The use of geophysical technologies for forest carbon estimation

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UCD Forestry

Outline

- Introduction to Ground Penetrating Radar (GPR)
  - Principles
  - Limitations
- Areas of GPR application
- CARBiFOR II GPR research objectives
- Site
- Micro-topography surveying
- Electrical Resistivity Tomography (ERT)
- GPR equipment
- Results
- Root excavation
- Analysis – progress report

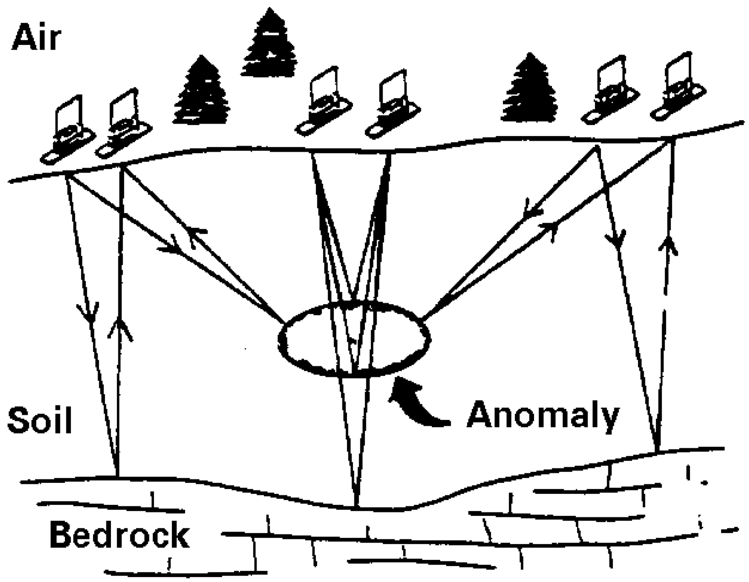
GPR – Principles (1)

- GPR is a non-destructive technology
- GPR uses high-frequency-pulsed electromagnetic (EM) waves to acquire subsurface information
- Energy is propagated downward into the ground from a transmitting antenna and is reflected back to a receiving antenna from subsurface boundaries between media possessing different EM properties
- The reflected signals are recorded to produce a scan or trace of radar data. Scans obtained as the antennae are moved over a surface are placed side by side to produce a radar profile

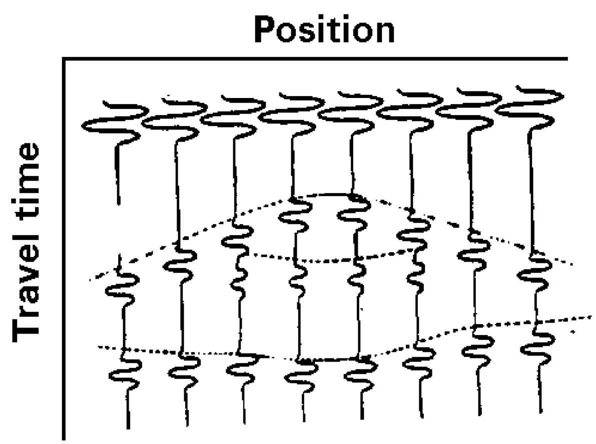
GPR – Principles (2)

- The vertical scale of the radar profile is in units of two-way travel time, the time it takes for an EM wave to travel down to a reflector and back to the surface
- The travel time may be converted to depth by relating it to on-site measurements or assumptions about the velocity of radar waves in the subsurface material under investigation
- GPR waves can reach depths up to 30 metres in low conductivity materials such as dry sand or granite. Clays, shale, and other high conductivity materials may attenuate or absorb GPR signals, decreasing the depth of penetration to 1 metre or less. The depth of penetration is also determined by the frequency of the signal emitted by the GPR antenna

GPR – Principles (3)



Schematic illustration of ground-penetrating radar detection of local underground anomalies as specific objects or interfaces.



Recorded position of the antenna and travel time of pulses are the main input data for the GPR system.

Hruska, J., Cermák, J. and Sustek, S. 1999. Mapping tree root systems with ground-penetrating radar. Tree Physiology 19: 125-130

