Controlled Traffic Farming under Central European conditions

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Abstract

No-tillage techniques react especially sensitively to compacted structures in the topsoil. With the driving strategy Controlled Traffic Farming (CTF) all work is carried out from permanent traffic lanes. There is never any traffic on the soil between traffic lanes, so the topsoil is never compacted. In a field trial with repeated blocks initially designed to last three years a CTF variant of the no-tillage technique is being compared with the classic ploughing regime and a conventional no-tillage technique. An intensive monitoring programme for various parameters was installed: Soil porosity, air permeability; soil moisture, soil air, redox, temperature an agronomical parameters like emergence rate and yields. Preliminary results from the first one and half years show differences in variants, but definite conclusions will only be available after the end of the field trial in 2011.

Keywords: Controlled traffic farming, direct seed, no till, soil compaction

1. Introduction

The main problem arising from no-tillage and mulch seeding techniques is lower yield, frequently caused by reduced emergence and delayed early development as a result of compacted structures in the topsoil. In addition to the negative agronomic impact of this compaction, it promotes nutrient leaching and soil erosion (Anken 2004 & 2007, Elsässer et al 1999). In Controlled Traffic Farming (CTF), based on GPS guidance systems and closely matched machine widths, all work is carried out solely from permanent traffic lanes. There is never any motorised traffic on the soil between traffic lanes and so the topsoil is never compacted (*Fig. 1*) (Chamen 2006a, Webb 2004, Hamza 2005). Air and water flow are improved and the soil is better able to buffer both heavy precipitation and periods of drought. (Chamen 2003) In Australia today several million hectares of wheat and sugar cane are managed using CTF.

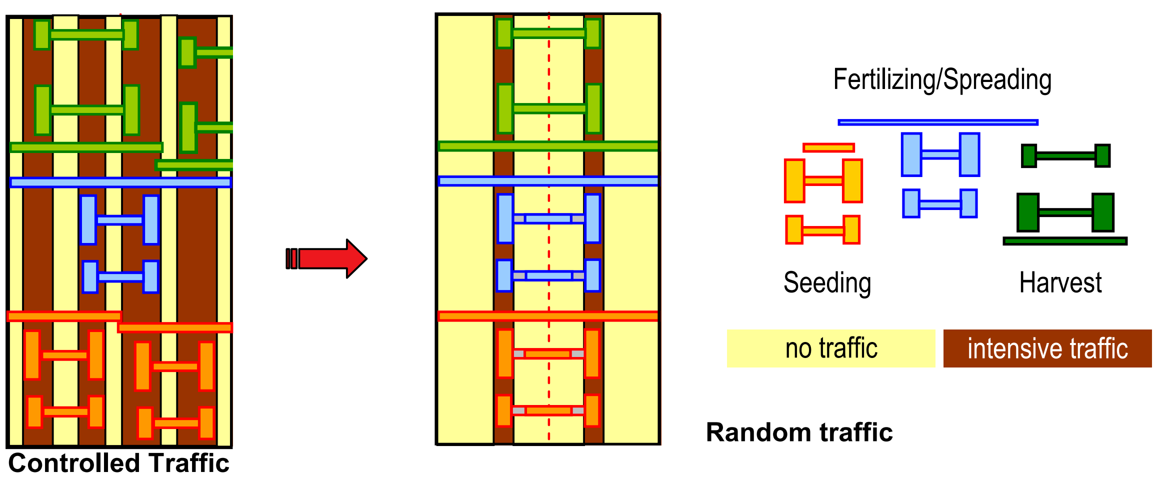

Fig. 1: Random traffic vs. controlled traffic. A large proportion of the surface is not trafficked, but

narrow tyres with high inflation pressures strain the tracks. Source: Agroscope ART

Results from Great Britain and the Netherlands suggest that even under central European conditions CTF can sustainably improve the efficiency of plant cultivation (Chamen 2003, Vermeulen 2007). As well as applying to arable farming, this regime could also be suitable for grassland. Positive effects could be seen in better yields and reduced nutrient leaching. The increasing spread of GPS guidance systems in Europe means that one basic prerequisite for the introduction of controlled traffic farming is being met (KTBL 2007).The prices of these systems are continually falling (Holpp, 2006) and, as RTK correction signals are increasingly obtainable as a service, it is no longer essential to have one's own correction station (Holpp 2010).

