Estimating peat (high-organic soil) moisture content using simulated HyMap reflectance

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Aim and objectives

- **Aim**
- To assess the extent to which the influence of moisture on simulated HyMap spectra can be decoupled from those of humification.
- **Objectives**
- To develop models to predict moisture content from HyMap spectra.
- To assess their sensitivity to humification Influences hydraulic conductivity and its effect on flood and landslide risk (Filip& Kubát, 2004)

How is Moisture related to peat humification?

- Controls microbial activity responsible for organic matter decay & release of nutrients (Nielsen *et al.*, 1995)
- Influences carbon budget: peat optimum moisture content of 50 -71% is carbon source. Wetter or drier peat is a carbon sink (Waksman, 1952; Amador & Jones, 1993).
- Source of error in spectral estimation of humification: lignin, cellulose & water share OH, so absorption features overlap.

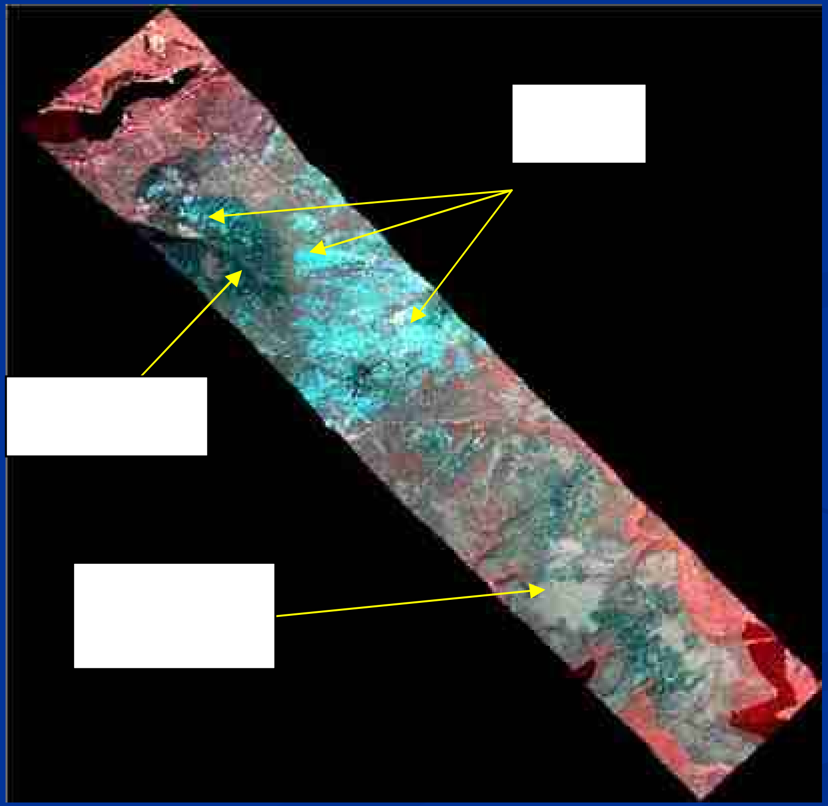
Spectroscopy to study peat moisture?

- Significant negative relationship between moisture and near infrared (NIR) and shortwave infrared (SWIR) (Bowers & Hanks, 1965, Al_Roichdi *et al*., 2003

- Major water absorption features are located in these two regions (1450, 1929 nm) (Al_Roichdi *et al*., 2003, 2004).

Study area location:

- The study area is a blanket bog moorland, located 30 km west of Manchester, in the south Pennines, UK.



