NATURAL ENVIRONMENT RESEARCH COUNCIL

For Office Use Only
Received ________________
Application No. ___________
ARSF Ref No. _____________
EPFS Project No. __________

Natural Environment Research Council
Field Spectroscopy Facility

Please complete and return to:

NERC FSF
School of GeoSciences
University of Edinburgh
Grant Institute
West Mains Rd
Edinburgh, EH9 3JW

Applications are reviewed every six months by the FSF Steering Committee at the beginning of June (for loans commencing between September and February) and December (for loans commencing between March and August). Applicants are expected to have read the 'Conditions of Loan' and 'Loan Applications - General Information' before completing this form. It is also advised that first-time applicants consult the Facility Manager before submitting an application form. Please submit one electronic copy by email and one signed copy by post or fax.

It is a condition of loan that all applicants are expected to present the results of their research at the FSF Users meeting, and all publications arising as a direct result of your loan should fully acknowledge the support of the Field Spectroscopy Facility. Failure to do so may jeopardise future loans.

NOTE. Contact details have been deleted from this loan application example at author's request. Any correspondence concerning this application should be addressed to FSF.

1. Principal Investigator (P.I.) / Applicant

Name: Dr Karen Anderson____________________________**Status:** Lecturer in remote sensing

Address:

____

Tel: ___________ Fax ________________________ **Email:**

2.a. Co-investigator

Name: Dr Klaus Kuhn____________________________**Status:** Lecturer in physical geography

Address:

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Tel: ___________ Fax ________________________ **Email:**

b. Other personnel involved in project (please provide names, affiliation and status)

N/A ____

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3. Research Project Title (maximum of 12 words)

"Exploring the potential of hyperspectral, multiple view angle measurements for soil property monitoring"

4. Proposed site(s) (Please also provide latitude and longitude)* ______________________________

Exeter University, United Kingdom, **Latitude** N 50.735 **Longitude** W -3.5343 _________________________

* *Please note that if you wish to take the equipment out of the UK during your loan you should provide further justification for your choice of site in section 10. FSF staff will be able to advise on customs issues, and will provide essential paperwork for your trip, but export and import will be the sole responsibility of the P.I. in charge of the project.*

5. Equipment

a. Instrument required: ASD FieldSpec Pro **and** Contact reflectance probe

b. Accessories required (please tick)

✓	Laboratory light source	✓	Tripod	✓	Spectralon Reference Panel		Fibre Optic extension (GER1500 only)		Cosine Diffuser (GER1500 / ASD only)

c. Would the loan of less or alternative equipment be of value? No

6. Prior use of this facility and training

a. Is this application associated with any previous applications to the NERC FSF? If so please provide the loan reference number(s), the name of the Principal Investigator(s), and the grade(s).

No

b. Do you, or the person who will be using the instrument require training in the use of the instrument and the post processing software? *Please note that for spectroradiometer loans if you have not been trained by an FSF member of staff in relation to a previous loan, you will be required to attend a short training course.*

No, Karen Anderson has used the equipment before and therefore does not require training

7. Period of Loan

a. Dates when equipment is required (inclusive)

At least three weeks loan is requested (rationale is provided in methodology). Suitable periods when the research could be undertaken are:

Between mid-July until 19th August
From 12th September onwards

b. Would the loan of equipment at an alternative date to those requested be of value?

We can be flexible but the period between 20th August and 11th September is not possible due to existing commitments.

c. Would the loan of equipment for a shorter period than that requested be of value?

SWIR capability is required (see methodology for rationale)

8. Funding

a. Please provide full details on the source(s) of funding for this research project (Research council / Departmental / EU etc.). *Please note that loan priority will be assigned to those projects currently in receipt of a NERC Grant or Studentship.*

Departmental

b. If in receipt of NERC funding please provide the full reference number of the grant or studentship, the title of the project and the grade assigned.

9. Other applications to this facility and other NERC facilities

If this application is in association with an Airborne Remote Sensing Facility (ARSF) proposal, please provide the ARSF reference number, PI name, project title, requested flight dates and grade below.

