



An integrated approach to mapping and understanding of vegetation: soil systems



William H. Verboom^{a,b,*}, John S. Pate^b

^a Department of Agriculture and Food, 10 Doney Street, Narrogin, 6312, Western Australia, Australia

^b School of Plant Biology, The University of Western Australia, 35 Stirling Highway, Crawley, 6009, Western Australia, Australia

ARTICLE INFO

Article history:

Received 13 August 2014

Received in revised form 14 October 2014

Accepted 11 November 2014

Available online 26 November 2014

Keywords:

Niche construction

Phytotarium

Plants

Soil

Biomineralization

Radiometric mapping

ABSTRACT

This research employs a raft of incisive strategies and technologies to define and interpret spatial relationships between native plant ecosystems and classes of soil across a range of scales. Building on traditional vegetation zonings and soil mappings, information on locations of key taxa, chemical composition of pisoliths and radiometric based technologies are used collectively to identify and delineate contrasting zonings in which principal base units (phytotaria) are distributed in patchy but well demarcated mosaics across soilscares. At broadest scale biomes are recognised in terms of species endemism, radiometric patternings and element balances of pisolithic ferricretes and in many cases shown to change predictably in stepwise fashion across environmental gradients. At finer scale georeferenced data for key players in selected phytotaria are matched against information from airborne radiometry to identify hallmark signalings derived from workings of potassium, uranium and thorium in parent profiles. By draping radiometric signals over digital elevation models, further insight was obtained on the complex relationships between specific phytotaria, topography and mineralogical status across a selected area. These southwest Australian case studies demonstrate how multiple sources of evidence might be mined and parcelled up to provide a comprehensive picture of heterogeneity and connectivity within and between phytotaria.

Crown Copyright © 2014 Published by Elsevier B.V. All rights reserved.

1. Introduction

Soil scientists researching how soils form and distribute across landscapes have long realised that no single all-embracing classification system does justice to the wide variety of soils encountered at local, regional and global scales (see Isbell, 1992; Van Wambeke and Dudal, 1978). With no consensus in sight, we now find a plethora of mutually-conflicting classification schemes whose idiosyncratic elements embody the range of characteristics which the respective authors happened to find useful (see comments of Isbell, 1992; Leeper, 1956; McBratney, 2000). Then, when it comes to delimiting spatial variability in a specific regional scenario, controversy and confusion may often arise as to order of groupings of soil classes at different scales of operation. Those grappling with such issues are well aware that hierarchies of modular elements are to be recognised within any regional situation and have mostly used vector mappings, as opposed to fuzzy representations of geographic boundaries, to parcel up soil variability into a series of spatially explicit nested objects. Inevitably, as one moves from fine to broad scale, the information required to completely describe

successive modules escalates to the point of unwieldiness, thereby tempting authors towards increasingly specious generalisations.

Plant ecologists, on the other hand, would be expected to have a relatively simple task when mapping vegetation, since they are usually able to identify clear groupings of plant associations by ground or aerial survey, and thereby delimit well defined boundaries between these and neighbouring ones of contrasting composition. As in the case of soil mapping, nested hierarchies in spatial distribution of vegetation types can be identified as implicit in the frequently employed terms Alpha, Beta and Gamma Diversity. Thus, in botanical context, Alpha Diversity represents richness and evenness of types of species, growth forms or functional groups within any habitat unit, while Beta Diversity measures differences in these respects between habitats. Then at greater scale, Gamma Diversity expresses the sum total of habitats and floral types within a landscape or region. Each of these expressions is considered to have relevance to particular facets of ecology and evolutionary biology.

Mapping schemes developed by soil scientists and plant ecologists, using the above principles, have enabled complexities of soil and vegetation distribution to be expeditiously displayed at a wide range of scales. This is especially obvious in the technologically-advanced environment of geographical information systems. Nevertheless, so long as an evaluative approach is based on intuitive and subjective elements one can only be critical of the veracity of the outcomes.

* Corresponding author at: Department of Agriculture and Food, 10 Doney Street, Narrogin, 6312, Western Australia, Australia. Fax: +61 8 9881 1950.

E-mail address: william.verboom@agric.wa.gov.au (W.H. Verboom).

Notwithstanding the above, notable attempts have been made to rigorously explore the foundations of how and why ecosystems and soils distribute across space in such a complex and patchy manner. For example, in relation to ecosystems, Wu and David (2002) state “Many ecologists take the view that modularity of terrestrial ecosystems, both in terms of structure and functionality, and the hierarchical nature of its component parts, emerged spontaneously during evolution because such systems tended to evolve faster and attain more stability, and thus are favoured by natural selection”. Similarly, in relation to soils, one finds in the pedological literature assembled by Phillips (2009) evidence of tight coupling between the development and evolution of such ecosystems and soil forming processes.

Our own thinking embraces both of the above insights, as we have already implied when introducing the concept of the “Phytotarium” (Verboom and Pate, 2006a,b, 2013). Here we attempted to define precisely the key higher plant and microbial players and niche construction processes which collectively contribute to operation and long-term functional stability of each specific base element/habitat unit, within a nested hierarchy of soil/vegetation types. The word ‘phytotarium’ is used to denote the players and end-products of soil habitat modification and to convey an analogy with ‘termitarium’ building by termites which harvest and ingest local plant and earthen materials and function in symbiotic association with gut flagellates, cellulose-decomposing bacteria and, in certain cases, nitrogen-fixing bacteria.