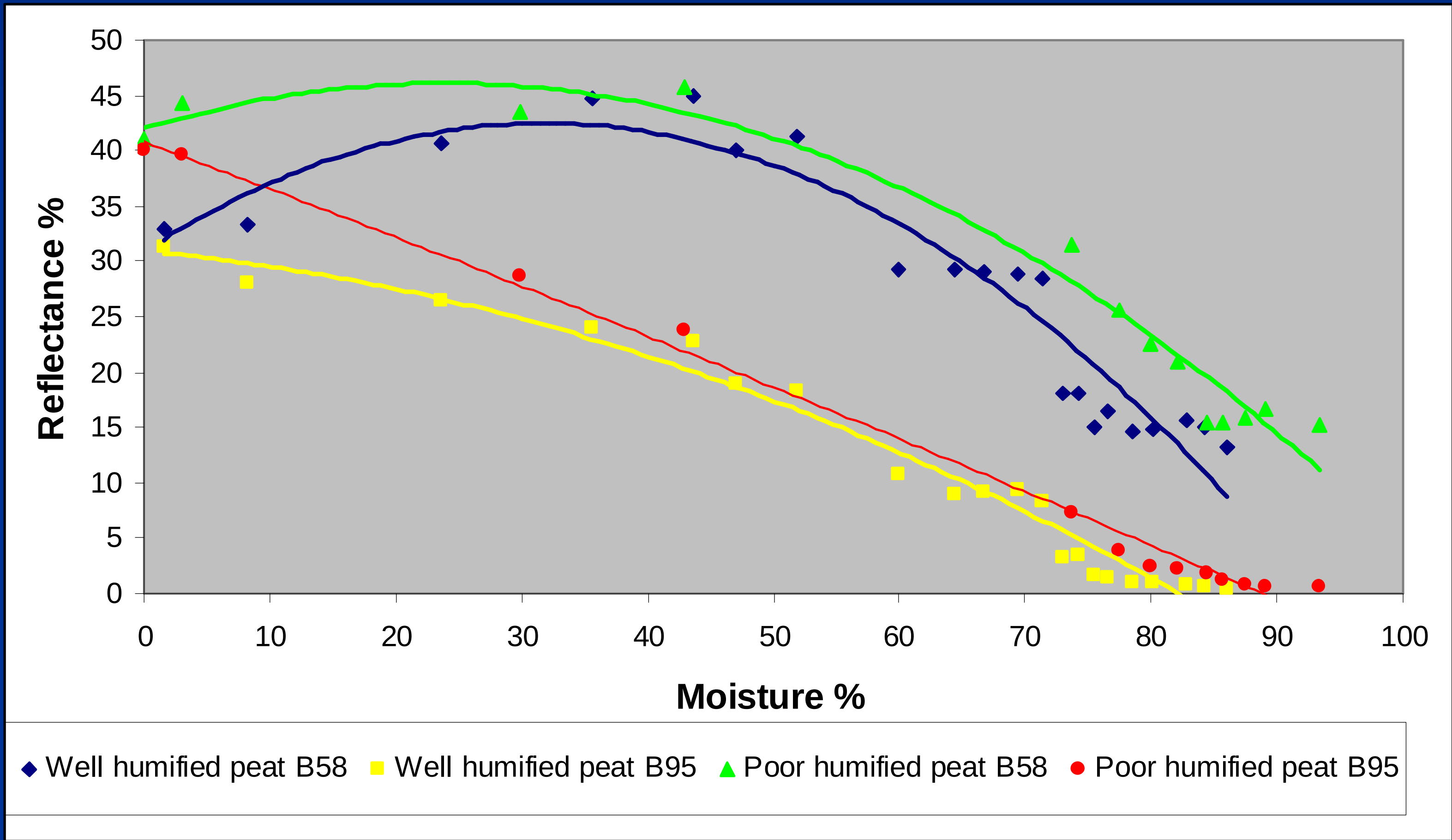
Field and laboratory method

- 34 peat samples were obtained, covering the range of humification
- Samples were saturated with water in the lab and gradually dried in a 25º C degree oven in 20 - 22 stages of 10 minutes each. Moisture content measured gravimetrically at each stage.
- At each drying stage, sample mixed to homogenize moisture then spectra recorded using the ASD in contact probe mode.
- Up to 22 spectra per sample at differing moisture contents.
- HyMap spectra were simulated from ASD using a filter for SHAC spectral band passes (McMorrow *et al.*, 2002)Humification was measured using a colorimetric method which measures transmission of light at 624 nm through a peat solution.
- The transmission value produced is inversely related to humification (Blackford and Chambers, 1993)

Data analysis

- 8 models were identified from a literature review of NIR spectroscopy for estimating soil moisture. Two are discussed here: linear stepwise regression modelling to estimate moisture content from (i) single-band reflectance (refs), and (ii) depth below the continuum (depth of absorption) (refs).
- Depth below the continuum was calculated by fitting of a straight line continuum between fixed shoulders.
- The relationship between moisture and first and second SWIR region is nonlinear (quadratic) in the SWIR (Fig 2), so moisture data were linearized by squaring
- There was high collinearity between simulated HyMap bands, so single band reflectance and depth below the continuum models were used over multiple regression model
- Bands 1,2,3, 66,95, 120-126 were excluded from the regression because they were noisy on the SHAC HyMap data
- 60% of samples used to develop the regression model. 40% for cross validation.