ARSF Application Number _N/A____

Principal Investigator ____

Full Title of ARSF Project ____

Requested Flight Dates ______________________________ Grade ______________________________

10. Research Programme: Scientific background to your proposal

a. Please use the space below to give details of the scientific aims and objectives of the project. Please describe in full the purpose of the study and why it is important. You should also include details of how the science you intend to undertake will contribute to scientific knowledge, and how it will fit with the aims of the NERC Strategy "*Science for a Sustainable Future*".[†] You should place the study in the wider scientific context, and cite related work from the published literature. If your research will be conducted overseas you should provide justification for taking the equipment abroad. If you require more space, please use additional sheets.

Science Case:

Soils experience rapid degradation of structure and composition in response to human induced land use and land cover changes (UNEP 1999). As a result of anthropogenic impacts, soil productivity declines, water retention is reduced, and greenhouse gases are released into the atmosphere. Many of the effects of land use and cover change on soil properties are known qualitatively, but spatially distributed quantitative information is scarce (Turner et al., 2001). This lack of information is problematic because neither current rates of soil degradation, nor the effectiveness of actions introduced to mitigate the impact of land use and land cover change on soil properties can be assessed precisely (Jetten et al., 1999; Lal et al., 2004). The main reason for the lack of information on soil condition is the effort involved in analysing the relevant soil properties using traditional techniques, mainly soil structure and organic matter content. Good soil structure is indicated by a high number of large aggregates (>5mm) (Bryan, 1968; Barthès and Roose 2002), which reduce vulnerability to erosion and increase the ability of the soil to absorb and store water (Torri et al., 1998; Gomez and Nearing, 2005). Soil structure is promoted by organic matter (Harris et al., 1966), which stabilises aggregates and provides a nutrient pool. Soils often begin to degrade when land use or land cover change interrupt the cycling of organic matter through soil, leading to a decline in the number of large aggregates and depletion of the nutrient pool (Slaymaker, 1998; Kuhn, 2005). Changing climate may also cause or enhance soil degradation by altering the water regime in the soil, the vegetation cover, and the organic matter input and decomposition (IPCC, 2001).

Currently, information on soil structure and organic matter content has to be collected through field sampling and, at least in a development context, relatively high analytical effort. Only a small number of chronosequences examining the long-term effects of land use and land cover change on soil structure and organic matter content have been established (Bravo-Garza and Bryan, 2005). Soil processes are also not presented in sufficient detail in models simulating climate change, due to a lack of knowledge about the feedback between changing climate and soil properties (Bryan, 2000). Clearly, a simpler method for collecting spatially-distributed information on soil structure and organic matter content could contribute significantly to a wider understanding of the impacts of environmental change on soil degradation.

Remote sensing techniques offer a means of collecting precise information on the nature, extent and magnitude of soil erosion and degradation through time. Furthermore, remotely sensed data may provide a more cost-effective means of monitoring soil properties over broad spatial extents, addressing the need for spatially-distributed information on soil types (Dwivedi et al., 1999). Bare, rough soils show variation in their reflected radiance due to the direction of the incident solar beam (in 'ideal' atmospheric conditions) and the direction at which they are measured by remote sensing instruments (Cierniewski, 1989). This is caused by the unique surface properties and defined by the bidirectional reflectance distribution function (BRDF). Soil surface roughness, and its change over time, reflect the size and stability of aggregates, and

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[†] *A PDF version of the NERC Five Year Strategy Document entitled "Science for a Sustainable Future" is available from the NERC web site http://www.nerc.ac.uk/publications/strategicplan/stratplan02.pdf. Please contact the Pool Manager if you require more information.*

thus give an indication of the quality of the soil structure. Since soil structure is a key indicator of degradation, it is therefore plausible to postulate that soils subjected to different erosion regimes may also exhibit varying directional reflectances as well as variations in the overall magnitude and shape of the reflected signal with wavelength. The latter statement is further supported by the fact that soil 'colour', for a given mineral composition and water content, is also known to be strongly affected by organic matter with darker soils (of lower reflectance) typically having higher organic content.

Recently, the advent of a new generation of pointable remote sensing instruments with directional imaging capabilities has provided a new dimension to the analysis of remotely sensed data. It is now possible to utilise the anisotropy of the reflected radiation field, such that spectral and angular domains can now be exploited to give information on both surface reflectance and, potentially, structure (Wanner et al. 1997, Barnsley et al. 2000, Abdou et al. 2001, Dial et al. 2003).

