The Power of Infrared Analysis in Agriculture: Unique Insights into Soil, Crops, Vegetation and Fungi

Jean Robertson

The James Hutton Institute

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Formed from The Macaulay Land Use Research Institute (Aberdeen) and the Scottish Crop Research Institute (Dundee) in April 2011

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scri living technology

Mixed Livestock and Arable Farming in Aberdeenshire

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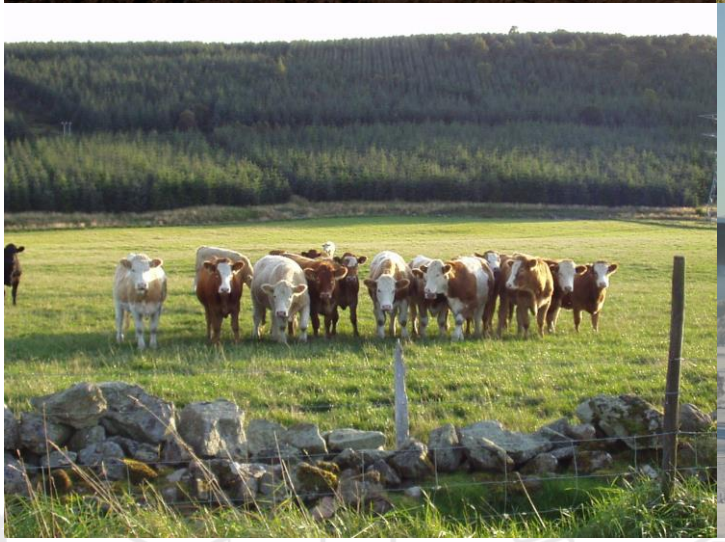
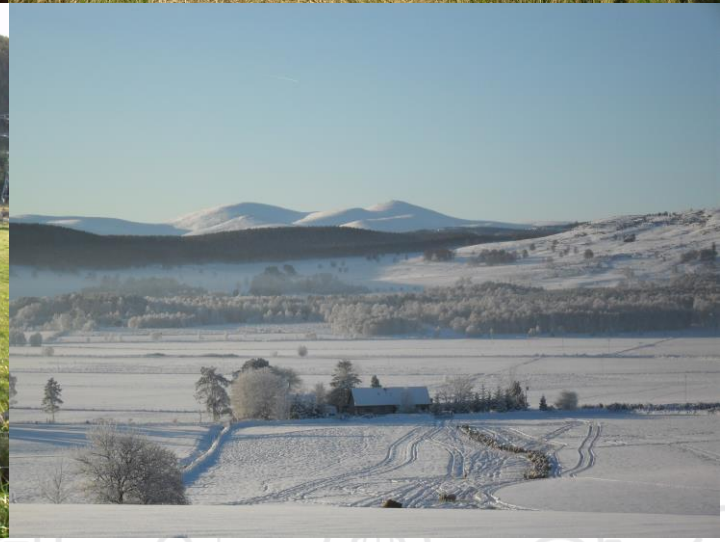
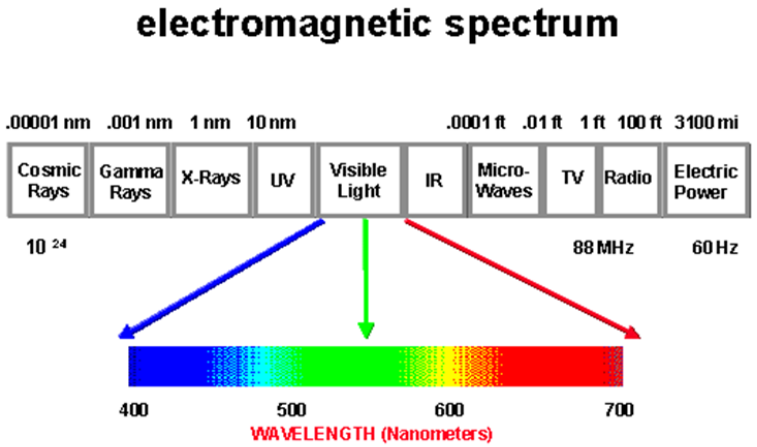




Why Use Infrared (IR) Radiation for Analysis?

- Infrared radiation is absorbed by a sample at specific frequencies depending on the chemical composition of the sample
- Allows us to “see” what something is made of
- Produces a chemical “fingerprint” or profile



Why Use Infrared (IR) Radiation for Analysis?

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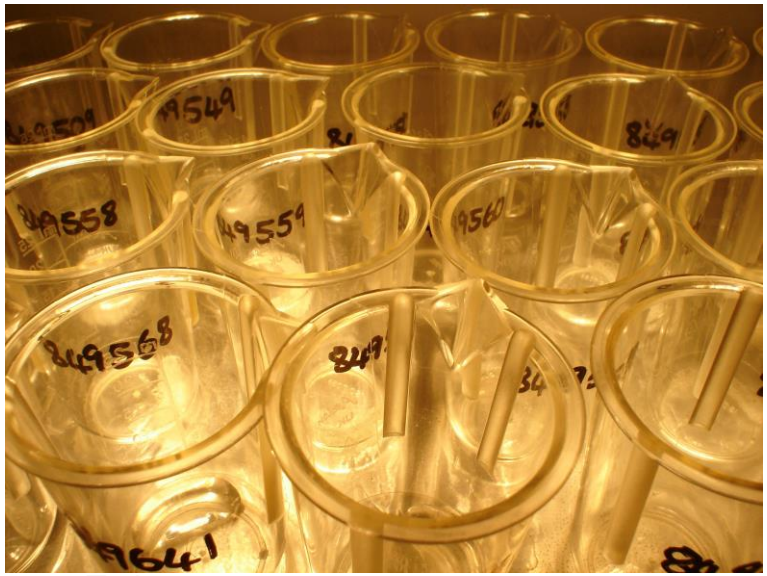
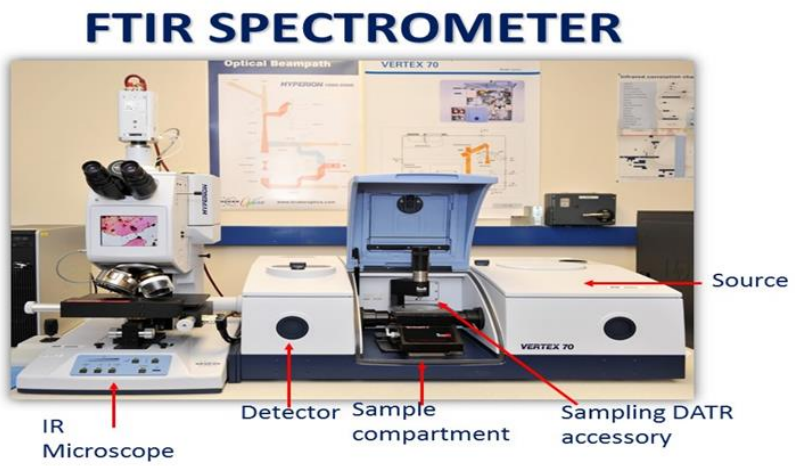
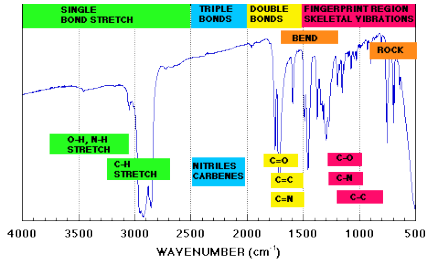
- Different regions of the IR spectrum give different information
- Most commonly use the mid infrared (MIR) or near infrared (NIR) regions
- Qualitative interpretation (MIR) – gives “insight”
- Quantitative prediction of properties (NIR or MIR) – can be used as a tool instead of “wet chemistry”
- Multiple parameters can be predicted at once



