How variable are Sr isotopes in soil associations and with depth?

– implications for extrapolating isoscapes

Carol-Ann Craig[1], Allan Lily[1], Andy Midwood[1,2], Gillian Green[1] and Barry Thornton[1]

[1]The James Hutton Institute, Aberdeen, AB15 8QH

[2] Present address, Terramera Inc., Vancouver, British Columbia, Canada

Email: Carol-Ann.Craig@hutton.ac.uk

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Introduction

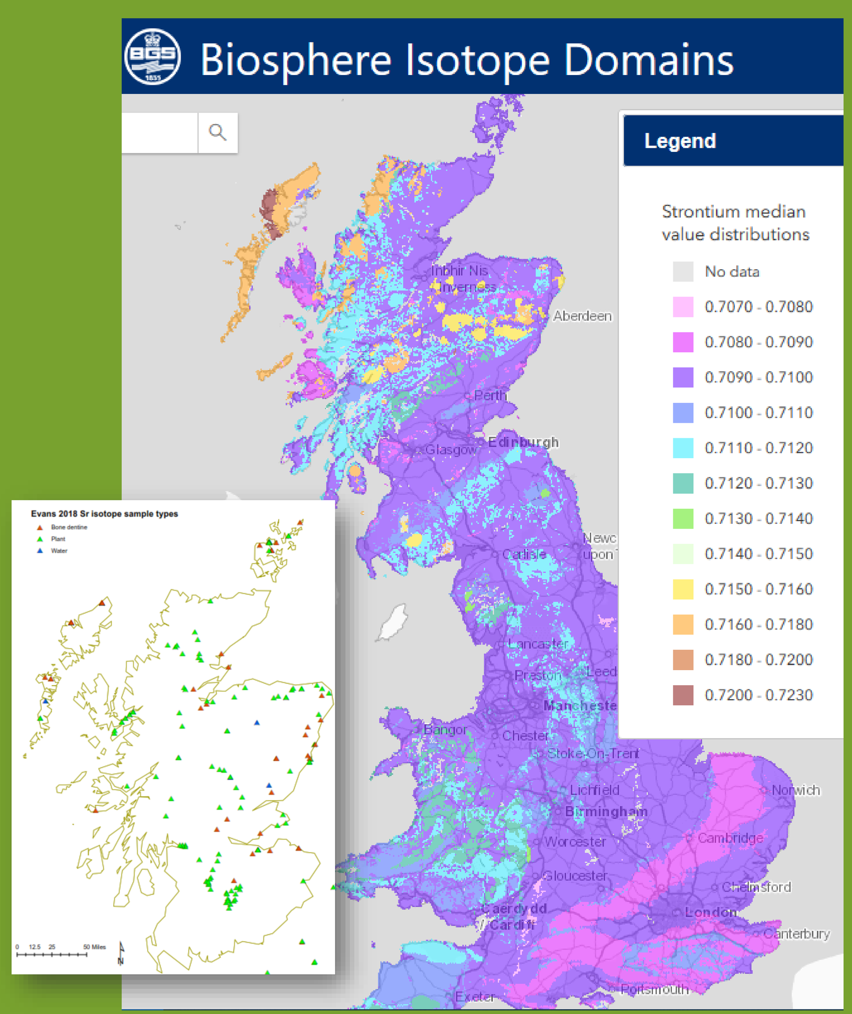

Figure 1 Biosphere Sr Domains reproduced with the permission of the British Geological Survey ©UKRI. All rights Reserved. Inset map – Sampling points and types from Evans et al., 2018 with the permission of the British Geological Survey

Currently, any food provenance, archaeology, environmental or criminal forensic investigation which attempts to use the natural geo-specific variations in bio-available isotopes are limited by the datasets available to compare against. The existing data sources for soil bioavailable Strontium (Sr) isotopes in Scotland are an extrapolated map produced by the British Geological Survey (Fig 1); and a baseline map of Europe as part of the GEMAS project (Hoogewerff et al 2019) . Unfortunately, the complexity of the Scottish landscape and the sparsity of datapoints in some areas can limit the usefulness of these maps. For food forensic provenance work bioavailable Sr is frequently in used in conjunction with other isotopes as Sr does not tend to fractionate easily. Crops source bioavailable Sr from the soil which itself is sourced principally from bedrock geology. Additional contributors such as rainfall (constant $^{87}Sr/^{86}Sr$ value of 0.7092), non-local mixed drift materials (tills, aerosols etc.) and soil treatments will also influence the final soil ratio (Holt et al. 2021) and hence affect crop Sr isotope signatures.

