A systematic study of resistant organic matter and soil carbon in southern African drylands

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Study rationale and location

Organic matter (OM) turnover in soils generally increases under warmer conditions and soil organic matter (SOM) content in dryland soils is typically low. The analysis of dryland SOM is, however, important as: 1) the area of the world's drylands implies that despite low absolute concentrations, dryland SOM represents a significant terrestrial soil carbon pool **[1]**; 2) the harsh oxidising conditions allow us to investigate mechanisms of SOM degradation; particularly processes of selective degradation and concepts of SOM "recalcitrance".

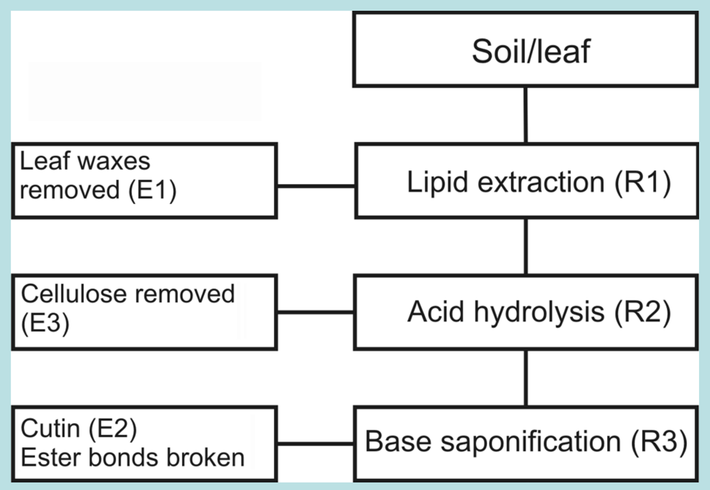
Bulk soil carbon measurements have previously revealed clear responses to environmental and ecological gradients **[2]**, but there has been little consideration of SOM at the molecular level. This study aims to:

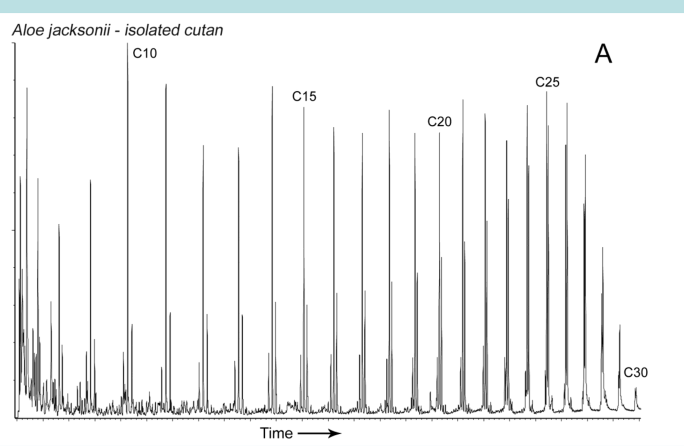
1. Characterise modern SOM pools in relation to environment (climate, substrate) and ecology (OM source).
2. Assess the occurrence of selective SOM degradation and the preservation of specific recalcitrant plant-derived macromolecules (e.g. cutan **[3]**).

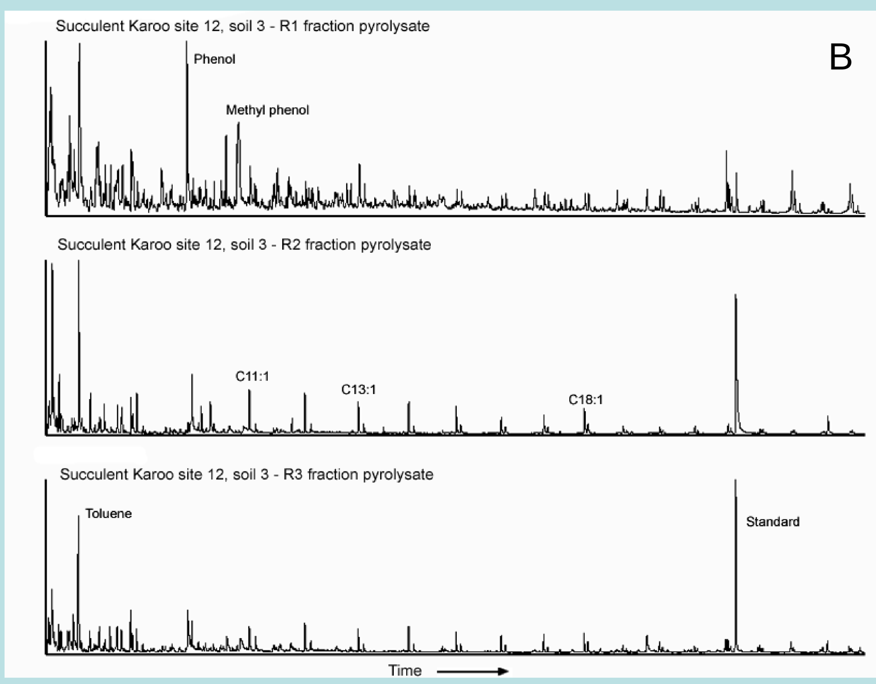
The west coast of South Africa provides an ideal study area. The Fynbos and Succulent Karoo represent biomes of globally significant diversity. The latter biome is famed for the abundance of succulent plant species; some species of which are hypothesised to produce the resistant macromolecule cutan **[3]**. Marked transitions in vegetation community are driven by distinct climatic gradients and geological substrate changes.

