The University of Manchester

MANCHESTER 1824

Controls on the formation, transport, and fate of charcoal from moorland wildfires

Gareth D. Clay

Geography, School of Environment and Development, University of Manchester, M13 9PL, UK

Contact: gareth.clay@manchester.ac.uk

Background

During a wildfire event, above-ground living biomass is converted into a mixture of smoke, ash, unburnt vegetation and charcoal. Charcoal, enriched in carbon, can form a large part of the post-fire landscape.

Whilst it can be relatively simple to estimate the amount of charcoal present after a fire, the controls which affect the amount of charcoal produced are less straightforward.

Furthermore, once the charcoal is created in the fire, the properties of the charcoal itself (density, porosity) will determine how it may be transported from a site and its ultimate fate within the environment.

This study draws a range of experimental data together to look at the properties of charcoal from UK fires.

Why is this important?

The density and porosity of charcoal are fundamental properties that affect its transport potential within an environment and also impact on its interaction with the hydrological cycle.

At its simplest, materials less dense than water (1 g/cm3) will float. Accurate density measurements such as those made using the He pycnometry technique can calculate bulk, envelope and skeletal densities (Figure 1).

Interactions with water or soil microorganisms are heavily dependent on the porosity of charcoal which in turn will dictate how long the carbon-rich charcoal will persist in the environment.

Once charcoal is formed it can be moved around the landscape in a number of ways with a significant amount ending up in river systems.

Classic studies of sediment transport in fluids (Shields, 1936), have defined the initiation of particle motion as a balance between shear stress and the particle's density and size:

$$\theta = \frac{\tau}{(\rho_s - \rho) g D}$$

Where: θ is the Shields parameter, τ is the dimensional shear stress, ρ_s is the density of the sediment, ρ is the density of the fluid, g is acceleration due to gravity and D is the diameter of the sediment.

Above a certain threshold particles will move in the fluid.

Therefore, it is important to know both the density and size of the particles in order to calculate potential transport.

Methods

A range of methods were employed to understand the formation and potential transport of charcoal.

Formation

Laboratory burning experiments focussing on mass loss and charcoal formation (Worrall et al., 2013).

Field based surveys of charcoal production from wildfires (Clay and Worrall, 2011) and prescribed burns (Worrall et al., 2013).

Transport

Helium pycnometry to calculate density and porosity of charcoal, important properties in the transport of material in fluvial systems (Brewer et al., in review).

Photo 1 Surface charcoal following a wildfire near Blackstone Edge reservoir, Rochdale in spring 2013.

He pycnometry

Helium (He) pycnometry calculates the density of a sample of known mass by accurately measuring the volume of a sample using He displacement.

Using an AccuPyc 1340 with a $1 cm^3$ chamber, the volume is measured by detecting the change in pressure due to the volume of helium displaced by the sample within the sealed chamber (Ideal Gas Law).

From this the skeletal density can be calculated (Fig. 1).

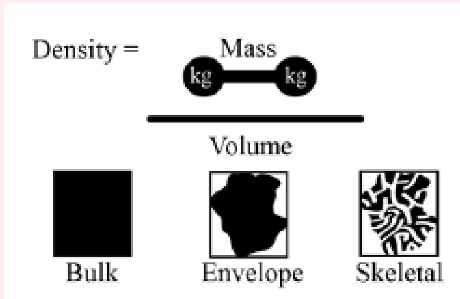

Figure 1 Types of density measurements from Brewer et al. (in review).