However, The CTF systems developed primarily for Australian conditions cannot, simply be transferred. There, in order to minimise the proportion of traffic lanes not used for crop cultivation, standard lane widths of ~3.00m and narrow tyres are used (Chamen 2006a). Tractors and trailers are being widened to harvester track width (*Fig. 2*). In addition to the investment cost this gives rise, among other things, to serious drawbacks in respect of the suitability of machines for road traffic as well as lower payloads and lower maximum tractor speeds. CTF needs to be adapted to European conditions if it is to gain acceptance in central Europe (Holpp 2009).

Fig. 2, left: tractor with increased track width, right: grain hopper wagon and tractor with increased track width and combine harvester with lengthened grain auger. Source: Agroscope ART

2. Project objective

A realistically designed field trial is being conducted in 2008-11 to investigate the impact of CTF on the soil, the agronomic potential, and the technical implementability with practical track widths and commonly used tyre widths. The aim is to determine whether, even under Central European conditions, CTF can sustainably improve the efficiency of crop cultivation in general and of no-till methods with a sensitive reaction to top soil compaction in particular.

3. Material and methods

3.1 Experimental area

It was possible to incorporate the CTF field trial into the tillage system comparison which has been ongoing since 1998. Plough and no-tillage variants are available as comparative methods. The soil in the no-tillage regime is therefore not firstly moved, but is already adequately settled. The trial is being run in randomized blocks in four replications (*Fig. 3*).

3.2 Design of CTF variant

If lanes are generally no longer to be taken out of production but to remain in partial use, the proportion of lane area must not be reduced to the maximum extent. A practical system for threshing crops, maize and grassland viable for different working widths in a mulch- or no-tillage seeding regime could then look as follows (*Fig. 4*):

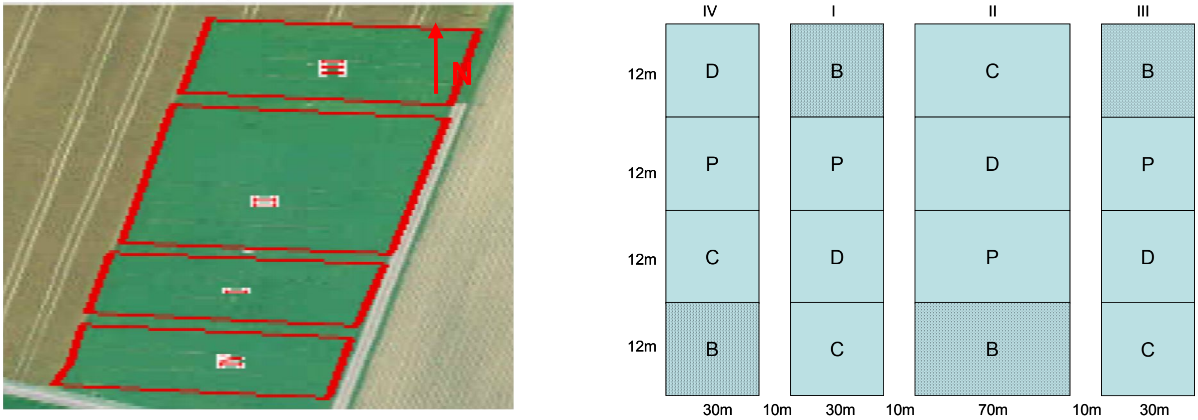

Fig. 3: Left: aerial view of trial field. Right: trial design with CTF no-till (C), no-till (D) and plough (P) variants. The organic plots (B) from the trial previously conducted are not included. Drawing not to scale. Source: Agroscope ART

The number of passages is minimised. The machines have the same basic working width, for example 6m. Fertilizing and plant protection are carried out with a multiple of this working width. All machines have the standard track width. This makes the combined track of tractor and harvester relatively wide, but the compaction risk is counteracted by the lower number of passages and low pressure tyres which reduce soil damage.
The land can now be divided into traffic zones: no traffic (yellow), minimal traffic (pale grey) and intensive traffic (dark grey). The minimal traffic area is driven on only twice a year, during soil tillage/seeding and harvesting. The intensive traffic area coincides with today's existing cultivation lanes. Depending on the basic working width, the no traffic area takes up 62-71%, the minimal traffic area 23-31% and the intensive traffic cultivation lanes 5-7%.

