HUNTING FOR HUMAN HISTORICAL IMPACTS IN FOREST ECOSYSTEMS: PATTERNS AND PROCESSES

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Abstract

Due to the long history of human habitation in KwaZulu-Natal I was interested to see if one could detect the traces of human impacts in KwaZulu-Natal forest systems. Previous work has indicated a lack of regeneration of canopy dominants in several KwaZulu-Natal forest communities. This is the case for Hluhluwe Forest, the site chosen for this study, where there is little or no recruitment under the canopy or in tree-fall gaps. I felt that pre-historical and historical human impacts could account for this phenomenon. Human impacts in this forest would have taken the form of swidden agricultural disturbance that would have created larger sized gaps than those created by even multiple treefall. However, this form of disturbance has been eliminated since the reserve proclamation 100 years ago. I aimed to detect the signs of historical recruitment in large-scale disturbances, possibly of human origin, using ecological and isotopic sampling.

1. Introduction

We relate to recent phenomena such as urban environments and commercial farmlands as anthropogenically created landscapes. However, historic anthropogenic influence may have been a lot more extensive than previously accepted. In Southern Africa we are surrounded by landscapes that have been influenced by humans to some degree. However, it is now beginning to be accepted that even wilderness landscapes previously labelled as “pristine” or “natural” could have been influenced or even potentially generated by humans in the past, indicating that not all human impacts are necessarily negative. This is the case for many KwaZulu-Natal forest systems, such as the coastal dune forest at Cape Vidal, which has been inhabited by people for over a thousand years and yet is still considered a fairly “pristine” or “untouched” area. This also seems to be the case for the coastal scarp forest of the Hluhluwe-Umfolozi Game Reserve, a forest that is thought to be a rare and classic example of pristine coastal scarp forest.

This paper deals with the search for the influence of humans, in forest environments that were previously considered to be pristine, in the Hluhluwe-Umfolozi Game Reserve. One aspect of this search involved a new isotopic tool that was used to show the presence of large-scale disturbance in these forests. The technique, developed during this study, is an isotopic technique using tree cores to determine the conditions under which trees recruited and established.

2. Why KwaZulu-Natal forests?

The work was conducted in the KwaZulu-Natal forests as they presented a suitable arena to test for human-dependent ecosystems. There is a long history of human habitation in the region (Beaumont ***et al***., 1978), and the current forest dynamics (Midgley ***et al.,*** 1995) indicate the potential for demonstrating this phenomenon.

Iron Age farmers moved into the north-eastern coastal lowlands of KwaZulu-Natal from the north (Hall, 1983) in about AD 200 (Hall, 1984) and spread southwards from there (Hall, 1987). By AD 500 the colonisation of the eastern and south-eastern savanna regions of southern Africa by Iron Age farmers was essentially complete (Maggs, 1984; Hoffman, 1997). At about AD 900 - 1000 farming communities expanded from the coastal lowlands via the river valleys into the higher-lying areas within the valley systems and the high grasslands of the interior plateau (Hall, 1984). Iron Age peoples have thus inhabited various regions of KwaZulu-Natal for between 900 and 1 700 years, and slash-and-burn farming, first practised in AD 200, still continues in KwaZulu-Natal today. When one regards the above information in the light of the current forest dynamics, the potential of the study site becomes apparent.

3. The forest dynamics dilemma

Work in several KwaZulu-Natal forests has shown a lack of regeneration of several canopy species (Midgley ***et al.***, 1995). These canopy species seem unable to recruit under the current disturbance regime of small-scale treefall disturbances. The canopy species are thought to be shade-intolerant, requiring large-scale disturbance in order to regenerate. However, the typical causes of large-scale disturbance, such as fire, hurricane blow-downs and elephants, have not been documented at present in these forests. Thus the mechanism for recruitment in these forests is currently unknown.

The hypothesis of my study at Hluhluwe was that humans created large-scale disturbances through agriculture and settlement, which after abandonment allowed the recruitment of these shade-intolerant species. Certainly it seems as if a low-density, slash-and-burn farming strategy within a forest would create large gaps that would be conducive to the recruitment of shade-intolerant forest species.

The study sought to conclusively show the presence of canopy trees that had recruited in large-scale gaps, to move a step closer to proving the role of humans in the Hluhluwe forest, a result that could then be applied to other forests. The remainder of this paper focuses on how to detect the presence of large-scale disturbances in a uniform canopy using a new isotopic tool.

