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FORUM

Nutritional characteristics of soils on an inferred chronosequence. A comment on Laliberté *et al.* (2012)

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Summary

1. We question the reasoning of the authors who claim that their evidence strongly supports a long-term ecosystem development model in which phosphorus (P) is the factor that leads to the regression phase of the succession. Parent material, relief (topography and drainage) and climates (past and present) are key factors that were not considered sufficiently or critically.

2. Their choice of P as the most important factor determining the direction of the succession overlooks other likely critical determinants of primary productivity on sandy soils such as the supply of water and nutrients other than P, particularly trace elements on calcareous soils.

3. The use of crop species as phytometers to determine which nutrients were limiting the primary productivity of native species at each site inevitably raises significant problems of interpretation.

4. *Synthesis.* The main problems with the paper (Laliberté *et al.* 2012) are (i) that the large differences in soil parent material between the dune systems and other factors make the sites of doubtful use for chronosequence work and, (ii) that errors arise in the discussion of nutritional characteristics because important literature has been overlooked. The paper exemplifies a larger problem where modern long-term chronosequence work tends increasingly to overlook the need for sites to be chosen which minimize changes in all the soil-forming factors other than time as expounded by Jenny (1941).

Key-words: acidic sands, calcareous sands, chronosequence selection, climate/climate change, ecosystem development, parent material, plant–soil (below-ground) interactions, succession/regression, topography and drainage, trace elements

Introduction

Recently, Laliberté *et al.* (2012) described a long-term soil and vegetation chronosequence on coastal sand dunes of the Swan Coastal Plain in south-west Western Australia and used a nutrient-limitation bioassay and other data in an attempt to provide support for the progression/retrogression model of ecosystem development (Peltzer *et al.* 2010). We contend that important aspects of experimental design and data interpretation should be re-evaluated for two main reasons. Firstly, a most important requirement for a chronosequence study is that the soil-forming factors other than time should be constant or vary ineffectively throughout all dune systems studied (Stevens & Walker 1970; Johnson & Miyanishi 2008). The authors concede in passing that the origin of the Bassendean sands is subject to considerable conjecture, but the same could be said about the provenance of both the Spearwood and Quindalup dune systems (see below). Secondly, the authors overlook extensive Australian literature on the complex and distinctive characteristics of calcareous coastal sands and vegetation and ignore the role that trace elements such as copper Cu), iron (Fe), manganese (Mn) and zinc (Zn) may play in the ecology of native species and the growth of phytometer species in their pot experiments.

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Site selection

Jenny (1941) formalized what is now the generally accepted notion that soils develop as a result of soil-forming factors (climate, parent material, relief – topography and drainage, and biota) interacting over time. A chronosequence of soils develops in situations where the soil-forming factors are constant over time. If any factor changes, then Time Zero is set again, and the suite of soil types, which had formed under the previous set of circumstances, become the parent materials of the next suite of soil types to form under the new conditions.

Against this background, it is of serious concern that the sites used by Laliberté *et al.* (2012) are derived from three quite different dune systems, two of which the authors claim were high in carbonate at their 'Time Zero' (i.e. Quindalup and Spearwood systems), whilst the oldest one (Bassendean) had a much lower carbonate content (Laliberté *et al.* 2012, p. 634). The oldest Quindalup dunes are < 7 ka old (Holocene), whereas the Spearwood and Bassendean sands are deemed mid–to-late Pleistocene and early Pleistocene, respectively (McArthur & Bettenay 1960; McArthur 1991). The latter have experienced multiple climate changes, and their origins are still in dispute (Hearty & O'Leary 2008, 2010; Bastian 2010), and they may not have been calcareous at all. Thus, the use of both the Spearwood and Bassendean dunes seriously violates the Jenny guidelines and, at the very least, required the authors to defend their decision and to give a detailed discussion of the problems of interpretation that arise. This work by Laliberté *et al.* highlights the major problems for chronosequence work when compared, for example, to a single series of very regular, subdued parallel beach ridges on the eastern Australian coast used by Burges & Drover (1953).

A related problem applies to all long-term chronosequence work which extends back for millions of years as in the present case. At such time scales, significant climatic changes, erosion and aeolian accession of dust from afar can have occurred (Chadwick *et al.* 1999; Hotchkiss *et al.* 2000), thus violating the Jenny guideline for constancy. The problem is usually acknowledged (e.g. Chadwick *et al.* 1999), but it does confound data interpretation and risky assumptions are always present.