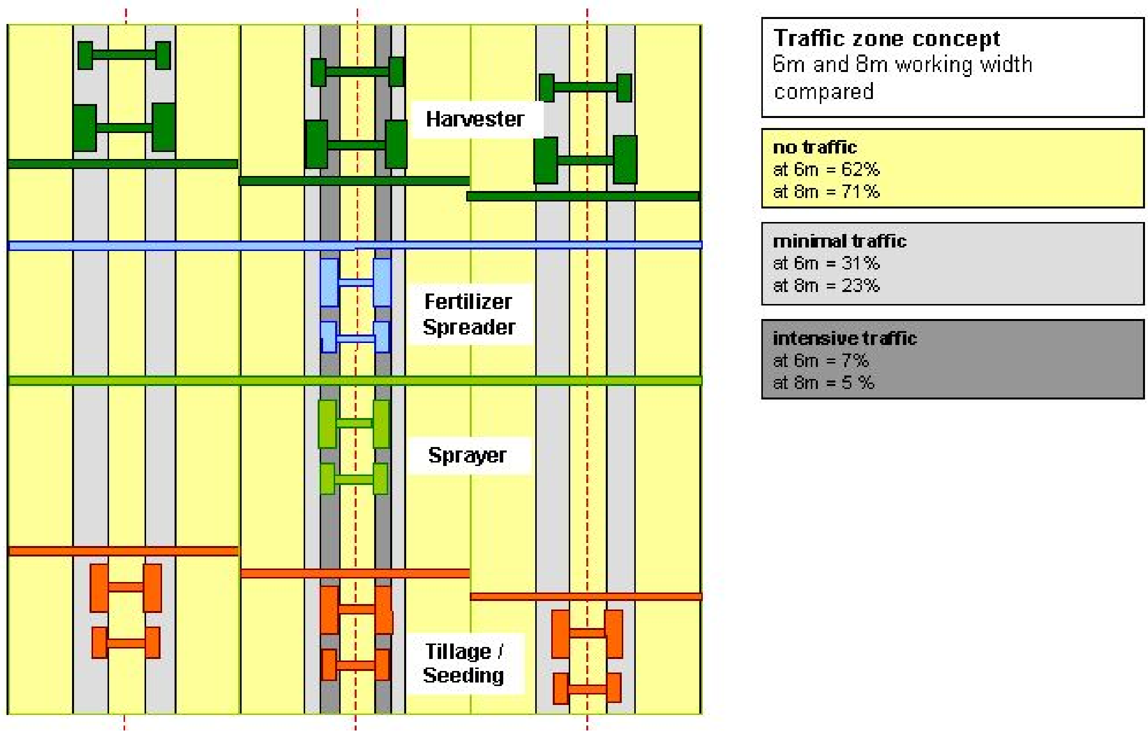

Fig. 4: Traffic zone concept: by including the areas of minimal traffic, 93-95% of the land is used for crop cultivation. Source: Agroscope ART

The hypothesis is that the plants in the minimal traffic area develop in a way similar to that of today's cultivation regimes and that a sustainable improvement in soil structure can be realised in the no traffic area, with benefits relating to both air- and water flow and yield stabilisation and increase.

3.3 Crop rotation

The crops grown are winter wheat (harvesting year (HY) 2008/09), winter barley (HY 2009/10) and temporary ley/forage crops (HY 2010/11). Forage crop cultivation, with four to six harvests per season, involves considerably more passages and a heavier load on traffic lanes. The suitability of CTF for grassland systems can be assessed in this way.

3.4 Machinery used

For technical reasons a two-furrow plough with a 0.70 m working width and a 3 m rotary harrow seeding combination is used for the plough variant, a 2.25 m no-till seed drill for the no-till variant and a 4.50 m no-till seed drill for the CTF no-till variant. The combine harvester has a working width of 4.50 m. Plant protection and fertiliser application for each plot are carried out via a central cultivation lane in the middle of each trial plot.
All the machines are equipped as standard with 420 to 800 mm tyres, preferably the wider, to match their performance rating (*Tab. 1*). In accordance with best practice the tractors operate with an internal tyre pressure of 0.8 bar, the combine harvester with 1.0 bar at the front axle and 1.2 bar at the rear axle.

Tab. 1: Overview of machinery used. Source: Agroscope ART

Machine	Unladen weight	Front axle		Rear axle	
		Tyres	Air pressure	Tyres	Air pressure
Same Dorado 75: plough, cultivator	3,950kg	360/70R20	0.8bar	420/70R30	0.8bar
John Deere 6920S: no-till	7,320kg	540/65R28	0.8bar	650/65R38	0.8bar
Fendt 411: plough/seed drill	5,770kg	420/70R24	0.8bar	460/85R34	0.8bar
John Deere 2254: combine harvester	12,900kg	800/65R32	1.0bar	540/65R24	1.2bar

3.5 Study parameters

The study parameters presented are measurements of soil surface roughness, cone penetration resistance, crop emergence rate, soil macroporosity volume and intermediate harvest. Due to a hail storm in spring 2009 no yield measurements could be taken in the first year. Additional study parameters are biological soil activity, soil moisture, content of oxygen and carbon dioxide in soil air, nitrous oxide concentrations in soil air, suction power, temperature and redox potential. Each of these parameters is measured at various depths. To date there are no results available for these measurements.