This project aims to undertake a feasibility study into the potential use of hyperspectral VNIR-SWIR multiple view angle measurements for determining whether measurable differences in reflectance exist over a range of soil types exposed to different erosion regimes. Specifically, directional hyperspectral measurements of soil surfaces will be used to determine whether the combination of the angular and hyperspectral domains permits the quantitative distinction of soils subjected to different erosion regimes. If successful, results from fine-scale directional hyperspectral measurements may indicate a potential application for pointable remote sensing instruments, and may create further opportunities for more rapid determination of soil surface structure and stability at a coarser spatial resolution, but over more spatially extensive areas.

10. Research Programme: Proposed Methodology

b. Please use the space below to provide details of the project methodology. This section should include details of how data will be collected and analysed, how the spectral data will contribute to the project and whether the spectral data will be related to other parameters (and if so what other parameters)

SOIL PREPARATION
Soil samples will be prepared prior to hyperspectral measurements, in the Sediment Research Facility of the University of Exeter. A state-of-the-art rainfall simulator will first be used to produce sequences of rainfall, with controlled cumulative kinetic energy (400 J h^{-1} mm^{-1}), inducing crusting, smoothing and compaction of the soil surface. Soils with different structure and organic matter content obtained from a variety of test sites in the UK and Europe, will be placed in containers and exposed to a sequence of artificial rainfalls.

Soil reflectance is known to vary according to mineral composition, organic matter, physical structure, surface texture and water content (Goldschleger et al., 2001; Weidong et al., 2002). Of these, water content is the main variable that we wish to control in this experiment because soil undergoes a familiar darkening following wetting (Lobell and Asner, 2002). This change results in a decrease in contrast between soil particles and their surrounding medium, resulting in an increase in the average degree of forward scattering and an increased probability of absorption before light is reflected (Lobell and Asner, 2002). Further investigations by Stoner et al. (1980) into this darkening effect have confirmed that the presence of water also modifies the shape of the soil reflectance spectra due to well-defined water absorption features. This effect was most marked in brighter soils and in the SWIR part of the spectrum (Weidong et al., 2002). As a result, variations in soil moisture may act to mask out variations in soil reflectance caused by changes in organic matter content (which is one variable of interest here). For this reason, the soils used in this experiment will be dried to air-dry conditions after each rainfall exposure. This will ensure that all soils have equal surface moisture at the time of measurement. A series of standardised soil methodologies will subsequently be applied to small sub-samples of each test surface. These will include:

a) Surface roughness measurements for characterising soil surface microtopography will be taken after rainfall of 30, 60, 90 and 120 minutes using a laser profilometer. These measurements will provide information on the generalised roughness of the surface;
b) An aggregate stability test will be applied, where the soil sample will be subjected to low intensity ultrasonic blasts, and will then be sieved using sieves of 0.05, 0.125, 0.25, 0.5, 1 and 2 mm diameter;
c) Soil organic matter content will finally be determined by burning a small sample of each soil at 500 degrees in a muffle furnace.

HYPERSPECTAL MEASUREMENTS USING THE ASD FIELDSPEC PRO

Hyperspectral reflectance measurements of each soil sample will be carried out before and after each rainfall simulation. These measurements aim to document changes in mineralogy and surface roughness, with increasing rainfall.

Firstly, high quality laboratory reflectance spectra collected using the contact reflectance probe will be analysed in relation to the diagnostic absorption features in the shortwave infra-red (SWIR), which are well-known to be linked to clay mineralogy. This is likely to be of importance in soils which develop surface crusts after exposure to heavy rainfall – since these crusts are known to be linked to changes in clay mineralogy at the surface (Goldschleger et al., 2001). This supports our request for the ASD FieldSpec Pro –we require SWIR capabilities in order to measure these diagnostic clay mineral absorption features, which would not otherwise be possible with a VNIR instrument.