Methods

97 soil samples were chosen from the Scottish National Soil Archive held at the James Hutton Institute. Soils were selected from transects across Scotland from four discrete soil associations (Table 1, Figure 2), each of which have similar parent materials or have developed within a particular landform. Additionally at 4 sites, two on managed land and two on natural/semi-natural land, samples were taken with soil depth down the profile. Bioavailable Sr was extracted using a method based on BS ISO19730:2009 (NH_4NO_3) and analysed for $^{87}Sr/^{86}Sr$ by Thermal Ionisation Mass Spectrometry.

(QC data SRM987 $^{87}Sr/^{86}Sr$ = 0.710254±19 2SD n=27; in-house top-soil $^{87}Sr/^{86}Sr$ = 0.710415±93 2SD, n=13)

Soil Association	Geological group	Parent material
Balrownie	Drifts from Sedimentary materials	Drifts derived mainly from sandstones of Lower Old Red Sandstone age, often water-modified
Countesswells	Drifts derived from igneous rocks	Drifts derived from granites and granitic rocks
Rowanhill	Drifts derived from sedimentary materials	Drifts derived from Carboniferous sandstones, shales and limestones
Strichen	Drifts derived from metamorphic rocks	Drifts derived from arenaceous schists and strongly metamorphosed argillaceous schists of the Dalradian Series

Table 1 Soil Associations used in this study

Results

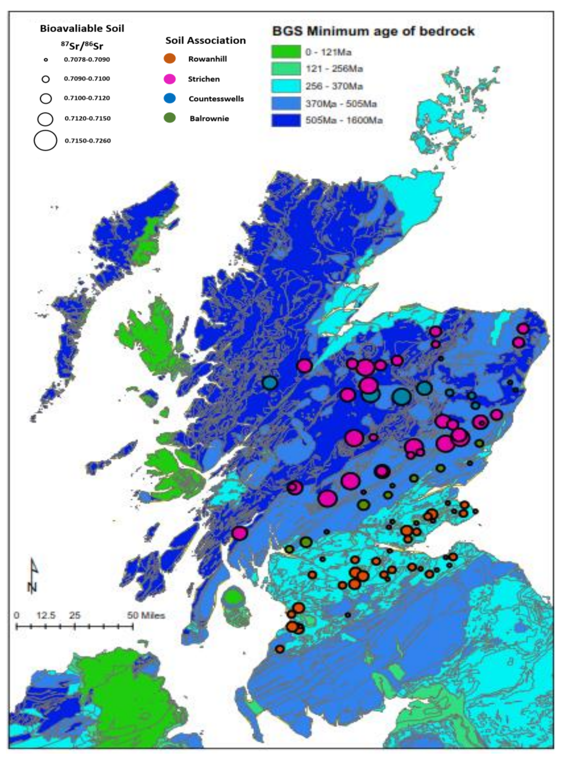

Figure 2 BGS Minimum bedrock age reproduced with the permission of the British Geological Survey ©UKRI and Bio-available soil Strontium isotope results by soil association

The results show no identifying trends of soil bioavailable $^{87}Sr/^{86}Sr$ ratio related to either soil association, land use or soil type, (Figures 2 and 3). Thus, extrapolation by soil association is not appropriate.
The expected relationship of $^{87}Sr/^{86}Sr$ with the age of the underlying geology was generally, though not universally, apparent. In Scotland where there can be local movement of soils, sediments, erosion of materials, and water input from areas of alternative lithology, plus soil management this relationship can be disrupted. Results suggest this is occurring in Scottish soils.

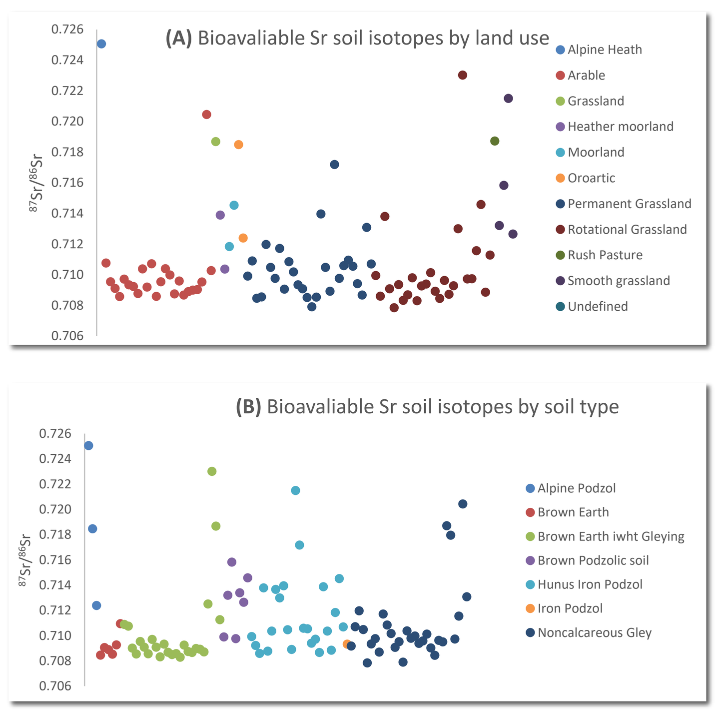

Figure 3 Soil Bioavaliable Strontium isotope ratios sorted by (A) land use and (B) soil type.