3.6 Surface survey

The soil surface of the plots was surveyed in September 2008 and 2009 prior to seeding with total station surveying (brand: Leica-Geosystems) (*Fig. 5*). Over the course of time this should make it possible to determine the differences in soil height caused by motorised traffic. Zones subject to traffic of differing intensity were defined and marked out with a measuring frame in a 0.20m grid over a width of 3.80m.

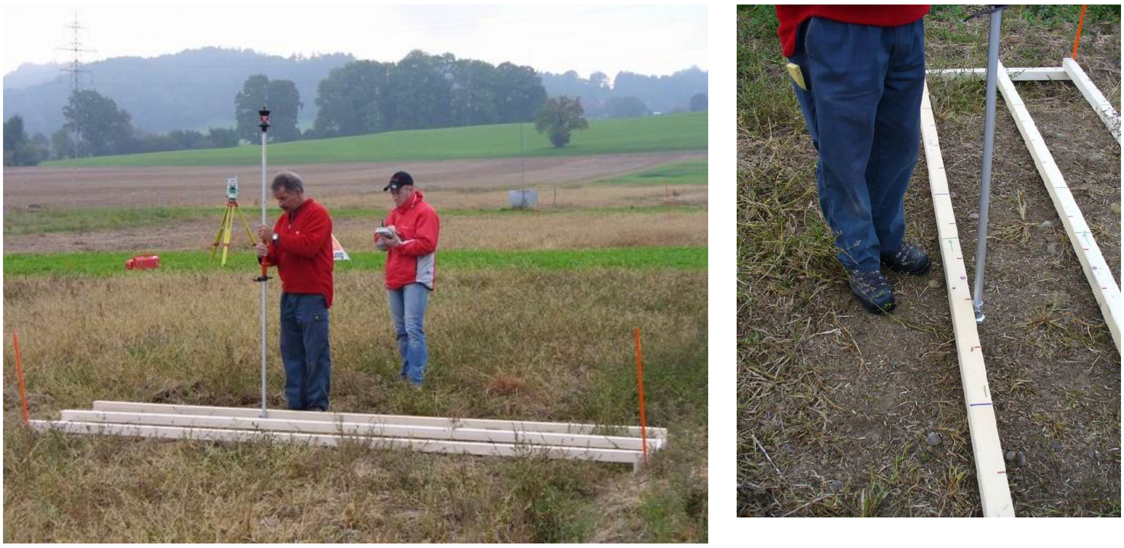

Fig. 5: The surveyor's office surveying the soil surface with a measuring frame. Source: Agroscope ART

3.7 Penetrometer Measurements
The soil penetration resistance of a 4cm2 cone was determined with a Panda-1 penetrometer manufactured by Sol-Solution. All the variants were sampled with a measuring frame across the cultivation lane in the centre of the plots, and in the case of CTF also in the marginal area, 20 cm apart over a 4 m width. The insertions were repeated in three replications 50 cm apart (*Fig. 6*).