Two versatile instruments

Fourier-Transform Infrared (FTIR)

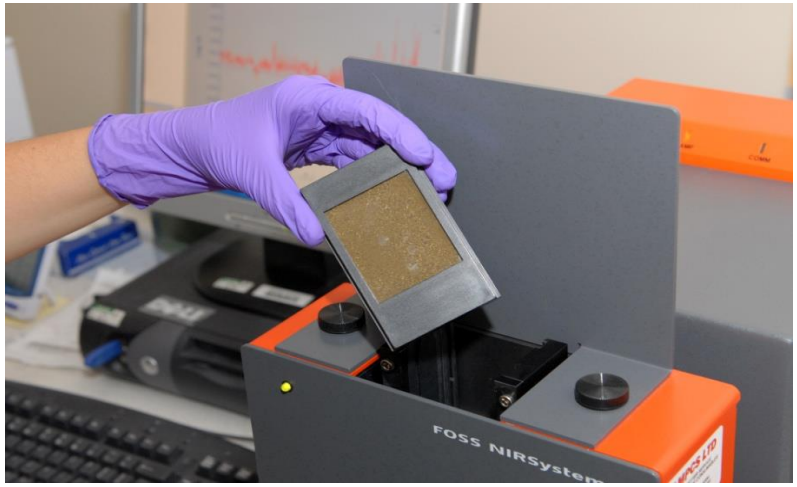


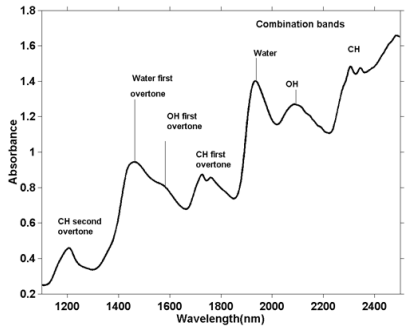


- Mid (4000-400 cm^{-1}) and far (600-50 cm^{-1}) infrared
- Fundamental vibration of molecules that absorb IR light
- Spectra provide fingerprints of substances which can be interpreted
- May require more sample processing

Two versatile instruments

Near Infrared (NIR)





- 1100-2500 nm
- Combination bands and overtones of MIR fundamentals
- Overlooked: complex spectra
- More energetic radiation: allows deeper penetration into sample
- Simple sample processing and analysis of intact samples

FTIR

Soils

Fungi

Vegetation

FTIR Spectroscopy is a versatile analytical technique capable of providing a chemical fingerprint for a wide range of both **inorganic** and **organic** samples.

INFRARED SPECTRUM: PLOT OF ABSORPTION VS FREQUENCY

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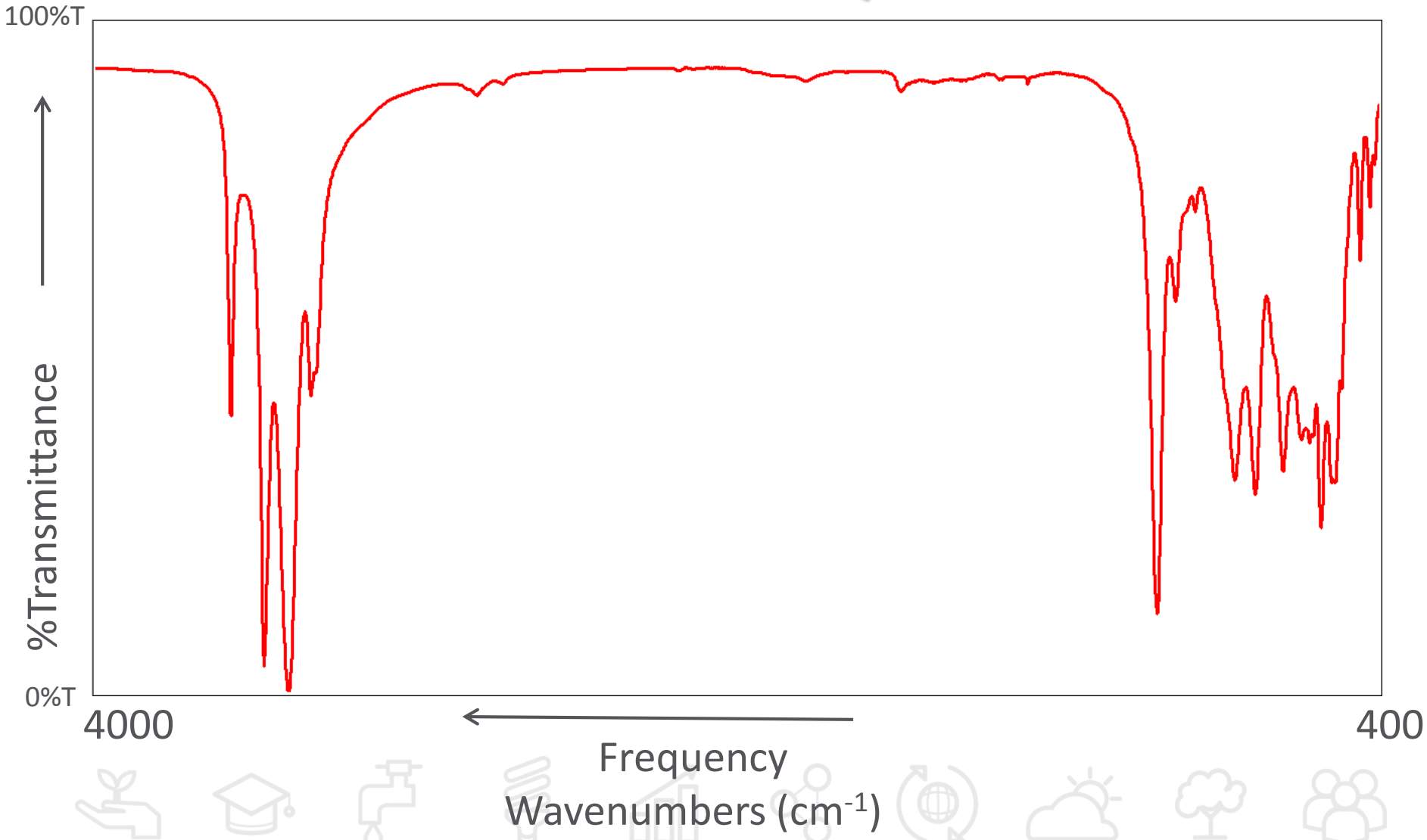