Results

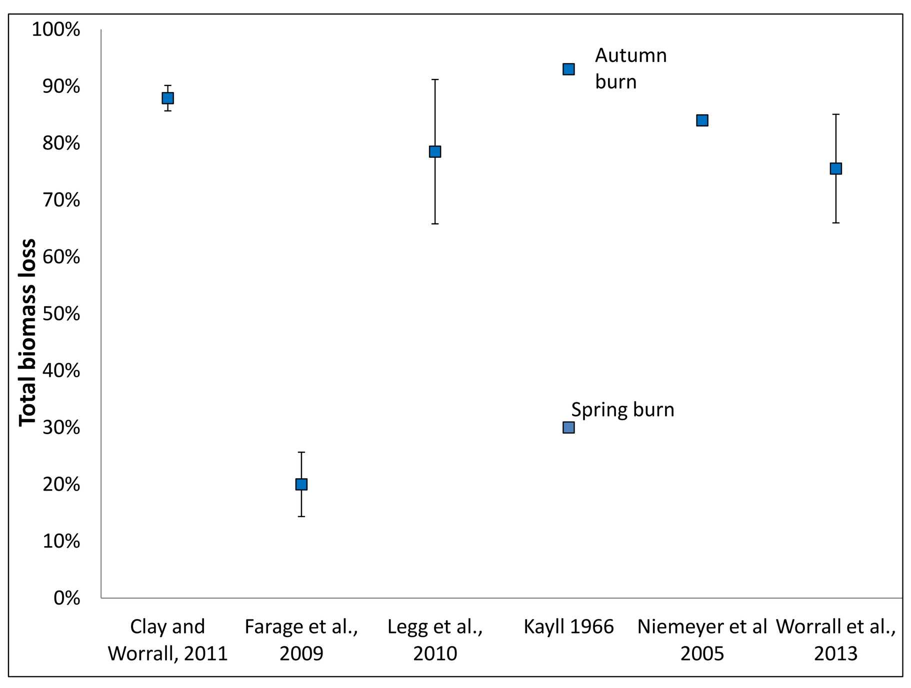

Figure 2 Summary of previous studies showing the amount of biomass consumed in a fire.

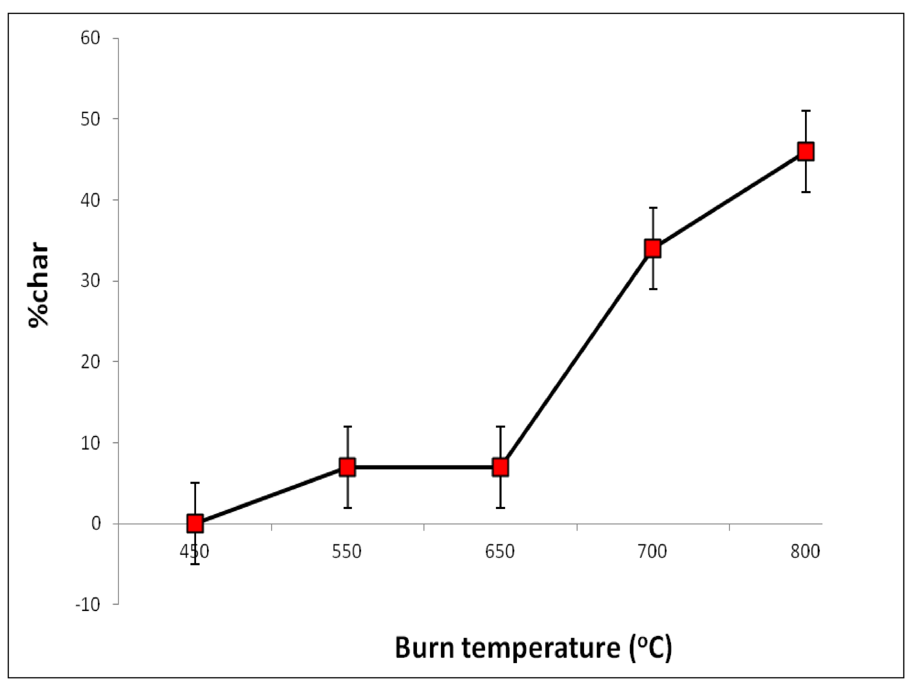

Figure 3 Plot of char formation at a range of burn temperatures (Worrall et al., 2013).

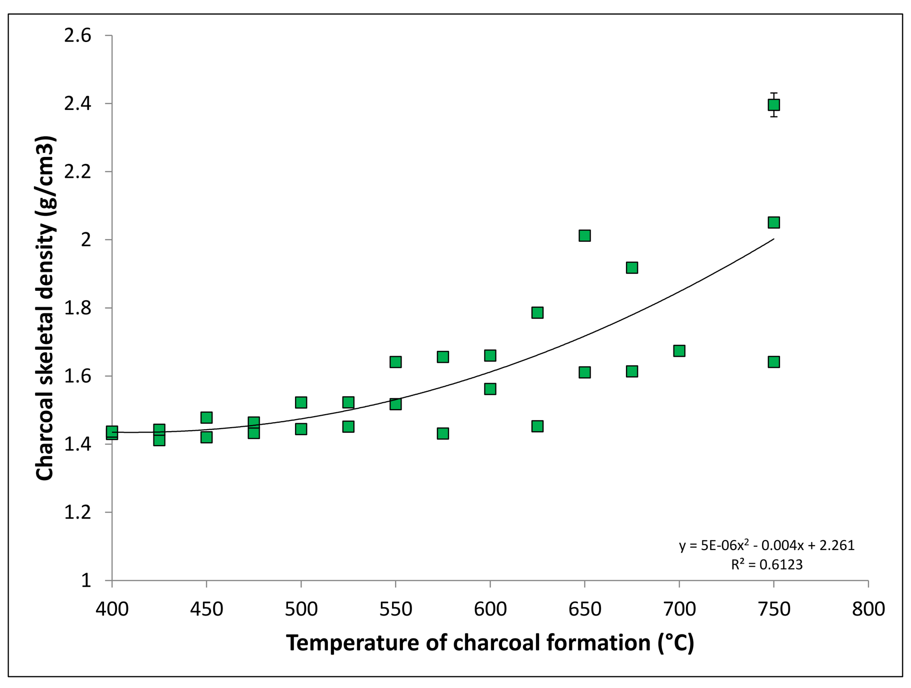

Figure 4 Relationship between burn temperature and charcoal density.

