A Photogrammetric Analysis of the Forest Boundaries at Skullbone Plains and the Vale of Belvoir, Tasmania, Australia

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Introduction

Extensive sphagnum bogs (courtesy of Tasmanian Land Conservancy archives)

Location: Central Tasmania, Australia
42°03'54.15"S to 42°00'33.64"S
146°18'47.14"E to 146°22'02.37"E

Skullbone Plains

Skullbone Plains is an expansive and pristine wilderness property set alongside Tasmania's Wilderness World Heritage Area, sharing a 16 km boundary with one of the largest world heritage sites on the planet. The property is an impressive 1618 hectares, and includes a wide array of threatened or endangered fauna species and plant communities – the Tasmanian Devil (*Sarcophilus harrisii*), Spotted Tailed Quoll (*Dasyurus maculatus*), Clarence Galaxias (*Galaxias johnstoni*), and *Sphagnum* peat bogs(TLC archives, 2012). In fact, this property contains the largest area of these endangered bogs anywhere in Tasmania, and includes some fascinating 'standing wave' structures found nowhere else in the world (TLC archives, 2012). This area shares many conservation values with the World Heritage Area, and will be critical in maintaining connectivity between the highly important habitats for these endangered organisms.

Lying less that 10 km from Lake St. Clair, Skullbone Plains shares the glaciated history of this frequented tourist destination. A strong wilderness feel pervades the Skullbone Plains though, as much of the property is only accessible by foot, which gives anyone visiting this site a deeply intimate feel for the glacial landscape. At one point in the past—approximately 18000 years ago—70 meters of ice covered the entire area, resulting in the flat dolerite plains we see today (TLC archives, 2012). The glaciation of the past has left behind three fully intact moraines, and soils that are poorly drained. This kind of landscape has been conducive to a remarkably diverse mosaic of woodlands, wetlands, moorlands, heath-fields, and grasslands.

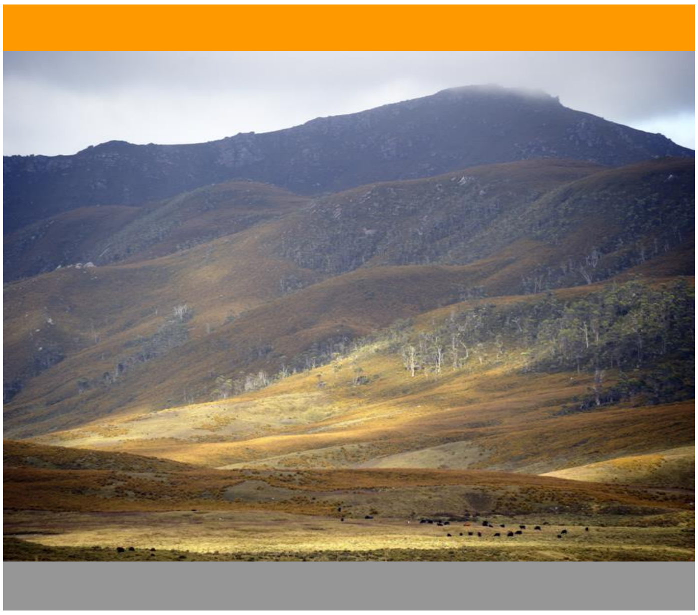
Historically, aboriginal peoples regularly occupied this area for thousands (if not tens of thousands) of years, evidenced by artifact scatters and campfires found around the property. The parcel was first surveyed by Europeans in the 1890s for the purpose of sheep grazing, which occurred in the area for close to 100 years, maintaining a grazing regime in which fire was used to promote regeneration of grasslands (Bruce Hays, 2012). Before Gunns Limited, a timber company founded in the late 19^{th} century, purchased the area for timber production, this grazing was the dominant disturbance on the landscape. After this purchase, in the early 1960s, timber harvesting didn't begin until 2000, leaving the area without disturbance for close to 40 years (Bruce Hays, 2012).

A question arises out of this absence of fire and grazing: Have the Eucalypt woodland to grassland boundaries changed without fire or grazing to affect growth and regeneration? Analysis of historical aerial photos, dating back to the late 1940s, was the main method we used in order to answer this question, and will allow the Tasmanian Land Conservancy (TLC) to formulate management plans for the future of this extremely biologically rich property. The high conservation value of this place remains the catalyst for further investigation into possible management strategies that could be employed by the TLC.