Limitations of GPR

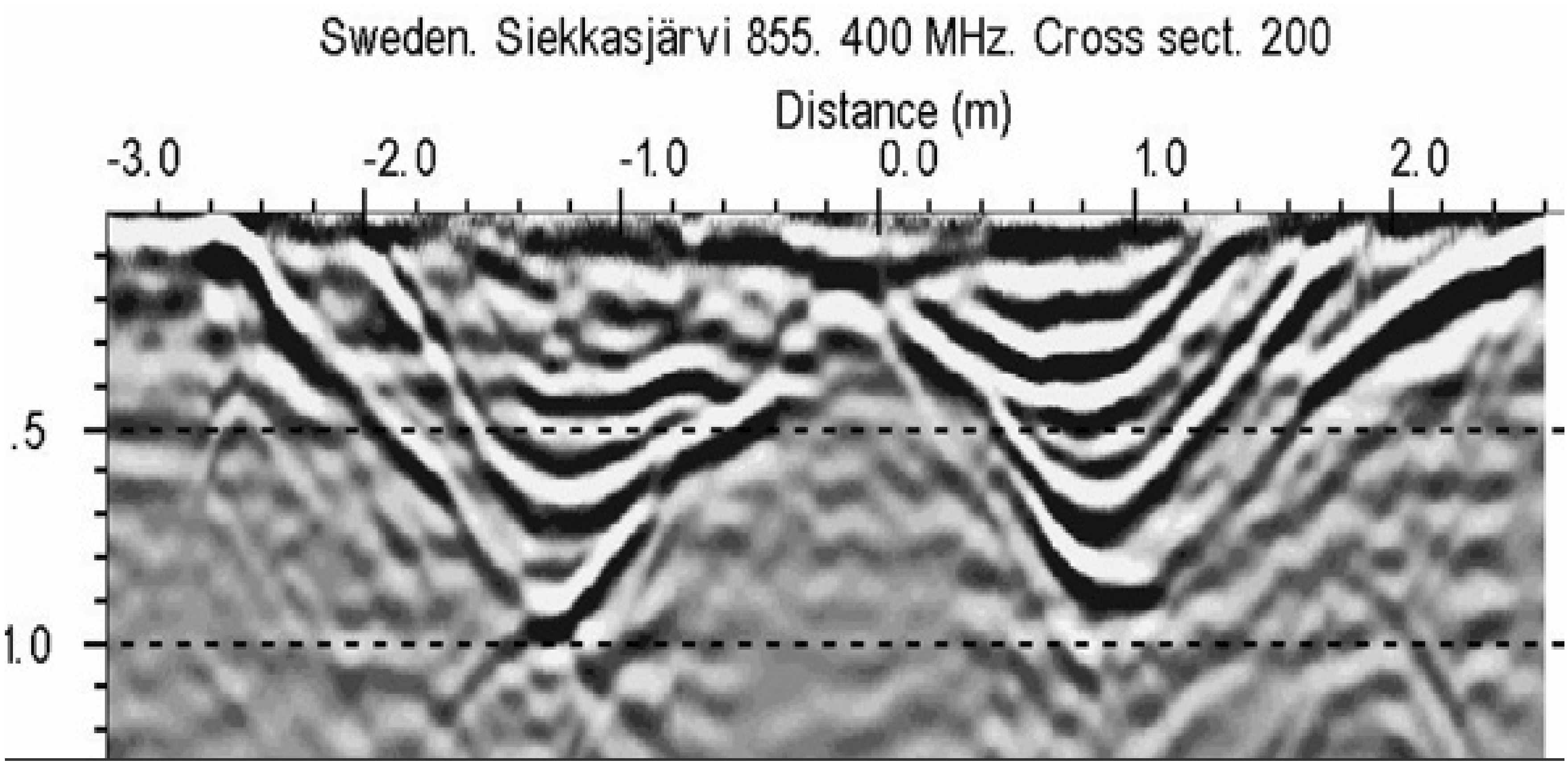
- GPR anomalies rely on a detectable contrast of subsurface electromagnetic properties between two media or within a medium. In the absence of a detectable contrast, no anomaly will be evident
- It is possible that ground conditions may contain targets that are absent from the GPR data. GPR data can also contain weak anomalies, which are difficult to interpret
- GPR signal cannot penetrate highly conductive material, e.g. beneath metal sheets or very wet ground
- Calibration should be carried out to obtain accurate depth estimates
- GPR data processing and interpretation can be complicated - specialised analysis and interpretation is required

http://www.scantech.ie/

GPR - Areas of Application

- Construction / Engineering
  - General Site Investigation
  - Utility Detection & Mapping (depth, position and direction)
  - Non-Destructive Testing of Concrete
  - Road & Rail Investigations
- Archaeological / Forensics
- Geological & Mining Applications
- Financial and Insurance Institutions
- Horticultural
- Environmental