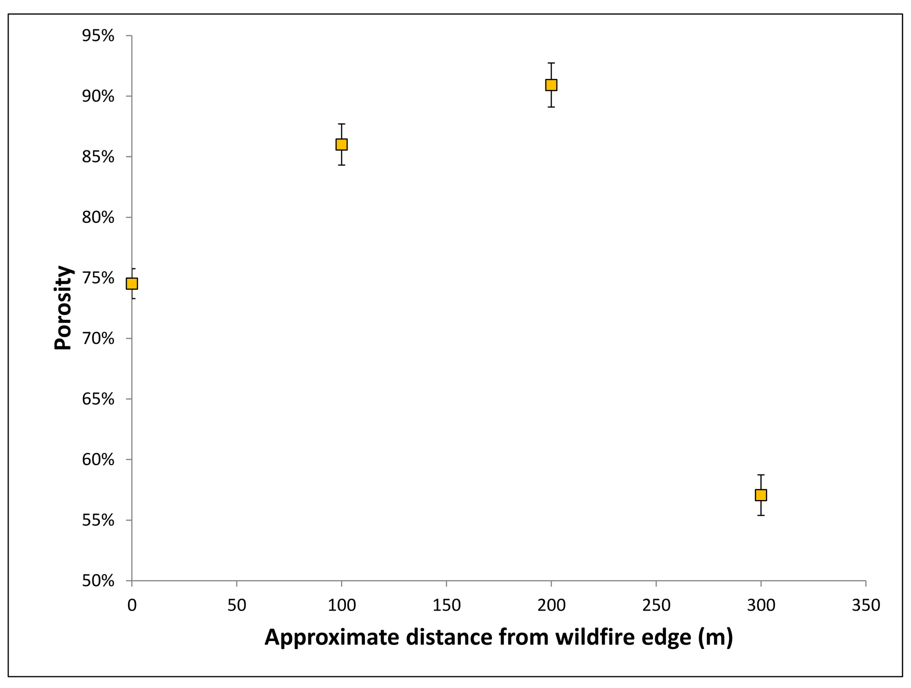

Figure 5 Porosity variation across a wildfire scar (same site as Photo 1).

From the data in Fig. 2 we can estimate the amount charcoal formed.

However, we do not know much about the properties of the charcoal formed.

We know that the temperature of the fire is an important control on the nature and amount of charcoal produced (Fig. 3).

The question is then: how does burning temperature translate into physical properties of density and porosity?

Fig. 4 shows that with increasing burn temperature, the skeletal density increases. This has implications for the potential transport of the charcoal.

Fig. 5 shows that there is a wide range in charcoal porosity values from a single event (between 55 to 90 %).

Future work

Whilst there are a number of existing datasets on charcoal formation in UK fire settings, this study has introduced some new and novel methods of charcoal quantification.

A good working knowledge of the transport of charcoal is needed in order to accurately incorporate this component of the carbon cycle into carbon budget estimates.

Future work will look at experimenting with charcoals of varying densities and assessing their transport potential.

Acknowledgements

Thanks to the land managers for access to the various research sites.

Thanks also go to Helge Gonnermann (Earth Science, Rice University, Texas) for the use of the He pycnometry instruments and to Catie Brewer (now at New Mexico State University) for answering all my questions on pycnometry and showing me how to use the equipment. Thanks to Emma Shuttleworth for proofing this poster.

References

Brewer, C. E., Chuang, V. J., Masiello, C. A., Gonnermann, H., Gao, X., Dugan, B., et al. (in review). Beyond biochar chemistry: measuring density towards an understanding of porosity and environmental interactions. *Environ Science & Technology, in review*, 1–30.

Clay, G.D. & Worrall, F (2011) Charcoal production in a UK moorland wildfire – how important is it? *Journal of Environmental Management* 92(3); 676-682

Shields, A. (1936) Application of similarity principles and turbulence research to bed-load movement *Mitteilungen der Preußischen Versuchsanstalt für Wasserbau (in English)* **26**. Berlin: Preußische Versuchsanstalt für Wasserbau.

Worrall, F., Clay, G.D., & May, R (2013) Controls upon biomass loss and char production from prescribed burning on UK moorland *Journal of Environmental Management* 120;27-36