# An investigation into the effect of traffic and tillage on soil properties using X-ray computed tomography

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## Background

- A randomised 3x3 factorial experiment (three tillage: deep - 250mm, shallow - 100mm, zero) x (three traffic: **RTF** - high pressure tyres, **LGP** - low ground pressure tyres, **CTF** - controlled traffic) with four replicated blocks (i.e. 36 plots - 4m wide x 80m long) was established in September 2012 on Large Marsh at Harper Adams University
- Spring oats (Aspen) were drilled 25th April 2016 at seed rate 350/m$^2$ (+30% on zero till plots) and harvested 7th and 8th September 2016
- ANOVA analysis showed there were significant differences for yields (Figure 1) between CTF and RTF due to tillage (p=0.057) and between tilled (deep and shallow) and untilled plots (p<0.001)

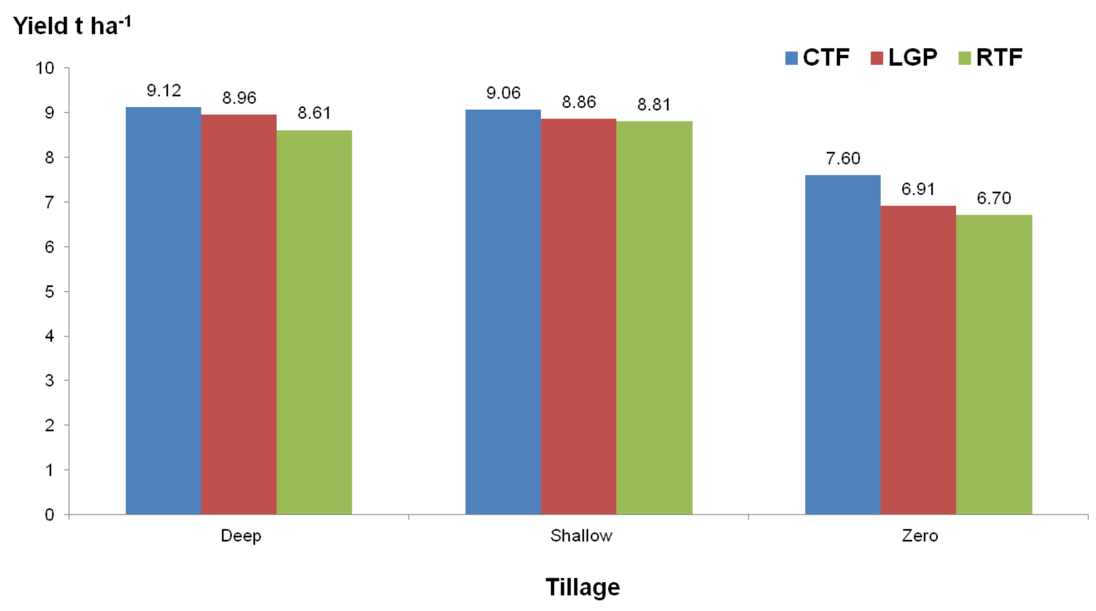


Figure 1: **Spring oats combine harvest mean yield t ha$^{-1}$**

- Studies have shown that soil macropore size and distribution affects plant development and that X-ray computed tomography can provide a three-dimensional model of soil pore structure (Pierret *et al*, 2002)
- **Question:** Could X-ray computed tomography be a suitable tool to investigate pore size and distribution in order to make comparisons to the differences in yield of spring oats under different traffic and tillage treatments?