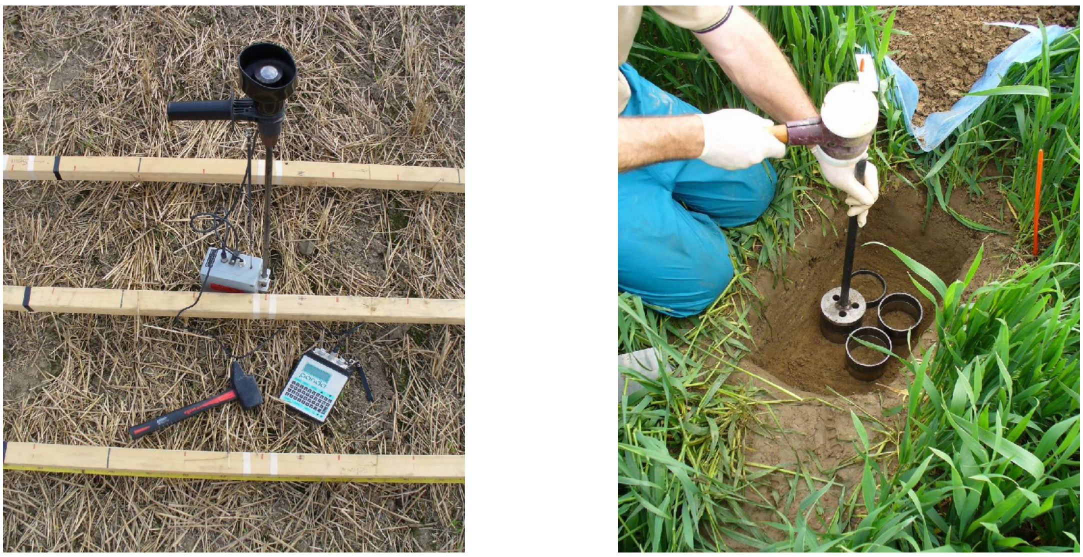

Fig. 6: left: Panda penetrometer with measuring frame in the field. Right: Taking samples with core cutters to determine macroporosity. Source: Agroscope ART

3.8 Emergence rate
In order to determine the emergence rate two measurement zones 50 cm in width and 5 m in length were established for each plot and variant roughly four weeks after seeding. In no-till and CTF no-till this corresponds to a width of 3 seeding rows, in ploughing to 4 seeding rows. Five strips 1 m long were counted out inside these zones. In CTF a distinction was made between zones with and without motorised traffic.

3.9 Intermediate harvest

For the intermediate harvest in mid-April 2008 and 2010 zones of 50 cm in width and 3 m in length were established in an extension of the emergence rate measurement zones. In five 60 cm long strips within these zones the plants were cut about 2 cm above the ground. To determine the dry matter the fresh matter was weighed, the samples oven-dried for 24 h at 105 °C and reweighed.

3.10 Macropore volume

In an extension of the emergence rate measurement zones, the areas for sampling to determine macropore volume were established at 50 cm in width and 2 m in length. Inside these zones four core cutters samples are being taken at depths of 10-15 cm and 35-40 cm, in each case in April/May 2009/10/11 (*Fig. 6*).

4. Preliminary results

4.1 Surface survey

In the figure showing the 2008 starting position values it is clear that the trial field slopes laterally and longitudinally (*Fig. 7*). The previous year's traffic lanes are visible in the ploughed plots. The CTF plots hitherto farmed using the mulch seeding method (max. 10 cm loosening depth) showed the least tracks. In 2009 the results looked very similar, there was no identifiable trend.

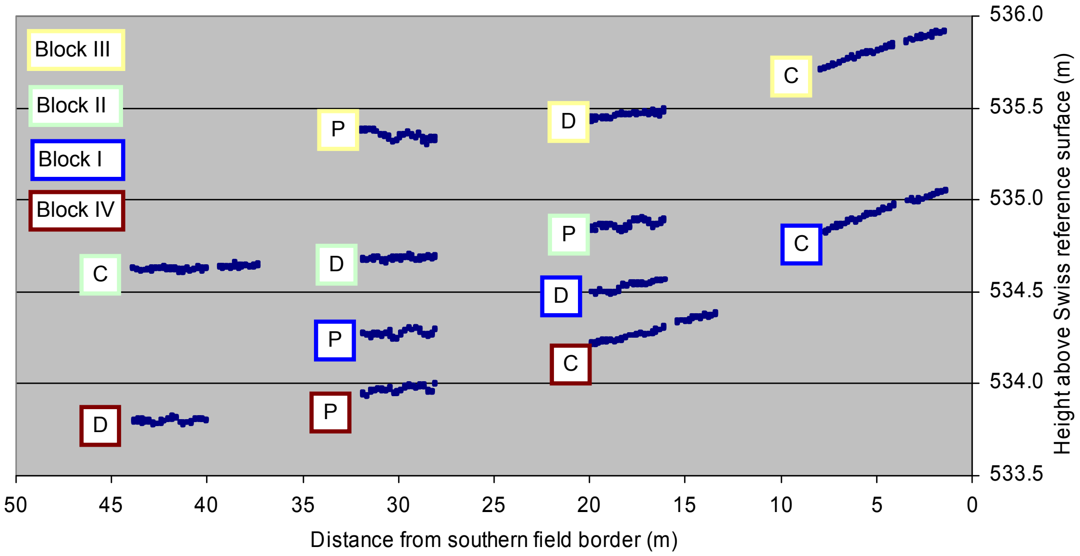

Fig. 7: 2008 surface survey. Legend: Plough (P), direct seed (D), controlled traffic (C). Source: Agroscope ART