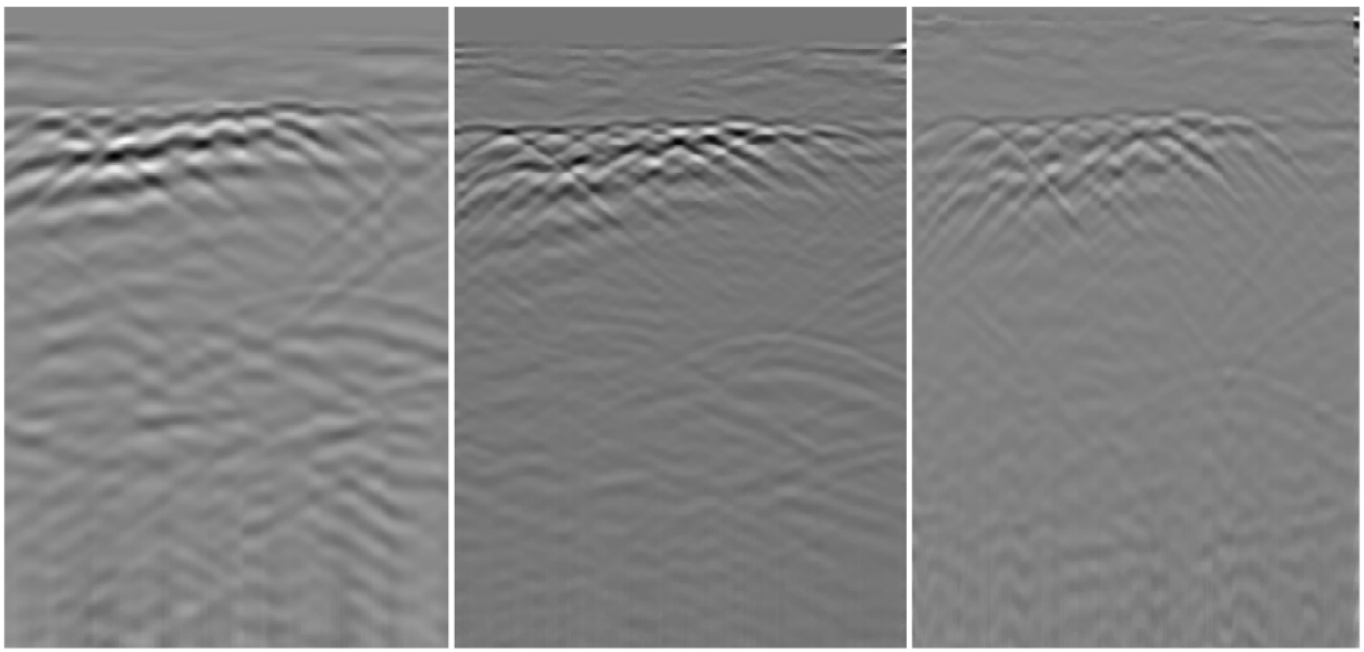
GPR - Road standard assessment



Saarenketo, T. Permanent Deformation. ROADEX Network Implementing Accessibility.
Northern Periphery Programme 2007-2013.

GPR – Forestry (1)

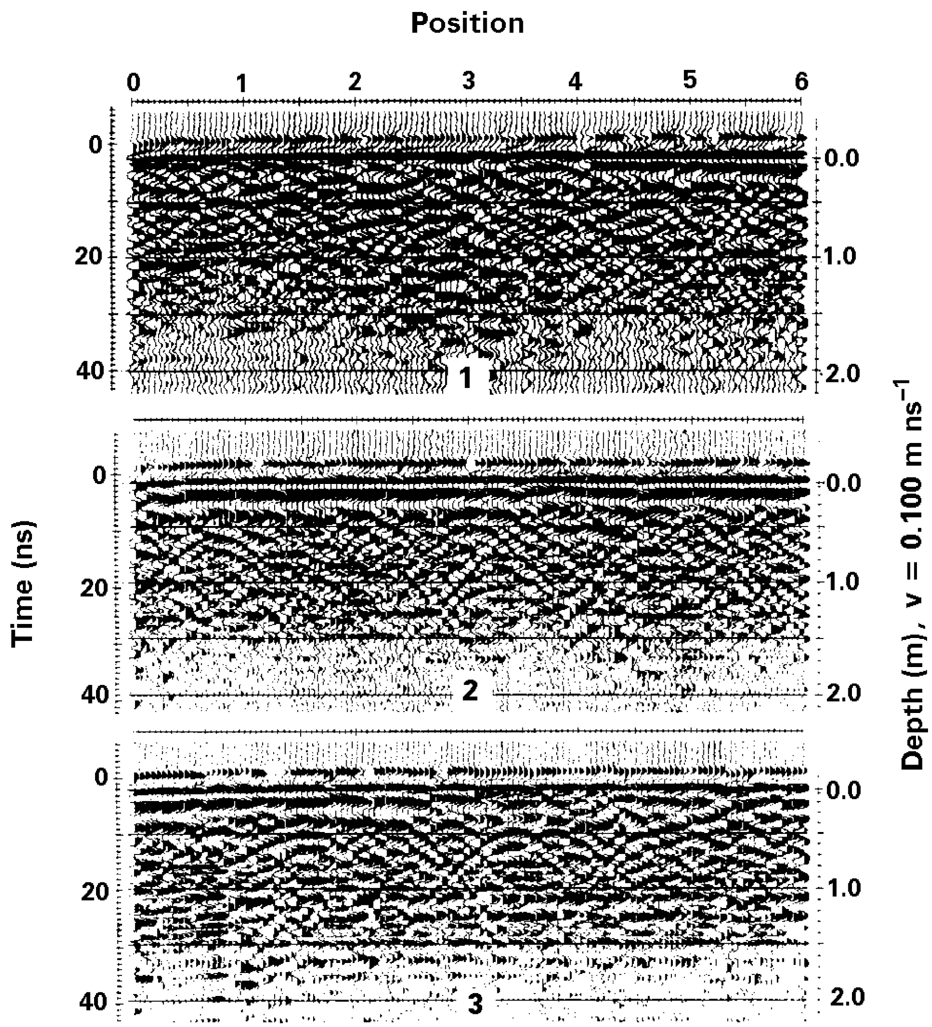
Radar profiles from three antennas (500 MHz, 800 MHz, 1 GHz) along a transect across the centre of nine roots of various sizes (10 - 1 cm diameter) buried 50 cm deep in a sand pit. Horizontal direction represents distance along the transect and vertical direction represents the travel time of the signal.



500 MHz 800 MHz 1 GHz

Barton, C. and Montagu, K. 2004. Detection of tree roots and determination of root diameters by ground penetrating radar under optimal conditions. Tree Physiology 24: 1323–1331

GPR – Forestry (2)



Ground penetrating radar profiles (1 to 3) at the experimental plot with numerous tree root indications. Recorded time is converted to depth.

Signal frequency 450 MHz.

