Dr Hugh Graham | CV

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➡ Experience

2022 - Present   **Remote Sensing Analyst**   Permian Global

➡ As a remote sensing analyst at Permian Global, I am responsible for the development and maintenance of complex, end-to-end data analysis workflows to deliver, robust, reproducible and scalable carbon accounting for high quality REDD+ projects.

➡ I develop machine learning pipelines to predict the above ground carbon stocks across REDD+ project areas. This is achieved by using forest plot data in combination with LiDAR, synthetic aperture radar (SAR), and multispectral satellite data to 'upscale' field observations to the landscape scale.

➡ Using robust software engineering practices, I have developed containerised workflows that track the status of code from input, through analytics to automated report outputs using the targets R package . This has proven to be essential for rapid iteration and improvement in response to auditors.

➡ I contributed to the successful verification of the Kuamut Rainforest Project. This project was rated by a market leading ratings agency and was awarded one of their highest ever ratings for an IFM REDD+ project.

➡ I have led the development of open source R packages to support access to and processing of spatial data. I firmly believe that the promotion of best practice through the dissemenation of open source code is essential for building confidence in carbon projects and the market as a whole.

➡ Another important aspect of my role is to evaluate and critique new relevant methods. For example, I led the writing of an e-letter and accompanying analysis book in response to the controversial Science article by West, et al. (2023)

➡ I have a 30% secondment role at the University of Exeter in the Terrestrial Ecosystem Science and Services (TESS) Lab where I provide supervision and technical/statistical support for MSc and PhD students. Current research projects that I am involved with include:
- Monitoring the distribution and spread of the alien invasive plant species *Prosopis* in SW Botswana (Slade, et al., in prep)
- Estimating Canopy Height in Tropical Forests: Integrating Airborne LiDAR and Multi-Spectral Optical Data with Machine Learning. (Pickstone, et al., in review)
- Repeated drone photogrammetry surveys demonstrate that reconstructed canopy heights are sensitive to wind speed but relatively insensitive to illumination conditions. (Slade, et al., in review)
- Assessing the accuracy of GEDI for mapping resilience in the Amazon rainforest along a gradient of disturbance to recovery. (Doyle, et al., in prep)

2019 - 2022   **Geospatial Research Assistant**   University of Exeter

➡ Lead geospatial data analyst on several research projects in partnership with Natural England, The Environment Agency, Natural Resources Wales, Scottish Natural Heritage and the Wildlife Trusts to model Eurasian beaver habitat and estimate the potential distribution and density of their dams for Great Britain. This required the automated reading and processing of hydrological, topographic and vegetation metrics from a range of remotely-sensed datasets using a geospatial processing pipeline comprising Python, R and GRASS GIS. Moving this workflow from the landscape to national scale taught me a huge amount in terms of designing stable workflows for processing big spatial data.

➡ To accompany this work, I produced an ArcGIS plugin and R shiny App to allow our partners to explore, interrogate and download the data.

➔ In this role, I also collaborated on a variety of other ecological and conservation projects such as:
- Modelling aboveground biomass using drone-based structure from motion to create globally relevant allometric models in low stature ecosystems (Cunliffe, et al., 2021).
- Forest connectivity modelling, in partnership with Cornwall County Council, in support of their nature recovery program to evaluate the feasibility of species reintroductions.

| 2014 - 2015 | **Aquatic Environmental Consultant** | Apem Ltd., Cardiff |

➔ Environmental analysis to support the production of environmental impact assessments (EIA) and monitoring projects.

➔ key roles included: data analysis and visualisation using R, geospatial analysis and mapping with ArcGIS, report writing and field work.

➔ Education

| 2015 - 2022 | **PhD in Geography** | University of Exeter |

➔ *Understanding the Impact of Reintroducing the Eurasian Beaver (Castor fiber) in Great Britain* (Graham, 2022).

➔ Using spatially distributed models, time series analysis, statistical analysis and remote sensing, I studied the impact of reintroducing the Eurasian beaver in Great Britain with a particular focus on: riparian woodland structure, hydrological flow regimes (Graham, et al., 2023), modelling future population dynamics to understand ecological carrying capacity and the impact of varying management regimes (Graham, et al., 2022) and predicting the spatial distribution of their habitat and dam building activity (Graham, et al. 2020).

| 2013 - 2014 | **MSc, River environments and their management (Dist.)** | University of Birmingham |

➔ Dissertation - 78%: An investigation into the impact of the Demon Shrimp (*Dikerogammarus haemobaphes*) on the benthic invertebrate community of the River Cherwell.

| 2009-2012 | **University of Exeter BSc (Hons), Geography (2:1)** | University of Exeter |

➔ Dissertation - 78%: A laboratory flume experiment investigating the interaction between bed-load transport, erosion and channel geomorphology.