Methodology

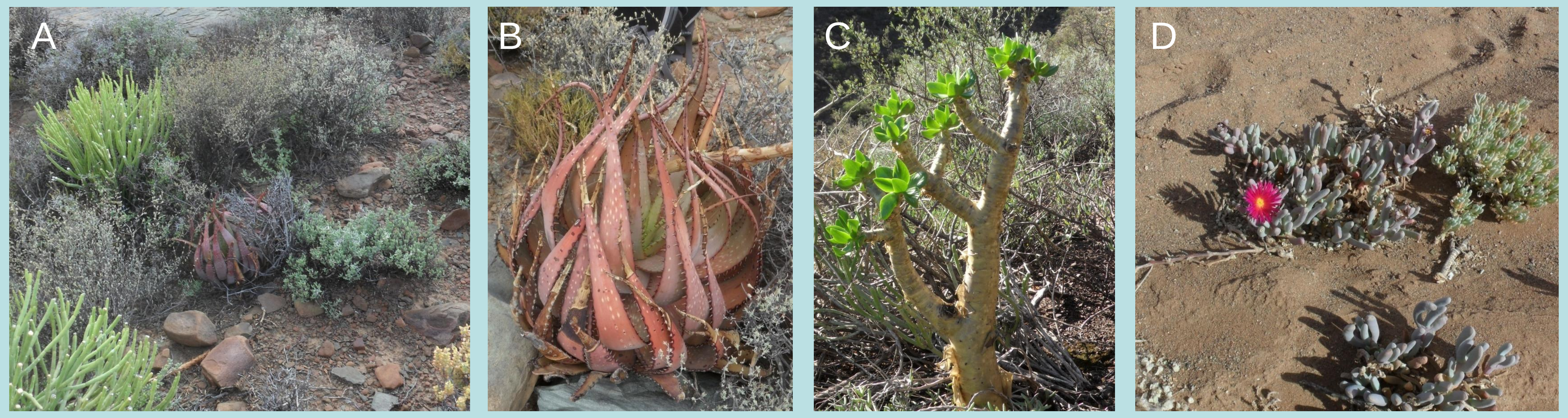
SOM was characterised using pyrolysis-GC/MS. The work-up protocol below (following **[3]**) isolates progressively more recalcitrant OM fractions, with each stage removing the most labile OM. The R3 residue is thus resistant to base-saponification and acid-hydrolysis, which in the case of the cutan macromolecule **[3]** produces a highly aliphatic pyrolysate (**A**, below). It has been possible to isolate such a fraction in a number of other soil samples from both the Fynbos and Succulent Karoo biomes (**B**).