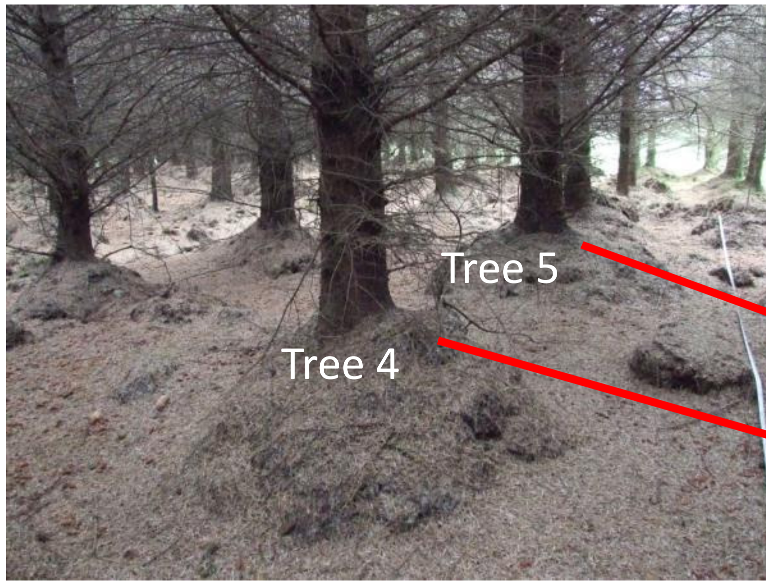
Hruska, J., Cermák, J. and Sustek, S. 1999. Mapping tree root systems with ground-penetrating radar. Tree Physiology 19: 125-130

CARBiFOR II GPR trials

- Assessment of the ability of GPR scanning to provide data to compliment other belowground biomass data from a typical forest stand / soil / environment
- Investigation of methodology to correct for site micro-topography
- Comparison of GPR data with data from excavation, soil cores and biomass functions
- Testing for use in detecting peat soil depth and the decomposition of roots and stumps

Site:

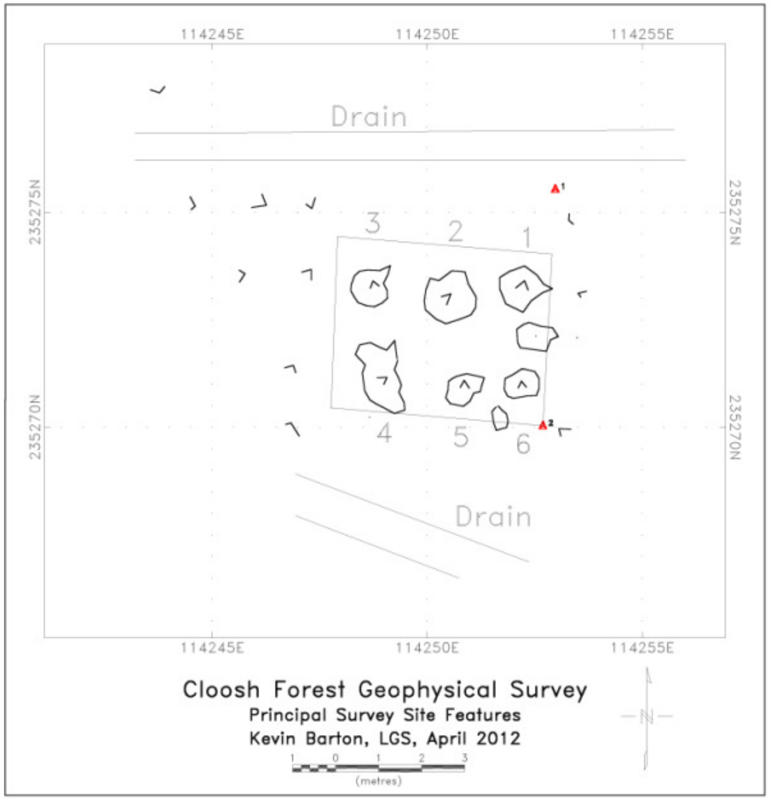
- Cloosh forest, Co. Galway (Coillte)
- Blanket peat
- Mounded, surface drains 10 m apart
- Sitka spruce, planted 1993, *c.* 2 x 2 m spacing



Main challenges:

- Soil (background) moisture close to root (target) moisture
- Site micro-topography
- GPR minimum root diameter detection limit

Site micro-topography (1)



Technical details:

- Trimble ag132 sub-metre GPS with differential corrections from the Irish Marine Radiobeacon network
- GridinQuest software
- Sokkia Set 500 total station with Sokkia SDR33 datalogger for topography and mapping
- Geosoft/Surfer software