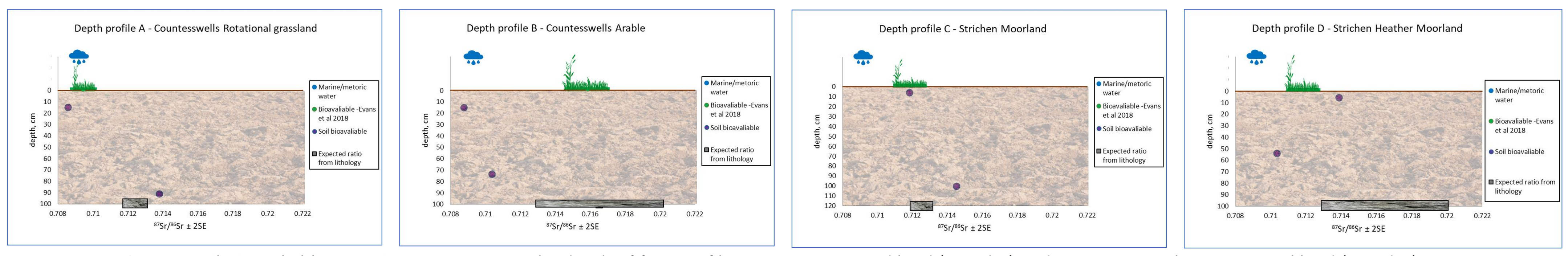

Figure 4 Soil Bioavaliable Strontium isotope ratios by depth of four profiles, two on managed land (A and B) and two on natural, semi-natural land (C and D).

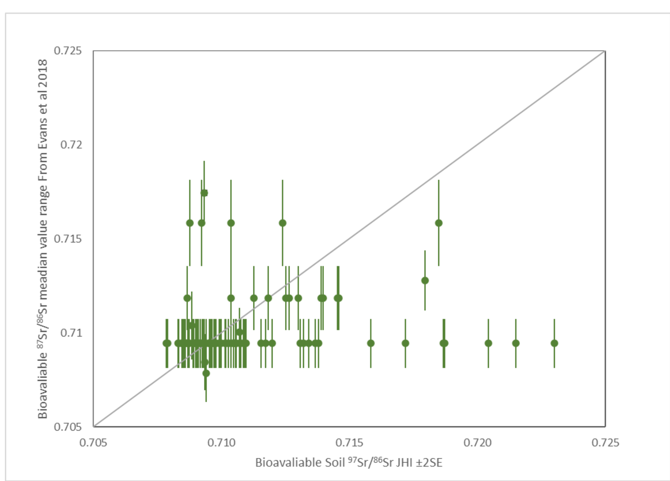

Figure 5: The $^{87}Sr/^{86}Sr$ ratios predicted from extrapolation of data in Evans *et al.* (2018) versus the $^{87}Sr/^{86}Sr$ ratios of soils measured in this study.

Samples from deeper within the soil profile tended to have 87Sr/86Sr ratios closer to the expected lithological ratios (age/minerology controlled) than shallower samples (Figures 4). An exception was observed (Figure 4D, heather moorland) where this relationship was reversed, potentially caused by the origin of this more organic material differing from the underlying lithology.

There were frequent differences between $^{87}Sr/^{86}Sr$ ratios predicted from extrapolation of data in Evans *et al.* (2018) and $^{87}Sr/^{86}Sr$ ratios of soils measured in the current study (Figure 5).

Conclusions

- The bioavailable $^{87}Sr/^{86}Sr$ ratios of soils was not related to soil association, land use or soil type, therefore extrapolation by soil association is not appropriate.
- An expected relationship between the bioavailable $^{87}Sr/^{86}Sr$ ratios and age of the underlying geology was generally but not universally apparent in Scotland.
- Deeper soils tend to have $^{87}Sr/^{86}Sr$ ratios closer to the expected ratios based on underlying lithology than shallower soils. This means in the provenance of crops their rooting depth requires consideration.
- There were frequent differences between $^{87}Sr/^{86}Sr$ ratios predicted from extrapolation of data in Evans *et al.* (2018) and $^{87}Sr/^{86}Sr$ ratios of soils measured in this study.

Future work

- We are expanding the database of soil bioavailable $^{87}Sr/^{86}Sr$ ratios of Scottish arable land and matching these with the harvestable components of relevant crops (berries, barley etc.).

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