4.2 Penetrometer Measurements

When evaluating the 2008 and 2009 penetrometry data (*Fig. 8*) it should be borne in mind that penetrometers generally react strongly to differences in soil moisture. The moister it is, the less the penetration resistance. It is better to interpret differences in relative terms than with absolute values. Major differences are therefore apparent in the annual comparison of depth classes 0-5 cm and 5-10 cm. Presumably within these two horizons it was moister in 2008 (36 l rain around 5d prior to measuring) than in 2009 (roughly ten days without rain). Such a great difference in soil structure appears unlikely.
The following points stand out when interpreting the charts:

- In 2009 in CTF the penetration resistance in the ‘C – no traffic’ zone was significantly lower than in ‘C – minimal traffic’ and ‘C – intensive traffic’. → Are the different traffic zones differentiated?
- In 2008 the penetration resistance in the 'C - minimal traffic' lanes travelled twice a year during seeding and combine harvesting was significantly lower than in the frequently trafficked 'C - intensive traffic' cultivation lanes. In 2009 the two were on a similar level, with 'C - minimal traffic' showing slightly lower values. → Are frequency and type of passage less critical than yes/no passage?
- Under the no-till regime in 2008 and 2009 the values of 'D - intensive traffic' cultivation lanes and the remaining 'D - trafficked' area were close, with 'D - trafficked' showing slightly lower values.
- Intensively and lightly trafficked CTF areas have a higher penetration resistance than no-till areas, only no-traffic CTF areas show slightly lower values. → Does the previous history of the plots show here that no-till already was no-till for 10 years, but CTF was shallow tilled to a depth of 10cm until 2007?