Relationship between moisture content and simulated HyMap band 58 and 90 for poorly and well humified peat



Results for single band reflectance

- Strong well-known negative relationship between albedo in SWIR and peat moisture content, but above 71% moisture content, SWIR is insensitive to moisture (Fig 3a)

- Largest residuals are for poorly humified peat (transmission > 25%) and washed (re-deposited) peat (Figs 3a & b), especially when moisture content below 25% so that water no longer masks humification signal

- Linear regression shows that band 98 (2002 nm) reflectance explained 93% (R2 0.93) of variation in moisture.

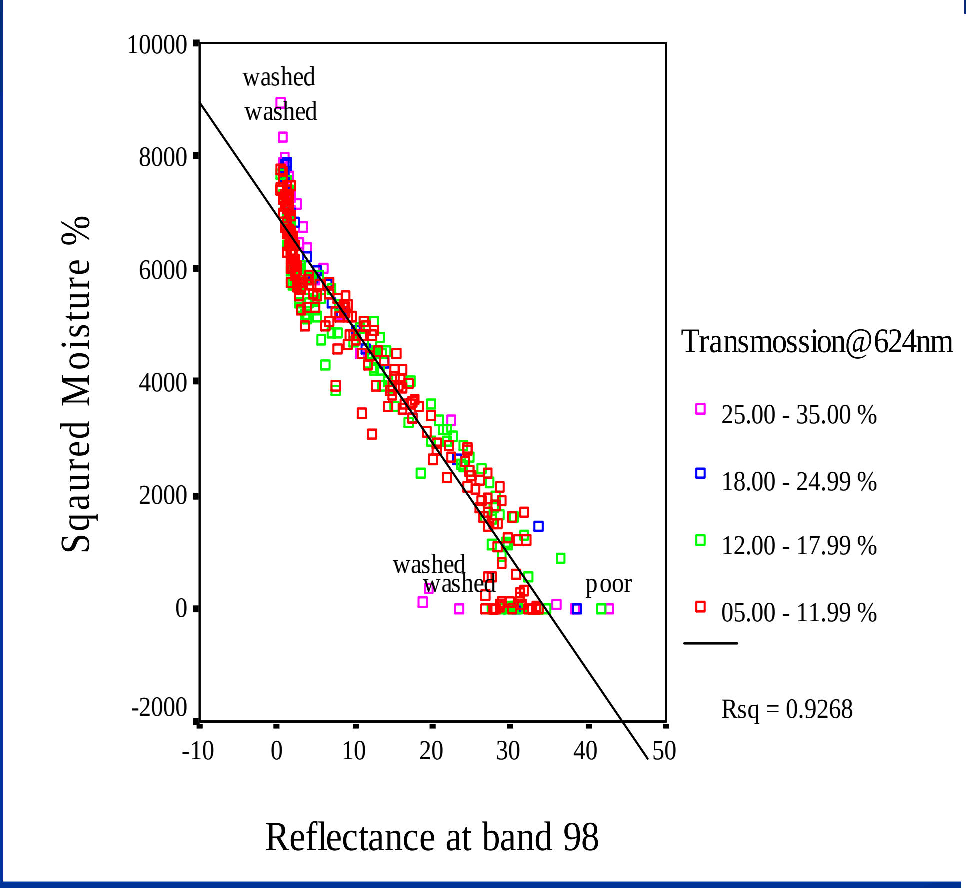
- Cross validation showed very good fit (adj. R2 0.92, SECV 0.02 (Table 1), especially between approximately 35 and 75% moisture (Fig.3b).