A final site selection issue is that the well-known large differences in soils and drainage between crests and swales in dune country (see e.g. Burges & Drover 1953) appear to have been disregarded by Laliberté *et al.* (2012) and thereby not taken into account in the soil sampling.

Nutritional characteristics of calcareous sands

Laliberté *et al.* (2012) propose that nitrogen (N) initially and P subsequently are the key nutrients limiting the primary productivity of the native species present on these dune systems. However, their account overlooks the fact that calcareous dune systems, similar to those they worked on, are widespread across coastal southern Australia (Northcote 1960, 1962) and that the nutritional characteristics of calcareous sands have been intensively investigated and reported on since 1938 (e.g. Donald & Prescott 1975). On the youngest, most alkaline sands, it is clear that, for crop and pasture plants, deficiencies of Cu and Zn are common and that responses to Fe also occur; Mn deficiency also is common on calcareous sands (Reuter, Alston & McFarlane 1988). Chlorosis is a common symptom of plants associated with these trace element deficiencies on calcareous soils or on acidic soils, which have been made alkaline by liming (Parsons & Uren 2007).

Despite this work, except for mentioning Mn analyses, Fe is the only trace element dealt with by Laliberté *et al.* (2012) and even then it is dealt with briefly, referring only to a standard textbook; further discussion was needed given the severe lime chlorosis in the white lupins on the highly alkaline youngest soils. No reasons are suggested for this chlorosis other than to use Liu & Tang (1999) to identify white lupin as a calcifuge, despite the fact that Liu & Tang (1999) discuss both Fe and Zn deficiency. Clearly, chronosequence work on calcareous sand systems needs to take into account the fact that trace element deficiency can be an important limiting factor in the early stages and that Fe, Mn, Cu and Zn can all be involved.

Other comments

HISTORICAL CONTEXT

In setting the context for their work, Laliberté *et al.* (2012) overlook some important and influential papers. Following the early English work by Salisbury (1925), the chronosequence work by Burges & Drover (1953) drew attention to the excellent opportunities provided by a very regular series of subdued parallel beach ridges on the eastern Australian coast, allowing much easier data interpretation than sequences like those used by Laliberté *et al.* (2012). Following this, Parsons & Specht (1967) described contrasting nutritional characteristics of young calcareous and older siliceous sand dunes (including the trace element story above) in South Australia, including some of the native vegetation differences.

Putting the work into its historical context in this way would have helped the reader assess to what extent the findings are applicable in other areas, if at all.

LIMITING FACTORS

The main limits to the primary productivity of each phase are most likely to be the availability of both nutrients and water. The agricultural history of the soils on these dune systems points to multiple nutrient deficiencies and droughtiness as the limiting factors and the consequent need for fertilisers and irrigation (McArthur 1991).

Laliberté *et al.* (2012) favour the availability of N and P, or P alone without reference to other possible limits such as trace element deficiencies mentioned above. Also, although they are aware of the role that water may play in determining succession on such a 'water-limited ecosystem', they do not consider that the hydrology of calcareous dunes must change as leaching removes calcium carbonate which makes up variously 25–50% by weight in Quindalup dunes (McArthur & Bettenay 1960; McArthur 1991). The role of plant–water relations on the species distribution of the Swan Coastal Plain in relation to rooting depth and seasonal variation in water availability is well considered by Groom (2004). Such changes in the hydrology and availability of water due to soil formation are sufficient probably to change the direction of the succession of native species just as dramatically as a change in nutrient status in these soils in a Mediterranean environment.

POT EXPERIMENT

The choice of wheat, white lupin and canola as phytometer species to provide evidence of the limits of the nutritional growth of native species is unusual because the disparity in the nutritional requirements between native species and agricultural species is substantial. Further their choice of white lupins is puzzling as the three soils from the Quindalup dunes were calcareous and it is well known, particularly in Western Australia, that white lupins invariably fail to grow on calcareous soils (White, French & McLarty 2008). Essential interpretation of the nutritional status of both the existing native vegetation and the phytometer species would have been made possible by foliar analyses, but they were not carried out. For these reasons and other experimental reasons, one could argue that the faith placed in the pot experiment was misplaced.

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