# The role of Field Spectroscopy in addressing the five key Environmental and Natural Resource Issues ("ENRI")

**NERC EPFS**

**Department of Geography**

**University of Southampton, UK**

Contact: epfs@soton.ac.uk

Web site: www.soton.ac.uk/~epfs

## Introduction

ENRI is an acronym introduced by NERC meaning "Environmental and Natural Resource Issues". ENRI's are considered to be the most important issues facing the UK's Environmental and Natural Resource Agenda.

NERC's Integrated Science Strategy focuses on five major issues on the UK's environmental and natural resource agenda: Global Environmental Change, Pollution and Waste, Natural Resource Management, Biodiversity, and Environmental Risks and Hazards.

This short document aims to highlight the contribution made to Science by the EPFS facility, broken down into the five ENRI's mentioned above.

## Global Environmental Change

Satellite sensors are uniquely suited to collecting data from the surface of the whole Earth and therefore have a key role to play in the study and monitoring of global change. However, the value of such data for investigating long-term changes to the Earth and its environment depends upon how reliable the data are, how well calibrated the sensors are, and on the quality of the models available to relate remotely-sensed data to key biophysical variables, such as soil moisture availability, albedo, and net primary productivity. Field spectroscopy has an important role to play in the study of global environmental change. It is used in the vicarious calibration of satellite sensors (Rondeaux et al., 1998), in the development and testing of physical models), and in fundamental research on the spectral properties of objects in the natural environment. EPFS users have done pioneering work on the estimation of albedo from multi-angle satellite sensor data which has made extensive use of field spectroscopy in the development and validation of physical models (e.g. Barnsley et al., 1997, [1] and [2]). EPFS has also provided instruments for UK scientists involved in large-scale international experiments, notably the First ISLSCP Field Experiment (FIFE), the Hydrology-Atmosphere Pilot Experiment in the Sahel (HAPEX-SAHEL), the Boreal Ecosystem Atmosphere Study (BOREAS), and, most recently, an extended loan to Professor Grace's group in support of their work on the photosynthetic efficiency of tropical forests as part of the Large scale Biosphere Atmosphere Experiment (LBA) [3].

Other examples of EPFS-supported research related to global climate change includes that by Watts-Tobin et al., (1995) on the impact of climate change upon the vegetation of the Kalahari desert and research to investigate the impact of global warming upon coral reefs in the Pacific (Clark et al., 2000) and the Caribbean (Malthus (in press)). Applied studies such as these have been complemented by experiments designed to elucidate fundamental relationships between biophysical variables and spectral reflectance, such as the study by Blackburn (1998) on the estimation of plant pigment concentration in senescent leaves and that by Rollin et al. (1998) on remote sensing of leaf water content.

Field spectroscopy also provides a convenient way to study the seasonal dynamics of plant communities, as demonstrated in a study by Blackburn and Milton (1996) which demonstrated how remote sensing could be used to study phenological changes in deciduous woodland, which is thought to be a sensitive indicator of climate change.

## Pollution and Waste

Pollution events involve chemical changes to the environment, and these can often be detected from their effect upon the reflected or emitted signal from the surface. There are many examples of remote sensing being used to *detect* the presence of contaminants, but in order to estimate the *amount* or *concentration* of a pollutant it is necessary to establish a quantitative relationship between the remotely sensed signal and the degree of contamination. Spectral data collected under controlled conditions in the field or the laboratory are very important in deriving and testing such relationships. For example, EPFS users have used field spectroscopy to develop methods to monitor the amount of hydrocarbon contamination at disused industrial sites (Jago et al., 1999) and to study the effects of elevated levels of ozone on leaf reflectance for several species of deciduous trees (Loizou et al., 1999). Field spectroscopy has also been used by researchers at Edinburgh to study the development of chemical tolerance in plant canopies and to model the way in which this might affect the ability of remote sensing to detect plant stress [8]. EPFS instruments have also been used in conjunction with airborne remote sensing to investigate the patterns of leachate from landfill sites (Splayt, 1999 [4] and [5]), to study the movement of nitrates and phosphates through an agricultural catchment [6], and to study leakage from pipelines carrying water [7] and natural gas (Smith et al, 2000).