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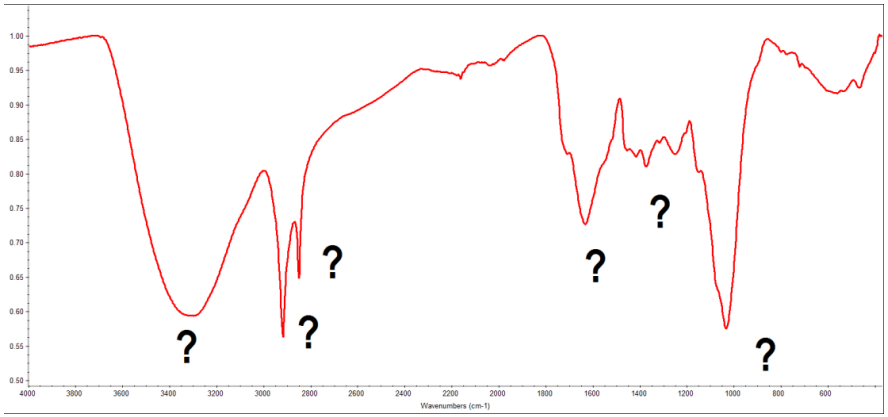
IR analysis of soil

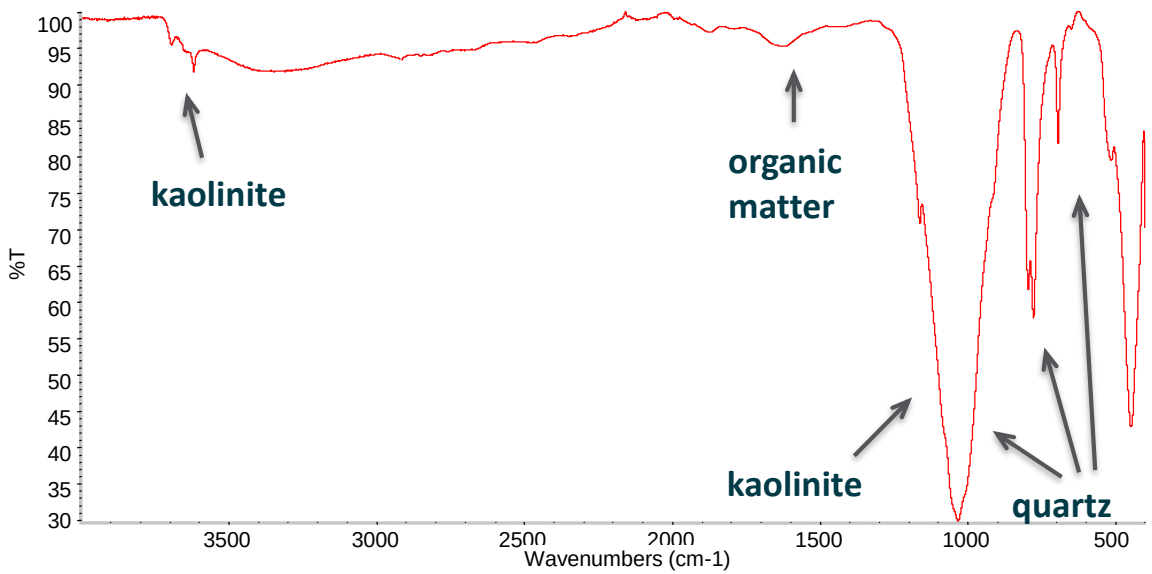


What can this tell us

Spectral features of MINERAL soils

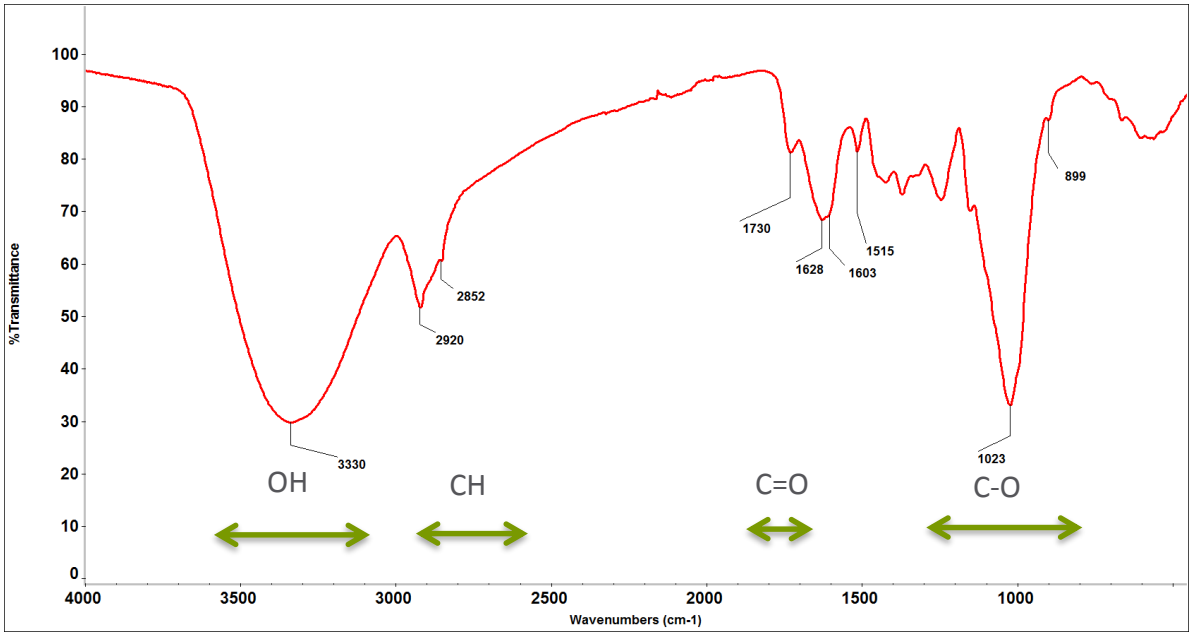
- The IR spectrum of a mineral soil sample provides an instant insight into the geology of the soil, including the proportion and nature of the clay minerals