➔ Key Qualifications/Skills

➔ Very strong proficiency with R and Python programming languages:

➔ During my PhD I focused much of my learning on improving my programming skills with a particular focus on geospatial. Since starting at Permian, I have further improved these skills with a stronger focus on the intricacies of handling remotely sensed data sources. The following examples are a selection of recent projects with a focus on geospatial data:

➔ chewie - An R package for simple and efficient access to point-level data from the Global Ecosystem Dynamics Investigation (GEDI) mission.

➔ chmloader - An R package that supports the downloading and evaluation of the recently released global 1m resolution canopy height model created by Meta/WRI (Tolan, et al., 2024). With an ever increasing number of vegetation datasets being released it is essential that we robustly evaluate their accuracy and precision.

➔ ezwarp - An R package that provides a simplified interface for the *gdalwarp* utility, enabling the reprojection, resampling and cropping of raster data with a single function call.

➔ gblidar - An R package that I work on in my spare time to improve access to the large catalog of LiDAR and derived products for Great Britain. This package, although still in development, is being used by a number of academic researchers.

➔ rsi - An R package to support the downloading, preprocessing and calculation of spectral/radar indices from open SpatioTemporal Asset Catalogs. My main role in this package was to support an intern with the direction and scope of the package. I have also made some feature contributions.

➡ More than 10 years of experience with a range of GIS software:

➡ Including: GDAL, Google Earth Engine, QGIS, GRASS GIS, Arc GIS (Pro) and their respective python/R APIs

➡ I have gained a strong background in fundamental geospatial concepts such as coordinate reference systems, geographic transformations, raster and spatial vector processing and the use of SQL to calculate efficient spatial queries.

➡ Extensive experience with version control

➡ I use Git version control software and GitHub on a daily basis to manage and track the progress of my software development, report writing and data analysis.

➡ I also have experience with setting up continuous integration pipelines using GitHub actions to support robust software development practices such as unit testing and code coverage.

➡ Experience with Docker containers

➡ I have experience with creating and managing Docker containers to support the reproducibility of my research and to ensure that my software can be run on a variety of platforms. This is essential in a research setting where reproducibility is integral to maintaining confidence in the results of a project.

➡ This software infrastructure has proved invaluable for sharing data analysis pipelines with auditors and collaborators.

➡ Experience with High Performance Computing

➡ SfM work is often computationally intensive and, during my PhD, I helped to move some of this processing to UoEs ISCA High Performance Computing (HPC) facility as part of Cunliffe, et al., 2021. This required the scheduling of distributed compute using the command line in combination with Python. I would enjoy the opportunity to further advance my skills with HPC, particularly for cloud-based processing.

➡ Extensive experience with Agisoft Metashape SfM photogrammetry software and its Python API

➡ During my PhD, I worked with drone-based Structure from Motion (SfM) photogrammetry to understand changes in vegetation structure. In order to improve the reproducibility and accuracy of these models, I developed two Python packages to streamline processing:
- sfm_precision a python module for Agisoft Metashape, which calculates SfM precision using Metashapes Python API. This builds on James et al., 2017, by improving computational performance and allowing greater scalability.
- sfm_gridz a python package to compute differences between digital elevation models with consideration of each models precision and error. These packages are extremely useful when working in structurally complex systems where an accurate understanding of uncertainty is critical. These packages were developed as part of our in review manuscript: Using aerial photogrammetry to detect significant canopy height change resulting from beaver foraging.

➡ Strong statistical analysis skills

➡ I have experience applying a wide range of statistical and Machine Learning (ML) techniques including: General Linear Models, Mixed effects models, General Additive Models, Principal Component Analysis, Quantile regression, Bayesian regression, Fuzzy inference, and numerous ML algorithms such as random forest and gradient boosting. One of primary roles in my secondment at UoE is to provide advice on statistical analysis to th research team.

➡ Cartography

➡ I enjoy using code for cartography. Some recent examples of my maps can be found here

➡ Experience piloting drones to undertake Structure from Motion surveys.

➡ Full and clean driving License

➲ Publications

Brazier, Richard E., M. E. Elliott, E Andison, R. E. Auster, S Bridgewater, P Burgess, J Chant, et al. 2020. "River Otter Beaver Trial: Science and Evidence Report. River Otter Beaver Trial, Devon." https://www.exeter.ac.uk/creww/research/beavertrial/.

Brazier, Richard E., Alan Puttock, Hugh A. Graham, Roger E. Auster, Kye H. Davies, and Chryssa M. L. Brown. 2020. "Beaver: Nature's Ecosystem Engineers." *WIREs Water*. https://doi.org/https://doi.org/10.1002/wat2.1494.