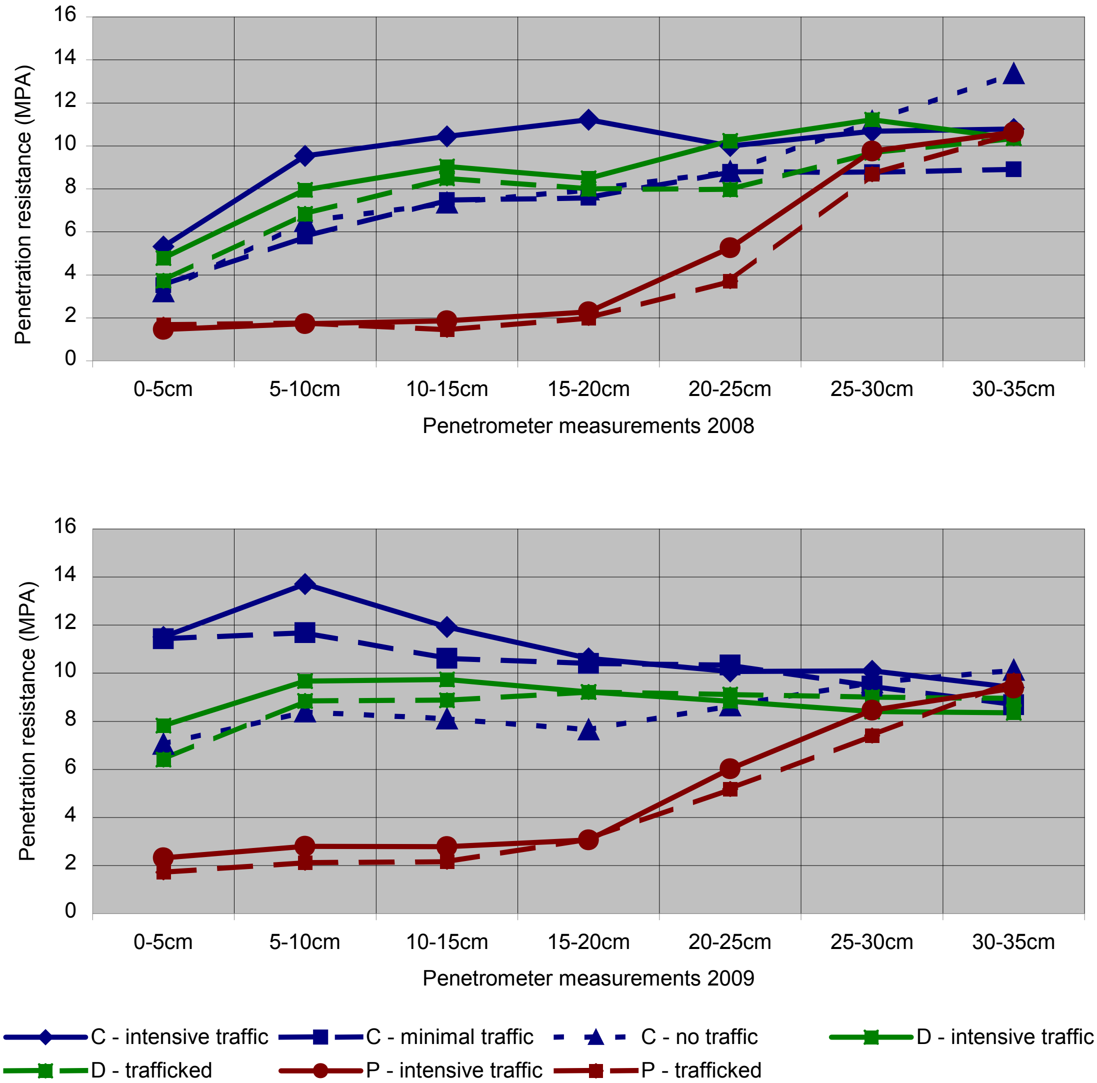

Fig. 8, top: Penetrometer measurements in September 2008 before seeding winter wheat. In July during the bean harvest the combine harvester already used the CTF tracks. Bottom: Penetrometer measurements in September 2009 before seeding winter barley. Legend: Plough (P), direct seed (D), controlled traffic (C). Source: Agroscope ART

4.3 Emergence rate

The emergence rate for winter barley in 2009/10 was considerably less heterogeneous than for winter wheat in 2008/09 (*Fig. 9*). In 2009 ploughing showed a significantly better emergence rate than any of the other variants. Seen in absolute terms, however, the differences are not significant, emergence rates were consistent in all the methods. These differences may be due to differing seed beds or differing seeding techniques.

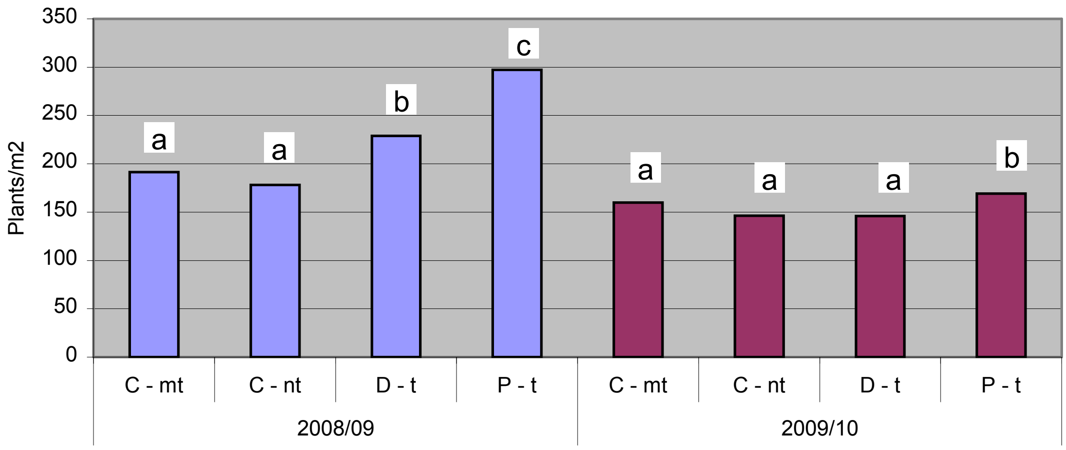

Fig. 9: 2008 and 2009 emergence rates, statistical comparisons within each of the corresponding years. Legend: C-mt = controlled traffic - minimal traffic, C-nt = controlled traffic - no traffic, D-t = direct seed - trafficked, P-t = plough - trafficked. Source: Agroscope ART

4.4 Intermediate harvest

In 2008/09 the average dry matter figures for the intermediate harvest in the CTF and no-till variants were close, ploughing dropped sharply after winterkill damage. In 2009/10 the values were closer together (*Fig. 10*).