- Silicates or carbonates usually dominate, but there are soils with other components e.g. gypsum (calcium sulphate – $CaSO_4$. H_2O)

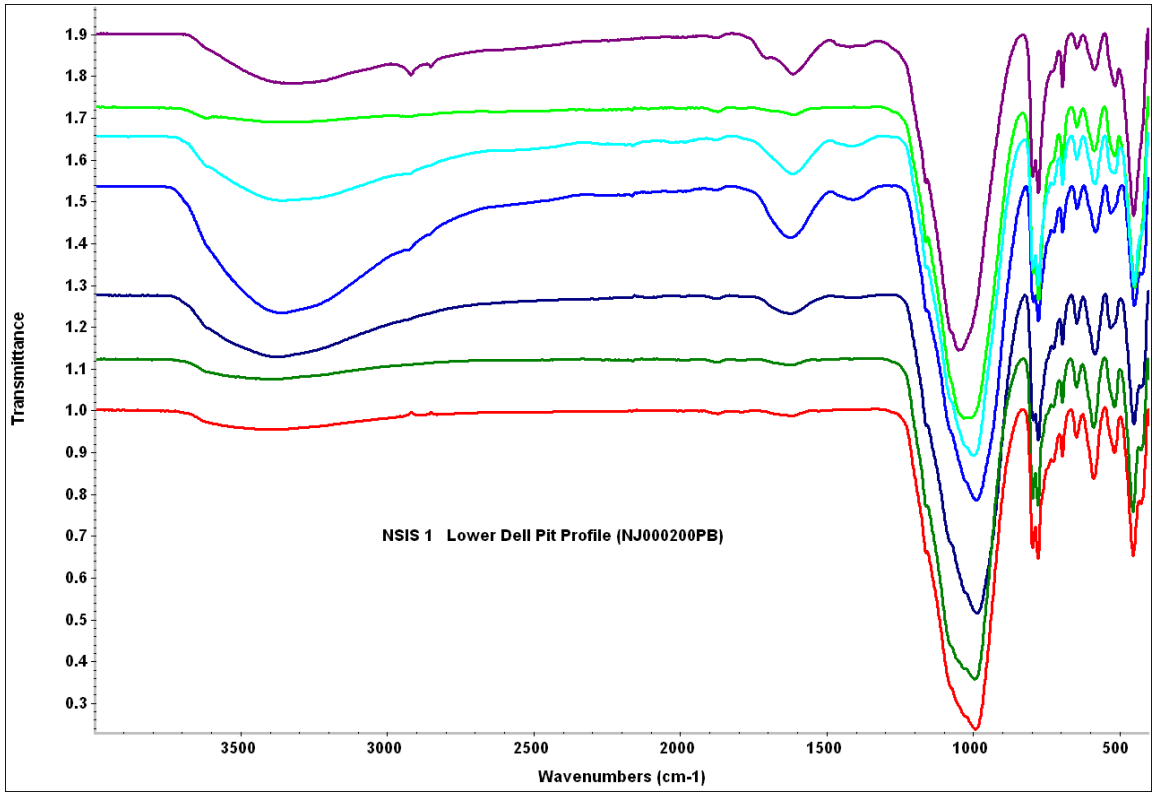


Spectral features of ORGANIC soils

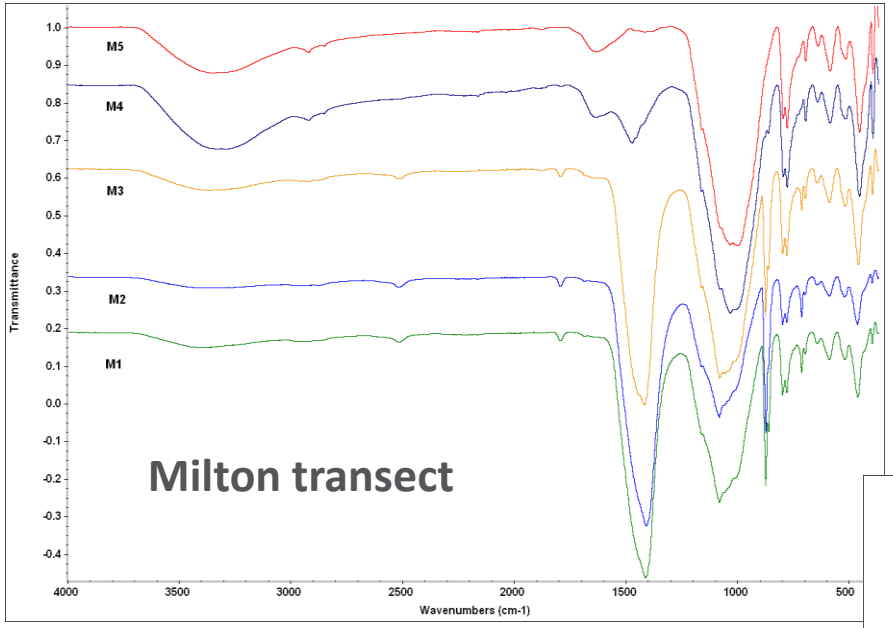
- Their spectra are related to that of un-decomposed vegetation, and will differ according to plant population
- The spectra will also differ from the vegetation depending on the extent of decomposition