## Natural Resource Management

Remote sensing is an important technology for monitoring and managing natural resources at a global scale because the key attributes of terrestrial and marine environments are amenable to being sensed remotely. Land cover, rock type and structure, plant health and biomass, and primary productivity in the oceans may all be studied using satellite or aircraft sensors. EPFS users have used field spectroscopy to correct satellite sensor data for the effect of the atmosphere prior to image classification (e.g. Bajjouk et al., 1998; Aplin et al., 1999) and the same technique has been successfully applied to airborne sensor data (e.g. Smith and Milton, 1999). Developments in sensor technology and informatics mean that more sophisticated sensors are being developed which could greatly enhance the ability of remote sensing to address natural resource issues. In particular, imaging spectrometry has developed as a powerful technique to estimate the biochemical composition of plant canopies and to detect specific minerals of economic importance. Imaging spectrometers produce huge volumes of data, and so efficient techniques are needed to extract the information required. Field spectroscopy is important in determining those wavelengths that contain most information on specific land cover classes of interest, for example Thomson et al. (1998) used an EPFS spectroradiometer to determine the optimum wavebands for the CASI sensor to provide accurate maps of the intertidal zone. EPFS-supported research by Hurcom et al. (1996) has demonstrated the use of feature selection based on factor analytical methods rather than band selection to reduce data volume still further.

Practical examples of field spectroscopy applied to natural resource survey include a project supported by EPFS which used field spectroscopy to identify those wavelengths needed to produce a map of water depth and bed type which was then used to assess the extent and quality of potential salmon spawning habitat in a chalk river in southern England (Acornley et al., 1995). A similar technique was also used by Winterbottom and Gilvear (1997) to map water depth in a gravel-bed river in Scotland.

## Biodiversity

Remote sensing offers data on the structure and composition of terrestrial ecosystems which complements that provided by conventional field survey. The complete coverage offered by remote sensing provides the spatial context for more detailed field sampling. Whilst individual species may not always be identifiable from remotely sensed data, there is evidence that the major functional groups may be distinguished, for example between C3 and C4 species. EPFS users have used field spectroscopy to study the spatial outcome of biological processes, such as the creation and modification of forest canopy gaps (Blackburn and Milton, 1996) and the patterns and processes occurring in response to vegetation stress and hydrological conditions in bog communities in the Flow country, northern Scotland [9]. The interactions between hydrology and ecology were also the focus of a study looking at plant communities and soil-water chemistry on the Insh Marshes on the floodplain of the River Tay (Grieve et al., 1995; Willby et al., 1997). Field spectroscopy has been used to assess whether remote sensing may be used to monitor the spread of diseases in crops, and to investigate the factors that influence gradational boundaries in semi-natural plant communities (Armitage et al., 1995; Trodd, 1996; Kent et al., 1997).

## Environmental Risks and Hazards

Remote sensing provides a technique to study and assess various types of environmental hazard, and, when used in a GIS, it provides the framework for a modelling risk to people and infrastructure from potential environmental hazards. Field spectroscopy is an essential underpinning technology in such uses of remote sensing. It is used for vicarious calibration of satellite sensors, without which the detection of long-term trends is impossible. It is also used in the development and testing of new sensors, particularly in conjunction with airborne remote sensing. Examples of research conducted by EPFS users related to environmental risks and hazards includes a study using field radiometry to calibrate satellite sensor data for the early detection of temperature anomalies on active volcanoes (Denniss et al., 1998), research on airborne remote sensing of flood routing and floodplain mapping (Winterbottom and Gilvear, 1997), and research to use field spectroscopy directly to study the characteristics of tension cracks in coastal landslides [10]. In some cases, the hazard itself may not possess a 'spectral signature', but its association with another, more easily detected variable, may be sufficient, as for example when field spectroscopy was used to establish the spatial pattern of radionuclide contamination in the intertidal zone of the Ribble estuary based upon its correlation with particular sediments (Rainey et al. (In Press)).

Field spectroscopy also has an important role to play in atmospheric studies, especially when combined with data from a sun-photometer, such as that which is also available to users from the EPFS. Studies in this area include remote monitoring of the aerosol plume from Mount Etna (Watson and Oppenheimer, 2000).

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## References cited

**Acornley, R.M., Cutler, M.E.J., Milton, E.J. and Sear, D.A., 1995.** Detection and mapping of salmonid spawning habitat in chalk streams using airborne remote sensing. *Remote Sensing in Action. Proceedings of the 21st Annual Conference of the Remote Sensing Society*, Remote Sensing Society, 267-274.

**Aplin, P., Atkinson, P. and Curran, P.J., 1999.** Fine spatial resolution simulated satellite sensor imagery for land cover mapping in the UK. *Remote Sensing of Environment*, **68**, 206-216.

**Armitage, R.P., Weaver, R.E. and Kent, M., 1995.** The derivation of spatial patterns in plant communities and transitional zones from remotely sensed data. *In:* Curran, P.J. and Robertson, Y.C., *ed. Remote Sensing in Action. Proceedings of the 21st Annual Conference of the Remote Sensing Society*, Remote Sensing Society, University of Nottingham, UK, 929-930.