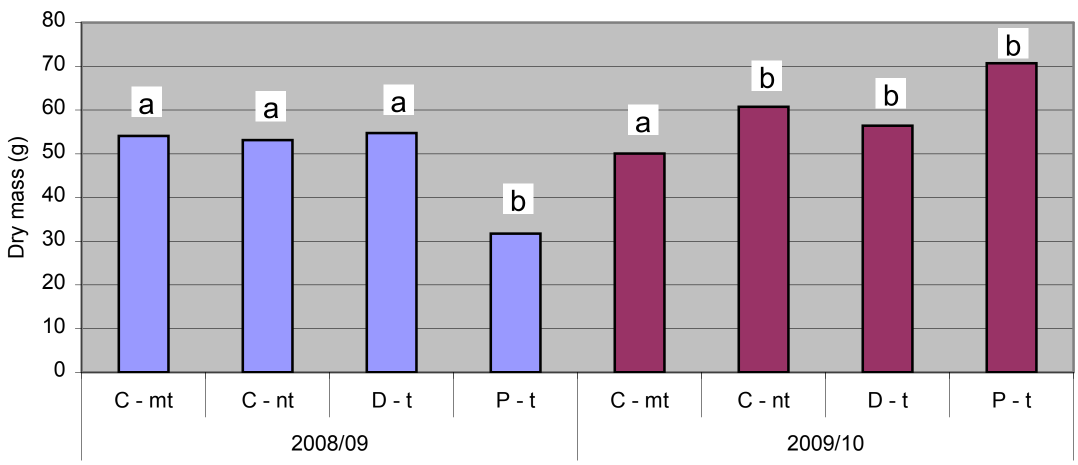

Fig. 10: Dry mass values after the intermediate harvests in April 2009 and 2010, statistical comparisons within each of the corresponding years. Legend: C-mt = controlled traffic - minimal traffic, C-nt = controlled traffic - no traffic, D-t = direct seed - trafficked, P-t = plough - trafficked. Source: Agroscope ART

4.5 Macroporosity

In the ploughing variant macropore volume in the topsoil (10-15 cm) was roughly twice as high as in the no-till and CTF no-till variants. There was no significant difference between no-till and CTF. In the subsoil (35-40 cm) the variants were closer together with higher values for ploughing and no-till, which were on the same significance level. The different survey zones in the CTF variant were not significantly different from one another (*Fig. 11*).

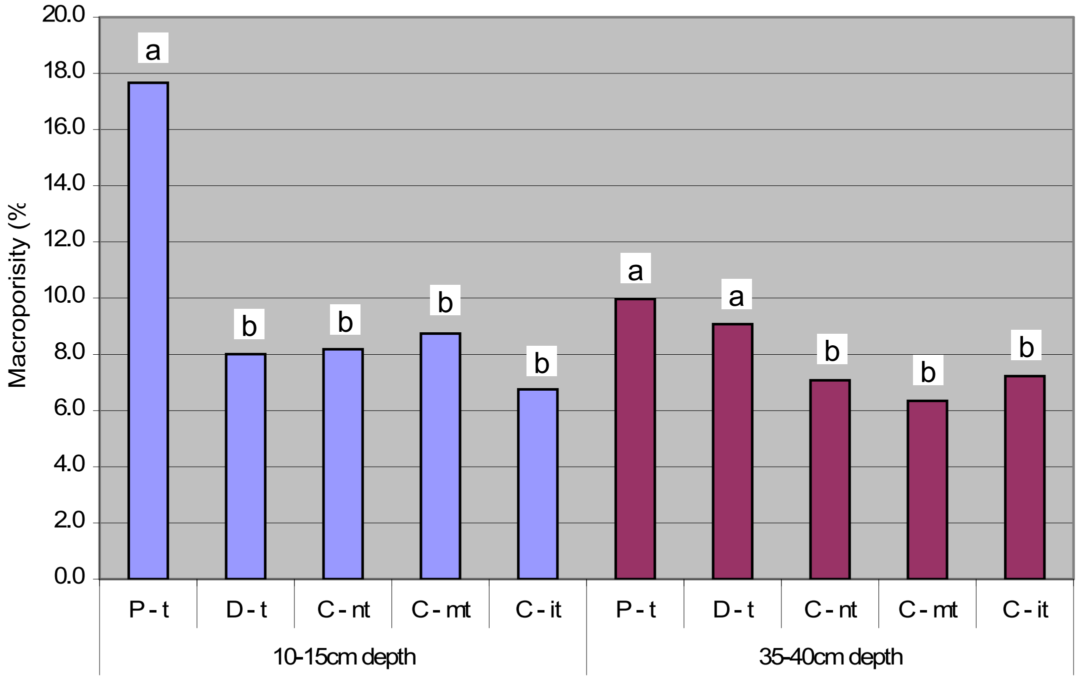

Fig. 11: Macropore volume (median) in the topsoil (10-15 cm) and subsoil (35-40 cm), statistical comparisons within each of the corresponding depths. Legend: P-t = plough - trafficked, D-t = direct seed - trafficked, C-nt = controlled traffic - no traffic, C-mt = controlled traffic - minimal traffic, C-it = controlled traffic - intensive traffic, . Source: Agroscope ART

5. Conclusion

The initial results of the various measurements show that methods differ from one another. At the present time, however, after one and a half years, it is too early to reach any conclusions. In-depth analysis and synthesis will be possible once measurement results are available for the 2009/10 and 2010/11 harvest years.

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