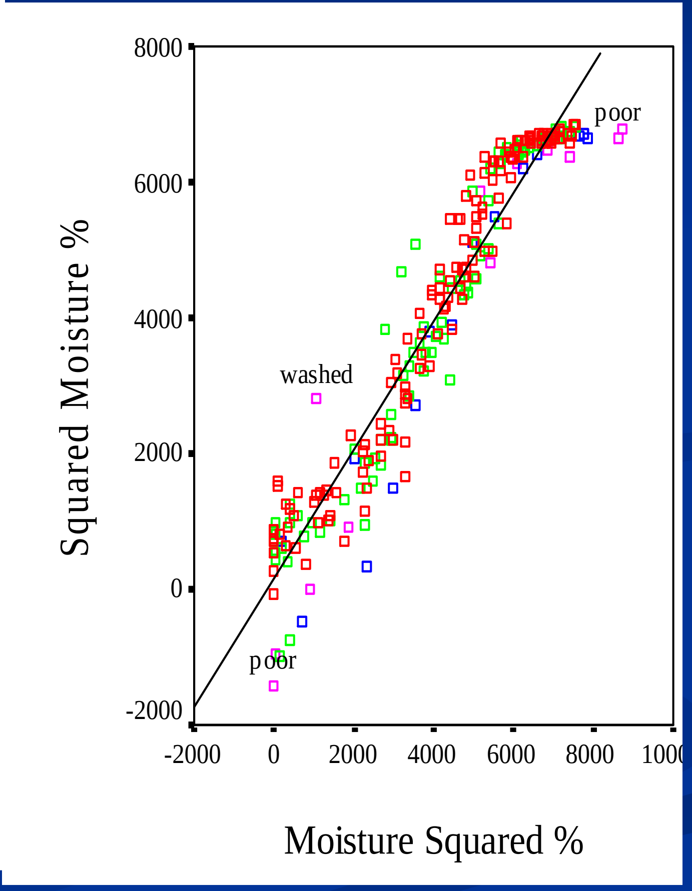
Table1:Linear regression and cross validation results for prediction of squared moisture from reflectance in band 98

Moisture	Regression	Cross Validation
R	0.965	0.95
R^2	0.931	0.92
Adj R^2	0.931	0.92
Std. Error	2.93	0.018
Beta	-0.965	0.963
F	4679	2881
Sig.	0	0

Figure 3: Relationship between: (a) squared moisture & band 98 reflectance, with humification classes indicated, (b) observed squared moisture and predicted squared moisture