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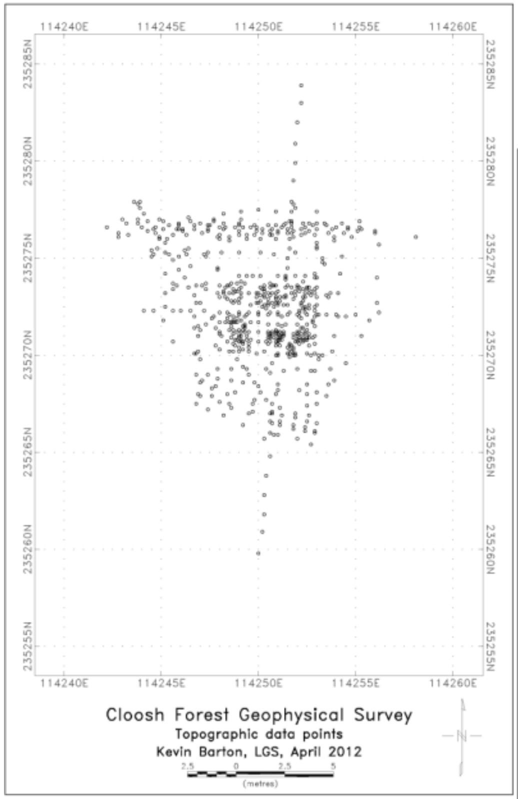
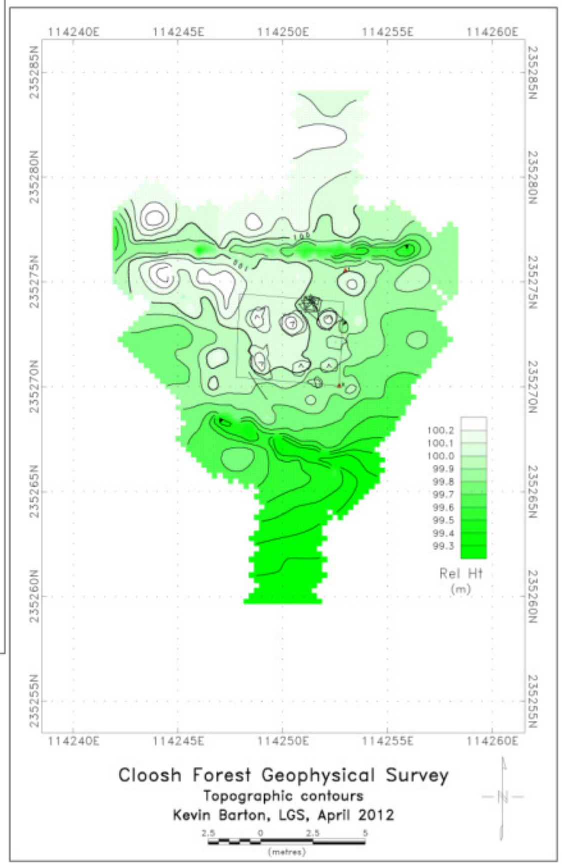
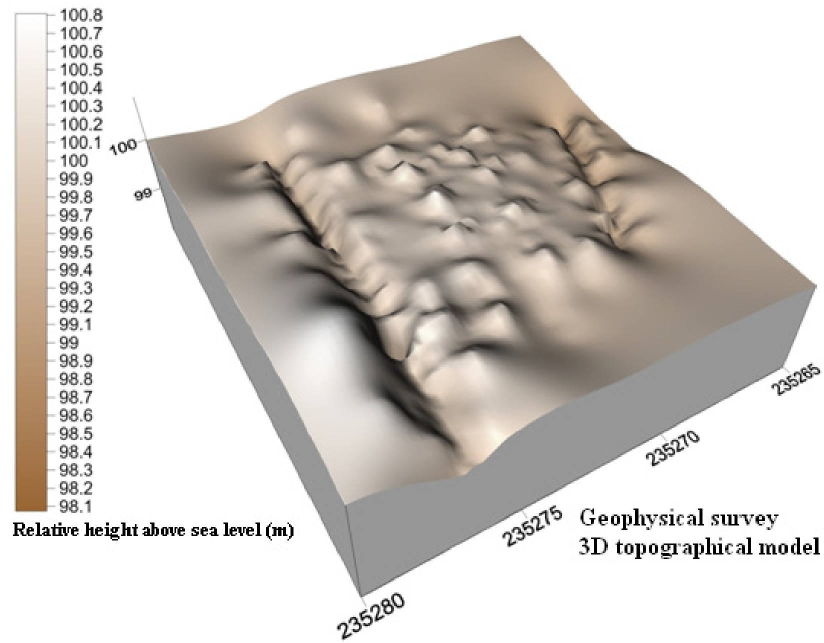
Site micro-topography (2)



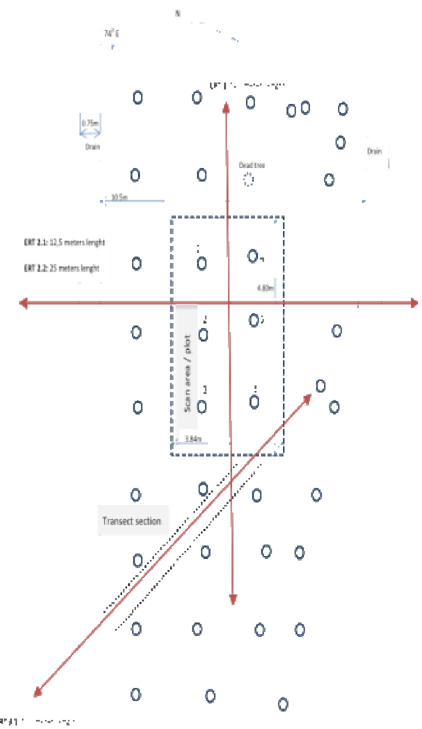


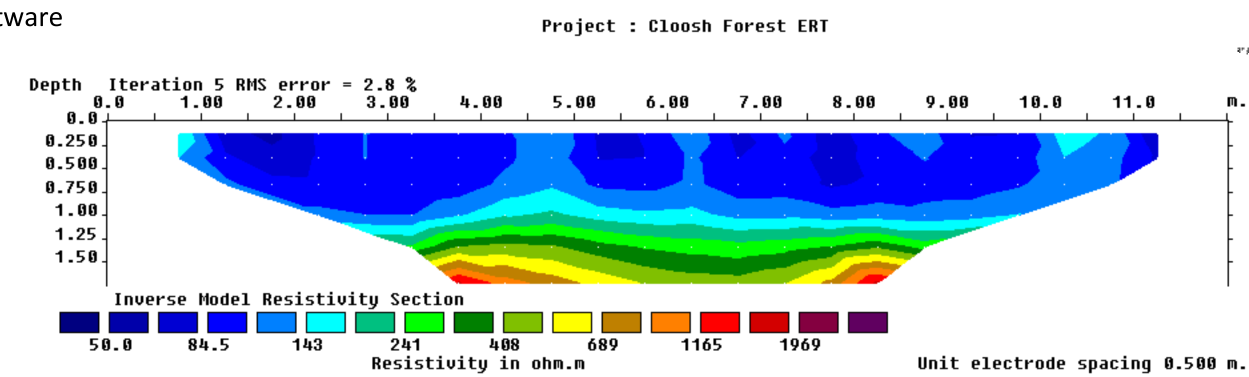


Electrical resistivity tomography (ERT) (1)