Monitoring changes down a pit profile

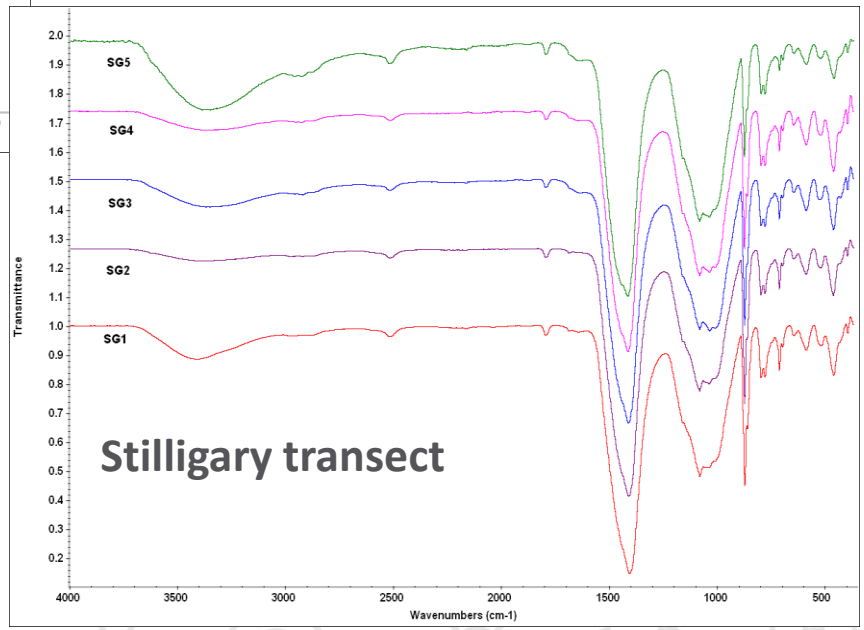


Soil Wind Erosion Studies

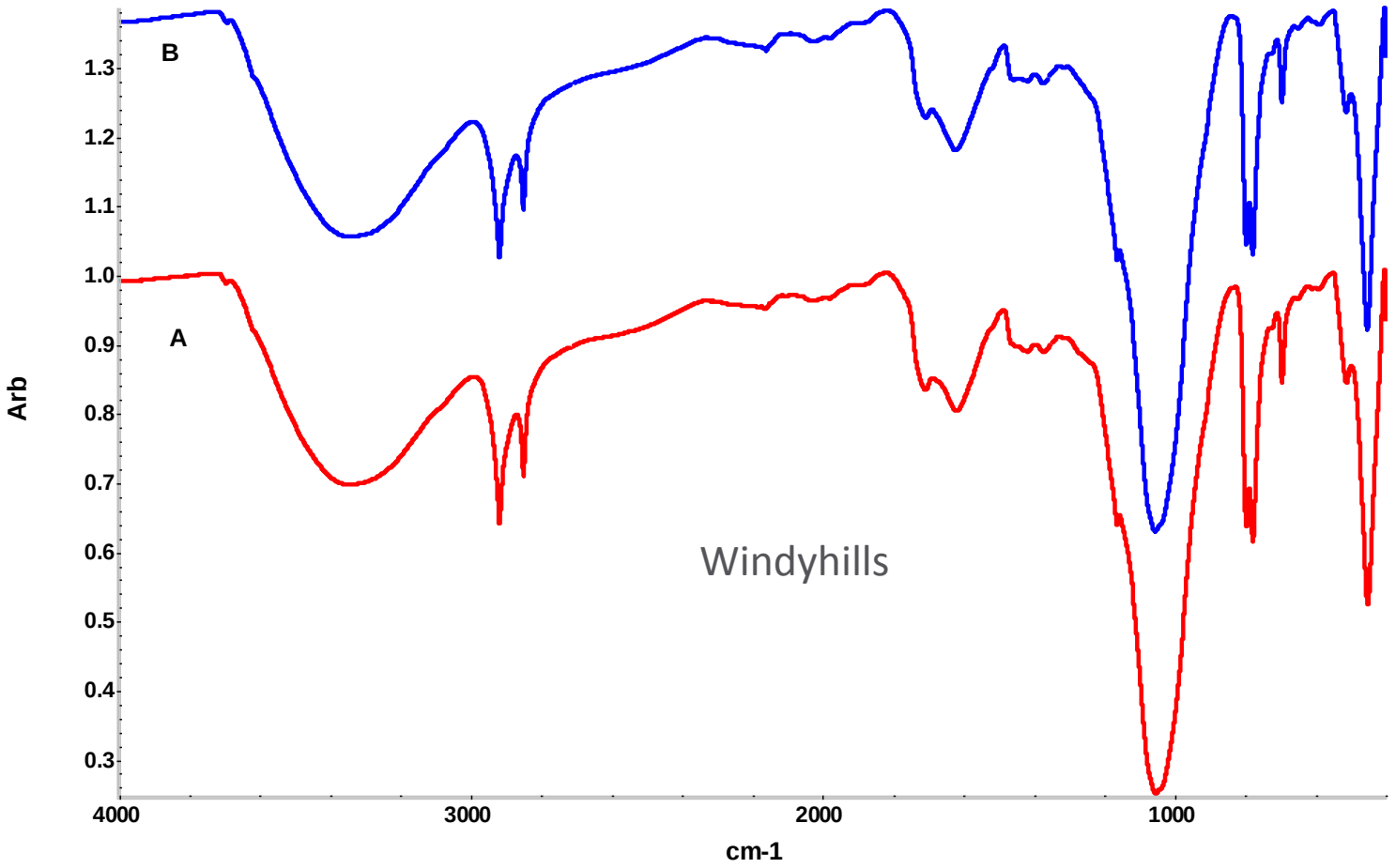


Some transects shows a change from carbonate dominated to purely silicate based soil as you move inland from the coast