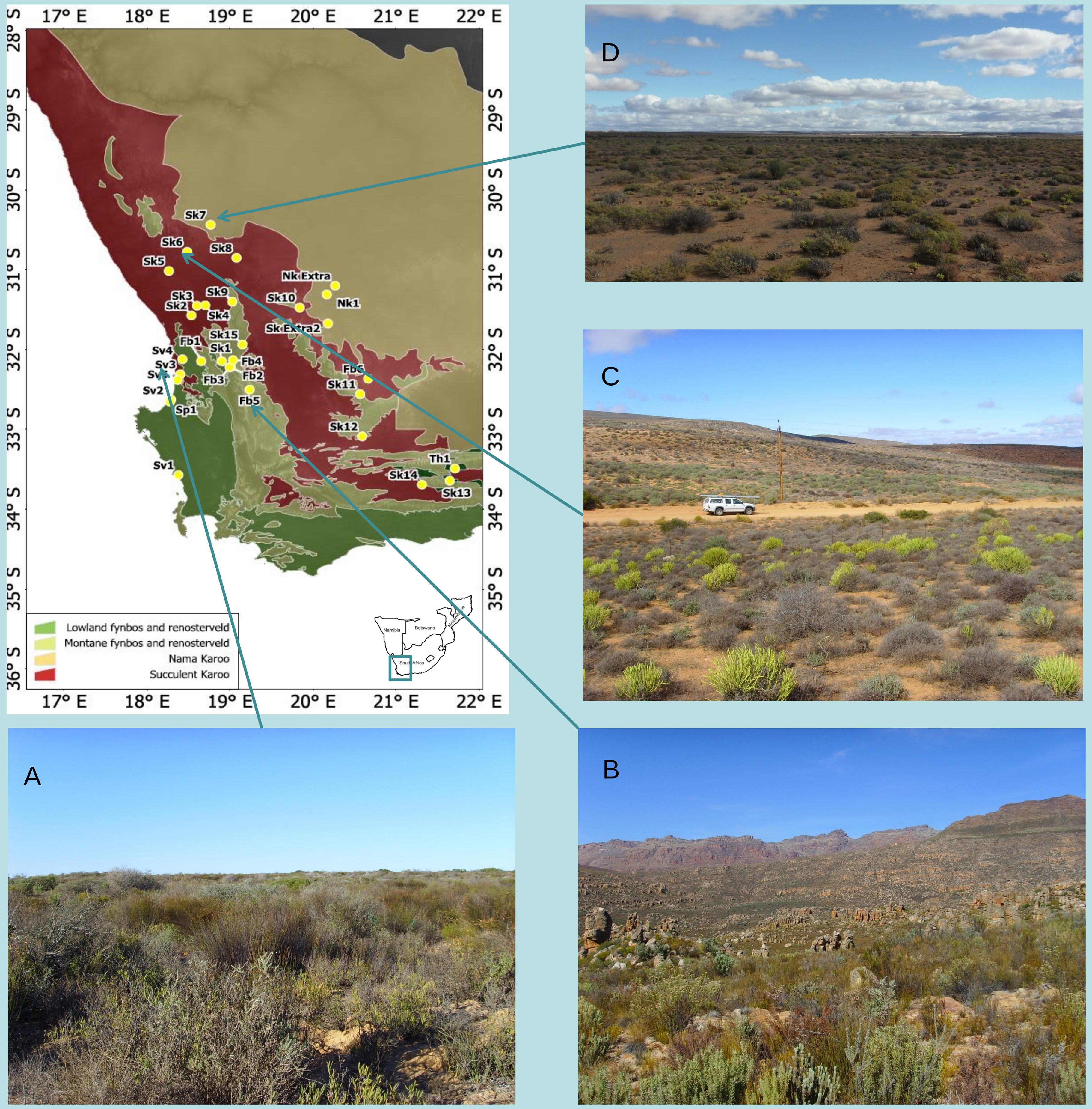




Above: Chromatograms produced from the pyrolysates of the R1, R2 and R3 fractions of a Succulent Karoo soil. Left: Pyrogram of the R3 fraction of an *Aloe jacksonii* cuticle.