4. The isotopic technique

The technique is centred on the identification of patterns in isotopic signals of tree cores from trees of known regeneration history. From this, patterns can be examined in unknown trees and human disturbance inferred. The $^{13}C/^{12}C$ ratio of plant tissue varies according to a variety of factors, including carbon source, CO_2 concentration, oxygen concentration, light intensity and water-use efficiency (Smith ***et al.***, 1976; Ehleringer ***et al.***, 1986; van der Merwe & Medina, 1989; Farquhar ***et al.***, 1989; Leavitt & Long, 1991; Hanba ***et al.***, 1997; Buchmann ***et al***., 1997). In forest ecosystems, three main factors governing variation in $\delta^{13}C$ are carbon source, CO_2 partial pressures internal and external to the leaf, and water-use efficiency (Berry ***et al.***, 1997).

Carbon source

There are two distinct CO_2 pools associated with forests:

- Atmospheric CO_2 that is found above the canopy
- CO_2 beneath the canopy.

These pools rarely mix. Subcanopy CO_2 is cycled through plants through uptake and decay and becomes progressively depleted in ^{13}C. Plants with their leaves in or above the canopy draw on CO_2 from the atmospheric pool, which is richer in ^{13}C.

Partial pressures of CO_2 and water use efficiency

The ratio of the partial pressures of CO_2 internal and CO_2 external to the leaf (C_j/C_a) is also responsible for the isotopic differences seen in forest communities. For example, if a leaf is experiencing strong light and high water stress, photosynthesis is high and the stomata are probably closed, therefore the CO_2 within the leaf would be the limiting factor. On the other hand, if a leaf is in low light and experiencing low water stress, photosynthesis is lower and stomatal conductance (and therefore internal CO_2) is high, which allows the plant to discriminate between isotopes, and use mainly ^{12}C. The CO_2 source and light intensity operate in the same way.

Thus, in a forest community one can envision trees in well-lit, open areas being isotopically heavier than shaded, sub-canopy trees, due to the combined effects of carbon source, light intensity and water-use efficiency. The record of the tree’s environment should thus be reflected by an analysis of carbon isotopes along the tree’s core.

4.1 Testing the technique: leaves

I tested this theory on leaves first, at Knysna and Hluhluwe. The reasoning was that if it worked for the simple example of leaves it stood a good chance of working for the complex situation of tree cores, where the wood is laid down by leaves at different positions. The results (Figure 1) indicate that shaded leaves have different signals from open leaves, as predicted.

But what about the influence of gaps? Do gaps drastically change the $\delta^{13}C$, and by so doing confuse the signal laid down in tree cores? Obviously, if a small tree-fall gap has the same signal as large open areas, the technique would be difficult to use to show large-scale recruitment. To check this, I sampled leaves in gaps of various sizes, and found that small gaps and closed forests gave similar signatures, and large gaps and open areas gave similar signatures (Figure 2). It was encouraging to be able to distinguish thus between large and small-scale gaps.

The next step was to test the technique on tree cores and then attempt to show large-scale disturbance in Hluhluwe.