while others show little change



National Soil Inventory of Scotland (NSIS) Dataset



A – NSIS 1 (1975) **B – NSIS2 (2007)**

Changes in Chemical Characteristics of Peat

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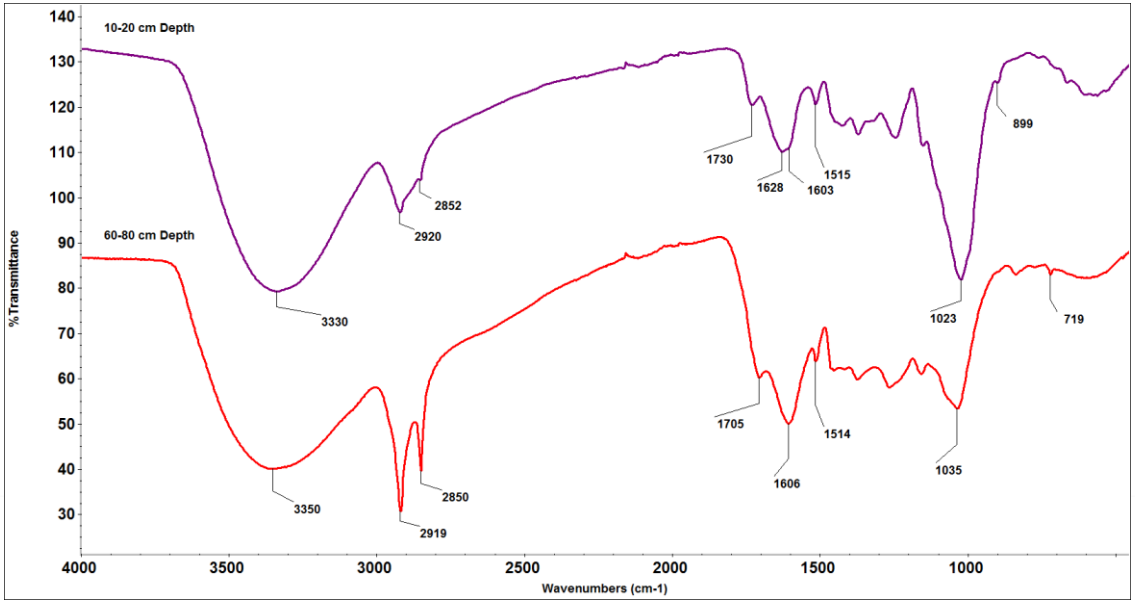
- Organic soils which are more decomposed (often deeper in the peat) are likely to have reduced polysaccharides (C-O 1100-900 cm^{-1})
- Although some ester may be present, there is likely to be predominantly carboxylic acid present (C=O ~1710 cm^{-1})
- The CH stretching region (3000 -2800 cm^{-1}) of these soils will also show evidence of long chain or waxy compounds with sharp distinct peaks at 2920 cm^{-1} and 2850 cm^{-1} which are derived from CH_2 stretching vibrations. In addition there is a small but sharp CH_2 "wagging" vibration which appears at 720 cm^{-1}



Changes in a Peat with Depth

Spectroscopy and Remote Sensing for Assessment of Peatland degradation

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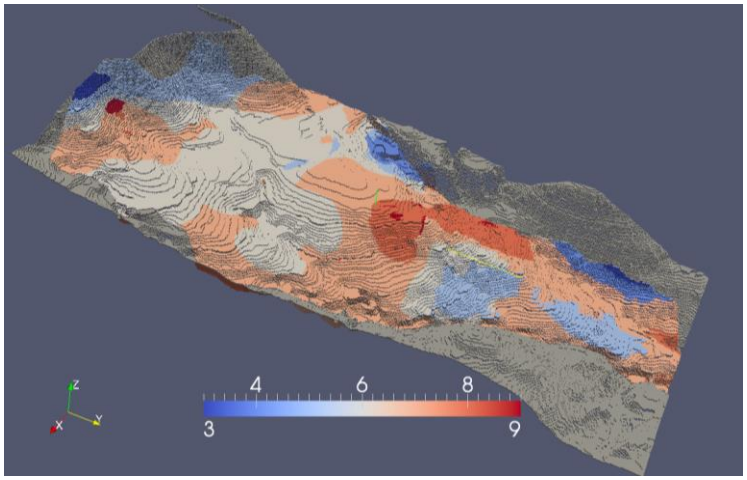
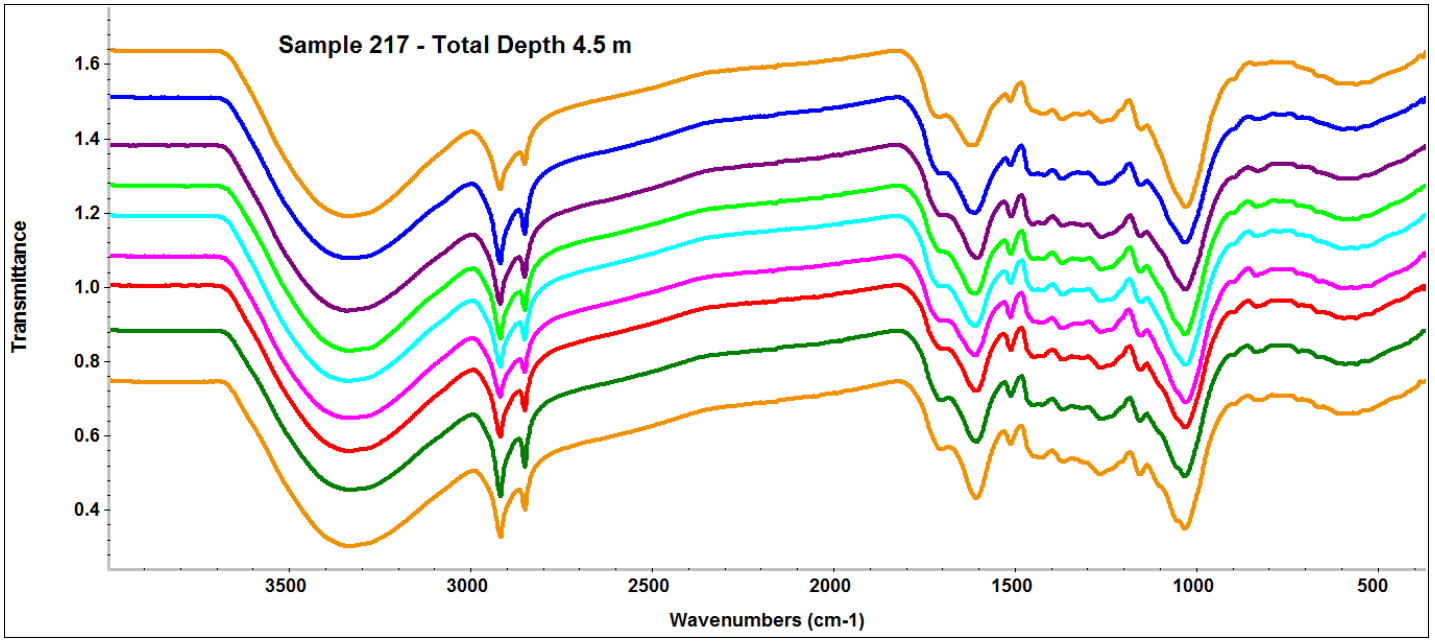