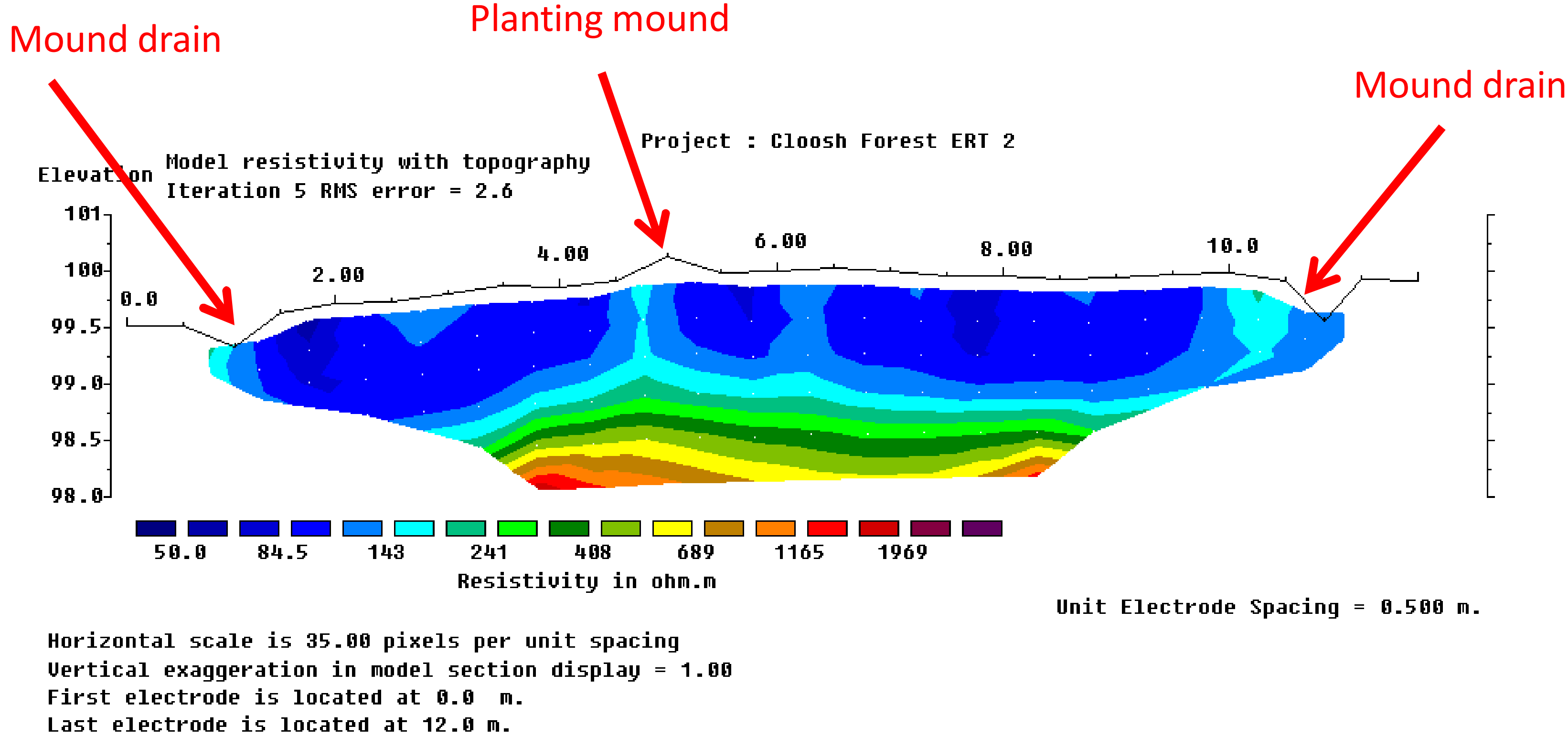
- Campus Geopulse Resistivity meter with Imager cable for ERT
- Res2Dinv software

- ERT aids the calibration, analysis and interpretation of the results provided by GPR scans
- ERT calculates soil resistivity by transmitting a current through the soil between a series of electrodes
- Depth of scan can be adjusted by varying the spacing of the electrodes
- Results presented in the form of a 2D image where the soil resistivity, largely reflecting changes in soil moisture, is differentiated by a colour gradient





Electrical resistivity tomography (ERT) (2)



- ERT scan lines are corrected for topography and elevation
- Resulting depth determination is used to calibrate the GPR scan depth

GPR scanning

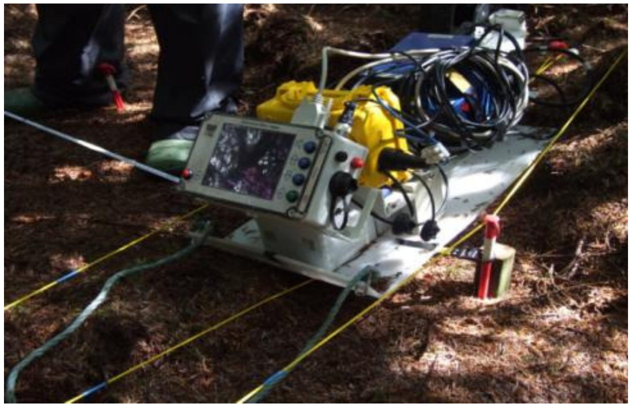
- Utsi GroundVue 3 GPR
- Sled-mounted
- Lateral distance wheel dragged behind sled to position scan image
- Problem: loss of contact with soil, producing data disruptions while travelling over mounds