When the timber harvesting finally did happen, the logging that occurred demonstrated a high level of expertise, and protected these areas of high conservation value, such as wetlands, and *Sphagnum* moss beds (TLC archives, 2012). Because of this selective logging, much of the properties ecological values have been conserved. This is a major reason why the TLC purchased the property in 2011, as a part of the New Leaf Project. The New Leaf Project's aim is to obtain and conserve 28000 hectares of native forests being offered for sale by Gunns Ltd. TLC's strategy with this project is a huge undertaking, stretching from ancient old-growth rainforests in the north-east to the forested valleys in the southern midlands. With its high level of ecological connectivity with the World Heritage Area, Skullbone Plains forms a crucial part of this project, and is the primary reason for the analysis of historical photography stretching back over 60 years.

The photogrammetric analysis that was performed was meant to measure the effects of this lack of disturbance on the property over the past 40 years. Had the Eucalyptus woodland boundaries shifted in the absence of grazing and fire? Is it necessary to reintroduce fire to this property in order to maintain the biodiversity in the area? If the boundaries have changed, at what rate have they been changing? These are a few of the questions we were asking, and by using aerial photography, we were able to present a quantitative answer. This photogrammetric analysis has given clear indication that the woodland boundaries have shifted substantially over recent history. If the vegetation communities are to remain as they are currently balanced, fire will need to be used in management decision-making of the future, otherwise, the woodlands will continue to encroach into the grasslands, which may lead to unforeseen shifts in the biological diversity of this property.

The Vale of Belvoir



Grassland expanse being grazed upon with Eucalypt woodland in background
(TLC archives)

Location: Northwest Tasmania, Australia
41°30’30”S to 41°35’25”S
145°52’E to 145°55’E

The Vale of Belvoir is a very unique and beautiful valley that is home to diverse and rare ecosystems, each of which contains rare or threatened species, some of which are endemic to the valley. The local landscape is composed of an amazing array of geologic features combined in a fashion not seen in most places of the world. These distinctive geologic features led it to be classified as a world class Geoheritage site. Within the valley there are the hard mafic igneous extrusions of basalt that came from the depths of the Earth’s crust, forming knolls that now support native highland grassland (Kirkpatrick and Duncan 1987), heathland, Eucalypt woodland, and *Nothofagus* rainforest with its nutrient enriched soils formed through weathering. Surrounding the knolls and composing the valley floor spotted with sinkholes, caves, and disappearing-reappearing rivers is the softer limestone karst land, originating from the depths of an ocean, now supporting native and endangered *Poa* grasslands. These combined with Jurassic Dolerite, Precambrian Quartzite, Pleistocene glacial till, alluvial deposits and other substrates comprise the complex system of which now frames the habitat for species such as the Hoary Sunray (*Leucochrysum albicans albicans var. Tricolour*) or the Ptunarra brown butterfly (Oreixenica ptunarra), both of which are endangered.

The history of the land is also very complex, starting in the times of pre-population and glaciations to then being occupied by Aborigines and their fire management actions and then the transition into the European occupation and their grazing regimes and fire managements. At present day the Tasmania Land Conservancy (TLC) owns the land and manages it for conservation of its biodiversity, especially the highland *Poa* grasslands. So how did these highly valued grasslands come about?

Due to the nature of the grassland system found within the conservation area, a regular low-intensity disturbance is required to maintain its integrity. This disturbance reduces competition for growing space (i.e. sunlight, water, nutrients, physical space, etc.) and may open up these factors for utilization by regenerating seedlings.

In prehistoric times up until two hundred years ago, the Aborigines used fire regularly for reasons including encouraging new plant growth and associated animal presence, as well as to make travelling between areas easier, all of which has consequently shaped the land and its biodiversity (Urbanowicz 2009 and Forest Education Foundation 2008).

As the Europeans began settling in this area, they replaced the Aboriginal fire regime with their grazing regime and autumnal burns to increase forage. In 1829 cattle were introduced and have been in the area ever since. The constant grazing has mimicked a high-frequency, low-intensity, low-severity (cool grass fire) type of disturbance. As for the effectiveness of this process, it has allowed the persistence of rare and threatened plant species through the times.