## Method

- 36 undisturbed soil cores (0-300mm deep) were collected in Ø50mm plastic tubes (Figure 2) using an Eijkelkamp liner sampler immediately prior to harvest. RTF and LGP samples were collected from plot primary wheelways and CTF from plot untrafficked soil
- Samples were x-rayed at the Hounsfield Facility, University of Nottingham with a Phoenix v|tome|x m CT Scanner (Figure 3) at 120 kV energy and 72 μm resolution
- Scans were reconstructed into 3D images using VGStudio Max and exported as image stack files (Tiff format) for analysis using ImageJ

Figure 2: **Undisturbed soil core**

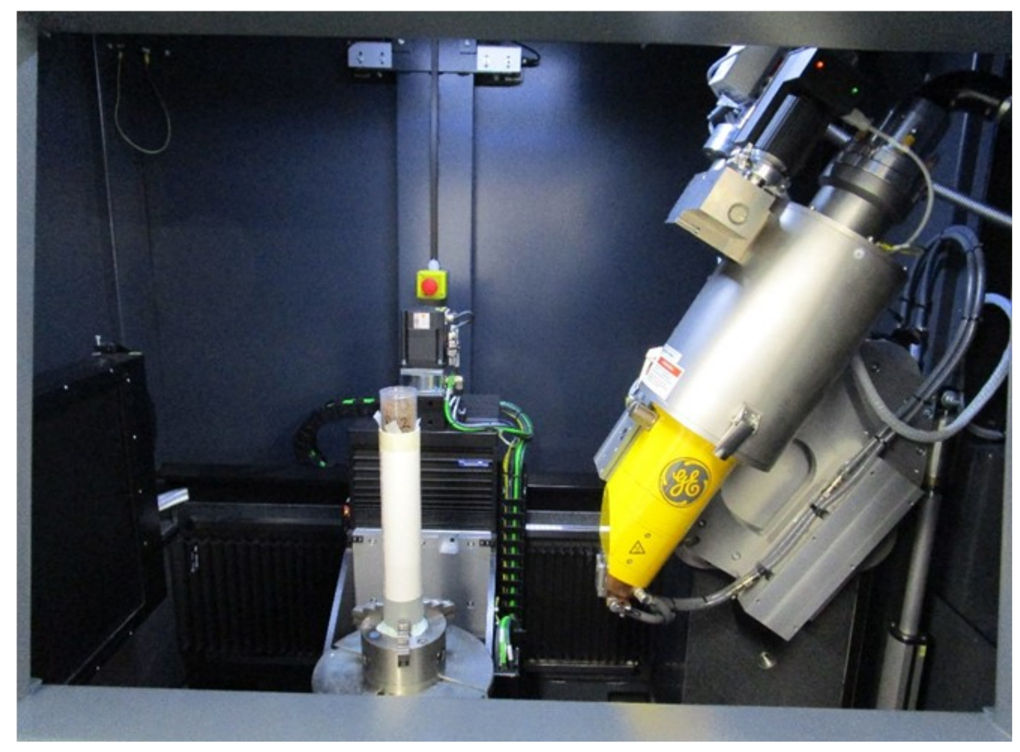

Figure 3: **Phoenix v|tome|x m CT scanner**

## Results

- The sample images in Figure 4 show the differences in soil structure between cores subjected to the different treatments. **Deep tillage**: The CTF core shows a reasonably open structure whilst the RTF and LGP show evidence of possible re-compaction after tillage. **Shallow tillage**: Samples show the effect of the shallow tillage in the upper zone (0-60mm) with RTF and LGP showing poorer structure around 150mm depth illustrated by horizontal cracking and lack of pore space. **Zero tillage**: Samples show poorer structure with the presence of horizontal cracking
- The graphs at Figure 5 were produced from the output from ImageJ. They illustrate the changes in soil pore numbers and relative porosity through the soil profile (depth = mm) for a soil core sample taken from RTF Deep tillage. It shows that the number of pores begins to decrease around 50mm depth and that porosity declines quickly at around 90mm depth