**Bajjouk, T., Populus, J. and Guillaumont, B., 1998.** Quantification of subpixel cover fractions using principal component analysis and a linear programming method: Application to the coastal zone of Roscoff (France). *Remote Sensing of Environment*, **64**, 153-165.

**Blackburn, G.A. and Milton, E.J., 1996.** Filling the gaps: remote sensing meets woodland ecology. *Global Ecology and Biogeography Letters*, **5**, 175-191.

**Blackburn, G.A., 1998** Spectral indices for estimating photosynthetic pigment concentrations: a test using senescent tree leaves. *International Journal of Remote Sensing*, **19(4)**, 657-675.

**Blackburn, G.A., 1998.** Quantifying chlorophylls and carotenoids from leaf to canopy scales: an evaluation of some hyperspectral approaches. *Remote Sensing of Environment*, **66**, 273-285.

**Barnsley, M.J., Allison, D., Lewis, P., 1997** On the information content of multiple view angle (MVA) images. *International journal of remote sensing* , **18(9)**, 1937-1960.

**Barnsley, M.J., Lewis, P., Sutherland, M., Muller, J.P., 1997** Estimating land surface albedo in the HAPEX-Sahel southern super-site: inversion of two BRDF models against multiple angle ASAS images. *Journal of hydrology,* **188-89**, 749-778.

**Clark, C.D., Mumby, P.J., Chisholm, J.R.M., Jaubert, J. and Amdrefouet, S., 2000.** Spectral discrimination of coral mortality states following a severe bleaching event. *International Journal of Remote Sensing*, **21**, 2321-2327.

**Denniss, A.M., Harris, A.J.L., Rothery, D.A., Francis, P.W. and Carlton, R.W., 1998.** Satellite observations of the April 1993 eruption of Lascar volcano. *International Journal of Remote Sensing*, **19**, 801-821.

**Grieve, I.C., Gilvear, D.J., and Bryant, R.G., 1995.** Hydrochemical variations across a floodplain mire: Insh Marshes Scotland. *Hydrological Processes.*, **9**, 99- 110.

**Hurcom, S.J., Harrison, A.R. and Taberner, M., 1996.** Assessment of biophysical vegetation properties through spectral decomposition techniques. *Remote Sensing of Environment*, **56**, 203-214.

**Jago, R.A., M.E.J.Cutler and Curran, P.J., 1999.** Estimating canopy chlorophyll concentration from field and airborne spectra. *Remote Sensing of Environment*, **68**, 206-216.

**Kent, M., Gill, W.J., Weaver, R.E. and Armitage, R.P., 1997.** Landscape and plant community boundaries in biogeography. *Progress in Physical Geography,* **21**, 230-268.

**Loizou, P.J., Blackburn, G.A., Broadmeadow, M., 1999.** The effects of ozone fumigation on the seasonal variations in spectral reflectance for three species of deciduous oak. *Proceedings of the 25th annual conference and exhibition of Remote Sensing Society.* , Cardiff, UK

**Malthus, T., Karpouzli, E., Place, C., Mitchell-Chui, A., Garcia, M., Mair, J., (In press).** Underwater light characterisation for correction of remotely-sensed imagery. *International Journal of Remote Sensing*

**Milton, E.J., Emery, D.R. and Lawrance, D.J., 2000.** A new dual-beam technique for precise measurements of spectral reflectance in the field. *28th International Symposium on Remote Sensing of Environment,* ERIM, Michigan, USA. CD-ROM.

**Milton, E.J. and Goetz, A.F.H., 1997.** Atmospheric influences on field spectrometry: observed relationships between spectral irradiance and the variance in spectral reflectance. *In:* Guyot, G. and Phulpin, T., *ed. Seventh International Symposium on Physical Measurements and Signatures in Remote Sensing,* Balkema, Rotterdam, 1, 109-114.

**Milton, E.J. and Rollin, E.M., 1988a.** The directional reflectance of heather canopies - towards a descriptive model. *Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS'88),* ESA, 829-832.

**Milton, E.J. and Rollin, E.M., 1988b.** A simplified descriptive model for shrub canopies. *Proceedings of the 4th International Colloquium on Spectral Signatures of Objects in Remote Sensing,* ESA, 147-150.

**Milton, E.J. and Webb, J.P., 1987.** Ground radiometry and airborne multispectral survey of bare soils. *International Journal of Remote Sensing,* **8**, 3-14.