The concept of fire exclusion was prominent in the mindset of the new settlers which led to an alteration of the forest composition and structure throughout the entire island. The climax state of the forest dynamic is the *Nothofagus* rainforest of which has taken over most of the forests. The rainforest is currently being considered as the"post-climax" stage and are surviving relicts of ancestral vegetation communities (Bowman 2000).

The Aboriginal fire management allowed for fire tolerant and adapted species such as the Eucalyptus trees to persist and form the Eucalypt Woodlands and conversely it kept the fire-sensitive rainforest tree boundaries at bay and subsequently led to the formation of rainforest 'islands' that are surrounded by Eucalypts.

The same concept, as in the reduced fire opted management, has affected the grasslands as well. When the fire regime was relinquished, so to where the standard conditions the ecosystem had adapted to. No longer was the growing space regularly renewed through burning. The same process that either eliminated or stunted shrub growth, now allowed shrubs to move into the grasslands. Although fire was not completely excluded, the new grazing regime sort of filled the niche of disturber in the system.

The effect of grazing is actually partially determined by which species of animal is doing the grazing, the intensity of the grazing regime, the season the grazing took place in, and whether or not the land had been given a resting period between any grazing (Leonard and Kirkpatrick 2004).

All in all the scope of this study is to determine if there were any shifts in the vegetation, mainly the forest boundaries, and to glean any possible evidence of fire shaping the landscape.

Methods

Aerial photographs were obtained for Skullbone Plains and the Vale of Belvior from DPIPWE (Department of Primary Industries, Parks, Water and Environment). The years selected are 1947 and 1974 for Skullbone Plains, and 1953, 1975, and 1984 for the Vale of Belvior. Images were taken from Google Earth to represent the most recent landscape available, which were from 2011. These photographs were then converted from JPG format into TIFF format, via Adobe Photoshop©, in order to avoid degradation of quality through repeated saving and alteration. Once the conversion of these photos was complete, we cropped the edges of the photographs to cut out flight information and borders, along with coordinates and other obstructions to the focused area. After cropping the unnecessary information off of the photographs, we then imported the images into ArcGIS 9.1 for georeferencing. Due to the two-dimensional nature of aerial photography, this process is a vital step toward gaining photographs that aren't distorted by the camera lens, the angle of flight by the aircraft, or any topographic misrepresentations may obscure direct observation. The layers used for reference were the property boundaries supplied by TLC, and also GPS points/tracks taken from ground truthing done at the sites. Visiting the geographic location itself was of high importance to give us a clearer perspective and allowed us to confirm whether certain areas corresponded to the vegetation we were seeing on the most recent images. This involved using GPS to track forest/woodland boundaries, plot any points of interest, and also finding the areas which we were focusing our attention on for this analysis.

Due to time constraints, we were forced to chose specific areas to focus on. These areas were chosen as locations to ground truth, and were areas that had initially showed much of the changes in forest/woodland boundaries. Road access was the primary reason for choosing the areas on the Skullbone Plains property, whereas, finding multiple representations of specific forest/woodland boundaries was the primary reason for the areas chosen at the Vale of Belvior. Possible bias as to the level of change that occurred can arise here, since we chose sites for the reason that they had shown to most significant change. A more complete study of forest/woodland boundaries would include the entire property's boundaries, and avoid using small areas of focus. This kind of study would ensure minimal bias and allow for more accurate assessment of fire-management potential.

After the images were georeferenced, mapping of forest/woodland boundaries was done by using ArcMap's editor toolbar, and the sketch tool to create vector points around the obvious forest/woodland edges. Since the properties are very large areas, we chose to focus on the areas that appeared to have displayed the clearest change. As a control to this, we also chose an area that appeared to have changed little to none. With boundaries mapped out in our areas of focus, we then proceeded to dissolve the attribute tables down to one row, enabling us to calculate areas and quantify the percentage of actual change that had occurred.

Averaging of change over time was accomplished by measuring distance in meters from one year to another. We took specific location within our areas of focus, and averaged the change into meters per decade. We then took the overall land-area change and averaged them to hectares per decade. These values were used to calculate the percentage of change over the years in which the photographs were taken.