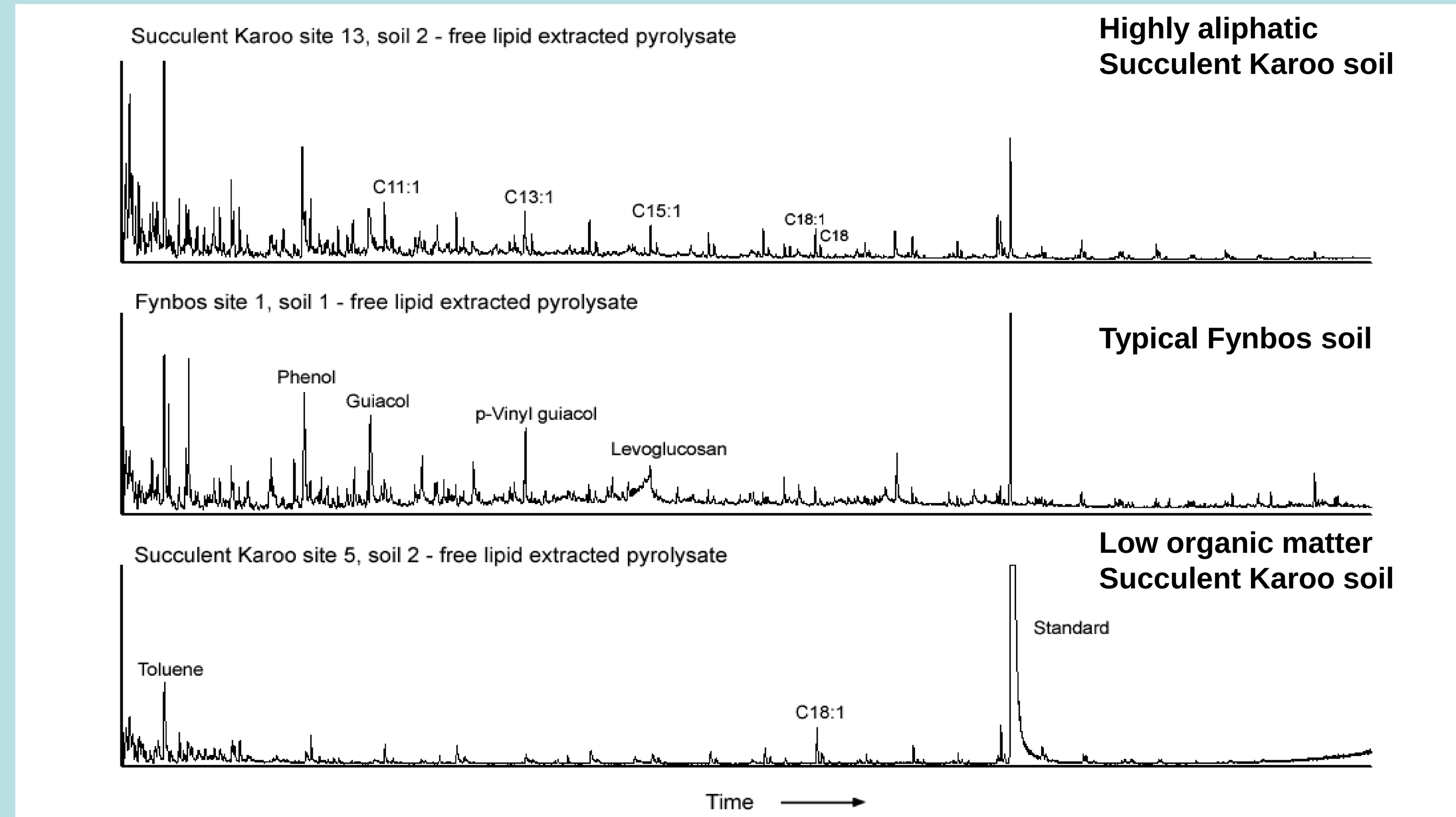
Succulent growth forms in the study area: A and B) *Aloe* sp; which produce the resistant macromolecule cutan. C) *Tylecodon paniculatus* (Crassulaceae), a succulent found in both the Fynbos and Succulent Karoo biomes; D) Succulents of the Mesembryanthemaceae family. These examples are associated with thin, low organic matter soils at the northern limits of the study area.