400 MHz

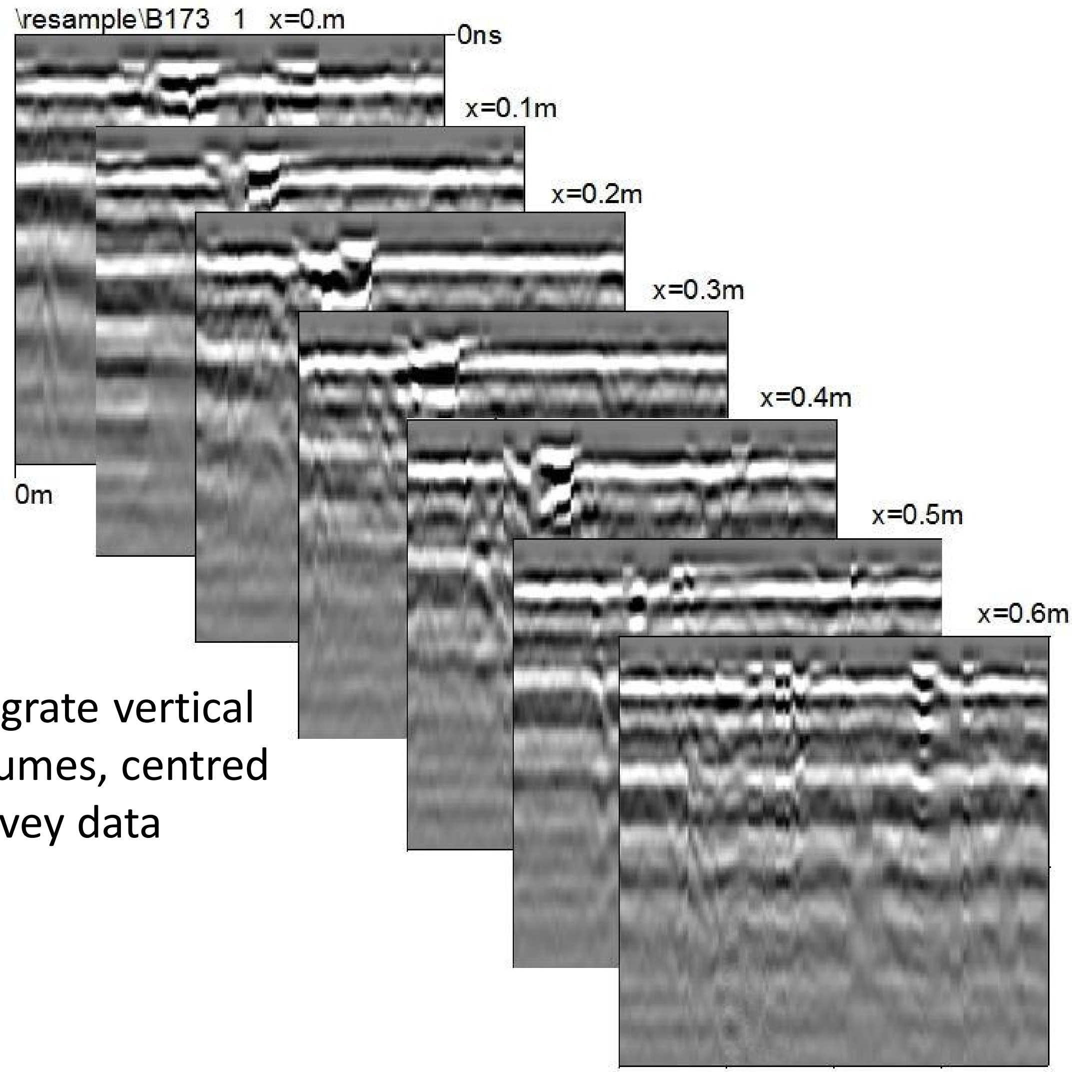
- 400 MHz antenna
- Scan lines 20 cm apart
- Good depth penetration
- Less clarity / resolution
- Physically larger antenna/receiver

1 GHz

- 1 GHz antenna
- Scan lines 10 cm apart
- Less depth penetration (max. c. 50 cm
- High resolution
- Smaller antenna/receiver



GPR scanning - outputs



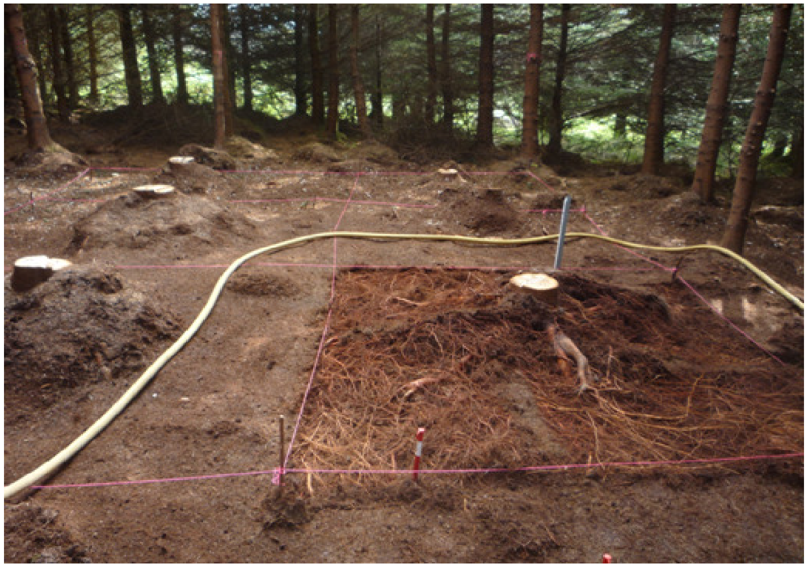
GPR slice software used to integrate vertical slices and reconstitute into volumes, centred around sample trees, using survey data