Results

Skullbone Plains

As figures 1.1 through 1.5 show, from 1947 to 2011, there has been substantial change in the Eucalypt woodland boundaries of Skullbone Plains. In certain areas along the western edge of the area of focus, the boundaries have increased by less than 10 meters over this time period, but have exceeded 60 meters of change in many of the other areas. Figure 1.5 displays the change that occurred in a clearing composed of *Richea scoparium* from 1947 to 2011. The clearing receded by approximately 30 meters during this time, but only along the north western edges, there has been little to no change along the southern and eastern boarders of this clearing.

The woodlands of the area of focus were at 101.829 total hectares in 1947, and increased to 136.032 hectares by 2011. This is a substantial increase of 33.589 percent cover over this period. The *Richea scoparium* clearing was 1.75627 total hectares in 1947, and decreased to 1.13234 hectares by 2011. This is a decrease in the size of the clearing of 35.526 percent.

Possible biases involved in this kind of quantification would include topographic misrepresentation (aspect and elevation gradient), discrepancies in the time of day when the photograph was taken (hillshade and vegetation shadows), and the angle of flight by the aircraft.

Figure 1.1

Figure 1.2

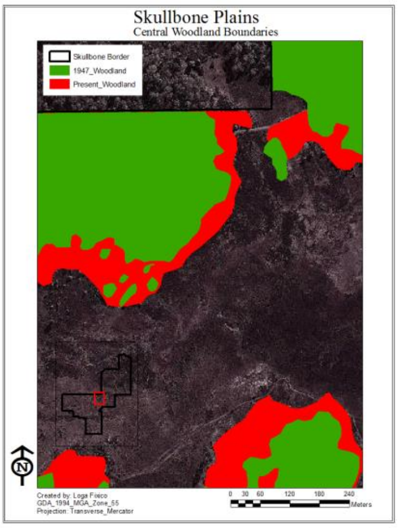


Figure 1.3

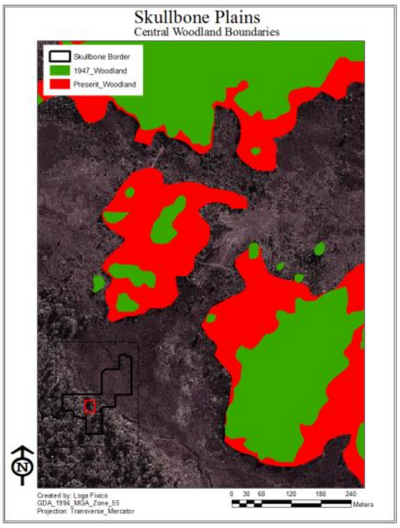


Figure 1.1 represent the western most edge of our area of focus. Figure 1.2 shows the central region of our focal area. Figures 1.3 and 1.4 focus on thesouthern most area, and Figure 1.5 displays the changes observed in the size of the *Richea scoparium* clearing

Figure 1.4

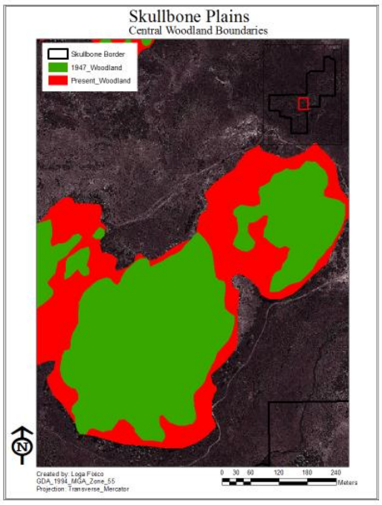
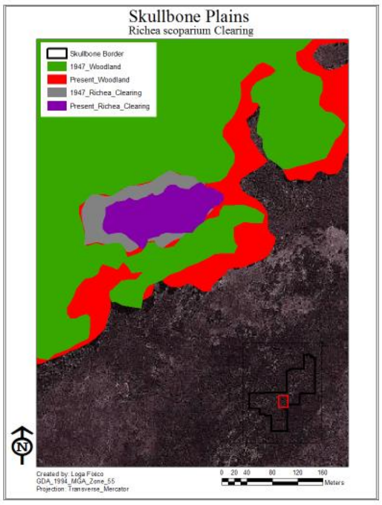