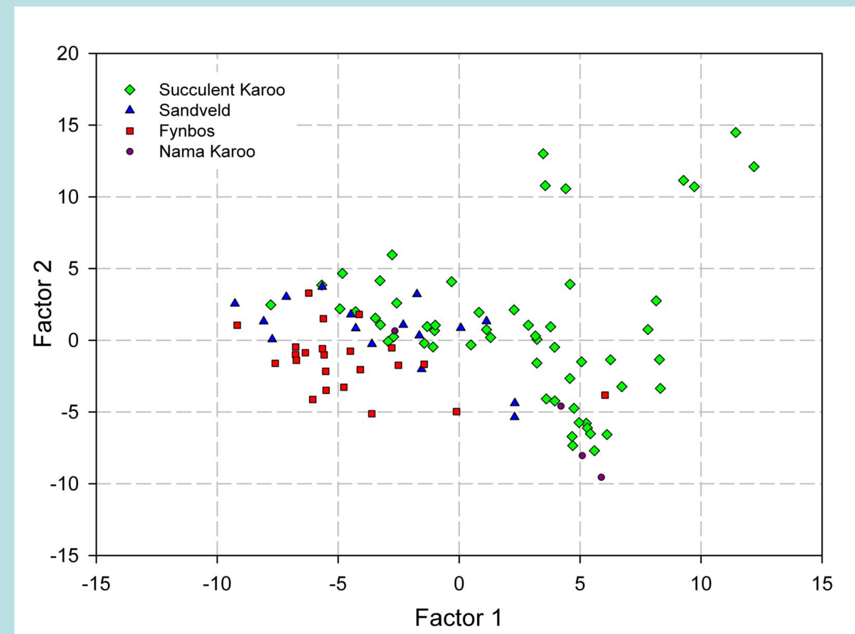


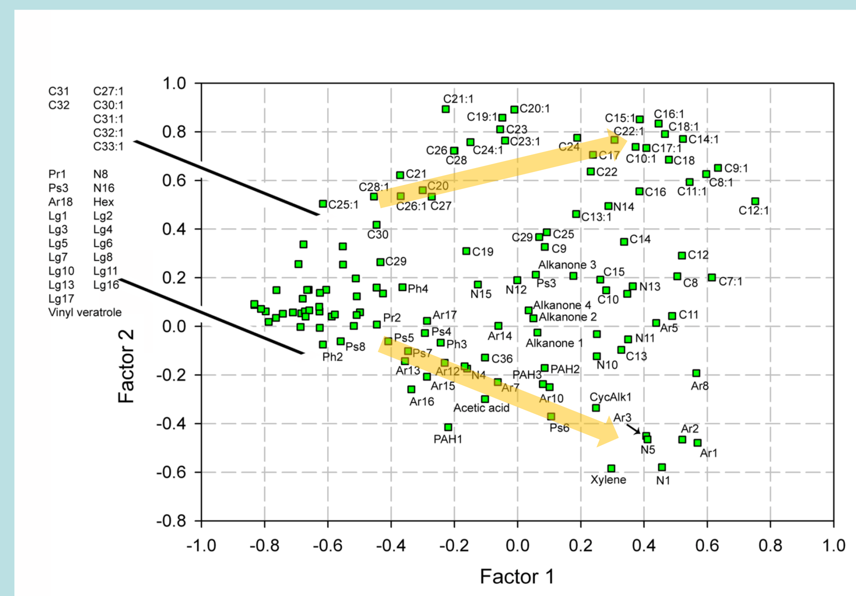
A) Typical Sandveld vegetation, which is transitional between karooid and Fynbos vegetation types, comprising a mix of grasses, woody shrubs and succulents; B)Typical Mountain Fynbos, characterised by sclerophyllous shrubs adapted to nutrient poor sandy substrates; C) and D) Succulent Karoo sites in the north of the study area (SK6 and SK7).

Results – initial SOM characterisation

The R1 fraction reveals marked contrasts in the diversity and abundance of pyrolysis products between and, in some cases, within the survey plots.







Principal component analysis of the R1 soil pyrolysates reveals that two factors account for 40% of the variance in the data, showing a clear separation of the major biomes, with Sandveld transitional. The individual variable (compound) loadings provide a chemical basis for this distinction:

- Fynbos sites (negative F1 loadings) are associated with an abundance of lignin pyrolysis products
- Some SK sites (upper right) are associated with more prominent short to mid chain length aliphatic compounds.
- Samples in the lower right are associated with aromatic pyrolysis products - associated with highly degraded OM e.g. **[4, 5, 6]**

Conclusions

Preliminary data show the differentiation of biomes in terms of overall SOM (R1 fraction) degradation (Factor 1), but considerable variation is apparent in the SK biome, with some soils notably more aliphatic in nature. Degradation of Succulent Karoo SOM at some sites suggests a progressive shortening of the aliphatic molecule chain length, implying distinct degradation pathways (yellow arrows).

References: **[1]** Lal, R (2004) Environmental Management, 33, 528-544. **[2]** Bird, MI et al (2004) Global Change Biology, 10, 342-349. **[3]** Boom et al (2005) Org Geochem, 36, 595-601. **[4]** Schellekens J. (2009) Org Geochem 40, 678-691. **[5]** Vancampenhout K et al (2009) Soil Biology and Biochemistry 41: 568-579. **[6]** Carr, AS et al (2010) Journal of Paleolimnology 44, 947-961

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