Secondly, reflectance factor measurements of soil samples will be collected under 'ideal' conditions in the field. Field spectral measurements will be collected from each sample on multiple dates in the nadir configuration, with the aim of determining the relationship between soil reflectance factors, and the solar zenith angle (SZA; Moran et al., 2001). These measurements will also be collected at different times of day to maximise the range of SZA's encountered. Determination of this relationship will sample one aspect of the BRDF and hence provide a preliminary indicator of the level of anisotropy in each soil surface response. A similar technique has previously been applied to characterise calibration surface responses to SZA (Moran et al., 2001; Anderson, 2005). The SZA associated with each spectral measurement will be calculated using a pre-developed computer program which can convert time-stamps from the header of the spectral data file into SZA for a given location. All nadir spectral measurements will involve collection of regular scans of a Spectralon calibration tablet (also at nadir) to minimise the impact of changing atmospheric conditions on the accuracy of derived reflectance factors. Spectralon measurements will be used to calibrate soil spectral measurements to an absolute reflectance scale. For such measurements we would plan to use 'white reference mode' to facilitate measurement of drift in the white reference scan, thus permitting regular updates of the white reference when required. In nadir configuration in the field we would require use of a tripod to minimise the effect of hand-positioning errors on derived reflectance factors, and thus ensure precision in the spectral measurement methodology (Rundquist et al., 2004).

Directional spectral measurements will address the final and most complex research question - whether multiple view angle measurements can be used to successfully discriminate soils exposed to different erosion regimes. Directional spectral measurements will initially be collected in the solar principal plane using the ASD FieldSpec Pro, where the pistol grip will be fixed to an A-frame device. The A-frame will be fitted with an electronic angle measure so as to precisely quantify the viewing (θ_r) angles at which measurements are collected. The rationale for prioritising measurements in the solar principal plane relate to previous studies of surfaces in the natural illumination environment where the BRDF generally shows most variability in this plane (Sandmeier et al., 1998), especially in relation to the hot-spot where $\theta_s=\theta_r$ (Moran et al., 2001). Reference measurements of a Spectralon panel will be collected at the nadir position and reflectance factors will subsequently be calculated using a ratio to the nadir flux of the Spectralon target. Further experiments (time permitting) will aim to collect spectral measurements at alternative azimuths – at the very least it is planned that a matching sequence of reflectance measurements (i.e. at the same view zeniths as in the principal plane) will be made in the orthogonal plane to provide a more complete view of the directional response of the surface.

Following collection of the spectral measurements outlined above, results will be analysed in relation to quantitative information on soil structure and composition, obtained from the laboratory diagnostic testing outlined in the previous section. As such, the experiment will use a novel and robust experimental approach to determine the feasibility of using directional hyperspectral measurements for soil property monitoring. It is also possible that these measurements may prove suitable for use with existing empirical or semi-empirical BRDF models; speculatively this may facilitate collaborative links with Jerzy Cierniewski (see Cierniewski, 1989).

Further to the above methodology, it is important to highlight the importance of a reasonably long loan period in this study (3-4 weeks is requested). Most of the spectral measurements will be collected in the field under solar illumination and require 'ideal' conditions to reduce the effect of changing irradiance distributions on the resultant spectra (Kriebel, 1976). For this reason, the requested loan period is required to ensure that suitable atmospheric conditions occur within the loan window.

References

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United Nations Environmental Programme (UNEP) 1999. Global Environmental Outlook 2000.

11. Your publication record

Please provide details of your publication record from the past five years in the space provided below. All publications are important, including conference proceedings, reports and poster papers. Those articles which are not directly related to remote sensing or field spectroscopy should also be listed. Please use the additional sheet at the back of the application form if you require more space.

Publication record:

<u>Karen Anderson's Publications</u>

Peer-reviewed

In press — Anderson, K. and Milton, E.J. *Calibration of dual-beam spectroradiometric data.* **International Journal of Remote Sensing.** *Accepted for publication June 2005.*

International conference presentations

2005 — Anderson, K. and Milton, E.J., 2005. *On the stability of ground calibration targets: implications for the repeatability of remote sensing methodologies. Proceedings of the 4th EARSeL Workshop on Imaging Spectroscopy, "New Quality in Environmental Studies"*, 27-29 April 2005, Warsaw, Poland.