Figure 1.5



Figures 1.6 through 2 reveal the amount of change that has occurred at these sites on the Skullbone Plains property over time. On average, the Eucalypt woodland boundaries have increased by approximately 10 meters per decade in some areas, and then an average of less than approximately 2 meters per decade in others. Mostly, the noticeable increase has been in the areas represented by Figures 1.6 and 1.8. Where only a few trees existed in 1947 and 1974, as of 2011, the woodland had completely taken over the landscape. This was confirmed by our ground truthing trip to the property with the siting of dense stands of Eucalyptus trees at both locations.

Figure 2 shows further proof that the woodland area is increasing. The *Richea scoparium* clearing receded by approximately 10 meters between 1947 and 1974, and then a further 10 meters between 1974 and 2011. This was only along the western most edge of the clearing. On the North side of the clearing, the increasing woodland is most evident between 1974 and 2011, increasing upon the *Richea scoparium* clearing by less than ten meters.

Figure 1.6

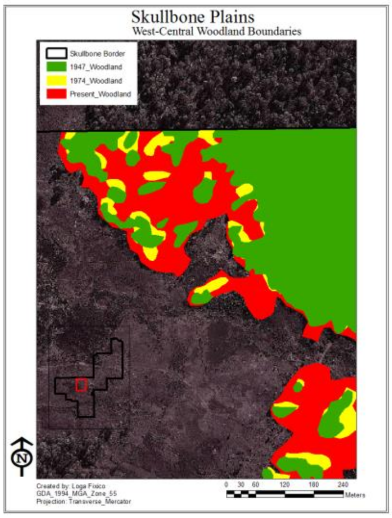


Figure 1.7

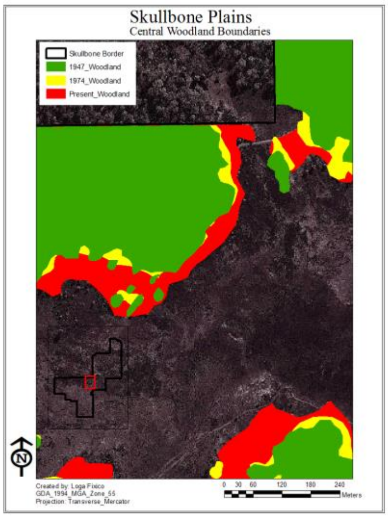


Figure 1.8

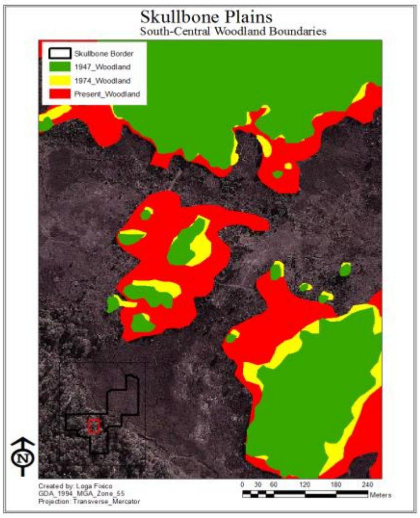
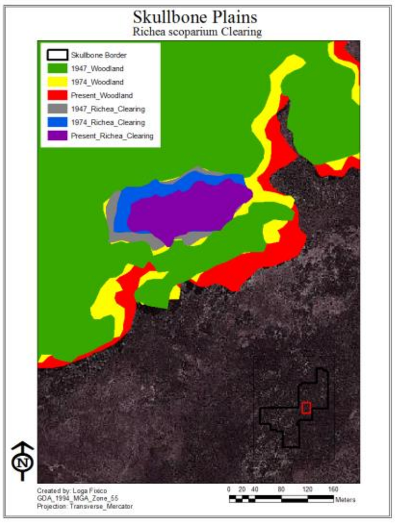


Figure 1.9

Figure 2



According to the aerial photographic analysis, followed by calculating the areas of each year's woodland cover, in 1947 the total area of Eucalypt woodland was 101.829 hectares This increased to 108.977 hectares (7.019%) in 1974, and then to 136.032 hectares (27.055% further increase) in 2011. The Richea scoparium clearing started at being 1.75627 hectares in 1947, receding to 1.51932 hectares (13.491%) in 1974, and then to 1.13234 hectares (25.471% further decrease) in 2011. All of these results indicate that woodland boundaries are encroaching into the grasslands.