for regression model using single band reflectance band 98





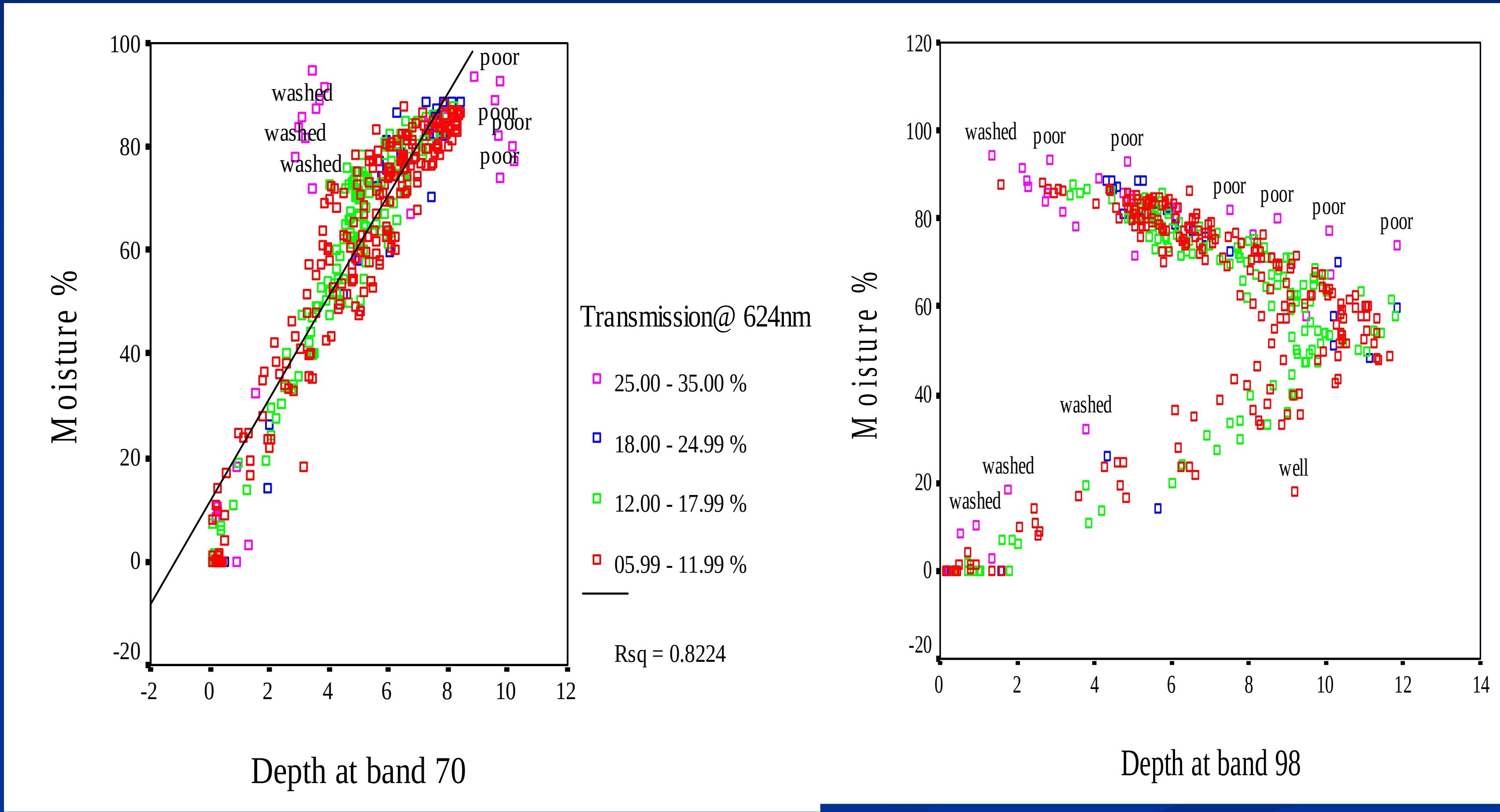
Results for depth below the continuum

- Depth beneath the continuum in the first region of SWIR shows positive linear relationships with moisture content, as expected, e.g. band 66 (1448 nm) (Fig 4a) and band 70 (1517 nm) (Fig 4b)
- Washed and most poorly humified wet peat cause scatter (Figs. 3b), i.e. humification signal present in SWIR even in wettest peat. Excluding washed peat increased R2 of band 70 from 0.84 to 0.89
- Nonlinear relationship in the second region of SWIR, ,or conditionally linear; negative for moisture >55%, positive for moisture <55% (Fig 4b)
- Regression restricted to bands 63 to 75 (1406-1571 nm) in the first region of SWIR so that non-linear relationships were excluded.
- Stepwise regression selected depth below continuum at band 70 as the most highly correlated with moisture. Useful for extrapolation to airborne data because avoids peak atmospheric water absorption at band 63.
- No multiple regression models used due to high collinearity.
- Slope of the regression line is more affected by moisture contents of less than 10% and higher than 70%.
- Linear regression using depth below the continuum in band 70 explained 89% of variation in moisture. Cross validation showed very good fit (adjusted R2 0.92, SECV 0.02) (Table 2)

*Table 2: **Linear regression and cross validation results for prediction of moisture from depth below the continuum at band 98***

Moisture	Regression	Cross Validation
R	0.942	0.936
R^2	0.887	0.876
Adj R^2	0.887	0.875
Std. Error	0.203	0.244
Beta	0.942	0.93
F	2664	1710
Sig.	0	0

Figure 4: Relationship between the depth below the continuum and moisture content for (a) band 66 (1449 nm) and (b) band 95 (1952 nm.



Conclusions

- Collinearity precluded use of multiple regression models.
- Most robust model predicting squared moisture content from reflectance used band 98 (1989 nm).
- Depth below continuum in the first SWIR region, especially at band 70 (1517 nm) is a good predictor of moisture content. The second region is unsuitable due to its conditionally linear relationship with moisture.
- Washed peat caused scatter in all relationships, but the residuals were not significant enough to exclude these samples.
- Fit is best for moisture of 35-70%. Above this, reflectance is insensitive to moisture. Below this scatter is due to humification. For very poorly humified peat, the humification signal is present even in the wettest samples.

Further work

- Test the other models: (i) reflectance normalized for differences ratio ; (ii) reflectance band ratios ; (iii) reflectance band slopes ; relative reflectance (divided by the maximum wet spectra) ; (v) first and second derivatives of reflectance
- Develop separate models for wet and dry peat using depth below the continuum in second SWIR region
- Use weighted least squares, partial least squares regression and artificial neural network as alternative to stepwise multiple regression.
- Model combined effect of moisture and humification