Causes and Management of Soil Compaction

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SWMC and CTF Europe
Causes of soil compaction

• Machines
  – pressure and weight under tyres
    • pressure dominates effects in topsoil
    • weight dominates effects in subsoil
    • rubber tracks are different

• Livestock
  – high pressure, low weight
    • effects mostly confined to topsoil
    – Rule of thumb for tyres
      • pressure (P) at the surface reduces to half its value at a depth equivalent to the width of the tyre

\[
P = \frac{W}{D} = \frac{W}{2}
\]
Causes of soil compaction

• Tillage
  – thin bands at tillage depth caused by poorly set or maintained machines, particularly discs
    • magnitude of effect much less than traffic and livestock
  – destabilisation
    • e.g. slumping after rain

• Rainfall impact
  – surface layer, recognised as “crusting”
Dynamics of soil compaction

Effect of increasing weight at same surface pressure

Effect of soil moisture content

From: http://www.extension.umn.edu/agriculture/tillage/soil-compaction/#causes
Tracks

- Lay down area in length rather than width – but pressure not even under this length

Accepted thinking: most stress under tracks is dissipated in the topsoil
Pressure at 0.3m depth

Challenger 765C 16t

MF 8480 Tractor 12.2t

Front/Rear

- MachXbib Low 0.7/0.7 bar
- MachXbib High 1.2/1.5 bar
- Axiobib Low 0.7/0.7 bar
- Axiobib High 1.2/1.5 bar
- Challenger

Outcomes of soil compaction
And it’s not just cultivated soils!
Wheels have a big impact!

One week later!
Effects of tracking on infiltration

non-trafficked > by average factor of 4

No obvious wheel track in stubble
375 mm/h infiltration

Wheel track evident in stubble
No measurable infiltration
Outcomes of poor infiltration
Compaction makes soils stronger

First video, no-till for 3 years with random traffic

Second video, no-till and no traffic for 3 years
Percentage savings in tillage draught on non-trafficked soil

% saving in draught

Depth of tillage, mm

- 60 at 100 mm
- 30 at 200 mm
- 20 at 500 mm
Compaction makes soil management more difficult and costly

- Energy to loosen. Energy to re-compact
- Loss of moisture
- Uneven germination and growth
  - Timeliness effects on subsequent chemical applications
  - Poor stale seedbed performance
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Random traffic vs. Non-trafficked soil
Managing compaction
First principles – try and avoid wet soils

- Maintain existing and consider introducing new drainage schemes
Effect of impervious layers on soil water content

After lunch demonstration
Managing compaction
Choosing and using tyres correctly

• Learn the principles
  – manufacturer’s literature and training workshops
    • tyre data book or pdf
  – lowest inflation pressure for load and speed
Tyres have very different characteristics – but also costs!
Demonstration of the effects of changing tyres

Combine on standard tyres
The effect of more tyres and lower pressures

Same day, same combine, duals at lower pressure
Tracks

• Advantages
  – Less area tracked on each pass
  – More efficient pulling power
    • 4% compared with 10% slip
  – Less rutting

• Disadvantages
  – Heavier than wheels
  – More expensive than wheels
  – Can do more damage to crops on turning
Tracks

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265 kW tracked tractor – 25% premium compared with equivalent wheeled tractor of 425 kW
Setting up machinery combinations properly

• Mounted cultivators
  – correct ballasting
  – 3-point hitch geometry
    • top link position should ensure weight transfer onto rear wheels

• Trailed cultivators
  – correct ballasting
  – particularly important with single tracks
Keep an eye on weight

- Take time to remove excess weight

Not always easy or appropriate

and can remove too much!
The effects of increasing weight

It’s load that does damage at depth

Could this be a reason for the plateau in wheat yields?

Timeline from the 1930s to the present day

Predicted pressure at 0.5 m depth, bar

850 kg Horse
11.2-28
12.4-36
16.9-34
18.4-38
16.9 R 34
710/70 R 38
800/65R32
1050/50R32

21 t vehicle

2.5 t vehicle
Managing compaction

Controlled Traffic Farming - CTF

• any system that confines all tracks to least possible area of permanent traffic lanes

  – CT is NOT prescriptive about tillage
  – CT is NOT just about keeping tramlines in the same place
  – Commitment to continual improvement
Increased crop yields

% increase in yield by crop type under controlled compared with random traffic

Numbers in brackets denote number of research results from which data were taken.
CTF – how?

• Match as many track gauges as possible

• Match implement widths

• Introduce a Global Navigation Satellite System (GNSS) with RTK correction
Matching track and implement gauges

“OutTrac” CTF system

Harvester e.g. 2.8 m

Other vehicles e.g. 2 m
East Hendred 10 m OutTrac system

20% tracked area
Is there compaction?

Is it economic to subsoil?

Are conditions right or will the wings smear?

Will subsoiling let out too much moisture?

Have we got time?

What depth to subsoil?