In parallel, the phytotarium is pictured as an ‘edifice’ maximizing long-term access of higher plants and their progeny to limiting resources of water and nutrients. At the same time, specific phytotaria act competitively against surrounding ones of another ilk, and thereby create habitat patch stability.

Looked at retrospectively we envisage phytotaria as underpinning the exceptional biodiversity expressed in semiarid heathlands and woodlands of Australia’s South West Botanical Province. Associated with this one finds exceptionally strong endemism and intense flocking of plant species across a number of taxonomic groupings, high levels of species turnover along broad environmental gradients, and, at more localised scale, between contrasting soil types (see Beard, 1984; Cowling and Lamont, 1998; Hopper and Gioia, 2004).

As seen in our reviews, precipitates, bioengineered by proactive components of certain prominent phytotaria, are of characteristic morphology, conform closely to lateral root platforms of responsible species and invariably contain certain ubiquitous elements, e.g. Al, Fe, Ca, Mg and K, at considerably greater concentration than in surrounding profiles. Phytotaria may also be seen to arise spontaneously in virgin situations such as dunes surrounding playa lakes (Pate and Verboom, 2009; Verboom et al., 2010). In other cases they exercise dominance over surrounding vegetation by overprinting with their hallmark signatures with or without the reworking of the original profile. Finally, we contend that phytotaria collectively express a level of ‘endemism’ much as seen amongst species of a region, because they are intrinsically coupled to plant and microbial evolution and as such likely to be guided by the same biological forces governing development and evolution of ecosystems. Here one finds our views corroborating and adding to those quoted above for Wu and David (2002) and Phillips (2009).

The primary objective of this paper is to exemplify the usefulness of an approach in which a broad range of datasets drawn from a range of currently available methodologies is utilised to generate an all embracing picture of plant/soil interactions and distributions at any of a range of scales. At the same time we retain focus on the phytotarial units as basic entities of the various systems under investigation.

All data employed relate to semiarid open woodlands, heath and shrublands of southwest Australia. In each mapping exercise we select the most appropriate approach for the scale at hand and, in the process, hopefully extract new insights into plant/soil relationships and forces perceived to shape their distribution. The paper will conclude with a general discussion of how different levels of complexity across map-

unit hierarchies can be better expressed in terms of rates and scales of key biological process mentioned above.

2. Materials and methods

2.1. Study area

The study area conformed generally to the South West Botanical Province (SWBP) as defined floristically by the Interim Biogeographical Regionalisation of Australia (IBRA, see Thackway and Cresswell, 1995) and in terms of soil type to the Department of Agriculture and Food’s (DAFWA’s) Western Region (see Schoknecht et al., 2004). Parts of the investigation focused on specific areas of interest within this general area.

2.2. Distributions of key taxa and groupings of species

These were sourced from the most recent information on locations of individual plant species (300–10 m accuracy) held in databases of the Department of Environment and Conservation and the Western Australian Museum (see DEC, 2007). Data were abstracted and plotted using the GIS package Arcview 3.2 against the network of roads across the area. Where appropriate floristic mappings were related to mappings of soil types as defined by DAFWA or floristic boundaries as defined for the southwest by IBRA.

2.3. Identification of phytotaria and their signature products

This was based on numerous investigations in the study area including floral inventories and auger, pit and air-spade excavations aimed at identifying the morphologically and chemically distinct precipitates laid down by key players of each of the phytotaria referred to in this paper (see references in introduction). Use was also made of an array of chemical information based on gridded samplings of pisoliths across the SWBP (see Cornelius et al., 2006). Pattern analysis using the PATN statistical package (see Belbin, 1993) was applied to the above, untransformed, set of analyses to obtain pairwise Bray Curtis dissimilarity statistics. This was followed by hierarchical agglomerative polythetic clustering using PATN’s UPGMA option. A dendrogram provided a visual summary of the clustering processes and intuitive similarity relationships between any sample and entire data set.

2.4. Airborne radiometric assays of soil distribution and products of certain classes of phytotarial activity

Broad, 50 m cell (pixel) size, coverage of the SWBP was obtained from Federal and State government as well as selected open file data sets (see Minty et al., 2009) acquired with a line spacing of 500 m or less. High-resolution airborne radiometric information (5 m cells) flown at a line spacing of 25 m and a height of 20 m and using half second count intervals was also acquired specifically for the 8000 ha comprising the Elashgin area (parameters of assay as specified by UTS Geophysics, 2002).

Of the three elements measured by the technique, potassium (K) concentrations were derived from gamma-rays released during the decay of ^{40}K and concentrations of thorium (Th) and uranium (U) were inferred from the characteristic gamma-ray emissions of their respective daughter isotopes ^{208}Tl and ^{214}Bi . For further information on application of the technique to soil mapping in south-west Australia see Cook et al. (1996), Pracilio (2007), Taylor et al., 2002. This information was mapped in GIS environment using conventional colour coding and intersected where appropriate with locations of key species.

Download English Version:

<https://daneshyari.com/en/article/4571384>

Download Persian Version:

<https://daneshyari.com/article/4571384>

[Daneshyari.com](https://daneshyari.com)