Figure 1: $\delta^{13}C$ values for leaves

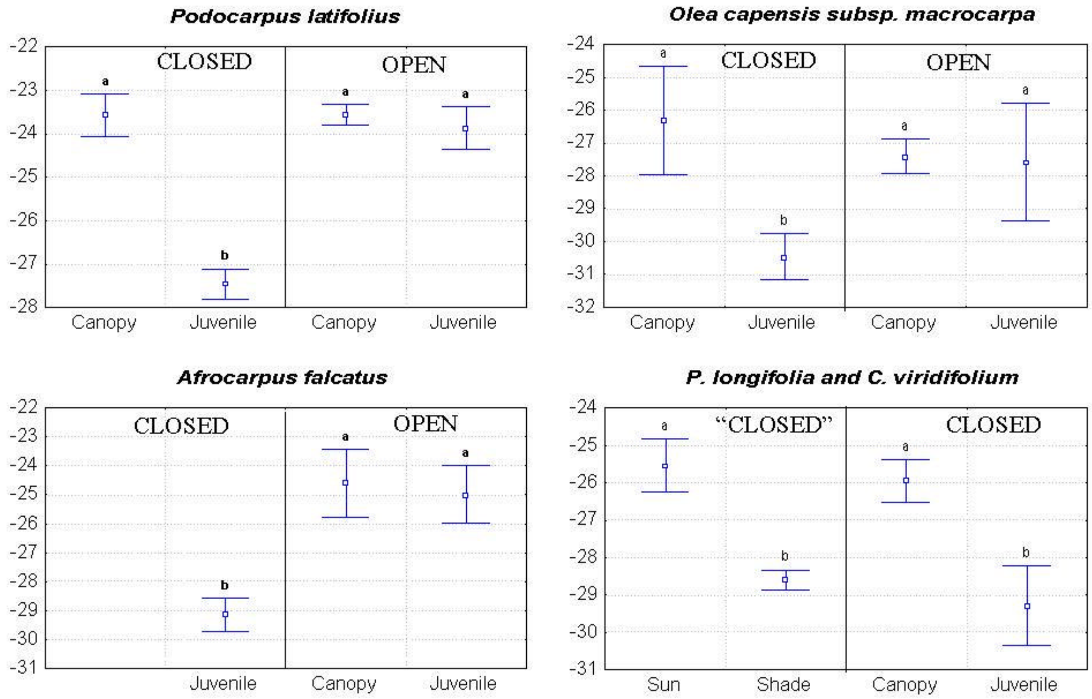
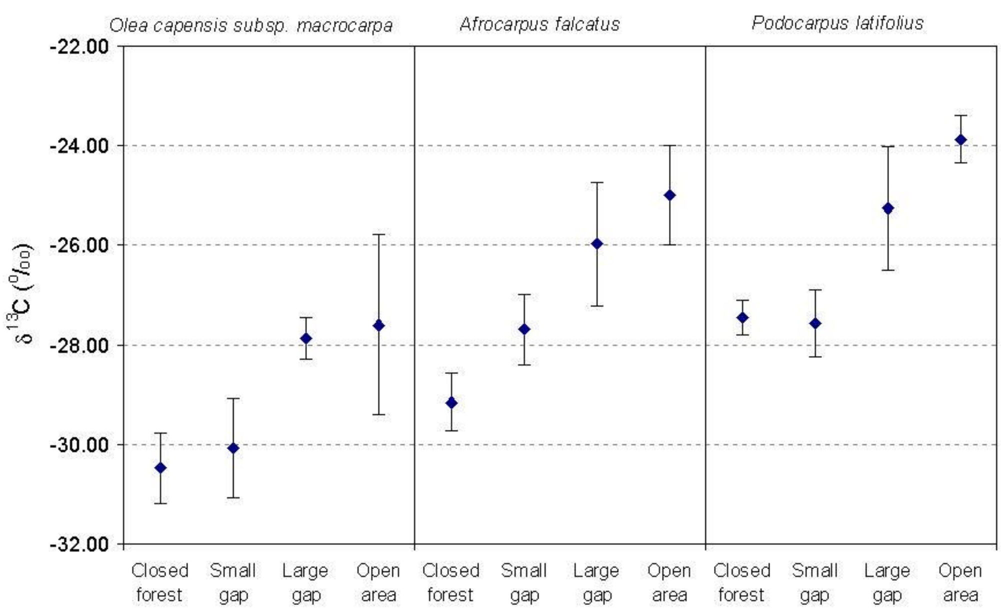


Figure 2: $\delta^{13}C$ of leaves from closed forest, small gaps (<400m^2), large gaps (>400m^2) and open areas



4.2 Testing the technique: tree coring

I examined trees of known regeneration history from the Diepwalle and Hluhluwe forests that recruited and grew from a shaded to light environment and from a light-to-light environment to see what signals they exhibited. I then cored trees in areas that I thought might well be the site of historic large-scale disturbance (patches) in Hluhluwe, and compared these to known trees in Hluhluwe. I selected the class among a diverse forest canopy. If one could show the signal of open recruitment in these patches it would have great significance for the study of human disturbance in these forest communities.

I interpreted the core information as a differential of inner wood minus outer wood (see Box 1). Thus the values presented in Figures 3 and 4 reflect core differentials that were derived in this manner. Figure 3 presents data collected from shade-tolerant trees of known regeneration history. “Shade-light” indicates trees that grew up through the canopy. “Light-Light” indicates trees that recruited and grew up in open spaces. “Field” represents the test case from Hluhluwe.

The data indicate that trees regenerating in the shade have negative differential whereas trees recruiting in the open have positive differentials. The “Shade-light” trend fits the pattern seen in the leaves (Figure 1). According to the theory, the “Light-light” differential should be neutral, however a positive differential is seen. This is most likely due to water stress in the juvenile trees causing an elevated signal in the early wood. This water stress is not seen in the leaf results (Figure 1) as I sampled during the wettest part of the year, when trees were unlikely to be water stressed.