Vale of Belvoir

After delineation of the forest boundaries, multiple representative samples were found within the valley. Most of the forest communities did not lie in the specific property boundaries of the Vale of Belvoir as owned by the TLC, but there is a grazing lease owned by the TLC that extends beyond the boundary and is included in the results of Fig.'s 2.1-2.4. All of the forest boundaries experienced different variations through the time frames that are being examined.

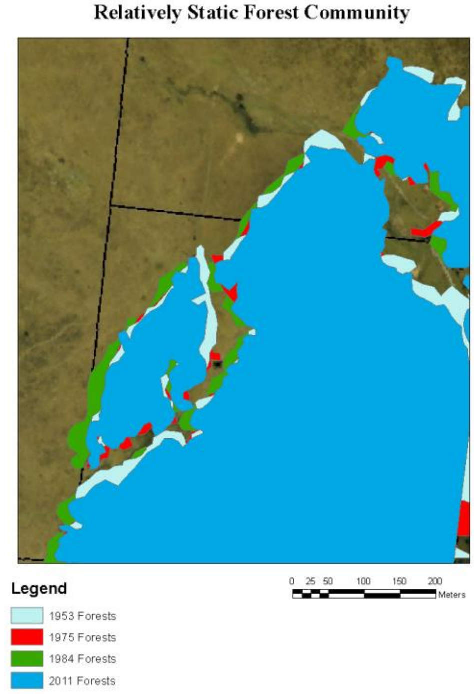


Fig. 2.1

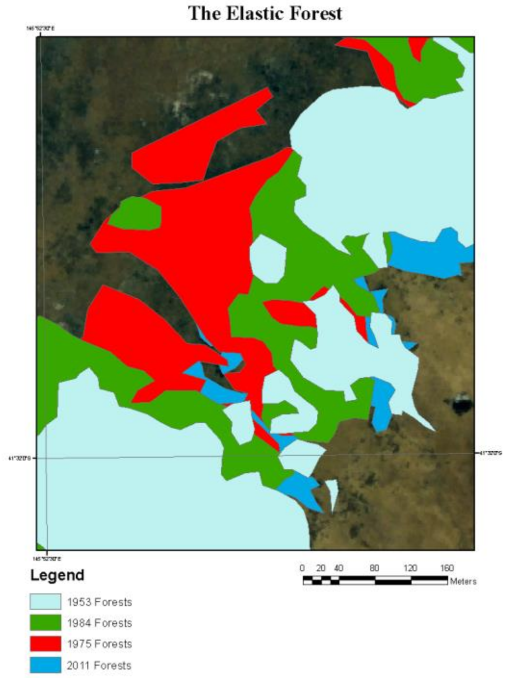


Fig. 2.2

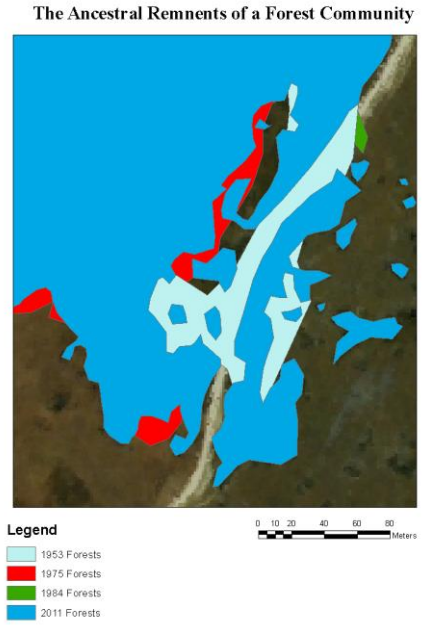


Fig. 2.3

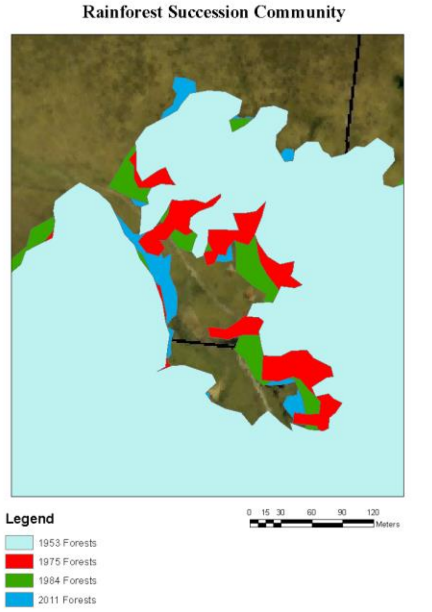


Fig. 2.4

Figure 2.1 represents the boundaries of the forest that have been relatively stable over the last 58 years. The distinctive island of forest on the left side of the figure is known as 'Rainforest Island'. This is a classic example of the Rainforest Island effect as explained by Bowman in (Bowman 2000). The 2011 forest layer was placed as the top layer in this figure so as to demonstrate that in this area, the forest had actually retreated up to twenty meters in some areas and as little as two meters in others. The later is the more common trend.

Other portions of the forest, such as those on the western side of the valley, experienced substantial changes. The most prominent of these changes was in Fig. 2.2, in which the 1975 photo showed the forest had expanded greatly out of the boundaries of the 1953 forest. There was also a subsequent decrease in forest cover as was observed in the 1984 photo. This sequence of events can only be explained by landscape scale disturbance and the conditions that allowed the event to take place. It is not currently known whether the changes were induced by human intervention in the form of logging or by a large fire that had been through the area. There were also possible biases based off of discrepancies in the distortions of the solar aspects captured in the photograph that may have led to a misrepresentation in the exact sizes of the forest at that time. In the diagram, the current forest, as observed in 2011, had increased along the eastern edge of the community. This could be evidence of a fire coming in from the