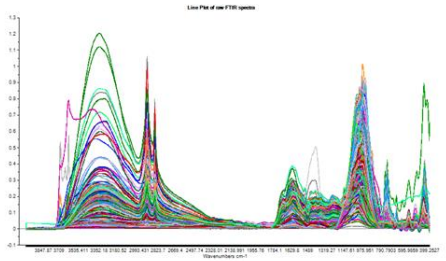
3D Humification Map from Remote Sensing

Increasing depth

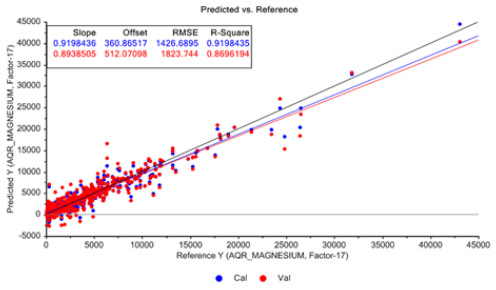


IR Spectroscopic Analysis of Soil

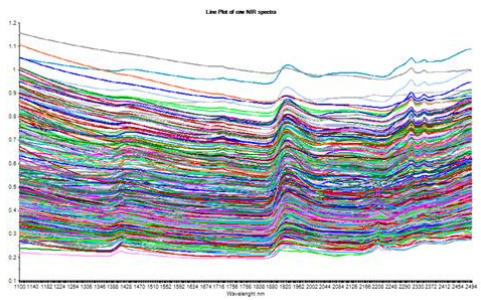
- Providing effective methods for rapid and economical monitoring of soil, through prediction of soil parameters
- Giving a valuable insight into variation in mineralogy and soil organic matter
- Allowing assessment of the extent of peat degradation



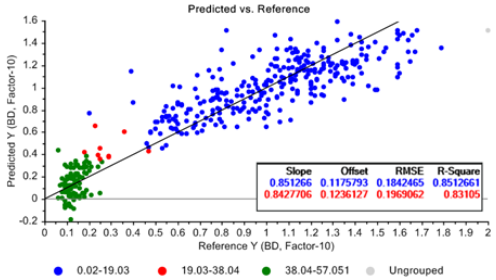
FTIR (MIR) spectra of the NSIS dataset



Calibration results for the prediction of Mg (FTIR)



NIR spectra of the NSIS dataset



Calibration results for the prediction of Bulk Density (NIR)

Changes in C Stocks after Afforestation

- 2 sets of samples:
  - "Archive": 183 horizons sampled between 1961-1988 (39 sites) prior to planting
  - "Recent": 227 horizons re-sampled in 2013 (same 39 sites) after period of afforestation
  - Bulk density (BD) values available for Recent but not Archive Samples
  - NIR spectra available for all samples
  - NIR prediction of BD allowed calculation of changes in C stocks

NIR for Forage Quality

- Near infrared spectroscopy (NIRS) can be a useful method to replace laborious wet chemistry for estimation of key plant determinants of diet quality for ruminants (e.g. fibre and nitrogen)

- We tested the utility of NIRS to assess diet quality of herbivores, by using it to predict quality of forage and faeces of both extensively grazing and wild ungulates in Scotland

Maris Piper potato plants at 4 different developmental stages

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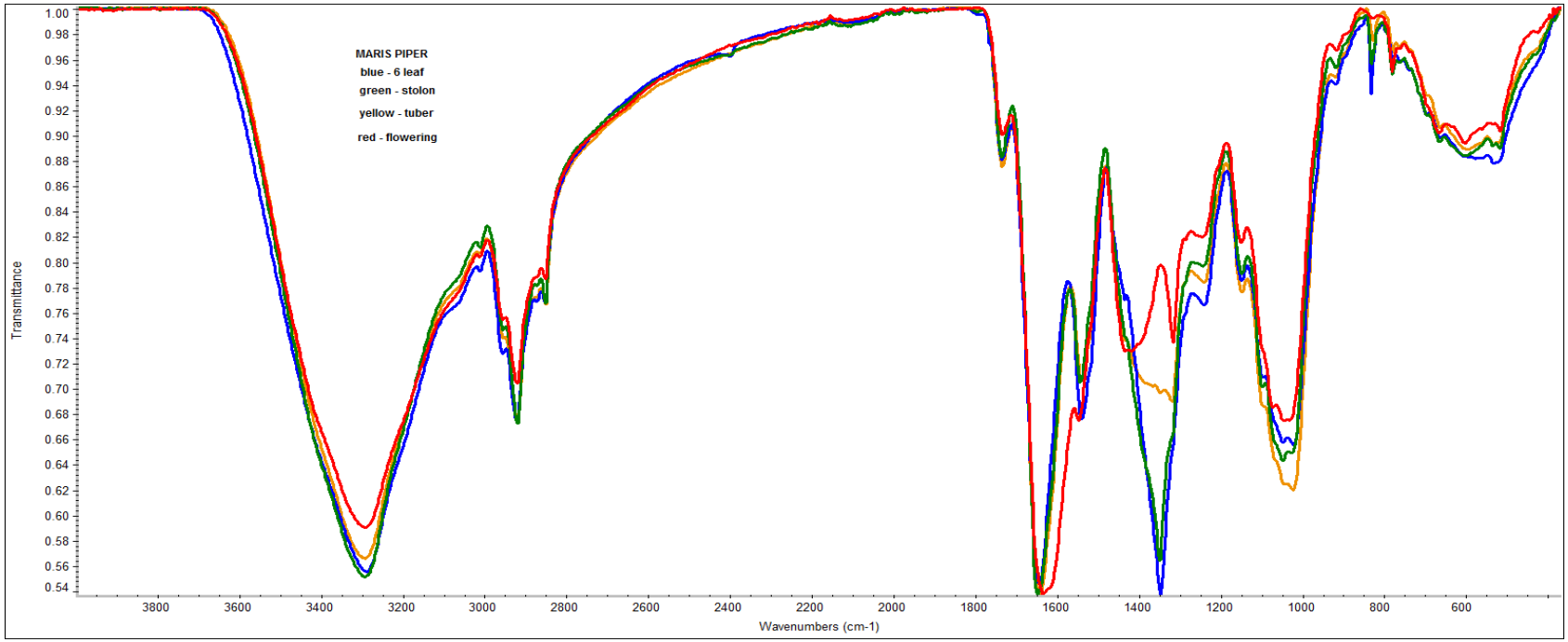