Campbell-Palmer, R., A. K. Puttock, H. A. Graham, K Wilson, G. Schwab, M. J. Gaywood, and R. E. Brazier. 2018. "Survey of the Tayside Area Beaver Population 2017-2018." https://www.nature.scot/naturescot-research-report-1013-survey

CampbellPalmer, Róisín, Alan Puttock, Kelsey A. Wilson, Alicia LeowDyke, Hugh A. Graham, Martin J. Gaywood, and Richard E. Brazier. 2020. "Using Field Sign Surveys to Estimate Spatial Distribution and Territory Dynamics Following Reintroduction of the Eurasian Beaver to British River Catchments." *River Research and Applications*. https://doi.org/https://doi.org/10.1002/rra.3755.

Cunliffe, A, K Anderson, F Boschetti, R Brazier, H Graham, I Myers-Smith, T Astor, et al. 2021. "Global Application of an Unoccupied Aerial Vehicle Photogrammetry Protocol for Predicting Aboveground Biomass in Non-Forest Ecosystems." *Remote Sensing in Ecology and Conservation*.

Graham, Hugh. 2023. "Quantifying the Impact and Expansion of Eurasian Beaver in Great Britain." Ph.{D}., University of Exeter. http://hdl.handle.net/10871/132143.

Graham, Hugh A., Alan K. Puttock, Mark Elliott, Karen Anderson, and Richard E. Brazier. 2022. "Exploring the Dynamics of Flow Attenuation at a Beaver Dam Sequence." *Hydrological Processes* 36 (11): e14735. https://doi.org/10.1002/hyp.14735.

Graham, Hugh A., Alan Puttock, Jake Chant, Mark Elliott, Roisin Campbell-Palmer, Karen Anderson, and Richard E. Brazier. 2022. "Monitoring, Modelling and Managing Beaver (Castor Fiber) Populations in the River Otter Catchment, Great Britain." *Ecological Solutions and Evidence* 3 (3): e12168. https://doi.org/10.1002/2688-8319.12168.

Graham, Hugh A., Alan Puttock, William W. Macfarlane, Joseph M. Wheaton, Jordan T. Gilbert, Róisín Campbell-Palmer, Mark Elliott, Martin J. Gaywood, Karen Anderson, and Richard E. Brazier. 2020. "Modelling Eurasian Beaver Foraging Habitat and Dam Suitability, for Predicting the Location and Number of Dams Throughout Catchments in Great Britain." *European Journal of Wildlife Research* 66 (3): 42. https://doi.org/10.1007/s10344-020-01379-w.

Pickstone, Bri, Hugh A. Graham, and Andrew M. Cunliffe. n.d. "Estimating Canopy Height in Tropical Forests: Integrating Airborne LiDAR and Multi-Spectral Optical Data with Machine Learning." *Journal of Photogrammetry and Remote Sensing*.

Puttock, Alan, Hugh A. Graham, Josie Ashe, David J. Luscombe, and Richard E. Brazier. 2021. "Beaver Dams Attenuate Flow: A Multi-Site Study." *Hydrological Processes* 35 (2): e14017. https://doi.org/https://doi.org/10.1002/hyp.14017.

Puttock, Alan, Hugh A. Graham, Donna Carless, and Richard E. Brazier. 2018. "Sediment and Nutrient Storage in a Beaver Engineered Wetland." *Earth Surface Processes and Landforms* 43 (11): 2358–70. https://doi.org/10.1002/esp.4398.

Puttock, Alan, Hugh A. Graham, Andrew M. Cunliffe, Mark Elliott, and Richard E. Brazier. 2017. "Eurasian Beaver Activity Increases Water Storage, Attenuates Flow and Mitigates Diffuse Pollution from Intensively-Managed Grasslands." *Science of The Total Environment* 576 (January): 430–43. https://doi.org/10.1016/j.scitotenv.2016.10.122.

Puttock, Alan, Mervyn Newman, Hugh Graham, Mark Elliott, Jake Chant, Roger Auster, and Richard Brazier. 2023. "Positive Coexistence of Water Voles and Beaver: Water Vole Expansion in a Beaver Engineered Wetland." *Mammal Communications*. https://doi.org/10.59922/GONL2514.

Slade, Glenn, Karen Anderson, Hugh A. Graham, and Andrew M. Cunliffe. 2024. "Repeated Drone Photogrammetry Surveys Demonstrate That Reconstructed Canopy Heights Are Sensitive to Wind Speed but Relatively Insensitive to Illumination Conditions." *International Journal of Remote Sensing* 0 (0): 1–18. https://doi.org/10.1080/01431161.2024.2377832.