northwest and damaging seedlings, thus eliminating their foothold and preventing establishment of a solid forest community, whereas the unaffected eastern edge was allowed to expand onto the grasslands. There are also signs of encroaching woodlands, but the extent is not known. Without further ongoing studies and more intimate ground truthing, it is not known if it is shrubs or forest that is extending out of the obvious forest boundary.

Figure 2.3 is yet more evidence to the Rainforest Island concept where David Bowman explains as a representation of the remnants of an ancestral vegetation community. This is a very interesting concept, because it implies that if there were regular disturbances preventing the establishment of forest communities that suddenly came to a halt, the natural succession of the environment would be allowed to progress. Albeit a simple theory, it holds true, given there are no disturbances of a major alteration quality, and is still yet only more evidence that there had been frequent burning brought about by the Aboriginal community keeping the grasslands in order. More on this will be addressed in the discussion portion of this paper.

Figure 2.4 is a sequence of rainforest succession as observed in the derived forest boundary near the hut in tandem with ground truthing, historical photos taken from ground level, and personal accounts with the land owners and other researchers who had been studying caves in the karst system on the property for the last 30 years. The area had been Eucalypt woodland with scattered trees in a savanna type distribution in the past. Now, as it is in the present day, is a rainforest composed of *Nothofagus cunninghamii* and tall shrubs, mainly the Mountain Pepper *(Tasmania lancelota)* lining the inner boundary, existing in the area. In other select areas surrounding the rainforest there are massive *Eucalytus coccifera,* which their age is gathered by the height, which is usually smaller than other Eucalypts, due to their alpine nature. This supports the selective nature of human beings in what inadvertently led to these massive Eucalypts surviving into the present age as gate-keepers to the hut roadways, as is represented by the extent of the figure 2.4 boundary near the road.