Root biomass excavation (1)

- Aboveground biomass weighed and removed
- 2 x 2 m squares marked for excavation

Root biomass excavation (2)

Roots excavated using an “air spade” (compressed air; *c.* 320 cm^3s^{-1})



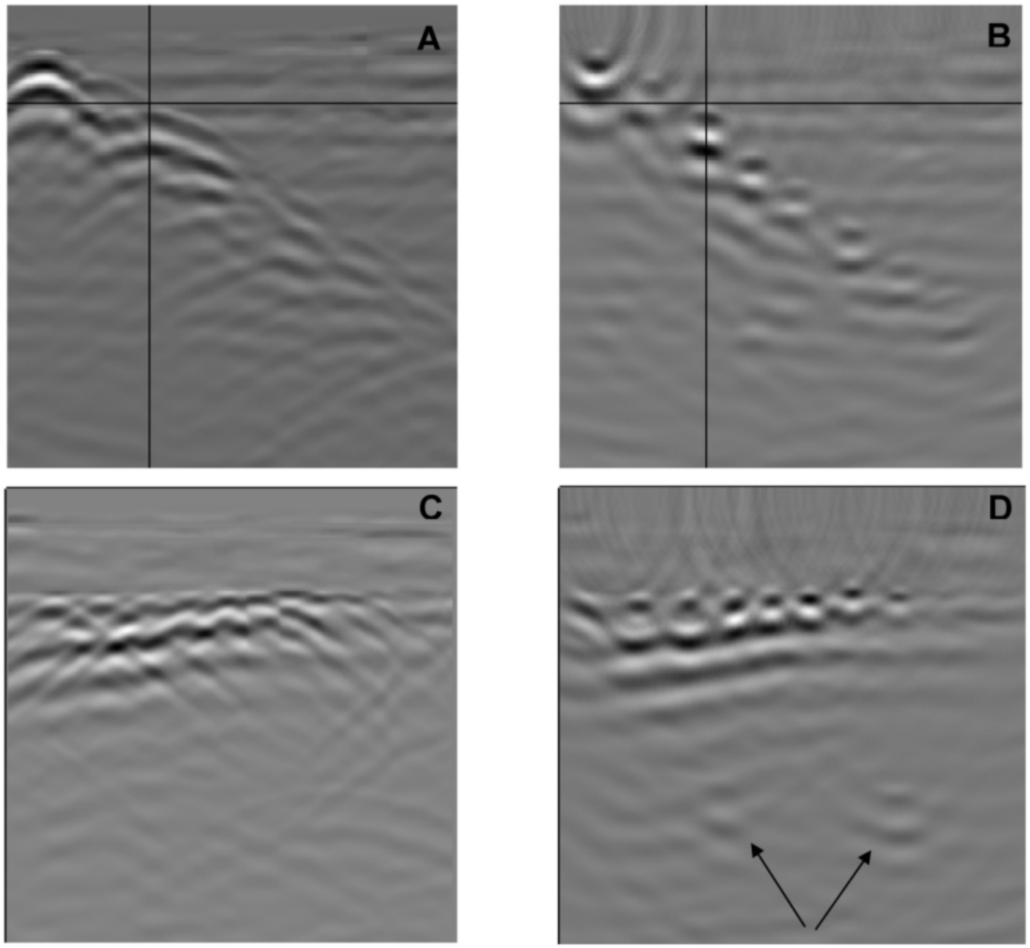
Root mass collected per sample tree
Divided between diameter categories:

- < 2 mm
- >2 mm and <10 mm
- >10 mm and <50 mm
- >50 mm

Analysis – progress report (1)

- Vertical depth slice scans have been semi-processed into sections, had linear gain applied and "rubberbanded" to fit the scan line lengths
- These data then need to be draped over the topography model to take mounding into consideration
- ERT scans will also be corrected for micro-topography and used to adjust the depth calibration of the GPR data
- The next stage is to apply/design filters to remove multiples/background and "sharpen" the images. The challenge is not to do much filtering as it may remove the signal due to the roots
- Return wave velocities need to be obtained by hyperbola matching to known obstacles
- Piece together the total root reflectance signal from the slice scans. The total reflectance signal will be compared with root biomass (divided in diameter classes)

Analysis – progress report (2)



(A) Radar profile from the 500 MHz antenna along a transect across the centre of eight roots of the similar diameter (5 cm) buried at various depths (15–155 cm). The characteristic hyperbolas are overlapping and interfering with each other, making interpretation impossible. (B) Eight roots clearly visible after the radar profile in (A) had been processed with the migration algorithm. (C) Radar profile along a transect across the centre of nine roots of various sizes (10 - 1 cm diameter) buried 50 cm deep. (D) Nine roots are clearly visible after the radar profile in (C) had been processed with the migration algorithm. Again the position of the roots is obvious. The arrows in (D) indicate the two roots buried at 155 cm.

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Barton, C. and Montagu, K. 2004. Detection of tree roots and determination of root diameters by ground penetrating radar under optimal conditions. Tree Physiology 24: 1323–1331

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