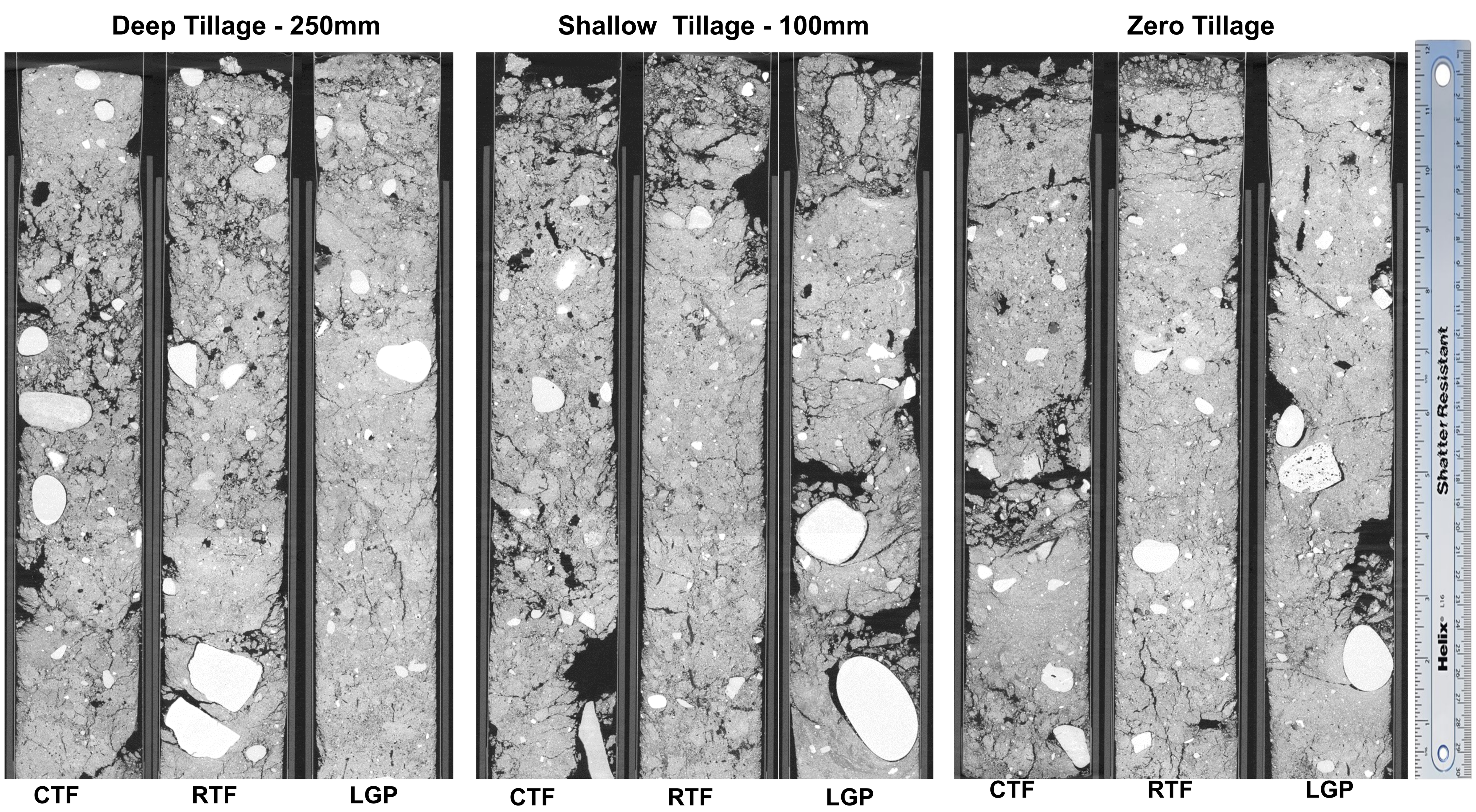


Figure 4: **X-ray computed tomography images through soil cores**

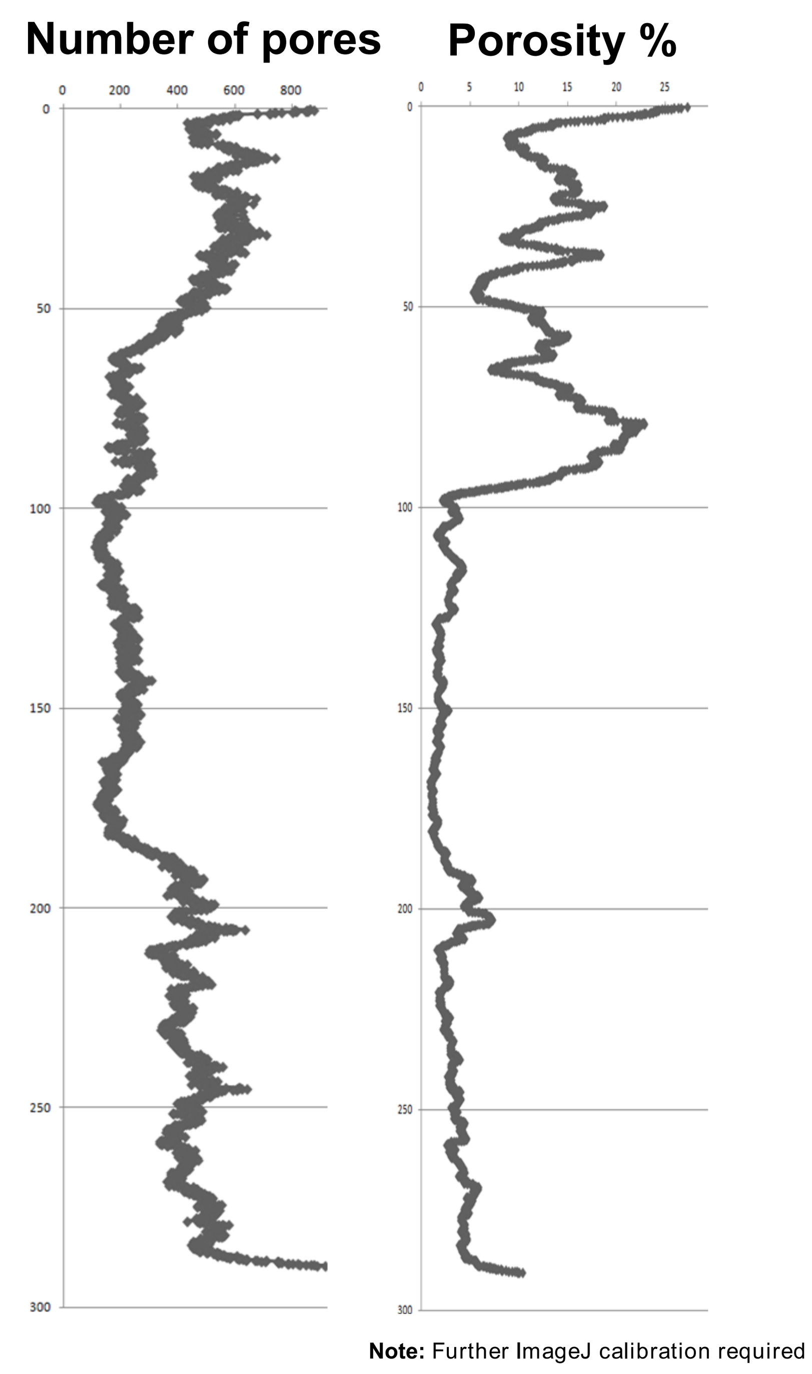


Figure 5: **ImageJ output for a RTF Deep tillage soil core**

## Conclusion

- X-ray computed tomography is an effective tool to analyse undisturbed soil cores both visually and by analysis using image processing software such as ImageJ
- ImageJ uses a threshold function to be able to analyse pore space derived from grey scale images. It is therefore necessary to ensure that the most appropriate threshold algorithm is used to capture sufficient detail on pore size and distribution

## Further Research

- Full analysis of soil core pore size and distribution using ImageJ
- Correlation of ImageJ results with soil bulk density, soil penetrometer and soil shear vane readings
- Comparison of findings with establishment, growth stage and hand harvest yield data

**Reference:** Pierret, A., Capowiez, Y., Belzunces, L. and Moran, C.J. 2002. 3D reconstruction and quantification of macropores using X-ray computed tomography and image analysis. *Geoderma*, 106, pp. 247-271.

**With thanks to:**

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