2005 — Anderson, K. and Milton, E.J., 2005. *Ground calibration target stability: implications for calibration/validation. Proceedings of the CHRIS-PROBA workshop*, 21-22 April 2005, Frascati, Italy.

2003 — Anderson, K., Milton, E.J. and Rollin, E.M., 2003. *Sources of uncertainty in vicarious calibration, understanding calibration target reflectance.* Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2003), Toulouse, France. On CD, 3pp.

2003 — Anderson, K., Milton, E.J. and Rollin, E.M., 2003. *The temporal dynamics of calibration target reflectance.* Proceedings of RSPSoc 2003: Scales and Dynamics in Observing the Environment, The Remote Sensing and Photogrammetry Society, Nottingham, UK. On CD, 14pp.

Commercial reports/conferences

2005 — Milton, E. J., Hughes, P. D., Anderson, K., Schultz, J., Lindsay, R. and C.T.Hill, 2005. Remote sensing condition categories on lowland raised bogs in the UK. Part 1 : Development and testing of methods. In: *Proceedings of the Peterborough Remote Sensing Workshop*, 30 Sept 2004, edited by Meade, R., English Nature, Peterborough, UK. ISBN 1-85716-873-9, pp26-35.

2003 — Anderson, K., 2003. *Processing of NERC ARSF digital imagery: A comparison of Monks Wood and PML processed CASI and ATM data.* A report to NERC and Plymouth Marine Laboratory, Technical report, GeoData Institute, University of Southampton, 10pp

<u>Klaus Kuhn's Publications</u>

Peer-reviewed

2005 — Kuhn, Nikolaus J. *Erodibility assessment in dynamic event-based erosion models*. In: Owens, P.N. and Collins A.J. (eds.) **Soil Erosion and Sediment Redistribution in River**

Catchments: Measuring, Modelling, and Management, accepted for publication by CABI 2005.

2004 Kuhn, Nikolaus J. and Yair, Aaron. *Spatial distribution of surface conditions, runoff generation and landscape development in the Zin Valley Badlands, Northern Negev, Israel*, **Earth Surface Processes and Landforms 29**, p. 1417-1430.

2004 Kuhn, Nikolaus J. and Bryan, Rorke B. *Drying, soil surface condition and interrill erosion on two Ontario soils,* **Catena** 57, p. 113-133.

2003 Kuhn, Nikolaus J. and Yair, Aaron. *Surface conditions and runoff generation in small arid watersheds, Zin Valley Badlands, Israel*, **Geomorphology**, 57, p.183-200.

2003 Kuhn, Nikolaus J., Bryan, Rorke B. and Navar, Jose. *Seal formation and interrill erosion on a smectite-rich Kastanozem from NE-Mexico,* **Catena**, 52, 149-169.

2002 Bryan, Rorke B. and Kuhn, Nikolaus J. *Hydraulic conditions in* experimental rill confluence and scour in erodible soils, **Water Res. Res.** 38(5), p. 1-22.

2001 Navar, Jose, Mendez, Jorge, Bryan, Rorke B. and Kuhn, Nikolaus J. *The contribution of shrinkage cracks to infiltration in Vertisols of Northeastern Mexico,* **Can. J. Soil Sci**.82, p. 65–74.

1996 Kuhn, Nikolaus J., Schütt, Britta and Baumhauer Roland. *Holozäne Seespiegelschwankungen im Gebiet der Laguna de Gallocanta, Nordostspanien, ("Holocene lake level changes in the Gallocanta Basin, NE-Spain")* **Geoökodynamik** 18 2/3, p. 109-131.

Peer-reviewed, in review

2004 Kuhn, Nikolaus J. *Environmental Change, Interrill Erosion and Sediment Properties: observations on crusting loam*, submitted to **Catena**.

2004 Kuhn, Nikolaus J. *Dynamic interaction between rainfall and runoff in an arid, semi-arid and humid environment,* submitted to **Geographical Review.**

Publications, non-refereed

2004 Kuhn, Nikolaus J. *Integrating short-term changes of soil erodibility into erosion prediction.* Proceedings of EUROSOIL 2004, Freiburg.