Prediction of Flavour Characteristics in Raspberries

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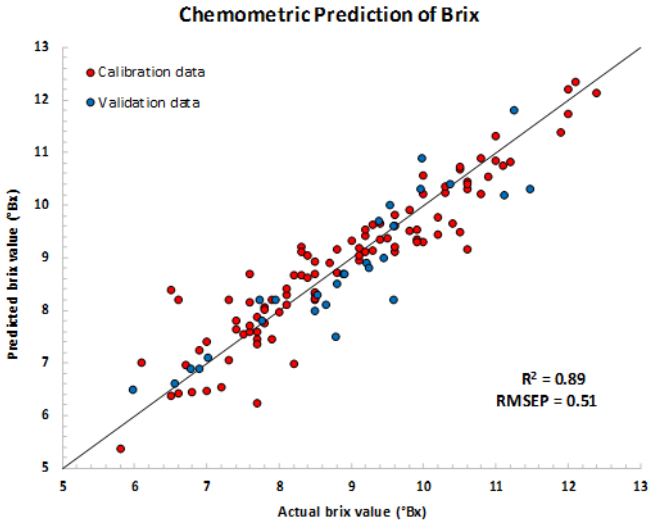
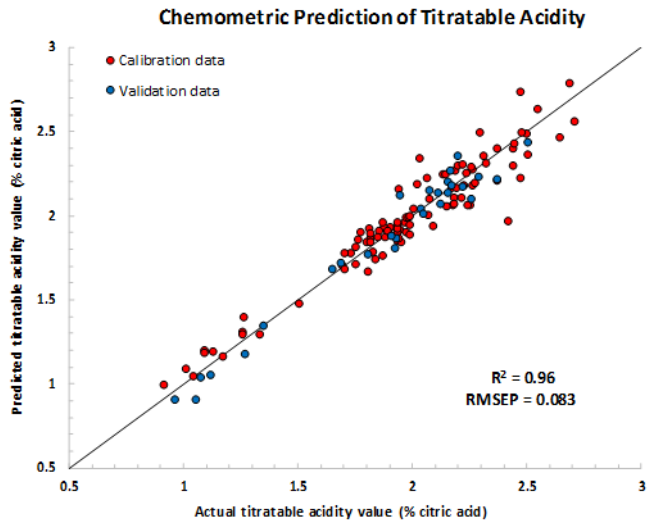
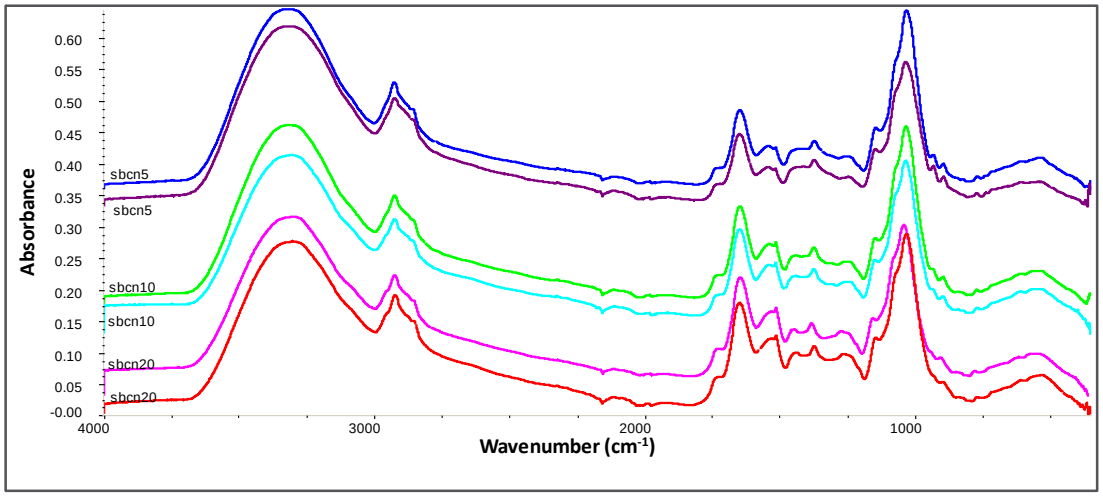




Effect of Changes in Environmental Conditions on Fungi



- Ectomycorrhizal (ECM) fungi contribute significantly to C fluxes and SOC build up in boreal forest ecosystems
- Understanding how the chemical composition of fungi changes with environmental conditions is relevant to the understanding of their role under changing conditions

Ageing of mushrooms

- Changes can be detected using IR before visible by eye
- Can be used to work out how old they actually are

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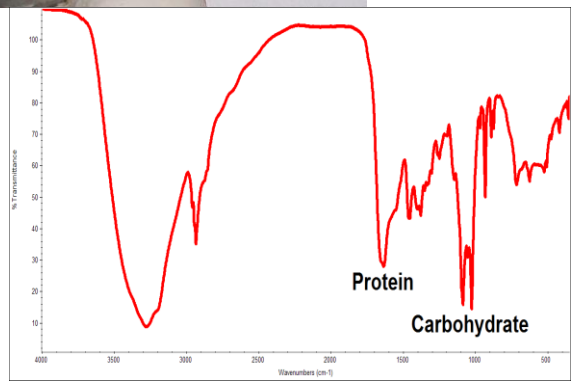
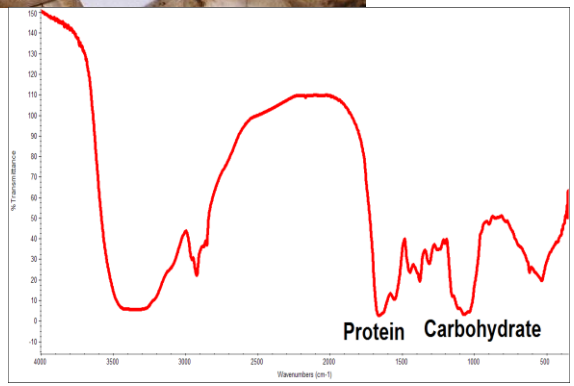
Fresh Button Mushrooms



Aged Button Mushrooms



Acknowledgements

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