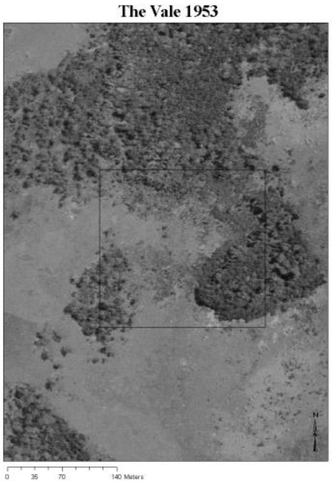


Fig. 3

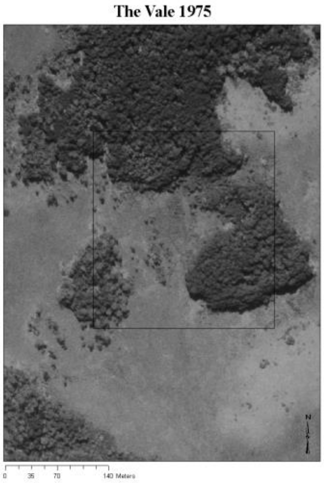


Fig. 3.1

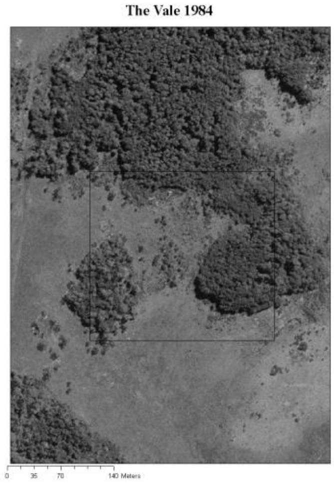


Fig. 3.2

In figures 3-3.2, the gap phase dynamic of rainforest succession is captured in these photos from 1953, 1975, and 1984. In 1953 you can see the top portion of the photograph shows woodland. By the time in 1975 when the next photo was taken the woodland had turned into a nearly closed canopy forest structure. In 1984 the area shows considerable expansion into the grassland.

Discussion

Photogrammetric analysis of both the Skullbone Plains property and the Vale of Belvior have shown substantial increases in forest/woodland boundaries along many of the areas of focus. Conversely, there were also areas within the sites that showed minimal change over the past 60 years. Previous literature has indicated these trends and supports our findings (Wood & Bowman, 2012), but has also indicated the level of change to be far less significant than what has been found by our analysis, stating that vegetation communities are relatively stable over time.

Although the literature states that the communities are stable, though changing the dominant vegetation component over time (Wood & Bowman, 2012), or that through fire a disclimax state is achieved in the form of grasslands (Jones 1969), conversely, Jackson suggests that after fire is excluded (or equivalent disturbance) the vegetation community will convert to rainforest (1968). Jackson's conclusions are much more representative of the observed shifts in forest/woodland boundaries on the two properties. There was no evidence of wide-spread fire on Skullbone Plains within the last 30 to 40 years, and this was confirmed by Bruce Hays in our interview with him (2012). This further supports Jackson's conclusions that these boundaries will shift in the absence of fire. At the Vale of Belvior, there was evidence of previous fires, as there were recently burned Button Grass (*Gymnoshoenous sphaerocephalus*) tussocks. Large tussocks were also observed wherever Button Grass communities were found, which is indicative of the frequent fire regime of the grazers that burned possibly every spring, which is supported by Mount's 'stable fire cycle' theory (Mount in Macphail, 2010).

From the photogrammetric analysis done on the Skullbone Plains aerial photography used in this project, there is conclusive evidence suggesting that Jackson (1968) is correct, and that, without fire, Eucalypt woodland boundaries cannot be maintained at present values, and will need management in the future if they are to be kept from encroaching into grassland areas. This raises three questions: How would future management reflect the conclusions of this analysis? Will fire be included into the management strategies enacted by TLC in the future? Or, will an alternative method of maintaining these boundaries be developed?

In order to conserve the present level of biodiversity at Skullbone Plains, the Eucalyptus stands will need a management plan that reflects their need for fire in their ecology, otherwise, they will continue to increase their boundaries, and may have negative impacts on the grassland diversity of this property.

As for the Vale of Belvoir, the most prominent observation is attributable to Mounts stable fire frequency theory. The types and intensity of the disturbances of the vegetation community had allowed them to persist into the times of today. A fire management plan is necessary in replacement or in combination with the current grazing regime to maintain the biodiversity of the grasslands and woodland boundaries. I suggest that fire should be the more prominent tool because of it's less likely ability to selectively choose what vegetation is burned as compared with the selective nature of grazers.

If there are no fires, will the woodlands convert to rainforest? Will shrubs encroach on the grasslands? Will the sensitive grassland species no longer be present?

As for other research I suggest soil surveys and nutrient availability tests to be conducted on select areas of interest tat are supporting rare or threatened species.

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