	44.6
Presowing preparation	580	10.0	32.0
Seeding	580	6.0	19.2
Protection, fertilization (spraying rows)	300	24.0	2.5
Harvest	800	7.5	21.7
Grain disposal	580	–	3.9
Straw ballers press	480	–	13.5
Straw bales disposal	460	–	3.9

Number of passes	Repeatedly run-over area, %
1	33.26
2	31.06
3	15.60
4	5.03
5	1.04
6	0.14
Run-over (total), %	86.13

Table 2

Frequency of agricultural machinery passes across a field (conservation tillage)

Conservation tillage	Width of tyres, mm	Working width, m	Run-over area, %
Stubble break	800	8	23.00
Desiccation – spraying	465	36	2.67
Shallow tillage	800	8	21.40
Seeding	800	8	20.20
Protection, fertilization (spraying rows)	300	36	2.81
Harvest	900	9	25.20
Grain disposal – truck	710	–	0.90

Number of passes	Repeatedly run-over area, %
1	39.26
2	19.56
3	4.41
4	0.51
5	0.01
Run-over (total), %	63.75

The results show a considerably high number of the tyre contacts with the soil. The total area covered by tyre passages calculated for conventional soil tillage is in average 96 % of the total area of the field. By conservation soil tillage technology the total area covered by tyres will be 65.5 % only and by using no-till technology it is only 42.2 %. This number shows the biggest benefit of controlled traffic farming. By using conservation soil tillage technologies and the system of permanent tramlines it is possible to achieve lower area compacted by tyres and lower soil structure destruction. The total area of passage is less than 30 %. It is very difficult to locate and rationalize soil compaction, because marks on the soil surface are not evident. Based on knowledge of the load intensity it is possible to optimize the depth of loosening pursuant maps of passes (Fig. 3). An interesting outcome is that the map of soil exposure to machinery time-dependent presence (tyre contact pressure) shows visible spots where machinery stayed for a longer time (i.e., seeder loading, sprayer filling up). It means more log-impulses recorded at a particular place marked by the darker colour in the map.

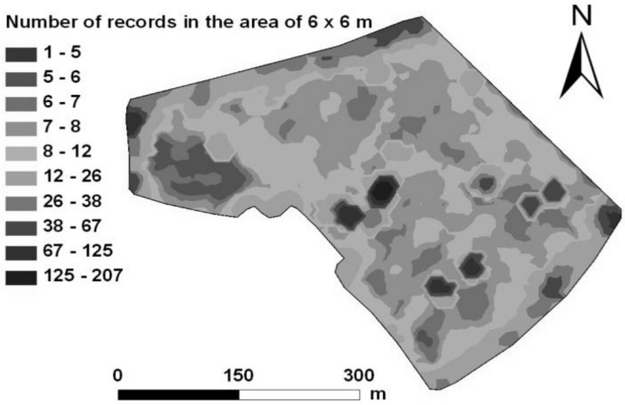

Fig. 3. **Map characterising intensity of traffic and time spent at a certain area**

The figure shows that the most exposed areas by loads are headlands and areas where the machines were weaned (Tab. 3). On Fig. 4 and Fig. 5 there are displayed tramlines of all machines turned on headland during the observed year. You can see there a big difference between these technologies. A number of field operations are dependent on the support of conveyance and require cooperation when working with these machines. Recordings made during the work of machines showed a number of reserves and deficiencies in these activities. Radford et al. [3] observed yield drop on headlands several years after heavy machine trafficking. Tullberg [4] notes that the energetic demand for soil tillage could be up to 40 % higher in places with a higher number on passes repetitions (depending on the soil type).

Table 3

Frequency of agricultural machinery passes on headland

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, %
1	4.58	1	10.38
2	3.24	2	0.00
3	5.18	3	8.46
4	16.51	4	7.65
5	0.16	5	1.36
6	7.71	6 and more	3.03
Run-over (total), %	37.38	Run-over (total), %	30.88

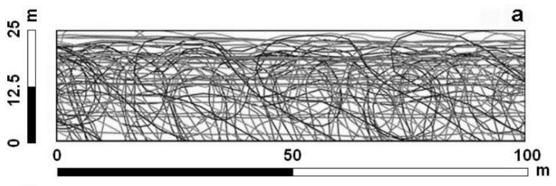

Fig. 4. **Headland in conventional soil tillage system with ploughing**

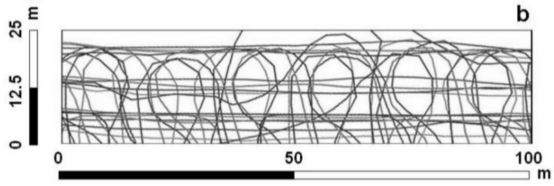

Fig. 5. **Headland in conservation soil tillage system with shallow tillage**

Conclusions

Reducing of soil tillage leads to lowering of soil compaction. Trafficking fields causes soil compaction which has many deleterious consequences in terms of the crop yield, soil functions, nutrient uptake, energy demands and seedbed quality. If this trafficking is random, it creates enormous potential for in-field variability. Choosing the tillage technology can significantly affect the final intensity of traffic in the fields throughout a cropping season. Intensity of traffic (number of machinery passes) in fields plays an important role in soil compaction, because soil deformations can increase with the number of passes.

However, the first pass of a wheel is known to cause a major portion of the total soil compaction. One possible tool for (further) machinery traffic reduction and therefore soil compaction reduction could be the fixed track system (in Controlled Traffic Farming). Recording the machinery position also provides information where the machinery passes are accumulated. The results showed that the use of GPS guidance offers a possibility to reduce overlapping and omission which leads to reduction of the run-over area of the field. A significant reduction of the wheeled area allows adopt bon of fixed tracks system for machinery traffic. Combination of fixed tracks system and optimal guidance lines with respect to the shape of the field and its slope may offer an additional increase in the effectiveness of the field work. Navigation can be used in logistics solutions of product removal from the field and could play an important role in ensuring erosion control measures. Controlled traffic farming is a relatively simple concept that uses the best available guidance and auto-steer technology, together with machinery matching, to confine traffic loads to the least possible area of permanent traffic lanes. The guidance systems and Controlled Traffic Farming system, which is based on maintaining the same wheel lane for several years for each field operation, are one of the tools which can be used in soil protection against soil compaction. As stated by Reeder [7] in his work: "The separation of machine traces out of cultivated land is one of the options how to reduce soil compaction".

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