All the trees in Figure 4 exhibit a positive differential, or a “light-light” signal. This is due to the fact that all trees had the same recruitment condition, that of the Diepwalle arboretum. Those labelled as “shade-light” were slightly smaller, leading me to believe initially that they had recruited under the canopy. However, in even-aged stands there is always a fluctuation of tree diameters. I view the fact that these cores all returned the same differential as a vindication of this method.

In both cases, the “field” test cases from Hluhluwe returned positive differentials (Figures 3 and 4) indicating that these trees recruited in large open patches.

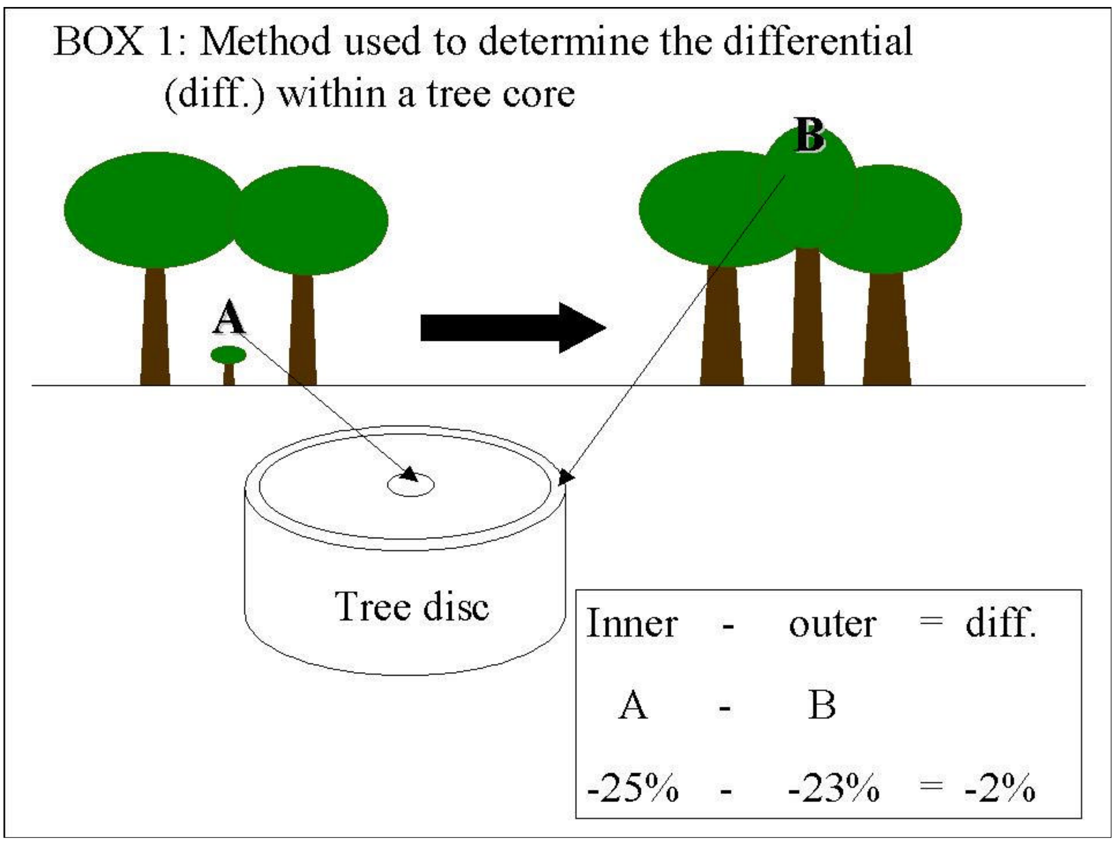


Figure 3: Tree cores: Shade-tolerant species

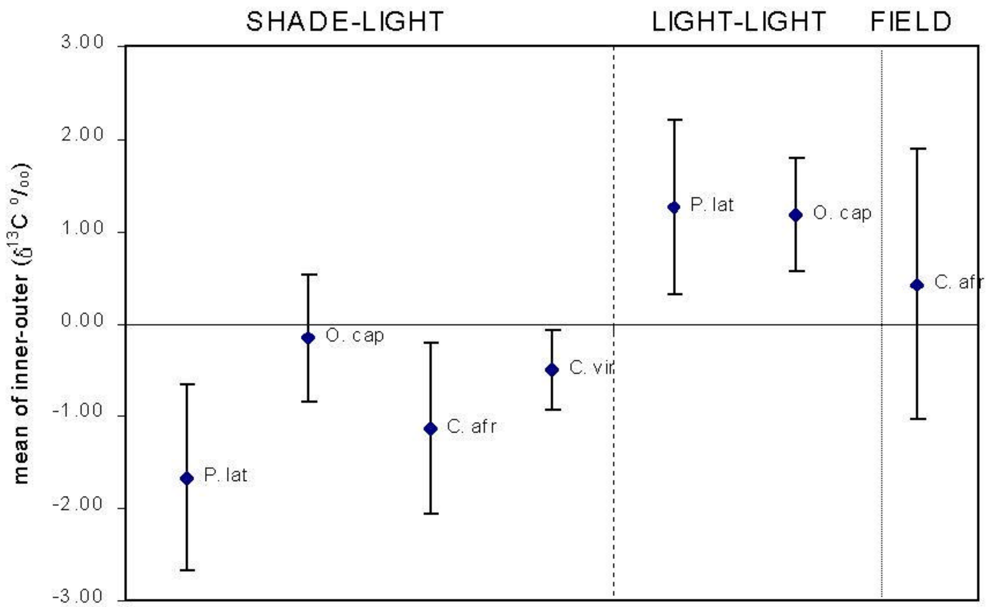
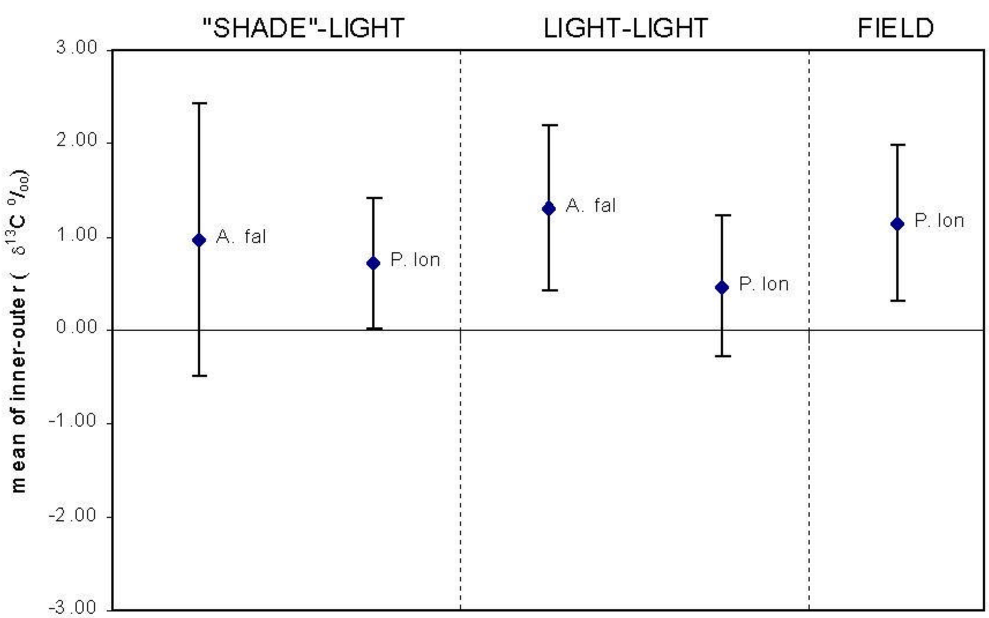


Figure 4: Tree cores: Shade-intolerant species



4.3 What does this technique show?

This technique shows that tree cores yield useful information that can be used to detect the presence of historic large-scale gaps in presently continuous forest canopies. Showing the presence of large-scale recruitment in the Hluhluwe forest is an important finding. As stated earlier, this brings us one step closer to proving the role of humans in these forest communities. This is a result that would have far-reaching management implications. However, this evidence alone is not yet conclusive, and requires corroboratory evidence from other sources such as the use of soil isotopes and demographic data, to piece together what has happened in this forest. Additional evidence could arise from the discovery of archaeological evidence in these forests. Certainly word-of-mouth evidence suggests that people would have farmed areas in the forests as they do to a limited extent outside of the reserve.

These additional techniques may also yield interesting results in themselves. Obtaining conclusive proof of human activities in the past is not easy. However the isotopic tool, in addition to other uses, could help add to the evidence of positive human disturbance in forest communities, by detecting the presence of large-scale recruitment in the past.

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