2004 Nikolaus J. Kuhn, *Incorporating rainfall and drying sequences into erosion assessment.* **Proceedings of the 13th Meeting of the International Soil Conservation Organisation**, Brisbane, Queensland, July 2004.

1998 Nikolaus J. Kuhn. *Strategies for reducing runoff and erosion on smectite-rich soils in northeastern Nuevo Leon*. **Report for the Centro Rural de la Universidad Autonoma de Nuevo Leon**.

1999 Kuhn, Nikolaus J. *Holocene lake level changes of the Laguna the Gallocanta, Iberian Range, NE-Spain*. **Report for the Ministry of the Environment of the Province of Aragon**.

1993 Kuhn, Nikolaus J. *Test des Abflussvorhersageprogramms NAM-LFW im Amt für Abfall- und Wasserwirtschaft Trier*. ("Testing the Rainfall-Runoff prediction software NAM-LFW at the Water Resource Agency Trier, Germany"). **Report prepared for the State Water Resource Agency of Rheinland-Pfalz, Germany.**

1992 Kuhn, Nikolaus J. *Gebrauch der Allgemeinen Bodenabtragsgleichung im Rahmen einer UVP*, ("Using the Universal Soil Loss Equation in the framework of Environmental Assessment"). **Report prepared for the Agricultural Planning Agency Trier, Germany.**

7/1992 Kuhn, Nikolaus J. *Erosionsgefährdung der Gemarkung Ernzen ("Erosion risk assessment for the township of Ernzen, Germany").* **Report prepared for the Agricultural Planning Agency Trier, Germany.**

Presentations at international conferences

2005 *Rainfall magnitude and spatial pattern of sediment sources in arid and humid environments*. Invited presentation at the annual meeting of the **German Geographic Society** ("Deutschen Geographentag"), Oktober 2005.

2004	*Environmental Change and Interrill erosion.* **COST 634 Meeting On- and off-site effects of soil erosion**, Bratislava, Oktober 2004.
2004	*Environmental Change, Interrill Erosion and Sediment Properties: observations on crusting loam.* **EUROSOIL**, Freiburg, September 2004.
2004	*Incorporating rainfall and drying sequences into erodibility assessment.* Accepted for **13th International Soil Conservation Conference**, Brisbane, Australia, July 2004.
2004	*Effect of soil-rainfall interaction on runoff generation and sediment delivery in an arid, semi-arid and humid environment.* **International Conference to honour Olav Slaymaker**, University of British Columbia, Vancouver, June 2004.
2003	*Is erodibility predictable?* Conference on **Soil Erosion and Sediment Redistribution in River Catchments,** National Soil Resource Institute (NSRI), Silsoe, September 2003.
2003	*Short-term changes of soil resistance to runoff and erosion on swelling and non-swelling clays.* **BGRG Annual Meeting,** Oxford, September 2003.
2002	*Surface conditions, runoff generation and landscape development in the Zin Valley Badlands, Northern Negev, Israel,* **BGRG Annual Meeting,** Leeds, September 2002.
2001	*Spatial distribution of surface conditions and runoff generation in small arid watersheds, Zin Valley Badlands, Israel*, **COST-623 Soil Erosion and Global Change Workshop,** Strasbourg, September 2001**.**
2001	*The effect of rainfall pattern on interrill erodibility*, presented at the **50th Annual meeting of Canadian Geographers,** Montreal, Canada, June 2001**.**
1997	*Holocene lake level changes of the Laguna de Gallocanta, NE-Spain***, Meeting of the IGU Commission on Geomorphology and Environmental Change,** Sienna/Italy, September 1997**.**
1997	*Rainfall simulation by nozzle simulators in the Soil Erosion Laboratory of the University of Toronto*, **BGRG workshop on Rainfall Simulation,** Utrecht, April 1997.

12. What output is expected from the research? (Please indicate time scale)

Expected research output will be at least one journal publication in an international journal, and the potential for presentation of the results at an international conference within two years. It is hoped that this preliminary study will also inform a grant application to NERC for a funded research project later in 2005-2006.

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13. Declaration

I have read and agree to abide by the Conditions of Loan.

Signature of Applicant ____ Date __________________________

Signature of Head of Department ______________________________ Date __________________________
or Institute Director