East Hendred, Julian Gold

“Once a CTF system is set up farming gets much simpler”
Baling at East Hendred
- dropping or moving bale to the right place

https://www.youtube.com/watch?v=ZMqBBsqKKq4
Example of OutTrac for maize

OutTrac CTF System

3.35 m harvester track gauge

6 m, 9 row maize planter, 0.67 m rows

2.01 m tractor track gauge
Matching widths

TwinTrac – tractors straddle harvester passes

Max 6 m wide implements or multiple of
Only an RTK GNSS system provides repeatable positioning.
## Costs for auto-steer systems

**October 2015**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost, GBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGNOS only, friction drive steering</td>
<td>2,500 (± 30 cm)</td>
</tr>
<tr>
<td>RTK with friction drive steering</td>
<td>8,000&lt;sup&gt;1&lt;/sup&gt; (± 2.5 cm)</td>
</tr>
<tr>
<td>RTK base station, installed and with back-up support</td>
<td>14,000</td>
</tr>
<tr>
<td>RTK base station only (no support)</td>
<td>9,000</td>
</tr>
<tr>
<td>RTK receiver on auto-steer ready vehicle</td>
<td>9,000</td>
</tr>
<tr>
<td>RTK receiver on bare vehicle</td>
<td>14,000</td>
</tr>
<tr>
<td>RTK receiver on bare vehicle with all controls, e.g. boom section, auto-shutoff, implement steer</td>
<td>Up to 24,000</td>
</tr>
</tbody>
</table>

<sup>1</sup> Does not include base station or other means of delivery of correction signal
Why CTF?

• Avoids soil damage from traffic on large proportion of field:
  – lower costs
    • less tillage needed
    • implements easier to pull
  – boosts crop yields
    • average increase of around 10%
  – no-till systems work better
    • managed traffic lanes
    • little or no yield loss in early years
  – reduces greenhouse gas emissions
    • nitrous oxide and CO₂
Soil conditions following onion harvest

Easier transition between crops

CTF

Conventional
CTF can allow direct planting of potatoes without tillage after onions for example
## Lower energy for CTF

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Conventional</th>
<th>CTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time for crop establishment, h/ha</td>
<td>1.21</td>
<td>0.86</td>
</tr>
<tr>
<td>Fuel needed, l/ha</td>
<td>38</td>
<td>23&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Energy, kWh/ha</td>
<td>71</td>
<td>22</td>
</tr>
</tbody>
</table>

<sup>1</sup>Equivalent to a saving of about £10/ha in fuel costs
Comparison of costs using Farm Management Pocketbook\(^1\) Clay soil

<table>
<thead>
<tr>
<th>Operation</th>
<th>Traffic, plough</th>
<th>Traffic, min till</th>
<th>CTF, min till</th>
<th>CTF, no-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsoiling</td>
<td>12</td>
<td>12</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Ploughing</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary cults</td>
<td>45</td>
<td>47</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Drill</td>
<td>26</td>
<td>26</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>Roll</td>
<td>15</td>
<td>15</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Totals</td>
<td>168</td>
<td>100</td>
<td>67</td>
<td>50</td>
</tr>
</tbody>
</table>

\(^1\)Nix, 2012. [www.thepocketbook.co.uk](http://www.thepocketbook.co.uk)
What makes a change to CTF difficult?

- Perceived cost
- Poor compatibility of machines
- Perceived need for extensive tillage
- Uncertainty and risk
- Complication and attention to detail
- An element of inflexibility
- Time and inertia
CTF can turn tracking on its head!

<table>
<thead>
<tr>
<th>Method</th>
<th>Percentage Tracked</th>
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<tbody>
<tr>
<td>Conventional</td>
<td>45 – 85% tracked each season</td>
</tr>
<tr>
<td>CTF</td>
<td>70 – 85% permanently not tracked</td>
</tr>
</tbody>
</table>
SOIL REPAIR AND PROTECTION
Subsoiling

• Consider carefully:
  – before
  – during
  – after
Soil looseners

- Chisel tine (Shakerator)
- Conventional Subsoiler
- High lift Winged Subsoiler
- Low lift wings + leading disc
- Paraplow
- Moleplough
Effect of wings

Draught
- Conventional subsoiler: 20.43 kN
- Winged subsoiler: 26.58 kN

Disturbed area
- Conventional subsoiler: 0.098 m²
- Winged subsoiler: 0.184 m²

Specific resistance
- Conventional subsoiler: 208 kN/m²
- Winged subsoiler: 144 kN/m²

After: Spoor and Godwin, 1978
Get the depth, spacing and angle right

• Depth just below compact layer

• Spacing:
  – 1.5 x depth for simple tine
  – 2.0 x depth for winged tines
  – 2.25 x depth for winged and leading tines

• Angle of share
  – 20 deg to horizontal
Subsoiling can make compaction worse!

![Graph showing penetration resistance vs. depth for different tractor types.](image-url)

- "As found"
- After subsoiling
- Large tractor
- Large + medium tractor
- Tracked tractor
- TT + medium tractor
Mole ploughing might be a better option

After subsoiling or mole ploughing is a good time to think about controlled traffic farming (CTF)
Loosening maintained with CTF
4 years after subsoiling