**Rainey, M., Tyler, A.N., Bryant, R., Gilvear, D.J. and McDonald, P. (In press).** The influence of surface and interstitial moisture on the spectral characteristics of intertidal sediments: Implications for airborne image collection and processing. *International Journal of Remote Sensing*

**Rollin, E.M. and Milton, E.J., 1998.** Processing of high spectral resolution reflectance data for the retrieval of canopy water content information. *Remote Sensing of Environment,* **65**, 86-92.

**Rondeaux, G., Steven, M.D., Clark, J.A. and Mackay, G., 1998.** La Crau: A European test site for remote sensing validation. *International Journal of Remote Sensing*, **19**, 2775-2788.

**Smith, G.M. and Milton, E.J., 1999.** The use of the empirical line method to calibrate remotely sensed data to reflectance. *International Journal of Remote Sensing*, **20**, 2653-2662.

**Splayt T., 1999.** 3-Dimensional Monitoring and Modelling of Leachate Flux from Landfills. *Presentation paper at the International Hydrological Association Conference*, Graz, Austria.

**Smith, K.L., Steven, M.D., Colls, J.A., 2000.** Remote Sensing of Vegetation stress due to leaking underground gas pipes. *Remote Sensing in Agriculture Conference*, 26-28 June 2000 RAC Cirencester UK.

**Thomson, A.G., Fuller, R.M., Sparks, T., Yates, M. and Eastwood, J.A., 1998.** Airborne and ground radiometry over intertidal surfaces - waveband selection. *International Journal of Remote Sensing*, **19**, 1189-1205.

**Tillotson, H.T., Snaith, M.S. and Huang, Y., 1994.** Image processing for road condition surveys. *International Conference on Advanced Technologies in Transportation and Traffic Management*, 439-446.

**Trodd, N.M., 1996.** Analysis and representation of heathland vegetation from near-ground level remotely sensed data. *Global Ecology and Biogeography Letters*, **5**, 206-216.

**Watts-Tobin, H.C., Clark, C.D.C. and Thomas, D.S.G., 1995.** Characterisation of interannual and spatial variability of Kalahari Desert vegetation - implications for potential aeolian activity. *In:* Curran, P.J. and Robertson, Y.C., *ed. Remote Sensing in Action. Proceedings of the 21st Annual Conference of the Remote Sensing Society*, Remote Sensing Society, Nottingham, UK, 1107-1114.

**Watson, I.M., Oppenheimer, C., 2000.** Particle size distributions of Mount Etna's aerosol plume constrained by Sun photometry. *Journal of geophysical research,* **105 (D8),** 9823-9829.

**Willby, N., Gilvear, D.J., Grieve, I.C., Murphy, K., 1997.** Hydrological-ecological interactions on the Insh Marshes *In:* Floodplain Rivers: hydrological processes and ecological significance *Edited by: Large, A.*BHS Occasional Paper No 8 40-52.

**Winterbottom, S.J. and D.J., G., 1997.** Quantification of channel bed morphology in gravel-bed rivers using airborne multispectral imagery and aerial photography. *Regulated Rivers: Research and Management*, **13**, 489-499.

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## Recent EPFS loans cited

**[1] Professor MJ Barnsley, Geography, UOW Swansea**

Estimating land surface biophysical properties from satellite sensor measurements of directional reflectance

**[2] Dr P Lewis, Geography, UCL**

Validation of EOS products

**[3] Professor J Grace, Inst of Ecology and Resource Management, University of Edinburgh**

Remote Sensing of Photosynthetic Efficiency in Caxiuana, Brazil.

**[4] Dr G Ferrier, Geography, University of Hull**

Monitoring and modelling pollution flux around contaminated landfill sites

**[5] Dr G Ferrier, Geography, University of Hull**

Assessing the effects of landfill leachate on vegetation using remote sensing data

**[6] Dr J Settle and Dr I Davenport, ESSC, University of Reading**

The use of EO techniques to improve catchment scale pollution predictions

**[7] Dr MD Steven, Geography, University of Nottingham**

Remote sensing of plant stress caused by leaking natural gas pipelines

**[8] Dr TJ Malthus, Geography, University of Edinburgh**

Evolution of tolerance: its influence on the ability of remote sensing to detect vegetation stress

**[9] Dr R Bryant, Geography, University of Sheffield**

Monitoring of Hummock Vegetation Stress and Hydrological Conditions on the Forsinard Bog, Scotland

**[10] Dr W Murphy, Engineering Geology, University of Portsmouth**

Spectral characteristics of landscape features from active, suspended and relic landslides.